Implications of open architecture on naval platforms

Richard Cross and Anna-Liesa S. Lapinski
DRDC – Atlantic Research Centre

Defence Research and Development Canada

Scientific Report
DRDC-RDDC-2016-R217
October 2016

Abstract

This document studies the impacts of Open Architecture for the Royal Canadian Navy (RCN), in particular the implications of the scheduled end of life of Global Command and Control System – Maritime (GCCS-M). This is done by discussing the current GCCS-M system, evaluating other solutions and studying the current work being done by the RCN. The indications are that Open Architecture can have a generally positive impact but there are costs and risks as well.

Significance to defence and security

The current version of Global Command and Control System – Maritime (GCCS-M) 4.1 is scheduled for end of life. The expected replacement of GCCS-M in the United States is the Maritime Tactical Command and Control (MTC2) system, which utilizes an open architecture. This document discusses the implications for the RCN, both ashore and at sea, if implementing an open architecture, whether it is MTC2 or another open architecture solution.

Résumé

Dans le présent document, on analyse l'incidence de l'architecture ouverte sur la Marine royale canadienne (MRC), en particulier les répercussions de la fin de vie prévue du Système mondial de commandement et de contrôle – Maritime (GCCS-M). On fournit une description du système actuel de GCCS-M, une évaluation des autres solutions et une analyse des travaux menés actuellement par la MRC. Selon ce document, l'architecture ouverte peut avoir une influence générale positive, mais elle entraîne des coûts et des risques.

Importance pour la défense et la sécurité

La version actuelle du Système mondial de commandement et de contrôle – Maritime (GCCS-M) 4.1 arrive en fin de vie. Le système devant remplacer le GCCS-M aux États-Unis, le *Maritime Tactical Command and Control* (MTC2), utilise une architecture ouverte. On analyse les conséquences pour la MRC, à terre et en mer, de la mise en oeuvre d'une architecture ouverte, que ce soit le système MTC2 ou une autre solution.

Table of contents

Abstract . . . i
Significance to defence and security . . . i
Résumé . . . ii
Importance pour la défense et la sécurité . . . ii
Table of contents . . . iii
Acknowledgements . . . iv
1 Introduction . . . 1
1.1 Narrative . . . 2
2 Why replace GCCS-M . . . 3
2.1 Current circumstances being experienced by the RCN . . . 4
2.2 Lack of transparency . . . 4
2.3 Canadian needs . . . 5
2.4 GCCS-M support ending . . . 5
3 Relevant open architecture initiatives . . . 6
3.1 Current RCN work . . . 6
3.2 GCCS-M replacement in the United States . . . 6
3.3 GCCS-J (United States) . . . 6
3.4 Other examples . . . 7
3.5 Remarks . . . 7
4 General pros and cons of open architecture to the RCN . . . 8
4.1 Implications . . . 8
5 Specific benefits to the RCN from GCI+ and open architecture . . . 9
5.1 GCI+ . . . 9
5.2 Leveraging previous work and lessons learned . . . 10
6 Other considerations . . . 12
6.1 Security impacts if implementing an open architecture . . . 12
6.2 Virtualization . . . 12
6.3 Microservices . . . 13
7 Concluding remarks . . . 14
References . . . 15
List of symbols/abbreviations/acronyms/initialisms . . . 17

Acknowledgements

We would like to thank Scott Syms and his team at Base Information Services (BIS) for many informative discussions involving the current and future of information systems in the RCN.

1 Introduction

The Canadian Armed Forces (CAF) has the broad mandate to protect Canada, defend Canada's sovereignty, defend North America, and contribute to international peace and security on the global stage [1]. Systems that enable Command and Control (C2) represent a critical capability for the CAF and its services. The Global Command and Control System – Maritime (GCCS-M) is one such system. The RCN relies on GCCS-M for the creation, management, and distribution of a Recognized Maritime Picture (RMP). This picture may be considered a visual representation of operational information from a variety of sources. The picture includes all aspects of the maritime operating environment. The RMP is one piece that helps the RCN achieve C2 and ultimately help fulfill the CAF mandate.

In the RCN, GCCS-M provides the mechanism for developing and maintaining the RMP. On the mobile platforms, GCCS-M is used to visualize the local vessel traffic based on the ashore data sources. In the ashore operations centres, the RMP is assembled using a multitude of maritime data sources and authoritative vessel databases. GCCS-M is used, in part, to associate the data points available from the many sources, into a coherent and clutter-free representation of vessel traffic. Once assembled, the RMP represents the water component of Canadian maritime domain awareness (MDA).

