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DATA STRATEGY AND DATA DESIGN FOR UNCLASSIFIED MARITIME DOMAIN AWARENESS

by

Soon Hee Samuel Ng and Vincent A. Mosley

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Thesis Advisor:	Dan C. Boger
Co-Advisor:	Scot A. Miller
Second Reader:	Robert C. Schroeder

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The Naval Postgraduate School Information Sciences Department is executing a multi-year campaign of integrated thesis research to explore issues, and develop ideas and concepts of operations (CONOPS), related to formalizing unclassified maritime domain awareness (MDA). This is the third thesis in this campaign.

The first thesis in 2016 developed the CONOPS to leverage unclassified, sharable commercial satellite imagery in support of the United States' Southeast Asia Maritime Security Initiative. A second thesis in 2017 developed an experiment plan for use in SEACAT 2018, a multilateral MDA information-sharing exercise held in the South China Sea region.

This thesis leverages the recommendations from the previous theses to evaluate the effectiveness of SeaVision as compared to other platforms, and examine the usefulness of social network analysis (SNA) to uncover dark networks in MDA. To evaluate SeaVision's effectiveness, the authors use a quantitative approach that examines the variables for 59 sanctioned vessels designated by the UN for the Democratic People's Republic of Korea. To examine the usefulness of SNA to uncover dark networks, they use the same set of sanctioned vessels, and 67 non-sanctioned ones associated with any of the 271 companies affiliated with the sanctioned vessels. The authors further propose an information strategy that can uncover the dark network of an unclassified MDA so that this information can be used by and shared with international partners.

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DATA STRATEGY AND DATA DESIGN FOR UNCLASSIFIED MARITIME DOMAIN AWARENESS

Soon Hee Samuel Ng
Major, Republic of Singapore Navy
BEE, Nanyang Technological University, 2007

Vincent A. Mosley
Chief Warrant Officer 4, United States Army
BS, University of Maryland University College, 2009
MS, University of Maryland University College, 2016

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requirements for the degree of

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NAVAL POSTGRADUATE SCHOOL
March 2019

Approved by: Dan C. Boger
Advisor

Scot A. Miller
Co-Advisor

Robert C. Schroeder
Second Reader

Dan C. Boger
Chair, Department of Information Sciences

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LIST OF ACRONYMS AND ABBREVIATIONS

ABM	Agent-Based Model
AIS	Automated Identification System
APP	Application
ASEAN	Association of Southeast Asian Nations
CASOS	Center for Computational Analysis of Social and Organizational Systems
CONOPS	Concept of Operations
COP	Common Operating Platforms
COTS	Commercial-off-the-Shelf
CSV	Comma-Separated Values
DA	Defense Analysis
DoD	Department of Defense
DoN	Department of Navy
DPRK	Democratic People's Republic of Korea
EEZ	Exclusive Economic Zone
EIA	Energy Information Administration
GIG	Global Information Grid
LRIT	Long-Range Identification and Tracking
IMO	International Maritime Organization
ISR	Intelligence, Surveillance and Reconnaissance
MDA	Maritime Domain Awareness
MMSI	Maritime Mobile Service Identity
MoU	Memorandum of Understanding
MSI	Maritime Security Initiative
MSSIS	Maritime Safety and Security Information System
NCIS	Naval Criminal Investigative Service
NGA	National Geospatial-Intelligence Agency
NMCOP	National Maritime Common Operational Picture
NMIC	National Maritime Intelligence Center
NSMS	National Strategy for Maritime Strategy

OCR	Optical Character Recognition
ONI	Office of Naval Intelligence
ORA	Organizational Risk Analyzer
PRC	People's Republic of China
RADAR	Radio Detection and Ranging
RMSA	Regional Maritime Situational Awareness
RSM	Random Subgraph Model
S2A	Sealink Advanced Analysis
SA	Situation Awareness
SAR	Synthetic Aperture Radar
SBM	Stochastic Block Model
SCS	South China Sea
SNA	Social Network Analysis
SPOTR	Surveillance, Persistent Observation, and Target Recognition
TSC	Theater Security Cooperation
UAV	Unmanned Aerial Vehicle
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNCTAD	United Nations Conference on Trade and Development
UNSC	United Nations Security Council
USN	United States Navy
VHF	Very High Frequency
VMS	Vessel Monitoring Systems
VOI	Vessels of Interest
VRMTC	Virtual Regional Maritime Traffic Centre

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I. INTRODUCTION

Maritime domain awareness (MDA) is defined by the International Maritime Organization (IMO) as "the effective understanding of anything associated with the maritime domain that could impact the security, safety, economy, or environment" (White House, 2013, p. 10). MDA includes "all areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, vessels, and other conveyances" (White House, 2013, p. 11). The U.S. Department of Navy (DoN) has been actively engaged in tracking vessels of interest (VOI) in the maritime domain in support of global security and the United Nations (UN) sanctions on the Democratic People's Republic of Korea (DPRK).

