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A Notional Shipboard Sonobuoy Processing System

A Software Defined Radio Approach

W. Campbell

Defence R&D Canada – Atlantic

Technical Memorandum
DRDC Atlantic TM 2011-140
June 2011

Canada

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Abstract

The Systems Architecture Group at DRDC Atlantic has been exploring open system and open architecture approaches for developing and delivering new sonar system capabilities to the Canadian Navy for a number of years. These efforts have resulted in the development of unique technologies that have culminated in an integration framework known as the system test bed (STB). DRDC Atlantic has successfully used the STB to develop and demonstrate new underwater sonar systems as part of its maritime program that include the MSTDCL, PLEIADES, and IMPACT systems.

The focus of this investigation was to evaluate the potential of using the current advances in software defined radio (SDR) technologies to develop a new sonobuoy processor capable of processing all ninety-nine sonobuoy slots allocated within the current sonobuoy radio frequency transmission band. Furthermore, this study looks at what would be required to support a flexible mix of sonobuoy types in order to support future naval operations.

This report shows that a SDR approach that is augmented with the technologies of the STB should be more than capable of providing a full-band sonobuoy processing capability. Furthermore, the approach taken has the flexibility needed to accommodate a mix of sonobuoy types that are likely to be used by the Canadian Navy for the foreseeable future.

Résumé

Depuis un certain nombre d’années, le Groupe de l’architecture des systèmes de RDDC Atlantique étudie les approches des architectures ouvertes et des systèmes ouverts dans le but de mettre au point de nouvelles capacités de système sonar et de les livrer à la Marine canadienne. Ces efforts ont eu pour résultat la mise au point de techniques uniques dont le point culminant a été un cadre d’intégration appelé banc d’essai. RDDC Atlantique s’est servi du banc d’essai avec succès pour mettre au point de nouveaux systèmes sonars sous-marins et en faire la démonstration dans le cadre de son programme maritime, qui comprend le système de détection, de classification et de localisation de torpilles à partir de capteurs multiples (DCLTCM), le système PLEIADES et le banc d’essai multistatique intégré actif/passif (IMPACT).

La présente étude devait porter sur l’évaluation des possibilités de se servir des progrès de l’heure réalisés dans les techniques de fonctions radioélectriques définies par logiciel (SDR) pour élaborer un nouveau système de traitement de bouées acoustiques (STBA) capable d’assurer le traitement dans les 99 fentes de bouée acoustique attribuées dans la bande d’émission RF des bouées acoustiques en place. En outre, la présente étude examine ce qu’il faudrait pour prendre en charge une combinaison souple de types de bouée acoustique à l’appui de futures opérations navales.

Le présent rapport montre qu'une approche fondée sur les SDR, auxquelles on ajouterait les techniques du banc d'essai, disposerait amplement des capacités nécessaires pour assurer la capacité de traitement de bouées acoustiques dans une bande complète. En outre, l'approche adoptée a la souplesse nécessaire pour la prise en charge d'une combinaison de divers types de bouée acoustique dont la Marine canadienne se servira probablement dans un avenir prévisible.

Executive summary

A Notional Shipboard Sonobuoy Processing System: A Software Defined Radio Approach

W. Campbell; DRDC Atlantic TM 2011-140; Defence R&D Canada – Atlantic; June 2011.

Background: The Systems Architecture Group at DRDC Atlantic has been exploring open system and open architecture approaches for developing and delivering new sonar system capabilities to the Canadian Navy for a number of years. These efforts have resulted in the development of unique technologies that have culminated in the System Test Bed (STB) integration framework. This framework has been successfully used to develop and demonstrate new underwater sonar systems such as PLEIADES. The focus of this investigation evaluated the potential of using the current advances in software defined radio (SDR) technologies and the STB to develop a new notional shipboard sonobuoy processing system (SPS) capable of processing all ninety-nine sonobuoy channels.

Principal results: The current state of SDR technology is such that commercially available hardware in the market place can be easy obtained to develop a front-end sonobuoy receiver capable of sampling the full sonobuoy radio frequency transmission band for subsequent processing within the STB. The maturity of the STB technology is such that its current dry-end processing, display, environmental modeling, and its detection, localization, and tracking components already provide a rudimentary sonobuoy processing system capability. This capability is currently being improved through active development of an STB based airborne SPS at DRDC Atlantic.

Significance of results: The approach taken that uses SDR and STB technologies offers the greatest degree of flexibility and adaptation to accommodate new advances in sonobuoy technologies. As such, it can provide the genesis for active sonobuoy R&D that can directly help the Canadian Navy mitigate their risks when adopting or fielding new sonobuoy technologies for the foreseeable future.

Future work: This report has shown that a notional sonobuoy processing system based on SDR and STB technologies should be more than capable of providing a full-band sonobuoy processing capability. Furthermore, such a system would also be able to demonstrate new capabilities and have the flexibility needed to accommodate a wide mix of sonobuoy types most likely required by the Canadian Navy for the foreseeable future. Therefore, this report recommends that the required SDR technologies be procured in order to proceed with the implementation of the sonobuoy processing system envisioned in this report.

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Sommaire

A Notional Shipboard Sonobuoy Processing System: A Software Defined Radio Approach

W. Campbell ; DRDC Atlantic TM 2011-140 ; R & D pour la défense Canada – Atlantique ; juin 2011.

Contexte : Depuis un certain nombre d'années, le Groupe de l'architecture des systèmes de RDDC Atlantique étudie les approches des architectures ouvertes et des systèmes ouverts dans le but de mettre au point de nouvelles capacités de système sonar et de les livrer à la Marine canadienne. Ces efforts ont eu pour résultat la mise au point de techniques uniques dont le point culminant a été un cadre d'intégration appelé banc d'essai. Ce banc d'essai a servi avec succès à la mise au point et à la démonstration de nouveaux systèmes sonars sous-marins, comme PLEIADES. La présente étude a permis d'évaluer les possibilités de se servir des progrès de l'heure réalisés dans les techniques de fonctions radioélectriques définies par logiciel (SDR) pour l'élaboration d'un nouveau système théorique de traitement de bouées acoustiques capable d'assurer le traitement dans les 99fentes de bouée acoustique.

Résultats principaux : Étant donné l'état actuel de la technique des SDR, il est facile d'obtenir du matériel sur le marché pour mettre au point un récepteur frontal de bouée acoustique capable d'échantillonner la bande d'émission RF des bouées acoustiques au complet en vue d'un traitement subséquent dans le banc d'essai. La technique du banc d'essai est à ce point avancée que son traitement actuel non immergé, son affichage, sa modélisation environnementale et ses composants de détection, de localisation et de poursuite assurent déjà une capacité rudimentaire de système de traitement des bouées acoustiques (STBA). Cette capacité fait l'objet d'améliorations dans le cadre de la mise au point active d'un SPS aéroporté fondé sur le banc d'essai à RDDC Atlantique.

Portée des résultats : L'approche adoptée, qui fait appel aux techniques des SDR et du banc d'essai, offre le degré le plus élevé de souplesse et d'adaptation en vue de la prise en charge de nouvelles percées dans les techniques des bouées acoustiques. Elle fournit la genèse de la R et D sur les bouées acoustiques actives qui peuvent aider directement la Marine canadienne à atténuer les risques au moment de l'adoption ou de la mise en service de nouvelles techniques de bouées acoustiques dans un avenir prévisible.

Recherches futures : Le présent rapport a montré qu'un STBA théorique fondé sur les SDR et les techniques du banc d'essai disposerait amplement des capacités nécessaires pour offrir une capacité de traitement des bouées acoustiques dans la bande au complet. En

outre, un tel système permettrait de faire la démonstration de nouvelles capacités, tout en ayant la souplesse requise pour la prise en charge de toute une gamme de types de bouée acoustique dont la Marine canadienne aura probablement le plus besoin dans un avenir prévisible. C'est pourquoi le présent rapport recommande l'acquisition des techniques requises des SDR pour permettre la mise en uvre du STBA envisagé dans le présent rapport.

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1 Introduction

The Systems Architecture Group at Defence Research and Development Canada (DRDC) Atlantic has been exploring open system and open architecture approaches for developing and delivering new sonar system capabilities to the Canadian Navy for a number of years. These efforts have resulted in the development of unique technologies that have culminated in an integration framework known as the System Test Bed (STB) [1]. DRDC Atlantic has successfully used the STB to develop and demonstrate new underwater sonar systems as part of its maritime program that includes the TIAPS[1] [2] [3], NUW[2] [4], MSTDCL[3] [5], and PLEIADES[4] [6] systems.

The focus of this investigation evaluates the potential of using the current advances in software defined radio (SDR) technologies to develop a new sonobuoy processor capable of processing all ninety-nine slots allocated within the current sonobuoy radio frequency transmission band. Furthermore, some consideration as to what would be required to accommodate a more flexible mix of sonobuoy types and new capabilities as part of any new system was explored to assess whether or not this kind of capability could be realized to support future Canadian Naval requirements.

This report shows that a notional sonobuoy processing system that is based upon using a SDR approach, augmented with the unique technologies of the STB, should be more than capable of providing a full-band sonobuoy processing capability. Furthermore, such a system would also be able to demonstrate new capabilities and have the flexibility needed to accommodate a wide mix of sonobuoy types most likely required by the Canadian Navy for the foreseeable future.