GCCS-M is one of several GCCS products that are produced for the United States' armed forces. GCCS officially became the joint C2 system of record in 1996 [2]. The distributer of GCCS-M, Space and Naval Warfare Systems Command (US Navy) (SPAWAR), state that, "GCCS-M provides maritime commanders at all echelons with a single, integrated, and scalable Command and Control system. GCCS-M fuses, correlates, filters, maintains, and displays location and attribute information on friendly, hostile, and neutral land, sea, and air forces, and integrates this data with available intelligence and environmental information to support command decisions." [3]. The GCCS products have been periodically updated to keep them current. However, the US has begun development on a new system that would replace GCCS-M. The new system, Maritime Tactical Command and Control (MTC2), is being designed by SPAWAR to solve identified maritime C2 gaps. SPAWAR is taking advantage of modern architecture trends by developing MTC2 based on an open architecture software system model, which GCCS-M does not employ.

The Canadian Director of Naval Requirements (DNR) is presently investigating options to "upgrade the tactical Command and Control system for HMC Ships and Submarines and replace the GCCS-M V4.0.3" [4] Using GCCS-M has had its challenges. For example, Canadian vessels can deploy globally. Issues related to security of transmission, bandwidth, etc. affect the functional use of GCCS-M for C2 on the global stage. Also, the current Canadian release of GCCS-M requires considerable support [5]. The RCN has a number of options in light of the retirement of GCCS-M:

1. keep using GCCS-M while addressing identified requirements of the future C2 capability (i.e. allied interoperability) until the lack of GCCS-M updates and support requires a complete new solution;
2. replace GCCS-M with the US MTC2 system that is in development; or
3. select an alternative C2 capability.

Option 2 (and likely option 3) will employ an open architecture system model, which has fundamental differences with the current system being employed by GCCS-M. Therefore, it is important to investigate the implications of switching to an open architecture system on naval platforms and shore installations.

Open source refers to software for which the source code is available. This paper refers to open architecture's impact on the RCN not the impact of open source.

Open architecture can be defined as "vendor-independent, non-proprietary, computer system or device design based on official and/or popular standards. It allows all vendors (in competition with one another) to create add-on products that increase a system's (or device's) flexibility, functionality, interoperability, potential use, and useful life. [It also] enables the users to customize and extend a system's (or device's) capabilities to suit individual requirements" [2]. The term open architecture can be used for both hardware and software systems. When used to describe hardware, it denotes hardware that is not tied to particular software and that can be replaced with another vendor's hardware. For software, the term refers to individual software components that can be replaced, swapped out, or modified, that are independent of the other software within the system. Software components can be either open source or not. Given modern C2 trends that are utilizing an open architecture model, and the US indications of a future C2 system based on the open architecture model, the paper explores how an open architecture-based C2 system might impact present day challenges. Broadly speaking, these impacts are related to the benefits and downfalls of utilizing an open architecture model.

1.1 Narrative

The remainder of this paper discusses, "The Why" (Section 2), "The How" (Section 3), and "The Effects" (Sections 4, 5, and 6) of Open Architecture on the RCN.

Section 2 makes the case for the RCN to replace GCCS-M. It identifies the reasons for replacement including an inability to cope with current circumstances being experienced by the RCN, the inability to extend GCCS-M to meet new needs, the inability to move Canadian needs to the forefront, and the fact that GCCS-M support will end in the near future. The section goes on to explore these issues and makes the case for the replacement of GCCS-M.

Section 3 examines other software projects that have an RMP generation component. In particular, it notes the consensus that Open Architecture provides a good basis for a software platform for the generation of an RMP.

Section 4 studies the implications, both positive and negative, if the RCN were to adopt an open architecture. The result is generally favorable from the perspective of compatibility and ease of use. On the negative side, the financial and labour costs have to be considered.

Section 5 reviews the work on GCI+ and how it benefits the RCN, in particular GCI+ and its implementation of Open Architecture. A discussion of the value of the lessons learned developing GCI+ is included to demonstrate the work done.

Section 6 discusses issues separate from architecture that would be affected by the choice of an open architecture system. Security, virtualization, and microservices are examined.

Section 7 provides the concluding remarks.

2 Why replace GCCS-M

The previous section lists three courses of action that the RCN will have to choose from to address the near future replacement of GCCS-M in the US with MTC2. The first option is to replace GCCS-M only when it becomes critical to do so. This section lays out some reasons why the RCN would benefit from not choosing option 1 and how they would benefit from taking the current opportunity to replace GCCS-M completely.

Four basic conditions lead one to consider the replacement of GCCS-M within the RCN. These conditions are:

1. The inability to cope with current circumstances being experienced by the RCN.
2. The lack of transparency regarding the software system. Lack of transparency limits understanding and the ability to modify the software system. The limitation results in the inability to extend the platform to meet new RCN needs.
3. The inability to move Canadian needs to the forefront of development.
4. That GCCS-M support will end in the near future.