1.1 System Test Bed

The System Test Bed is an open source open architecture computing environment developed by DRDC Atlantic for greater than fifteen years [1]. It is a collection of software components that provide active and passive sonar processing and display functionality for sensor, feature, contact, track and environmental data. The development and evolution of

[1]The Towed Integrated Active Passive Sonar (TIAPS) system was developed by DRDC Atlantic to demonstrate concepts for advanced low frequency active/passive underwater sensors. This was the initial concept development work that led to what is now formally known as the STB integration framework.

[2]The Networked Underwater Warfare (NUW) system was built to demonstrate the effectiveness of conducting underwater warfare between multiple cooperating platforms capable of sharing information via a common networked infrastructure.

[3]The Multi-Sensor Torpedo Detection Classification and Localization (MSTDCL) system was built to address a perceived capability gap in the defense of Canadian Forces warships against torpedo attack.

[4]The PLEIADES system is DRDC Atlantic's advanced sonar concept demonstrator that is built on the current STB infrastructure. This system is DRDC Atlantic's primary platform for evolving this technology using the open source/open standards approach to architecture development.

this integration framework began in 1996 to support various sonar system development projects within DRDC Atlantic. Furthermore, the STB has been designed to provide flexible, portable, reusable, scalable components for a wide variety of sonar applications. It's functionality is split among similar components designed to maximize generic functionality while minimizing functionality that is application specific. As an open source open architecture computing environment, the STB was developed to facilitate the integration of new underwater capabilities that evolved from the maritime R&D program at DRDC in an effort to support the development and demonstration of new active and passive sonar system technologies to the Canadian Navy. The architecture and framework of the STB has therefore undergone a continuous development and evolution as a consequence of the activities undertaken by DRDC Atlantic as part of its ongoing R&D program to support maritime operations.

Consequently, systems like PLEIADES and MSTDCL were therefore designed, built, and assembled by system integrators from a combination of existing (or newly developed) STB components in order to meet overall system requirements that were focused on producing new system capabilities for trials and demonstration to the Canadian Navy. In addition, third party application integration is readily supported through the adoption of mainstream commercial interface protocols to further facilitate system development, testing, and fielding of experimental underwater systems in order to support future naval requirements.

A basic understanding of the concept behind the STB, its design, and its potential uses are described more fully in Reference [1]. This reference provides an overview of the STB definition, its purpose and objectives, its design approach and principles, and presents the overall STB design. It also illustrates the potential uses of this technology by way of a description of an example application that utilizes the framework and components of the STB. It is not intended to document specific STB-based applications nor does it provide instructions for developing STB-based applications. Figure 1 provides a block diagram representation that illustrates typical STB inputs and outputs[5]. It shows representative components that include sensor data status and control elements, visualization and display elements, user commands, external interface elements, and a system configuration and logging capability supported by an off-line documentation facility.

The technologies and functionality currently available in the STB are therefore well suited for designing, building, and demonstrating much of the dry-end functionality required of a ninety-nine sonobuoy processing system that would be capable of supporting shipboard operations. However, any such system would require a radio communications system to act as a front-end receiver for the STB. This front-end radio system would have to be capable of receiving and pre-processing any sonobuoy transmissions in order to provide the associated sensor data to the STB for subsequent processing and display. A software defined radio is one such choice for providing the STB with the required front-end for realizing the notional shipboard sonobuoy processing system envisioned in this report.

[5] This figure was reproduced from [1] for use in this report.

A block diagram of one portrayal of the STB is shown in Figure 1.

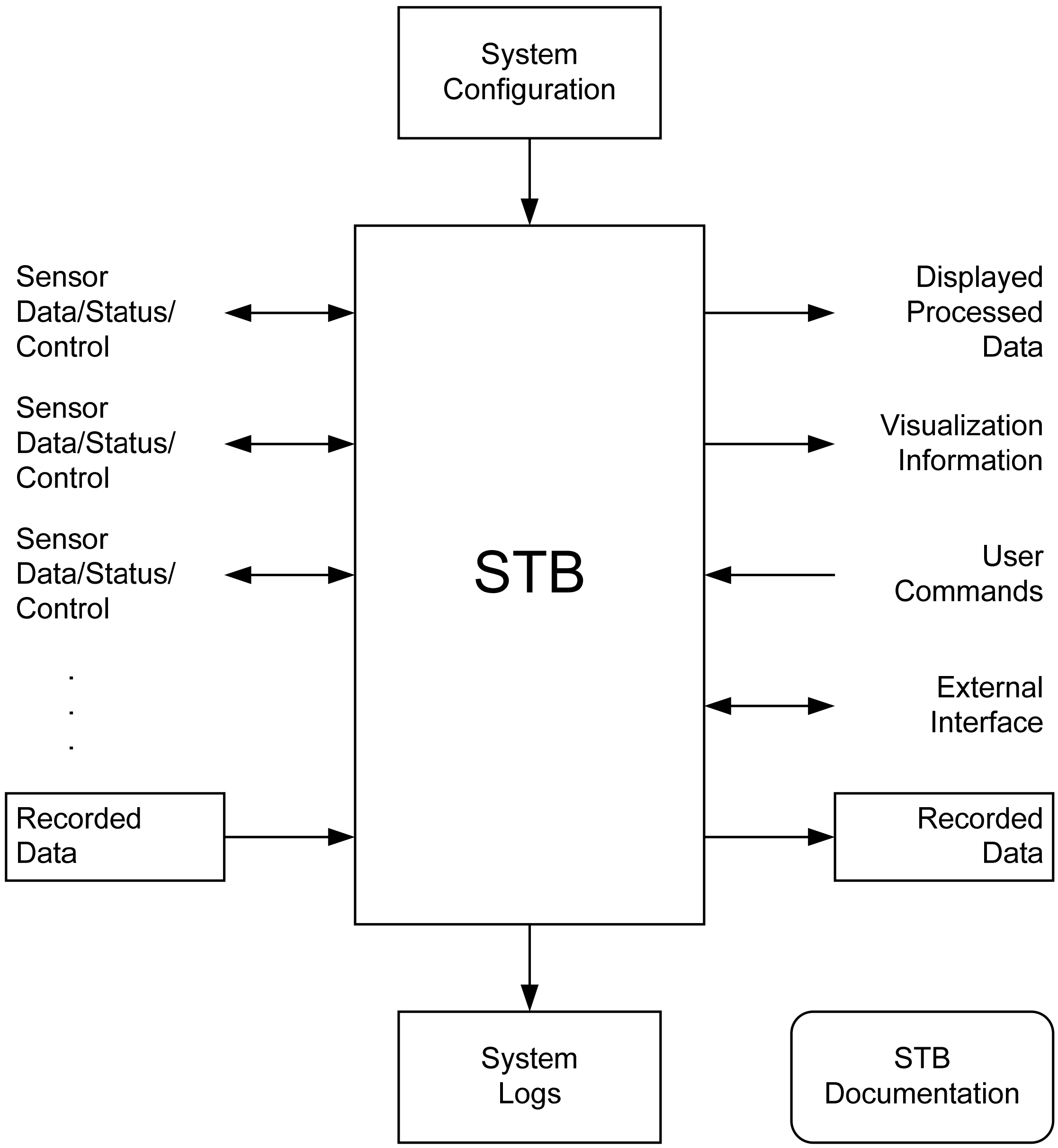

Figure 1: STB Block Diagram.

Figure 1: *System Test Bed Block Diagram.*

Figure 1 shows inputs and outputs of the STB. The Recorded Data can be raw and/or processed data. The External Interface(s) show how a system built with the STB can interface to other systems to either provide data and/or consume data. The STB includes all off-line documentation written to describe, instruct, and or archive specific STB systems.

1.2 Software Defined Radio

This section discusses and provides some background material about software defined radio (SDR) and how that technology might be integrated with the STB to create a demonstrator of a shipboard sonobuoy processing system.

1.2.1 Background

The software defined radio approach, and the technology it has generated, is promoted by the United States Department of Defense to replace tens of thousands of single protocol (waveforms) - single use radios with a common platform that is both reprogrammable and reconfigurable to ensure interoperability [7]. This approach is also being considered by other militaries and public safety organizations around the word for the same reason. At the center of this new technology is the software architecture upon which these radios are built and the communication protocols implemented. Many proprietary architectures exist, but to ensure portability and interoperability of the protocols on different radios, an open architecture had to be developed. The Software Communications Architecture (SCA) is just such an architecture. It defines a set of specifications describing the interaction between the different software and hardware components of a radio and provides software command specifications for their control. The SCA has been developed by the U.S. Department of Defense Joint Tactical Radio System (JTRS) project [8] and has been adopted by the Wireless Innovation Forum [9], which was established in 1996 with the goal of driving technology innovation in commercial, civil, and defense communications worldwide. By doing so, the JTRS development program has proven to be a significant driving force for the standards behind SDR design and implementation.

The JTRS program goal of producing radios that were flexible and interoperable was achieved by using the internationally endorsed open SCA standards that use CORBA on POSIX operating systems to coordinate various software modules. As a result, the JTRS program is providing a flexible new approach to meet diverse warfighter communications needs through software programmable radio technology where all functionality and expandability is built upon the SCA. Despite its military origin, SCA is under evaluation by commercial radio vendors for applicability in their domains as well. The inherent flexibility of SDR can yield substantial benefits over the long run, once the fixed costs of implementation have gone down enough to overtake the cost of iterated redesign of purpose built systems. This then helps to explain the increasing commercial interest in this technology. Education, research, and commercial development programs requiring SDR are directly supported by the SCA-based infrastructure software and by the rapid development tools provided by the Open Source SCA Implementation - Embedded (OSSIE) project [10], as well as, by commercially available development tools now on the market.[6]

[6]For example, commercially available development tools for supporting SDR projects include but are not limited to Simulink & Matlab from Mathworks, DK Design Suite from Celoxica, CE (Component Enabler) from Zeligsoft, and Integrity RTOS & PJFS from Green Hill.

1.2.2 Approach

A software defined radio (SDR) is a radio communications system whose components are implemented either in part (or in whole) in software either on a general purpose computer or on embedded computing devices [11]. Components so implemented can include mixers, filters, amplifiers, modulators and demodulators, detectors, etc. that have typically been implemented in hardware. A basic SDR consists essentially of the following major components: a radio frequency (RF) front-end receiver, analog-to-digital (ADC) and digital-to-analog (DAC) converters, and a signal processing computer of some sort. Such a design produces a flexible and adaptive radio that is capable of receiving and transmitting a wide variety of protocols (waveforms) solely based upon the software implementation used.

A block diagram showing the major components of a SDR is provided in Figure 2. This figure shows the RF, intermediate frequency (IF), and base-band components of a typical radio, as well as, where one might notionally replace functionality by software implementations. The top plot of this figure converts the outputs of the IF section to the digital domain where general digital signal processing (DSP) can be implemented on the base-band signals. Furthermore, the remaining two plots shows the effect on the sections of the radio when digital conversion takes place in the IF and RF components. As the digital conversion moves to the left in these diagrams, the speed and performance of the ADC/DAC increases considerably if high bandwidths or multimode operations are required for a particular application.

Some of the benefits that are usually attributed to the SDR approach promote their:

- Flexibility to be reprogramed with new features and functionality that promises reduced obsolescence, reduced costs, and longer operational life.
- Role as a smart radio that can be configured (or reconfigured on the fly) for multi-band/multi-mode operations in order to accommodate evolving requirements.
- Ability to be adapted to a wide variety of commercially available networks and the ease with which they can be configured to support multiple data sources that can include not only voice but data and video streams as well.
- Ability to facilitate interoperability among the communications systems used by the military, police, and civil authorities to support domestic operations such as search and rescue.

Some of the technical challenges include:

- Keeping up with the requirement for higher data rates that continue to push the limit on the speed and precision provided by the current generation of converters (ADC/DAC).

- The cost associated with the steep learning curve with regards to using modern development tools to support low volume “one-of-a-kind” SDR applications.
- Concerns over the reliability of the software implementations built using open source open architecture computing environments.
- Concerns regarding the overall security (encryption) of these devices for use in operations envolving the military, police, and civil authorities.

It should also be noted that converting the full allocated RF bandwidth for sonobuoys can be readily achieved using currently available technology in the market place[7]. With this in mind, an implementation of a front-end receiver for a STB based sonobuoy system can be realized in the form shown in the bottom plot of Figure 2. That is, to filter and digitize the full sonobuoy RF band from the antenna and make that sensor data available for either further pre-processing within the SDR itself or within the STB using general purpose processors to further extract and process the individual sonobuoy channels. Such a system design should not only be flexible but imminently adaptable as well for satisfying new or evolving requirements.

[7]For example, D-TA Systems Inc. has utilized the SDR approach in its products to simplify high-end sensor processing system development for use in radio, radar, signal intelligence, wireless communications, sonar, and test and measurement equipment by leveraging leading edge technologies to develop solutions that drastically cut deployment time and costs [12].

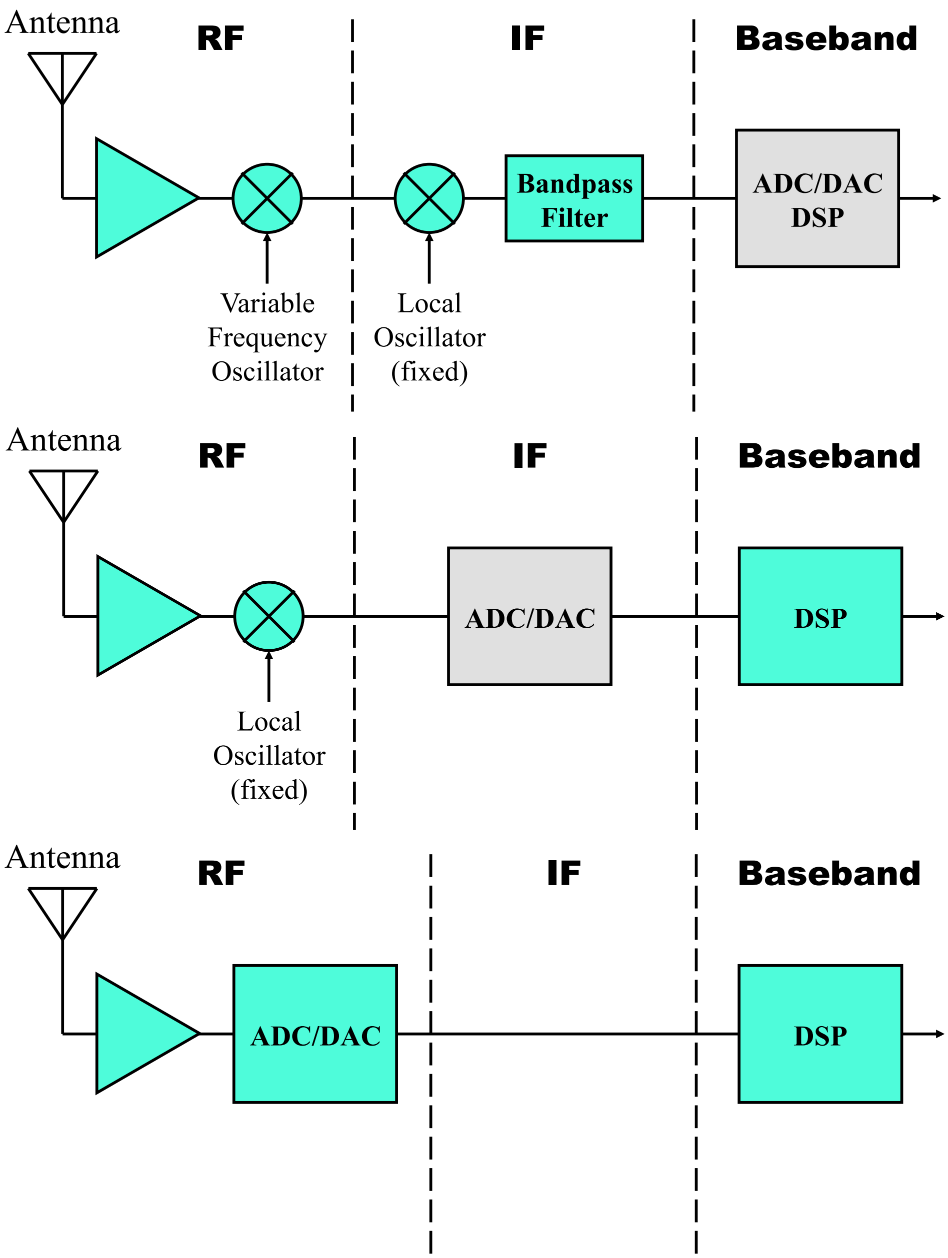

Figure 2: *Software Defined Radio Block Diagram.*

1.2.3 A Technical Solution

DTA Systems Inc. has published a number of technical notes on their website [12] describing their line of products and how they can be effectively leveraged to meet the requirements for a wide variety of high-end multi-channel applications[8]. In particular, they describe an implementation of a multi-channel sonobuoy transceiver based upon their DTA-2210 digital IF transceiver and their DTA-3200L RF up and down converter [13]. Both of these products have a 1 U form factor and cost under 20 K$ each, which offers a cost effective solution for building and demonstrating a ninety-nine channel sonobuoy processing system. Furthermore, the technical specifications of their products support a great degree of flexibility in how the processing components of such a sonobuoy system can be implemented as illustrated by the major SDR components shown in Figure 2. This flexibility is the genesis for addressing requirements associated with technical obsolescence, refresh, and technology insertion typical of not only R&D projects but for meeting the needs of the CF as well.

The DTA-3200L [14] RF up and down converter covers the RF band from 20 MHz to 1 GHz and is well suited to radio communications applications. It offers an instantaneous bandwidth of 40 MHz anywhere in the the 20 MHz to 1 GHz band and it is designed to operate seamlessly with the DTA-2210 digital IF transceiver. This affords the end user with the ability to directly connect to an antenna and obtain a frequency coverage of 20 MHz to 1 GHz. The up converter allows the user to generate a RF signals with up to 40 MHz bandwidth anywhere in this coverage, while the down converter allows acquisition of signals anywhere in this coverage to a maximum bandwidth of 40 MHz. Some of the technical specifications of the DTA-3200L are provided in Table 1.