Changes to the RCN operating environment help illustrate how these conditions have become important[1].

Over the past 15 years, there has been a dramatic increase of the amount of automatically generated ship information available to feed the RMP. In 2000, the International Maritime Organization (IMO) raised a new requirement for certain ships to carry automatic identification systems (AISs) transmitters. The international maritime safety treaty from the International Convention for Safety of Life at Sea (SOLAS) implemented this requirement. The requirement came into effect at the end of 2004.

AIS shares identity and course information with nearby ships and coastal receivers automatically. As AIS was installed, it soon became evident that this was a valuable source of information for building the RMP. It not only provided ship location, but also ship name and other metadata about the ship.

Over time, it was discovered that the AIS transmissions could be collected by AIS receivers attached to Low Earth Orbiting Satellites. This essentially opened the door to obtaining a global picture of AIS carrying vessels. Space-based AIS allows for coverage of areas beyond the range of littoral-based receivers, as well as areas with no littoral-based receivers.

The value of AIS information has led to both government and privately funded initiatives to collect AIS information; for instance, the coastal Canadian Coast Guard National AIS system, and the Space-based AIS collection services sold by exactEarth and ORBCom. AIS has contributed to a significant increase in vessel information fed to the RMP. The Coast Guard National AIS

[1] Note: the focus of this report is on the implications of the GCCS-M follow-on system being an open architecture system. We illustrate here only one issue that highlights the four conditions that exist for considering a replacement for GCCS-M. It should not be seen as the only issue.

system can process 2000 reports a minute and have an update interval as short as two seconds [6]. exactEarth can provide multiple reports on 110,000 vessels [7] daily.

On one day in January 2014, AIS reports made up 99% of the 13 million position reports flowing into the recognized maritime picture [8]. The remaining 1% would represent what was available before AIS. This gives an example of the significant increase in data available to the COP since AIS was mandated.

In modern terminology, 13 million position reports per day, with accompanying metadata, create a “big data” set. It has caused a big data problem for the RCN’s legacy RMP applications. Side effects of the problem can help illustrate how the four conditions above lead one to consider the replacement of GCCS-M within the RCN.

2.1 Current circumstances being experienced by the RCN

GCCS-M 4.0.3 has a maximum track limit, which is less than the incoming raw data volumes that the RCN is collecting. A work around is in place (see Sections 3.1, 5.1) that filters the amount of data provided to the operator. As a result, the operator is not provided all the data that are collected.

It is also reasonable to expect that additional data sources will be made available in the future, which will compound the existing problem. The modern information volumes available for building the RMP are already tasking the system and are likely to increase. As the Navy looks forward to the GCCS-M follow-on, a system that can handle current and future “big data” information volumes would be ideal. This will allow the operators to have access again to all available data through their RMP generating system.

It should be noted that the track limit will be removed in GCCS-M version 4.1.1. This may or may not solve this problem. However, the next two conditions show how being at the mercy of the system developers of a closed system is not in an ideal situation.

2.2 Lack of transparency

In Halifax, the Navy’s BIS Vessel Monitoring Support provides software mitigation and new capability around the RMP. Since GCCS-M is a closed system, VMS has not been able to modify the core software to solve the problem of sending big data through GCCS-M without a work-around. GCCS-M customization involves the configuration of definitions to determine which segments and how much of the Common Operating Environment (COE) to load [9].

Canada maintains experts in the installation and maintenance of GCCS-M, but there does not appear to be many resources that have the know-how, or ability, to modify the GCCS-M source. The lack of transparency issue is not only an issue regarding the increase in data noted above but also whenever GCCS-M is behaving in a manner that does not meet the RCN’s needs. For example, GCCS-M 4.0.3 has issues with stability, data quality, and usability (limited windows compatibility). The RCN has been waiting two years for a new version of GCCS-M [5]. In addition, GCCS-M does not conform to modern Open Architecture standards such as Java Messaging Service (JMS) for communication and JavaScript Object Notation (JSON) for data objects.

2.3 Canadian needs

Since the RCN is unable to modify the source for GCCS-M to solve their big data problem, Canada is dependent upon the US for upgrades and support of the core GCCS-M product. In the past, this has caused issues and delays. Switching to a system that allows the RCN to modify their own system to meet their own needs would be of benefit to the RCN. This is true whether the issues are big data issues or other issues not yet encountered.

2.4 GCCS-M support ending

GCCS-M is scheduled for end of life. If, while being supported, Canada is having trouble with GCCS-M due to our big data problem (for example), then it is logical to expect compounded problems when it is not supported. When GCCS-M ceases to be supported, it will be equivalent to the common experience of one's computer or mobile device having an operating system that is older than the current version. While the system will work as it has in the past, for the first while, there will come a time when the evolution of modern technology and/or the evolution of the user needs will make the system obsolete. If there is an opportunity to modernize the current C2 system, to keep step with current C2 technology trends, it would advantageous to the RCN to do so before the need becomes critical. The big data issues that are already present reinforce this recommendation.