The DTA-2210 10 GbE Network attached IF transceiver is designed for spectral monitoring and surveillance, RF test and measurement, arbitrary waveform generation, tactical radios, radar and sonobuoy systems, and other applications [15] [16]. The system features a 16-Bit 160 MHz ADC, a 16-Bit 500 MHZ DAC, external reference input for phase locking multiple units, a large user programable FPGA[9] for implementing custom digital signal processing functions, and separate 1 GbE and 10 GbE network interfaces for control and data transfer. The 10 GbE network can support the full bandwidth of the IF transceiver; however, a high-end server class host is required [15]. Furthermore, full source code API and sample codes are available to assist with the integration of this technology and pre-existing technologies such as the STB. Some of the technical specifications of the DTA-2210 are provided in Table 2.

[8] The DTA technical notes and product data sheets can be obtained at their website, http://www.d-ta.com.

[9] A Field-programmable Gate Array (FPGA) is an integrated circuit designed to be configured by the customer or designer after manufacturing. These devices contain programmable logic components and a hierarchy of reconfigurable interconnects that allow those components to be rewired to deliver new functionality. However, some FPGAs may also have analog features such as differential comparators for direct connection to differential signals or they may have ADC/DAC circuitry to allow them operate as a system-on-a-chip.

DTA-3200L: 1 GHz Tunable RF Transceiver		
Features	**Receiver (Down Conversion)**	**Transmitter (Up Conversion)**
Frequency Coverage	20 MHz to 1 GHz	Same
Single Channel	Optional multi-channel synchronization	Same
Instantaneous Bandwidth	40 MHz, Others optional	Same
Tuning Step	500 kHz	Same
Phase Noise	-98 dB / Hz @ 1 kHz	-95 dB / Hz @ 1 kHz
Image Rejection	60 dB	60 dB
IF Out	70 MHz, Others IFs optional	Same
Noise Figure	10 dB	–
Complex (I,Q)	–	IF in
Gain Control	30 dB in 1 dB steps	–
Harmonics	–	$<$ -60 dB
Input Power	+20 dB (no damage) / -20 dB (no saturation)	–
Output Level	–	- 10 dB
Optional Custom Pre-filters	Yes	Yes
Development Kits	C code API and example code available for control	
Form Factor	19" enclosure, 1 U high, 18.5" deep	
Power	110V/220V AC	

Table 1: *DTA-3200L 1 GHz Tunable RF Transceiver specifications.*

The capabilities of the DTA-3200L and the DTA-2210 are more than adequate to meet the requirements associated with capturing, or transmitting into, the full RF spectrum allocated for sonobuoy transmissions. Given that the availability of the 502 sonobuoy receiver [17] currently in use with the Canadian Navy is by no means certain for supporting DRDC projects over the coming years suggests that an alternative receiver be found or developed to meet the lab's R&D requirements. The combination of the DTA-3200L and the DTA-2210 provide a viable alternative that currently exists in the market place that could meet this need. Furthermore, DTA also offers a complete solution that includes a high end server and data acquisition and replay subsystem (DTA-5000) that complements the DTA-3200L and the DTA-2210 [18] [19].

The DTA-5000 is a network based signal recording and playback system that is matched to the DTA-2210 with data transfers occurring over the 10 GbE port. This system is marketed as having unsurpassed scalability and performance with sustained recording speeds of over 800 Mbytes/sec per recorder and data storage capacities from 18 TB to 96 TB per recorder. Furthermore, multiple recorders can be linked and synchronized from a single command and control interface. This unit uses SATA-II disks for data storage and provides the stored data over the network via a variety of protocols that include: SMB, NFS, unix remote copy, and FTP. The system also offers a networkable GUI-based command and control interface to provide overall system configuration and status monitoring capability. Further, the DTA-5000 also supports a socket-based interface for complete control of all system functions via

DTA-2210: 10 GbE Network attached IF Transceiver	
Features	**Specifications**
ADC Sampling Rate	16-Bit 160 MHz
ADC Dynamic Range	$>$ 90 dB
DAC Conversion Rate	16-Bit 500 MHz
DAC Dynamic Range	$>$ 75 dB
Clock Generation	VCO and built in PLL divider with divide ratio of 1 to 32
VCO Tuning Range	375 to 415 MHz
FPGA	Virtex 5 SX50T Standard Optional SX50T for dual 10 GbE
Data Network Interface	One 10 GbE MAC in FPGA CX-4 port can drive cables $>$ 15 m Full duplex operation
Control Interface	One 1 GbE with MAC for interface to host
Memory	64 MB SDARM 8 MB QDR-II SRAM for DAC FIFO buffer
Development Kits	Full source code software development kit API and Demo code included Firmware development kit available for FPGA development
Form Factor	19” enclosure, 1 U high, 11” deep
Power	110V/220V AC with an optional DC input

Table 2: *DTA-2210 Digital IF Transceiver specifications.*

a well defined message interface that a user application can use to control the unit over the network. Some of the major features of the DTA-5000 are provided in Table 3.

A complete solution for building a sonobuoy receiver system could be built using the DTA-3200L, DTA-2210, and the DTA-5000 subsystems. Such a system could be configured to recover all ninety-nine sonobuoy channels and their associated data for subsequent processing. The signal processing, detection, localization, and tracking of the acoustic contacts would be more ideally performed using the components of the STB as we will see later on in this report. However, such a fixed configuration lacks the degree of flexibility to accommodate newer sonobuoy technologies, nor would it allow easy insertion of new capabilities that might be desirable from an R&D perspective. Therefore, such a sonobuoy receiver should be configured with the greatest degree of flexibility. In particular, capturing the full RF sonobuoy transmission spectrum for subsequent processing by STB components is seen as providing a dry-end processing capability that is both adaptable and flexible enough to meet the requirements of the underwater warfare programs at DRDC for the foreseeable future with regards to sonobuoys R&D activities.

The DTA-2210 together with the DTA-3200L are ideal platforms for implementing a SDR based sonobuoy receiver that can accommodate the required acoustic processing in a large user programmable FPGA, or provide wide-band data directly to the user for subsequent

DTA-5000: Configurable Data Recorder	
Features	**Specifications**
Network Interface	10 GbE Interface
Control Interface	Networked, Local GUI, or Socket Interface
Recording Speed	800 MBytes/sec continuous and sustained
Recording Duration	5 Hours with 18 TB disk @ 800 MBytes/sec
Storage Capacity	18 TB Standard Upgradable to 96 TB
Compatibility	Seamless operation with DTA-3200L and DTA-2210
Options	GPS or IRIG B time stamping and synchronization Archiving to LTO-3 or LTO-3 Tapes Multiple recorder synchronization Integrated with application code Voice annotation during record External Storage Capability
Form Factor	19” enclosure, 4 U high, 20” deep
Power	110V/220V AC

Table 3: *DTA-5000 Configurable Data Recorder specifications.*

processing and use. Furthermore, the RF up converter of the DTA-3200L allows the user to generate RF signals with up to 40 MHz bandwidth anywhere in the 20-to-1000 MHz band with the IF signal generation taking place in the DTA-2210. Such a system could be configured to directly recover the full 99 sonobuoy channel signals for subsequent processing by the user. However, its ability to capture the full RF sonobuoy spectrum for subsequent processing also provides a direct upgrade path for accommodating new developments relating to sonobuoy technologies. Furthermore, the possibility of establishing a direct communications channel between sonobuoy systems for synchronization, and a tactical shared awareness, between collaborating platforms has the potential to offer new network enabled capabilities not currently available to the Canadian Navy.

Consequently, it is recommended that the DTA-3200L and DTA-2210 be purchased and configured for wideband reception of the full sonobuoy RF transmission spectrum for integration with the STB. The integration of these components into the STB would go a long way to providing a replacement for the 502 sonobuoy processor needed to support ongoing sonobuoy R&D activities in underwater warfare at DRDC. Furthermore, the processing capabilities currently available in the suite of STB components will be shown later in this report to be more than sufficient to establish a basis for developing the notional shipboard sonobuoy processing system under consideration. It is not so clear that the capabilities of the DTA-5000 are needed given the current recording and replay capabilities resident in the STB. If the STB is found to be incapable of meeting the data storage and replay requirements of the notional sonobuoy processing system, then further consideration regarding the acquisition of an appropriate DTA-5000 system can be entertained if required.

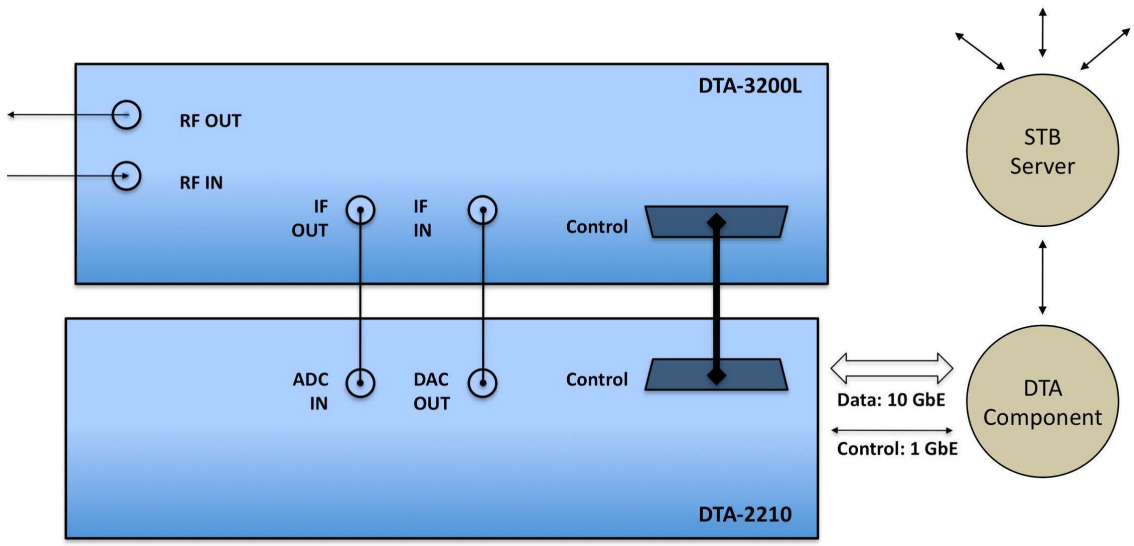

Figure 3: *A DTA based sonobuoy receiver.*

Figure 3 is a block diagram representation of DTA sonobuoy receiver integrated with the STB. At this point, it is uncertain as to whether the DTA component will be a STB application that directly controls and acquires the sonobuoy data from the receiver. The possibility exists that this component could be developed to provide a direct interface between the STB and the DTA high-end data server rather than talk to the DTA-2210 directly. Before a decision can be made, the technical risks and costs associated with these options need to be assessed. However, either solution is viable in this author's opinion.

2 Naval UWW Requirements

In order to take advantage of the current advances in SDR and the technologies of the STB to develop any sort of sonobuoy processing system needs requirements that are relevant to the Canadian Navy. To do this, the notional shipboard sonobuoy processing system being proposed here must be able to demonstrate that it can meet or exceed some (if not all) of the Navy's stated requirements in UWW.

Stated UWW Deficiencies

The Department of National Defence (DND) has initiated the Underwater Warfare Suite Upgrade (UWSU) project with the stated purpose of providing "an Under Water Warfare (UWW) systems refresh onboard the HALIFAX Class frigates to address current and projected submarine and torpedo threats" to the end of the frigate's projected operational life [20]. The following excerpt from the Capability Investment Database (CID) lays out the UWW capability deficiency that this project is trying to address:

1. **Passive and Active Detection:** The passive AN/SQR 501 Canadian Towed Array Sonar System (CANTASS), the AN/SQS 510 medium frequency, active, hull-mounted sonar and the Sonobuoy Processing System (SPS) are the primary UWW sensors in the Canadian surface fleet. The technical specifications of these systems were developed in a Cold War open ocean context with particular emphasis on very low frequency passive performance. The evolving threat, along with the emergence of multi-static active-passive detection techniques requires the use of the full bandwidth available to all sensors. For example, currently, due to its limited acoustic processing capability and previous focus on very low frequency operations, CANTASS processes and displays only the lower half of the frequency spectrum available by the in service AN/SQR 19 towed array. The requirement to monitor the entire available acoustic spectrum to improve the detection, classification and prosecution of UWW threats is dictated by the evolution of the threat and a change in the operating environment. In addition, transient noise sources, particularly those related to torpedo launch, provide significant detection opportunities that are not currently exploited by CANTASS. As is the case with CANTASS, the acoustic processing capabilities of the AN/SQS 510 are limited and do not allow for the full exploitation of its active transmission or passive detection capabilities. As an example, when the AN/SQS-510 is operating in active mode, it is not possible to monitor the transducers in passive, wideband mode. In addition to the threat detection, there is an environmental concern. Current best practice to mitigate the effects of naval active sonars on marine mammals in a training/exercise environment is to listen for mammals vocalizations before transmitting and then to slowly ramp up the transmission levels, rather than transmitting at high power and surprising the animals. This is the approach mandated in MARCORD 46-13 [21]. The AN/SQS 510 currently has

no ability to ramp up its power levels creating a shortfall in the ability of the Navy to mitigate the possible effects of medium frequency active sonar transmissions on marine mammals.

2. **Sonobuoy Receiver and Processor (SPS):** The Sonobuoy Processing System (SPS) is an integral part of the shipboard UWW system. Effective UWW operations in littoral waters, increased surveillance using larger sonobuoy fields, torpedo defence and acoustic intelligence gathering are but a few of the operational scenarios where a high performance SPS is crucial to mission success. Inherent in this is the ability to access the signal spectrum that overlaps with active sources including AN/SQS 510, DICASS and the Cyclone Dipping Sonar. Strongly desirable would be access to the active-intercept bands as there are current and planned sonobuoys that provide passive coverage in these bands. Further, the sonobuoy receiver must be able to address all sonobuoy radio frequency channels in current use and have an upgrade path toward the control of active buoys and access to high dynamic range passive buoys. The current AN/SPS 501 system fitted in the HALIFAX Class is only capable of receiving low frequency data, cannot access 68 channels of the 99-channel Sonobuoy radio frequency band, can only monitor 4 channels at a time and has an outdated man-machine interface.

3. **Environmental Support:** Since its adoption, the Canadian Allied Environmental Support System (C-AESS) has been fraught with hardware/software faults and has suffered from insufficient database support. Having limited abilities to conduct both active and passive acoustic range prediction has had significant negative operational impact for ships, submarines, or Sea Component Commanders. The impacts include the inability to develop realistic and effective Anti-Submarine Warfare (ASW) screens, conduct successful sonar searches in all environments, and achieve effective weapon placement criteria. In its current unstable state, C-AESS does not provide a valid range prediction capability for most environments, and, combined with its limited database, cannot be relied upon to support ASW operations.

4. **Target Motion Analysis (TMA):** The current manual approach to TMA on surface ships limits the effectiveness of the UWW Team. Due to the complexity of TMA and personnel limitations, an automated tool to assist the UWW teams effort would significantly enhance ASW and the ability to produce accurate and timely target positions.

5. **Technical Obsolescence, Refresh, and Technology Insertion:** The existing sonar processing hardware and software were designed in the early 1990s with upgrades in the years following. While it continues to perform, the purpose-built hardware is becoming increasingly difficult to support and software upgrades have become unaffordable, due in part to the age of the software development environment. It is critical that the following points be considered in the development of future sonar systems:

(a) long-term maintainability of the hardware/software;

(b) leveraging from commercial and/or military off-the-shelf development;

(c) leveraging DND investment in sonar R&D that has already taken place through Technology Demonstration Projects (TDP);

(d) positioning to enable effective/timely transition of technological improvements into the Fleet; and

(e) Establishment of a formal Sonar Technology Refresh process.

Furthermore, the planned deliverables for this project are stated in the CID to be:

1. **Sensor Integration, Advanced Processing and Display Systems:** The project will deliver an integrated UWW suite with interfaces to existing sensors and post Halifax Class Modernization (HCM) Command and Control System (CCS) using the current sonar interfaces.

2. **Sonobuoy Receiver:** The project will deliver a sonobuoy processing subsystem with the ability to utilize most, if not all, sensors in NATO inventory such as DIFAR directional passive sonobuoys, DICASS active sonobuoys, and Low Frequency Active (LFA) buoys. The system would control, monitor, process and display data from 12 or more sensors, accessing all of the 99 available RF channels. Consideration will be given to the advantages/disadvantages of commonality with other sonobuoy receiver systems in CF inventory.

3. **Acoustic Range Prediction System (ARPS):** The project will deliver a modern acoustic range prediction system.

4. **Target Motion Analysis (TMA) Tool:** The project will deliver an automated, integrated tool.

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3 Proposed Demonstrator Capability

The requirements and the deliverables stated in Section 2 give a reasonably clear indication of the capabilities that the next generation SPS must meet as part of the UWSU project. That being the case, any notional shipboard SPS being envisioned here must take these requirements into consideration and be capable of demonstrating that it can meet or exceed some (if not all) of these requirements.

3.1 Sensor Integration, Advanced Processing, and Displays

Any proposed demonstrator should also be forward looking and try to demonstrate new capabilities beyond those captured within the CID for currently active projects. With that in mind, the following is a list of possible candidate capabilities that any SPS demonstrator might want to investigate or consider for demonstration beyond those identified in Section 2:

1. **Monitor the Entire Acoustic Band:** This capability could look at more than just trying to improve the detection, classification, and localization of UWW threats as is stated in the CID for the UWSU project. In particular, this monitoring function might consider:
   (a) **Cetacean Alerting:** This function could actively monitor the available sonobuoy acoustic spectrum for the presence of marine mammals to mitigate environmental concerns associated with the use of active naval sonars [22][10]. Append B talks more to the recent findings of a DRDC study [23] that specifically looked at monitoring cetaceans in areas of concern to the Canadian Navy using shipboard passive acoustic sensors.
   (b) **Tools for Detection, Classification, and Location:** Over a number of years, DRDC Atlantic scientists have developed a number of algorithms and tools focused on the problem of detection, classification, and localization of underwater contacts. The MSTDCL TDP developed specific capabilities focused on the problems posed by torpedos; whereas, R&D systems like PLEIADES and IMPACT[11] have focused on traditional underwater contacts using towed arrays and airborne deployed sonobuoys, respectively. In the last several years, a number of DRDC research activities have focused on cetaceans [24] [25] [26] [27] to support the navy's mitigation strategy [22]. Moreover, there is currently

[10] This document is a management plan that talks to the mitigation measures required to avoid environmental impact of naval operations in MARLANT's operational area of responsibility. It specifically addresses measures for marine mammal mitigation.