3 Relevant open architecture initiatives

The development teams described below are currently working on software systems that have an RMP component. They have concluded that the use of an open architecture is a good choice for their solutions. This approach is expected to influence the RCN and the RCN's choice for its GCCS-M follow-on. This section outlines some relevant open architecture initiatives to demonstrate its widespread use in relevant situations.

3.1 Current RCN work

As mentioned earlier, there has been a significant increase in ship information available to the RMP and a track limit imposed in GCCS-M. To address these challenges, work by BIS on GCCS Canadian Interface Plus (GCI+) was undertaken. The goal was to both improve the quality and to control the amount of data being sent to GCCS-M. BIS had to develop a solution to manage the data before they were sent to GCCS-M. Effectively, this undertaking was intended to limit the data being consumed by GCCS-M, thereby avoiding its inability to cope with current conditions. Specific limitations being avoided are related to data association to form vessel tracks and limits on the number of tracks.

GCI+ is an open architecture solution. BIS evaluated what software paradigm would best suit their needs and arrived at the conclusion that open software in an open architecture offered the best technical solution for current and future operational needs. In Section 5 we outline some benefits of this choice.

3.2 GCCS-M replacement in the United States

In preparation for the end of life of GCCS-M, the US began development efforts for a replacement. First, a proof of concept was developed called the Command and Control Rapid Prototyping Continuum (C2RPC). Following the testing of C2RPC, the lessons learned and user feedback were used to begin a new development: the Maritime Tactical C2 (MTC2) system. The MTC2 project's scope is broader than that of BIS's GCI+. As such, the MTC2 project is using software tools geared towards an Enterprise level production environment. MTC2 is currently in definition and early development but the decision to build using an open paradigm has been made.

If MTC2 is developed according to current US plans, then there are already beneficial compatibilities with GCI+ that can be exploited. After discussions with MTC2 technical staff it has become clear that their architecture solution is remarkably similar to the solution developed by BIS for GCI+ [10].

3.3 GCCS-J (United States)

The Global Command and Control System – Joint (GCCS-J) is also moving towards a more open and network-centric architecture [11]. The move from what is known as Block IV of the base code to Block V began the migration from the Common Operating Environment (COE) kernel to a new kernel. The COE kernel was client server based. The new kernel is transitioning to Web

Services and Service Oriented Architecture (SOA), which is an open architecture. The more open and network-centric architecture they are considering would have the advantages and disadvantages as described later in this paper.

3.4 Other examples

While the previous examples are based on modern uses of open architecture, the US Navy switched to an open architecture design philosophy and business model for their sonar combat systems in the 1990s. In spring 2008, Capt. Jim Stevens, the Tactical Systems Integration Branch Head of the Submarine Warfare Division (N87), published an article on why the USN made the switch, and how they were utilizing the benefits of such a design [12]. The following summarizes the highlights of that article.

The why: using the typical closed architecture/closed business model, that has software tied to hardware, was causing the systems to be obsolete in performance by the time they were installed. In addition, the cost of repair and maintenance was too expensive given that the processors installed were obsolete by the time they were put in. In order to respond to the constantly evolving threat, they had to switch to a new model that allowed their system to keep pace. The Acoustic Rapid COTS Insertion program (ARCI) was introduced. They instigated an open architecture/open business model system, where software was developed independently from the hardware. This allowed software and hardware to keep pace with the modern capabilities.

The how: new capabilities for the submarines were based on fleet-driven requirements. Once a requirement was determined, proposals were solicited to develop the software solution. This was a significant shift: the software application development was open to the best candidate for the job, something using an open architecture model allowed for. Once the algorithms were tested and deemed fit to be inserted, the new software was placed in the next software build. There was a new software build produced with added capabilities every odd year. The even year software builds only supported new hardware. A schedule was set for software and hardware updates so that the submarines could stay up to date.

In addition to the change in business model, the change to an open architecture model made it easier and more cost effective to update capabilities. At the time of the article, the program was deemed a success for improving performance of the submarine sonar combat systems in a timely fashion, as well as keeping costs down.

3.5 Remarks

These are just a few relevant examples of open architecture use. Open architecture is a noted trend in RMP generating systems. The benefits (and drawbacks) of open architecture systems will be discussed in the remaining sections.