[11] The Integrated Multistatic Passive/Active Concept Testbed (IMPACT) is an airborne processor developed at DRDC Atlantic for the real-time processing of sonobuoy signals.

significant activity and interest in this area of research not only by defense departments but by the academic community as well [28] [29] [30]. Given that much work has already been done for traditional underwater contacts, any proposed sonobuoy demonstrator should be able to demonstrate such a capability for these kinds of contacts. Such a demonstrator would also need to explore the potential for being able to detect, classify, and possibly locate cetaceans as part of its overall concept for demonstration as well.

2. **Monitor the Entire Sonobuoy RF Transmission Band:** The ability to monitor the full sonobuoy RF transmission spectrum could not only improve the assignment of RF channels to sonobuoys but provide the ship with new capabilities as well. In particular, this monitoring function might consider:
   (a) **Sonobuoy RF Channel Allocation:** This function could monitor the available sonobuoy transmission spectrum for the presence of interfering signal sources due to transmissions or natural increases in the spectral noise. The parts of the spectrum that are found to be quiet could then be used to identify the associated RF channels for potential sonobuoy allocation in order to manage sonobuoy assignment between cooperating platforms. In addition, once an RF channel has been allocated, and a buoy launched, it could be continuously monitored in order to alert the operator to any changes in the status or health of that particular sensor.
   (b) **Subnet Relay[12]:** During the Networked Underwater Warfare (NUW) Technology Demonstration Project (TDP) a new technology was employed to collaborate and share data and information to develop a shared awareness of the UWW picture. This technology was called Subnet Relay [31]. It provided an IP based network over an established (secure) RF network. This allowed members of the task group, and those in the reach back cells, to collaborate and share situational awareness (SA) elements in near-real time during NUW's final demonstration trials [32]. Therefore, monitoring of the sonobuoy transmission band for unused spectrum would allow for the possibility of using part (or all) of this unused spectrum to establish such an IP based network. The monitoring, processing, and transmission into the RF sonobuoy spectrum are currently supported by technology that is readily available in the market place[13].

[12]Subnet Relay (SNR) is a realisation of a mobile narrowband ad-hoc network produced by Rockwell Collins Government Systems Canada (formerly IP Unwired). This technology was developed to support maritime users by providing Internet protocol (IP) connectivity between vessels. An SNR node controller is capable of utilizing existing HF, VHF or UHF narrowband radio equipment, existing link encryption devices, as well as modems resulting in relatively low deployment costs. It has been tested during several sea trials (including NUW TDP trials), and the AUSCANNZUKUS countries stated objective looked at implementing this technology before 2009.

[13]For example, D-TA Systems Inc. has utilized the SDR approach to developed a 1GHz tunable RF transceiver (DTA-3200L) [14] and a 10GbE network attached IF transceiver (DTA-2210) [15] [16] that directly support sonobuoy RF processing [13]. Furthermore, since this technology has a transmit capability it has the potential to support collaborative information and data sharing between acoustic platforms using any unallocated RF sonobuoy channels in a 2U rack configuration.

(c) **AIS Processing via the Sonobuoy RF Transmission Band:** This function could monitor the available sonobuoy transmission spectrum for the presence of interfering signal sources that might be currently transmitting into neighboring RF bands. For example, the Automatic Identification System (AIS) in use to avert maritime shipping collisions broadcasts into the lower end of the sonobuoy RF transmission spectrum[14]. That being the case, the proposed sonobuoy demonstration system should be able to process this signal and provide the associated data and information to the ship as either its primary AIS source or as a secondary system to provide redundancy. The potential to monitor signals between the sonobuoy channels also exists and could be exploited to support operational awareness. In addition, this data could be made available to the UWW operators collaborating across a task group via Subnet Relay to further facilitate situational awareness and compilation of the UWW picture.

3. **Process All Sonobuoy RF Channels:** As stated in the CID, the current SPS is unable to process all ninety-nine sonobuoy RF channels nor does it have the capability to access the active-intercept bands as there are current and planned sonobuoys that provide passive coverage in these bands. Furthermore, there is a requirement to have an upgrade path toward the control of active buoys and access to high dynamic range passive buoys as well. At a minimum, the sonobuoy demonstrator should be capable of demonstrating that it can process all sonobuoy RF channels and that it offers a desired upgrade path identified in the CID to meet the requirements associated with the active and the high dynamic range passive buoys as part of its demonstrations.

4. **Process a Mix of Sonobuoy Types:** The ability to receive all transmissions in the sonobuoy RF transmission spectrum coupled with a distributed processing capability hosted on modern processors offers the potential to exploit new active and passive sonobuoy developments. Furthermore, such a demonstrator should be able to process a mix of sonobuoy types currently in use by the Canadian Navy, particularly those used aboard ship [36]. The potential also exists to demonstrate the use of newer high dynamic range passive buoys and provide the necessary control of active sonobuoys given that the demonstrator is planned to have a transmit capability offered by the Subnet Relay IP based network capability discussed above.

[14] The following two RF channels have been designated for AIS use worldwide as: AIS 1 (Channel 87B, 161.975 MHz) and AIS 2 (Channel 88B, 162.025 MHz) [33]. These two channels lie directly between sonobuoy channels No. 99 (161.125 MHz) and No. 34 (162.250 MHz) [34] (see Appendix A), and as such, could be received and processed along with the active sonobuoy channels. Furthermore, congestion in the VHF maritime mobile band (156 MHz - 174 MHz) has become a serious problem for which the introduction of new technology, or the re-planning of the frequency bands, is a current recommendation of the ITU Radiocommunications Assembly to the International Maritime Organization (IMO) [35]. This means that this part of the RF transmission spectrum will likely get significantly more cluttered over the coming years, and as such, any sonobuoy processing system must be able to coup with the congestion, or possibly even exploit any new transmissions in this band.

5. **New Visualization and Display Capabilities:** In order to build the UWW picture, a new sonobuoy processing system must have appropriate display elements to allow the operator to not only use the system but control it as well. Such controls can cover activities from the initial allocation, deployment, and monitoring of sonobuoys in use to tools that allow the operator to detect, classify, and locate contacts of interest whether they be cetaceans or underwater objects that are of interest to the navy. DRDC has a long history of building experimental UWW systems, and has recently done studies on both visualization [37][38][39][40] and humans factors studies [41][42][43], that should provide general guidance for producing appropriate control and display elements for visualizing the data and information generated by the system. These new capabilities will have to be born network-centric if they are to facilitate a collaborative environment that is not only efficient and effective in sharing UWW data and information but capable of establishing a shared situational awareness among all participants. Clearly, this would also require that appropriate measures of performance (MOP) and measures of effectiveness (MOE) be developed and demonstrated[15].

3.2 Sonobuoy Processing System

Recently a preliminary design study was undertaken to port the IMPACT airborne processor to the STB.[16] The selected porting methodology and the design of the signal-processing architecture, data manager, and display processor are described in the preliminary design document of Reference [48]. The implementation that was undertaken based upon the proposed design has shown that the software environment of the STB is particularly well suited to this task given that it was developed for implementing UWW signal-processing and display components.

The PLEIADES system currently uses the STB passive signal processing functionality developed for the IMPACT system to process sonobuoys when the system is deployed. A description of the passive processing currently utilized within this system is provided in Reference [47]. Furthermore, the MSTDCL system design documents also provide a description of the PLEIADES interface to the 502 sonobuoy receiver [17] and the current sonobuoy displays used by this system [49] [50]. From a sonobuoy perspective, the PLEIADES system currently processes both DIFAR 53 and 53F (GPS equipped) buoys as

[15] As in the NUW TDP, the development of the system performance metrics required careful consideration that accounted for the design of the data architecture and the data sharing concepts envisioned for this system, which led to the development of effective, and useable, information exchange requirements [44][4][45][46].

[16] This airborne sonobuoy processing system has been under ongoing development in excess of fifteen years and the current version of the system has reached obsolescence [47]. In particular, the life of the system was deemed to be limited because its current hardware configuration was dated as was the tight coupling of its software to this hardware. The design study was undertaken to address this deficiency in order to safeguard DRDC's investment and to continue to provide R&D in support of maritime UWW operations.

a matter of routine on deployments[17].

The implementation of the proposed STB IMPACT system design uses general-purpose, commercial-off-the-shelf (COTS) computer equipment and reuses STB signal processing and data management software appropriately modified to meet the unique system requirements of this airborne sonobuoy processing system. In particular, the current STB-based display software did not meet the requirements of the IMPACT system. Therefore, new displays were created using current graphics software technologies with the hope that ongoing development and widespread use of these technologies will help prevent obsolescence in the near future. Specifically, the displays were implemented using Gimp Toolkit library (GTK+), an open-source toolkit for graphical user interfaces (GUIs). Furthermore, the signal processing and display software was designed with extensibility in mind. The details associated with the current implementation and its level of functionality and integration with the STB are provided in Reference [51].

Although the integration of the IMPACT functionality was not fully completed, it provides considerable leverage and means to realize the notional shipboard SPS proposed in this report in that it provides a native STB sonobuoy dry-end processing and display capability. The IMPACT implementation has demonstrated that an airborne processor can be successfully built using open-source software, COTS hardware, and the STB integration framework. The GTK+ graphics toolkit has been shown to integrate nicely with the STB data server and the current implementation activity concentrated on integrating DIFAR, ETI, and Tacplot displays along with their associated signal processing components. As a direct result of this, the implemented STB IMPACT system successfully demonstrated display and signal processing performance adequate to meet the requirements associated with a 16-buoy replay system. The performance attained suggests that a full ninety-nine channel sonobuoy system is technically doable using current technically. Furthermore, the overall performance of this new system can only benefit from the native UWW acoustic prediction and localization components currently available within the STB.

The use of the STB adds to the new IMPACT system connectivity with other STB-based sonar systems and applications. The combination of STB use, COTS hardware, and the current display technologies should address issues of technical obsolescence, refresh, and technology insertion. Furthermore, future STB enhancements should be easily leveraged by all STB based systems. As such, these systems can be tailored to provide focussed R&D efforts designed specifically to address the unique requirements associated with the Navy's UWW programs.

[17] In order to process the DIFAR 53F, a demodulator strips the NEMA GPS stream off a 30 kHz carrier on each audio channels before transmitting it through a 232 serial interface to the STB, which has a component that reads this serial stream and parses the associated NEMA GPS messages for use by the system.

3.3 Acoustic Range Prediction

DRDC Atlantic has a long history of research and development associated with acoustic modeling and prediction. One of the systems developed to realize this capability was the Environmental Modeling Manager (EMM), which was initiated in 2000 as part of the sonar information management system (SIMS) [52]. SIMS provided a set of operator tools for the detection and tracking of acoustic signals to support the development of a target motion analysis (TMA) capability. The environmental modeling management concept developed at that time was to provide distributed access to the environmental and acoustic prediction data provided by C-AESS[18] and bathymetry database files to assist the UWW sonar operator by providing the tools needed to detect and track underwater contacts.

Over the intervening years, the detection and tracking of acoustic signals were further developed and integrated as components of the STB to support underwater tracking [54] [55]. In so doing, the EMM evolved into a client/server system that predicts ocean acoustic propagation conditions to directly support tactical decision aids and displays for the operator. The EMM application itself generates propagation path, transmission loss, signal excess, and detection performance estimates for operator displays. This component of the STB has successfully demonstrated interfaces to real time and archival data sources with the ability to import XBT and XSV data files[19]. Furthermore, both transmission loss and acoustic sensitivity experiments have been carried out aboard CFAV Quest to validate the EMM predictions [56]. As a real time mission planning and execution tool, the EMM has been integrated with external interfaces and with the PLEIADES system and has been successfully demonstrated aboard HALIFAX Class frigates. As an acoustic prediction tool, the EMM provides a mechanism for supplying acoustic tactical decision aids with a consistent source of acoustic model predictions.

As a major STB component, the EMM continues to be enhanced as part of the PLEIADES system [57]. The EMM has been extended to read network common data form (NetCDF) sound velocity data from independent oceanographic laboratories in order to validate EMM predictions of future ocean propagation conditions in order to enhance the effectiveness of naval operations. Furthermore, the PLEIADES based EMM demonstrated the ability to visualize and accommodate large amounts of gridded sound velocity predictions aiding in the understanding of the measured sound velocities profiles. The ability of the EMM to access models of ocean parameters means that the tactical decision aids can receive updated predictions that are key to keeping their recommendations accurate and current.

[18] The Canadian Allied Environmental Support System (C-AESS) provided sonar performance prediction and tactical decision aids and was supplied to the Canadian Navy by the US Navy under a foreign military sales case [53].

[19] The Expendable Bathy-thermograph/Expendable Sound Velocimeter (XBT/XSV) are devices used to measure the temperature/sound velocity data as a function of depth from a moving ship. This data is telemetered to the shipboard data processing equipment via a pair of fine copper wires that transfer the data to ship for recording and subsequent processing to support real time acoustic range predictions to support UWW operations.

These efforts have improved the overall accuracy of acoustic modeling provided by the EMM.

Finally, the EMM has been enhanced to support the Navy's mandated marine mammal mitigation strategy regarding the use of active naval sonars [21] [22]. This policy requires any naval operations involving the use of active sonars to take reasonable steps to mitigate the impact of those operations on marine mammals. A key component of this mitigation approach is understanding the zones of possible influence, based on transmitted power and local oceanographic conditions. Recently, a new Marine Mammal Mitigation (MMM) component was developed as part of the EMM that uses ocean acoustic prediction to provide an estimate of the influence ranges in all directions to allow more informed decisions regarding employment of active sonars [58]. A future enhancement to this component is looking at the possibility of integrating a marine mammal database that includes habitat information, sound level sensitivities, depth profiles, and time at depth information, as well as, overlays of marine mammal habitants. Such information is critical if the Navy is to meet the stated requirement of the UWSU project regarding marine mammals, as outlined in Section 2 of this report.

3.4 Target Motion Analysis

DRDC Atlantic has a long history of research and development associated with underwater tracking using passive acoustic sensors. This research has led to the development of demonstration systems like IMPACT [59] and the Passive Localization System (PLA) [60] for the respective processing, tracking, and display of sonobuoy and towed-array detections. The tracking capabilities in IMPACT have been aided by research that has produced algorithms capable of tracking fields of sonobuoys in order to improve overall system performance [61] [62]. As for towed array tracking, algorithm development has included Kalman based techniques [63] [64] that were integrated into both the PLA and SIMS. This research has continued and has developed a general purpose grid search technique [65] that is capable of using not only passive sensor data but active as well. This capability has been integrated into the PLEIADES system as a standard STB component [66] [6], and as such, it offers a native underwater tracking capability for systems configured to use this component.

The grid search localization component integrated into the PLEIADES system has an autonomous capability to detect and localize both narrowband and broadband acoustic signals. This capability was initially employed in the MSTDCL project before it was ported into the PLEIADES system where the grid search localizer was enhanced to handle a variety of sensors [66]. Along with improvements in the narrowband and broadband bearing and frequency estimation components the addition of the localization component greatly enhanced the overall tracking performance of the system. Furthermore, a number of tools developed as part of the SIMS initiative were tailored to meet operator requirements to localize acoustic contacts [6]. These tools were integrated into the PLEIADES system as well. As a result, a number of tactical technologies are now integrated into this system as STB components that substantially improve the ability of the system to track acoustic contacts.

The current capability of the grid search localizer not only accepts sonobuoy data but any acoustic data (active or passive) based upon the specifics of its associated attributes. For the data attributes that are not currently supported by the localizer, the tracking is suboptimal. However, the structure of this algorithm and its STB components make it easily extensible if a requirement exists to exploit all of the information provided by these acoustic sources. This flexibility provides a direct upgrade path to support the development and implementation of new STB components capable of meeting the future UWW requirements envisioned by the Navy as currently stated in the CID. In particular, the STB approach and its growing number of components can be extended to address and mitigate the technical issues associated with the Canadian Navy using the new breed of active and passive (high dynamic range) UWW sensors.

3.5 Technical Obsolescence, Refresh, and Technology Insertion

The capabilities described in this section of the report show that the stated UWW deficiencies outlined in Section 2 are exactly what the STB development approach and philosophy are designed to address. In fact, many of the stated UWW deficiencies associated with the UWSU project are being addressed either in part, or to a substantial degree, by the current development activities associated with the STB. This is clearly seen in the new capabilities offered by the PLEIADES, MSTDCL, and IMPACT systems build using STB components and integrated using the STB framework.

The STB is an open source open architecture computing environment that follows the open systems approach in its design, development, flexibility, and its evolution. Its architecture and framework has undergone a continuous development and evolution as a consequence of the activities undertaken by DRDC Atlantic as part of its ongoing R&D program. Consequently, systems like PLEIADES, MSTDCL, and IMPACT were therefore designed, built, and assembled from a combination of existing (or newly developed) STB components. The technologies and functionality currently available in the STB are therefore well suited for designing, building, and demonstrating much of the functionality needed to help the Navy meet the overall requirements of the UWSU project.

The design philosophy of the STB means that it must routinely address issues associated with technical obsolescence that requires timely refreshes of the technologies upon which it is built that includes a consideration of both its hardware and software components. More importantly, the STB development activity strives to integrate new capabilities and technologies to achieve concurrency in its evolution and flexibility with main stream developments. The ability of the STB to meet this particular requirement has been successfully demonstrated through direct operational support aboard CF vessels during numerous deployments of PLEIADES and MSTDCL. Furthermore, the number of projects leveraging the STB continues to grow as does the interest in this technology by DRDC's industrial partners. This trend means that the maturity and robustness continues to be improved and advanced. This would suggest that systems like PLEIADES can be used to directly help mitigate the Navy's need to address procurement issues, risk, and the longevity of its future UWW systems. To meet these future needs, the Navy needs an exploratory capability having the degree of adaptation and flexibility exemplified by the systems currently being built and demonstrated using this technology.

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4 Summary and Recommendations

The STB approach, design, and flexibility for building and integrating UWW applications and systems has been successfully demonstrated by the MSTDCL, PLEIADES, and IMPACT systems built using this technology. As a result of these activities, the STB now has a number of components that can be used to build a standalone shipboard sonobuoy processing system. In particular, the STB has a variety sensor and system interfaces, signal processing and display elements, and tactical operator aids for addressing marine mammal mitigation concerns, for acoustic modeling and for detecting, localizing, and tracking underwater contacts of interest.