4 General pros and cons of open architecture to the RCN

The previous section has shown that military and commercial vendors are choosing to build tools on open source components, to address needs relevant to the RCN. To identify the implications of switching to an open architecture system, it is important to note the pros and cons for an open architecture model. For example:

- Pro: An adoption of open architectures would allow for the use of standard COTS hardware, which could reduce the cost to the RCN. Closed systems or architectures tie the RCN to not only the software but usually to the hardware configuration for that software.
- Pro: Open architecture systems are a main area of focus in the private sector. The private sector has invested large amounts of capital in the development of tools and in research for open systems. The RCN could leverage this investment by the private sector to provide robust solutions at a reasonable cost.
- Pro: The RCN can be called upon to perform a wide variety of missions. The use of an open architecture could allow an increase in flexibility and a decrease in time to implement mission fit solutions. If the RCN adopts open architecture, it would allow for ease of integration of existing open tools. This would give a wider variety of tools available and thus increased flexibility. The time to integrate these tools would be less than in a stove pipe solution and decrease the time to implement.
- Pro: An open architecture based on messaging would allow for the optimization of bandwidth to naval platforms. The COP transmitted to a particular platform could be optimized so only information relevant to that platform would need to be transmitted. This could be based on geographic criteria for the platform or be customized for mission fit.
- Pro: The modularity of an open architecture would allow for testing of components outside of the completed system. Faults could be caught earlier resulting in a lower cost for testing and a higher reliability for the completed system.
- Con/Pro: While an open architecture allows for multiple developers to work on a system, “interfaces such as file formats, message files and databases must be saved in a form that allows them to be accurately described and easily processed by other tools” [13]. While some may see this as a disadvantage, it will force the RCN to have artifacts describing the internals of a working system.
- Con: The switch to open architecture represents a significant change from the existing software baseline of GCCS-M. As such, there will be some effort associated with this switch. The cost of this effort may be more significant than providing a quick fix for the problems of the day.
- Con: Running an open architecture will require management of the network and its configuration. The ongoing management will have a cost associated with it.

4.1 Implications

There are both positive and negative aspects to switching to an open architecture system. The standout implications of going with an open architecture are the compatibility and ease of change that it will allow in the future. The primary negative aspects will be the initial cost and labour to affect the switch. Specific benefits to the RCN will be discussed in the following sections.

5 Specific benefits to the RCN from GCI+ and open architecture

The previous section identified general pros and cons of open architecture. This section summarizes specific benefits to the RCN from current development involving open architecture.

5.1 GCI+

Halifax BIS has implemented an open architecture solution to the GCCS-M big data issue, via GCI+. This has allowed some desirable technical features to be enabled. The following is a selection to demonstrate the benefits of an open architecture system:

- BIS implemented a Java Messaging System (JMS) that allows the distributed software components to be loosely coupled and pass messages reliably and asynchronously. The exchange of the messages is the mechanism by which data are passed between the software components. The advantages of messaging include solving "many architectural challenges such as heterogeneous integration, scalability, system bottlenecks, … , and overall architecture flexibility and agility" [14].
    - An increase in scalability can be achieved by allowing multiple messaging processors for the handling of more messages. Further, if more processing power is required, software components can be allocated across multiple processors using messaging to communicate.
    - System bottlenecks can be identified and reduced. Rather than connecting and sending data to each naval platform, it is intended for a single message to be sent to the messaging system. The messaging system can then decide how to deliver the data to all the appropriate naval platforms. A message-managing algorithm reduces the chance of bottlenecks. Using performance-monitoring software, components can be identified that are restricting the performance of the system as a whole. The behaviour can then be modified to lessen the impact on the system.
    - Improved flexibility and agility mean an improved ability to respond more quickly to change. The developer only has to implement messaging to be able to communicate with the open system. Thus, they are free to develop their software platform in whatever language and system they wish. This permits the integration of heterogeneous platforms. By implementing messaging software, platforms can be swapped out for others as long as they support the same messaging. This allows the system to be more responsive to change.
- BIS continued the use of open standards by encoding data using Java Script Object Notation (JSON). JSON has an attribute value pair structure and is an alternative to XML. Data received to be incorporated into the RMP are translated into JSON, placed in a JMS message, and passed between software components. Although the JSON abbreviation mentions Java Script it is an accepted open standard for the transmission of data. JSON has several advantages over XML in the context of processing data. For example, data represented in JSON is smaller than the same data represented in XML [15]. It is also quicker to process JSON messages [15] due to their simpler syntax. The smaller size of

JSON data will also reduce the amount of bandwidth required by the system. The disadvantage of JSON is that because it is an attribute pair structure, the representation of complex types becomes more difficult.

- The recording of data to files and databases for future use is termed persistence. To achieve data persistence BIS selected a combination of PostgreSQL, for short-term SQL storage, and MongoDB, for long-term NoSQL storage. PostgreSQL is free and open source software implementing an SQL database. MongoDB is free and open software under the GNU Affero General Public License. MongoDB is a NoSQL database based on JSON like documents. An advantage[2] of NoSQL over traditional SQL databases is the ability to handle big data, or "enormous quantities of semi-structured data" [16]. The downside of choosing a NoSQL solution over SQL is that SQL databases adhere to the ACID (Atomic | Consistence | Isolated | Durable) properties to maintain data integrity [16]. NoSQL databases only support two of the CAP (Consistency | Availability | Partition Tolerance) properties [16]. The result is that in order to achieve usability of the large amounts of data, there may be issues with the data integrity. MongoDB provides the open architecture back end to BIS's solution for the GCI+. The GCI+ solution also contains open architecture/source components for source code control, build management, and data routing.

These features of GCI+ have been made possible by using an open architecture. The features provide examples of the types of benefits an open architecture can bring the RCN. It also highlights features of GCI+, if it becomes part of the GCCS-M follow-on system.

5.2 Leveraging previous work and lessons learned

RCN investment and effort can be built upon, if an open architecture system is utilized. Investment has already been made to develop the open architecture based GCI+ project. If the RCN were to move to a more open architecture after GCCS-M, the GCI+ work could be leveraged:

- The effort spent keeping GCCS-M operational with the GCI+ work was done in such a manner as to likely make it compatible with MTC2 or most open architectures.
- The following improvements could be leveraged by an open architecture system, if required:
  - GCI+ is reaching a level of maturity that it replaces some, or improves upon, some of the functionality provided by GCCS-M.
  - In terms of persistence, GCI+ currently persists more data than the current version of GCCS-M. This model for, and implementation of, persistence could be implemented in an open architecture system.
  - The data cleaning of GCI+ is under control of the RCN. Therefore, it can be customized to meet Canada's needs.

[2] Note that further research into the pros and cons of NoSQL and SQL databases, from the perspective of the needs of the RCN, is taking place.

Besides leveraging existing experience and technology, lessons from the past can also be leveraged. For example, an open architecture system would have bypassed two significant issues from the recent past, if implemented sooner:

- The work required for the GCI+ project would not have been required if an open architecture had been in place. The main driving force for the development of GCI+ was the track limit in version 4.03 of GCCS-M. In an open architecture, a different persistence engine could be substituted to overcome performance shortcomings. In this case, GCCS-M is a stove pipe that the RCN has little ability to modify to meet their goals. If the RCN were to move to a more open architecture, it would be less susceptible to similar restrictions in the future.
- In the past, eXtensible COP (XCOP) was a project proposed as a GCCS-M replacement. After time and development efforts were spent working with XCOP, the project was found to be an insufficient replacement for GCCS-M by the RCN. If the RCN were to move to a more open architecture, then it would be less susceptible to changes in systems that are out of RCN control.

6 Other considerations

6.1 Security impacts if implementing an open architecture

Any open architecture deployed by the RCN would be exposed to security risks from feeder systems, exposure to the internet on the unclassified environment, and, if for mission fit, an ally nation or friendly was given access.

The three main concerns with security in an open architecture are: authentication, authorization, and secure communication [14]:

- *Authentication* verifies that a user connecting to the open architecture is who they claim to be. An example of this would be a username and password. The simplest form of authentication is to use a username/password model.
- *Authorization* identifies what the user is allowed to do once authenticated on the system. This can limit the data they can access or what data they can provide.
- *Secure communication* ensures that information is passed in the manner required for the security level of the content.

If a JMS system for passing messages is used, like the one used currently in GCI+, other forms of authentication are available from JMS providers such public key or secret key authentication, if required. Various JMS vendors can also provide the required levels of authorization. Regarding the third concern, the RCN has all the mechanisms to provide secure communication.

Given the closed nature of the RCN's system, the security implications of moving to an open architecture are not expected to introduce any unusual problems. Authentication, authorization, and secure communication are common components of securing a military system.

6.2 Virtualization

Virtualization is the process of abstracting the operating system and software running on a configured machine to one software package that can be run with a virtual machine player. To the user it appears as a real instance of hardware and software. For the RCN the result could be cost savings in the configurations of installations both ashore and at sea. This section introduces how an open architecture system would enable the use of virtualization to help the RCN with configuration and maintenance of onboard and ashore systems. If this is an RCN requirement, this would be a benefit of an open architecture system. However, there is a performance cost that needs to be accounted for if employing virtualization, as is outlined below.

Virtualization is not specific to open architecture but is frequently used in open systems to manage components within the open system. It is sometimes referred to as Platform as a Service (PaaS). VMPlayer is used in the BIS system, though BIS may be changing their PaaS in the future. Red Hat Openshift and other products are available to provide COTS solutions for PaaS.