The current suite of capabilities offered by the STB components are more than adequate to build, implement, and demonstrate the notional shipboard sonobuoy processing system envisioned in this document. The only major component not currently available as a STB component is the front-end sonobuoy receiver. Currently, the 502 receiver is used to acquire sonobuoy data for the PLEIADES system but with its future availability in question suggests that a suitable replacement be purchased or developed to support our R&D activities at DRDC. Section 1.2 outlined the SDR approach for meeting this challenge. In particular, the technical implementation outlined in Section 1.2.3 uses current technologies offered by DTA Systems Inc. to provide one means for realizing a replacement for the 502 sonobuoy receiver.

Therefore, it is recommended that the technical solution using DTA offerings as proposed in Section 1.2.3 be pursued. Specifically, a DTA-3200L 1GHz tunable RF transceiver and a DTA-2210 10GbE network attached IF transceiver be purchased and configured so that this sub-system samples the full sonobuoy RF transmission band. The data so sampled would then be integrated into the STB where the recovery of channel specific data would be accomplished in software through the reuse of existing STB components. Furthermore, new STB components could then be developed to address the requirements for integrating and processing new or novel next generation sonobuoys that might be of interest to the Canadian Navy.

Once the notional shipboard SPS has been demonstrated with its new DTA front-end, the new capabilities discussed and outlined in Section 3.1 can then be addressed. This would require that a number of new STB components be developed to meet each of the specific requirement associated with the capabilities selected for implementation. Furthermore, once this system is functionally demonstrated, it would provide the catalyst to address and mitigate the Navy's risks associated with meeting its future UWW requirements.

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5 Conclusions

The Systems Architecture Group at DRDC Atlantic has been exploring open system and open architecture approaches for developing and delivering new sonar system capabilities to the Canadian Navy for a number of years. These efforts have resulted in the development of unique technologies that have culminated in an integration framework known as the system test bed (STB). DRDC Atlantic has successfully used the STB to develop and demonstrate new underwater sonar systems as part of its maritime program that include the PLEIADES, MSTDCL, and IMPACT systems.

The focus of this investigation was to evaluate the potential of using the current advances in software defined radio (SDR) technologies to develop a new sonobuoy processor capable of processing all ninety-nine sonobuoy slots allocated within the current sonobuoy radio frequency transmission band. Furthermore, this study looks at what would be required to support a flexible mix of sonobuoy types in order to support future naval operations.

This report shows that a SDR approach that is augmented with the technologies of the STB should be more than capable of providing a full-band sonobuoy processing capability. Furthermore, the approach taken has the flexibility needed to accommodate a mix of sonobuoy types that are likely to be used by the Canadian Navy for the foreseeable future.

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Annex A: Sonobuoy RF Channel Allocations

Sonobuoy RF Channel Assignments					
RF Channel	Frequency (MHz)	RF Channel	Frequency (MHz)	RF Channel	Frequency (MHz)
1	162.250	34	136.750	67	149.125
2	163.000	35	137.125	68	149.500
3	163.750	36	137.500	69	149.875
4	164.500	37	137.875	70	150.250
5	165.250	38	138.250	71	150.625
6	166.000	39	138.625	72	151.000
7	166.750	40	139.000	72	151.375
8	167.500	41	139.375	74	151.750
9	168.250	42	139.750	75	152.125
10	169.000	43	140.125	76	152.500
11	169.750	44	140.500	77	152.875
12	170.500	45	140.875	78	153.250
13	171.250	46	141.250	79	153.625
14	172.000	47	141.625	80	154.000
15	172.750	48	142.000	81	154.375
16	173.500	49	142.375	82	154.750
17	162.625	50	142.750	83	155.125
18	163.375	51	143.125	84	155.500
19	164.125	52	143.500	85	155.875
20	164.875	53	143.875	86	156.250
21	165.625	54	144.250	87	156.625
22	166.375	55	144.625	88	157.000
23	167.125	56	145.000	89	157.375
24	167.875	57	145.375	90	157.750
25	168.625	58	145.750	91	158.125
26	169.375	59	146.125	92	158.500
27	170.125	60	146.500	93	158.875
28	170.875	61	146.875	94	159.250
29	171.625	62	147.250	95	159.625
30	172.375	63	147.625	96	160.000
31	173.125	64	148.000	97	160.375
32	136.000	65	148.375	98	160.750
33	136.375	66	148.750	99	161.125

Figure A.1: *Sonobuoy RF Channel Assignments.*

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Annex B: Passive Acoustic Monitoring of Cetaceans

A recent study by Cormier et. al. looked at the passive acoustic monitoring of cetaceans in areas of concern to the Canadian Navy as a key component to mitigate the impact of UWW operations on marine mammals [23]. The impact mitigation approach for naval vessels looked at the potential for developing passive acoustic techniques for the detection, classification, and localization of cetaceans based upon the animals vocalizations in close proximity to the ship's acoustic sensors. It also catalogued the acoustic sensor capabilities used in UWW for comparison to cetacean vocalization characteristics to determine the potential for making such detections using available acoustic sensors. Although the current suite of sonar sensors used do cover a wide range of cetacean vocalizations it was found that some species might not be detected unless a major sensor upgrade is undertaken.

The report also compiled a list of available acoustic sensors and noted their associated bandwidths matched against the known vocalization spectra of the cetaceans of interest. The study did not however consider the signal processing capabilities of the current sensors on received vocalizations but did conclude that the passive sensors available to the CF were in fact capable of detecting the presence of some species of cetaceans covered in the study. In addition to the frequency bands listed, the types of vocalizations (signatures) and their durations were listed for a variety of cetaceans; however, research in this area is currently very active and far from complete. This work therefore provides a basis for evaluating the inherent sensor capabilities for detecting and possibly classifying cetaceans simply based upon the potential of capturing underwater signals without addressing the issues associated with implementing a proper signal processing system.

Individual sonar sensors were found to only cover parts of the range of mammal vocalizations but as a suite they covered the majority of the vocalization spectrum, thus allowing for the possibility for processing most of the known signatures. Although any given sensor might have a limited frequency range of operation, they certainly can contribute to the detection and classification of cetaceans. The sensors that were considered in this study that are relevant to shipboard UWW include:

- **AN/SSQ-62 (DICASS):** The directional Command-Activated Sonobuoy System receives on one-omni-directional and two directional (sine and cosine) channels. It is normally deployed by maritime patrol aircraft, and could be from surface ships subject to some hardware changes. Channels are selected prior to deploying.
- **AN/SQS-510:** This is the hull-mounted sonar (HMS).
- **AN/SQR-19 (CANTASS):** The Canadian towed array sonar system is only found on the CPF for anti-submarine warfare. It has several groups of hydrophones for detection and direction.

- **AN/SSQ-53 and AN/SSQ-53F (DIFAR):** Directional Frequency Analysis and Recording Sonobuoy, the AN/SSQ-53 is the most widely used sonobuoy in the CF. It can be deployed from the air or from surface ships. The AN/SSQ-53F is an omnidirectional sensor with a wide band response.

In addition to these sensors found aboard ship, the following sonar sensors are also available to the CF but not currently in service:

- **AN/SSQ-101 (ADAR) and the AN/SSQ-981 (Barra):** These air-deployed active receivers have arms that form a horizontal planar array once it entered the water. It is not in use, not in stock in Canada, but can be obtained commercially.

- **AN/SSQ-565 (A-CASS):** The A-sized Canadian Active Sonobuoy System has transducers arranged as a VLA, but is currently under development by UEMS with CF funding. Although it has received extensive DRDC and CFMETR testing, it has never been operationally tested.

- **AN/SSQ-77B (VLAD):** This sonobuoy is essentially a standard DIFAR with its omnidirectional hydrophone replaced by a vertical line array (VLA) of hydrophones. Although it could be deployed from the air or from a surface ships, it is manufacturing discontinued, thus neither being used nor will be used in the future.

A comparison of the acoustic spectrums associated with the cetaceans and the available sonar sensors found that the bulk of the cetacean species of interest to the CF have vocalizations that have spectral content in the 10 Hz to 100 KHz range with a few that vocalize in the 500 KHz to 800 KHz range. All of the sensors considered in this study operate within the lower 10 Hz to 100 KHZ band and therefore considerable overlap exists between the cetacean vocalizations bands and that which can be sensed acoustically. For this investigation, the sensors of most interest are the DIFAR (53) and its enhanced version (53F) because they are good candidates for monitoring both marine mammals and underwater contacts from the ship.

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The Systems Architecture Group at DRDC Atlantic has been exploring open system and open architecture approaches for developing and delivering new sonar system capabilities to the Canadian Navy for a number of years. These efforts have resulted in the development of unique technologies that have culminated in an integration framework known as the system test bed (STB). DRDC Atlantic has successfully used the STB to develop and demonstrate new underwater sonar systems as part of its maritime program that include the MSTDCL, PLEIADES, and IMPACT systems.

The focus of this investigation was to evaluate the potential of using the current advances in software defined radio (SDR) technologies to develop a new sonobuoy processor capable of processing all ninety-nine sonobuoy slots allocated within the current sonobuoy radio frequency transmission band. Furthermore, this study looks at what would be required to support a flexible mix of sonobuoy types in order to support future naval operations.

This report shows that a SDR approach that is augmented with the technologies of the STB should be more than capable of providing a full-band sonobuoy processing capability. Furthermore, the approach taken has the flexibility needed to accommodate a mix of sonobuoy types that are likely to be used by the Canadian Navy for the foreseeable future.

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