The process of virtualization can help the RCN with configuration and maintenance of onboard and ashore systems. For training and operation needs, preconfigured systems could be stored and started onboard, as needed. Ashore, systems could be started based on user needs and the needs of the operation centre.

Performance can be monitored and optimized in a virtualized environment. PaaS systems generally provide monitoring tools so that the administrator can see which processes are consuming more or less computing power. The administrator can allocate additional resources to those processes that require them and fewer resources to those processes that do not require them. This allows for better performance and better utilization of the resources available. Performance can also be easily improved with the addition of further computing resources and in a virtualized environment processes can easily be allocated to these new resources.

Although performance can be monitored and optimized, there is still a performance cost of running virtual machines [17]. Access to physical components of the hardware used for communications, memory, etc. have a cost and this cost will be higher in a virtual environment. The resulting degradation of performance can be minimized by monitoring the virtualized environment and allocating hardware to those virtual machines that require it to perform their functions. Therefore, while virtualization has its benefits, a performance cost needs to be managed.

6.3 Microservices

Although not an initial goal in developing GCI+, the team has adopted the microservice architecture model. “Microservice architecture is a method of developing software applications as a suite of independently deployable, small, modular services in which each service runs a unique process and communicates through a well-defined, lightweight mechanism to serve a business goal” [18]. In other words, rather than develop one large service, many smaller services are built and connected. Websites such as Netflix, Amazon, and eBay have also adopted the microservice architecture [19]. If the RCN were to select a GCCS-M replacement that implemented a microservice architecture it would be able to leverage the advantages of microservices which are:

- small with an easy to understand code base;
- easy to scale;
- easy to throw away;
- easy to deploy;
- able to use a different technology stack for each service; and
- system resilient [20].

7 Concluding remarks

Choosing an open architecture system to replace GCCS-M would continue the trend of modern system development both nationally and internationally. The implication of choosing an open architecture system has both positive and negative aspects. Initial cost and labour would be the primary upfront negatives. There are technical downsides as well depending on which configuration is used, but all technical solutions will have their limitations. The object is to pick technical solutions that have minimal downside for the task. What the RCN gains from an open architecture system is compatibility, freedom, and ease of change, as their needs evolve. For the near future, they also get to evolve the system as technology evolves. An open architecture enables Virtualization that has its own benefits to the RCN. The long-term implications of switching to an open architecture system, when GCCS-M is replaced, seem to be positive.

While not the focus of this report, it should be noted that there currently exists an opportunity to minimize the future difficulty interfacing GCI+ and MTC2 after development is complete, assuming GCI+ is still being utilized as part of the GCCS-M follow-on solution. GCI+ and MTC2 are expected to use similar architectures, both systems will be dealing with similar data and both are currently under development. If an effort is made to standardize the data model used by the systems, then the systems could interface easily. This could result in significant savings in development effort for the RCN.

References

[1] Canadian Armed Forces (27 Jan 2016), National Defence and the Canadian Armed Forces (online), http://www.forces.gc.ca/en/about/canadian-armed-forces.page (Access date: 17 March 2016).

[2] Director Operational Test & Evaluation (1998), FY98 Annual Report: Global Command and Control System (GCCS) (online), GlobalSecurity.org, http://www.globalsecurity.org/military/library/budget/fy1998/dot-e/other/98gccs.html (Access date: 9 June 2016).

[3] Global Command and Control System – Maritime (GCCS-M) (online), SPAWAR, http://www.public.navy.mil/spawar/productsServices/Pages/GlobalCommandandControlSystem-Maritime(GCCS-M).aspx (Access date: 21 October 2016).

[4] Maritime Tactical Command and Control (online), National Defence and the Canadian Armed Forces, http://www.forces.gc.ca/en/business-defence-acquisition-guide-2015/naval-systems-995.page (Access date: 09 October 2015).

[5] Syms, S. (2016), N631– GCCS-M (presentation), From the Program Management Review meeting, 19–21 April 2016, San Diego, CA, USA.

[6] Automatic Identification System (AIS) (online), Canadian Coast Guard, http://www.ccg-gcc.gc.ca/eng/CCG/Maritime-Security/AIS (Access date: 15 October 2015).

[7] exactAIS Premium Product Information (online), exactEarth, http://main.exactearth.com/prodinfo-exactais-premium (Access date: 15 October 2015).

[8] Syms, S. (2014), Personal Communication.

[9] Northrop Grumman Corporation. (2002), COE 4.7 developers course, 2–12.

[10] GCCS-M Program Review Meeting (2015), Discussion (personal communication).

[11] Kenyon, H.S. (2009), Global Command and Control Rebooted, *SIGNAL Magazine*, November 2009.

[12] Stevens, J., Capt. (2008), The How and Why of Open Architecture, *Undersea Warfare* (37).

[13] Wasserman, A.I. and Pircher, P.A. (1989), The Open Architecture of the Software through Pictures Environment, In M.V. Zelkowitz (Ed.), *Requirements for a Software Engineering Environment*, pp. 150, Intellect Ltd.

[14] Richards, M., Monson-Haefel, R. and Chappell, D.A. (2009), Java Message Service, 2nd Edition, O'Reilly Media, pp. 3–5, pp. 222–223.

[15] Markup Languages: What are the advantages of JSON over XML? (online), Quora, https://www.quora.com/Markup-Languages/What-are-the-advantages-of-JSON-over-XML (Access date: 15 October 2015).

[16] Basu, S. (5 Nov 2014), Red Pill or Blue Pill? Choosing Between SQL & NoSQL (online), Telerik Developer Network, http://developer.telerik.com/featured/decide-neo-blue-pill-red-pill/ (Access date: 15 October 2015).

[17] Drepper, U. (2008), The Cost of Virtualization, *Virtualization* (electronic journal), Volume 6, issue 1. https://queue.acm.org/detail.cfm?id=1348591 (Access date: 15 October 2015).

[18] Huston, T. What is Microservices Architecture? (online), SMARTBEAR, https://smartbear.com/learn/api-design/what-are-microservices/ (Access date: 6 October 2016).

[19] Richardson, C. Pattern: Microservices Architecture (online), microservices.io, http://microservices.io/patterns/microservices.html (Access date: 6 October 2016).

[20] Dvorkin, E. Seven micro-services architecture advantages (online), http://eugenedvorkin.com/seven-micro-services-architecture-advantages/ (Access date: 6 October 2016).

List of symbols/abbreviations/acronyms/initialisms

ACID	Atomic | Consistence | Isolated | Durable
AIS	Automatic Identification System
ARCI	Acoustic Rapid COTS Insertion program
BIS	Base Information Services
C2	Command and Control
C2RPC	Command and Control Rapid Prototyping Continuum
CAF	Canadian Armed Forces
CAP	Consistency | Availability | Partition Tolerance
COE	Common Operating Environment
COP	Common Operating Picture
DNR	Director of Naval Requirements
DRDC	Defence Research and Development Canada
GCCS-J	Global Command and Control System – Joint
GCCS-M	Global Command and Control System – Maritime
GCI+	GCCS Canadian Interface Plus
IMO	International Maritime Organization
JMS	Java Messaging Service
JSON	JavaScript Object Notation
MDA	Maritime Domain Awareness
MTC2	Maritime Tactical Command and Control
PaaS	Platform as a Service
RCN	Royal Canadian Navy
RMP	Recognized Maritime Picture
SOA	Service Oriented Architecture
SOLAS	Safety of Life at Sea
SPAWAR	Space and Naval Warfare Systems Command (US Navy)
XCOP	eXtensible COP

This page intentionally left blank.

DOCUMENT CONTROL DATA

(Security markings for the title, abstract and indexing annotation must be entered when the document is Classified or Designated)

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.)

   DRDC – Atlantic Research Centre
   Defence Research and Development Canada
   9 Grove Street
   P.O. Box 1012
   Dartmouth, Nova Scotia B2Y 3Z7
   Canada

2a. SECURITY MARKING (Overall security marking of the document including special supplemental markings if applicable.)

   UNCLASSIFIED

2b. CONTROLLED GOODS

   (NON-CONTROLLED GOODS)
   DMC A
   REVIEW: GCEC DECEMBER 2013

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.)

   Implications of open architecture on naval platforms

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

   Cross, R.; Lapinski, A.-L.

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

   October 2016

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

   26

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

   20

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.)

   Scientific Report

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

   DRDC – Atlantic Research Centre
   Defence Research and Development Canada
   9 Grove Street
   P.O. Box 1012
   Dartmouth, Nova Scotia 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.)

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-RDDC-2016-R217

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.)

   Unlimited

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), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

This document studies the impacts of Open Architecture for the Royal Canadian Navy (RCN), in particular the implications of the scheduled end of life of Global Command and Control System – Maritime (GCCS-M). This is done by discussing the current GCCS-M system, evaluating other solutions and studying the current work being done by the RCN. The indications are that Open Architecture can have a generally positive impact but there are costs and risks as well.

Dans le présent document, on analyse l'incidence de l'architecture ouverte sur la Marine royale canadienne (MRC), en particulier les répercussions de la fin de vie prévue du Système mondial de commandement et de contrôle – Maritime (GCCS-M). On fournit une description du système actuel de GCCS-M, une évaluation des autres solutions et une analyse des travaux menés actuellement par la MRC. Selon ce document, l'architecture ouverte peut avoir une influence générale positive, mais elle entraîne des coûts et des risques.

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.)

open architecture; operational; command