In 2005, the President of the United States approved the National Strategy for Maritime Security (NSMS) plan, which mandated all U.S. government agencies and departments to make improvements to organic processes and capabilities. The purpose was to fully safeguard crucial U.S. national security interests across the maritime domain (White House, 2013). Operators make use of common information systems and processes, such as common operating platforms (COP) and databases, to share information with maritime authorities, from collection to analysis and dissemination (Lavoie & Wreski, 2017). It is important, therefore, to overcome the inherent complexity of sharing critical data within the Department of Defense (DoD) Global Information Grid (GIG) between appropriate federal, state, and international mission partners and civilian partners. For this purpose, the DoN has taken the lead through ongoing research to establish an unclassified joint informational environment by combining "commercial-off-the-shelf (COTS) intelligence, surveillance and reconnaissance (ISR) capabilities to build a comprehensive COP" (Lavoie & Wreski, 2017, p. 1). The ultimate goal is to provide a dynamic combination of technological systems, networks, people, and services that will empower commanders, host nations, and commercial carriers with the ability to identify suspicious activities while neutralizing non-traditional threats.

A. PROBLEM

A well-shared MDA starts with establishing a COP with like-minded national and international partners. Currently, most of these COP leverage automatic information systems as the track-development agent. Emerging computer vision technologies, applied to video, imagery, and even to coastal synthetic aperture radar, have been added to these COP so that they can offer different and better methods of tracking, assurance, and redundancy. The United States Navy (USN) currently uses web-based COP (SeaVision) when working with international partners for MDA-related operations or exercises. COP such as MyShipTracking and MarineTraffic offer similar capabilities.

Furthermore, COP could only show where a VOI was located geographically using Automated Identification System (AIS) data; the VOI's navigation status, such as whether is it at anchor or underway; or its course and speed. VOIs operating illicit activities, however, might turn off their AIS and avoid coastal radar detection, so that the enforcement authorities would not track them. Uncovering these VOIs required additional efforts based on intelligence cueing, allowing investigators to focus their search on a particular area or group of suspicious vessels.

Lastly, these networks and systems for sharing MDA data are mostly component-centric and lack interoperability with other departments or agencies (MarineTraffic, n.d.c). International stakeholders also often exhibit a "silo mentality," in that they do not share information willingly. Decision makers rely heavily on timely and accurate information sharing, on the other hand, to anticipate threats such as overfishing, weapons, drugs, and contraband smuggling; terrorism; illegal immigration; and military actions (MarineTraffic, n.d.b). Barriers to MDA communication hinder the security and processes critical to move resources without disruption and allow the global capital markets to expand and blossom.

B. PURPOSE

Previous thesis research at the Naval Postgraduate School (NPS) developed the concept of operations (CONOPS) in 2016 to leverage unclassified, sharable commercial satellite-derived imagery in support of the United States' Southeast Asia Maritime Security Initiative (MSI) (Lavoie & Wreski, 2017). A second thesis in 2017 developed an experiment plan to use SeaVision as the COP of choice, in SEACAT 2018, a multilateral MDA information sharing exercise held in the South China Sea (SCS) region (Greenway & Sipes, 2018). Separately, the Defense Analysis (DA) Department at NPS also worked on MDA-related topics and used social networking analysis (SNA) and various sources of maritime information to develop the Gray MDA networks in the SCS (Porter et al., 2017; Sollish, 2017). The present thesis leverages the recommendations from the last two theses to evaluate the effectiveness of SeaVision as the COP, as compared to other web-based applications, as well as propose an information strategy to incorporate SNA, enabling the discovery of the dark network within unclassified MDA.

This thesis first evaluates the effectiveness of SeaVision against that of MyShipTracking and MarineTraffic, the other commonly used MDA COP. To conduct the evaluation, the thesis research uses the list of 59 UN sanctioned vessels designated for the DPRK by the UN Security Council. The purpose of the evaluation is to determine whether additional resources are necessary to improve the current usability and capability of SeaVision.

The next section of this thesis employs SNA to examine the network of the 59 sanctioned vessels together with their affiliated companies to find other non-sanctioned vessels under these affiliated companies and to uncover the dark networks associated with the DPRK. Uncovering the associations between suspicious vessels, their companies, and the subsequent VOIs ultimately creates a comprehensive view of the dark network.

Finally, to enhance the willingness of international partners to share information, this thesis attempts to develop an information strategy on how to gather necessary information for building an unclassified MDA and its dark network. In order to address such a strategy, this research focuses on answering the following questions:

1. What is the appropriate comprehensive information strategy to build an unclassified MDA data?

2. Should additional factors, such as SNA, be employed in the strategy?

By addressing these questions, the authors of this thesis seek to uncover a more effective information strategy and provide a rationale that will enable the United States, its allies, and all partners who have a stake in MDA to share unclassified data with transparency and to benefit more fully from information sharing.

C. SCOPE AND LIMITATIONS

This research focuses on resources available for gathering unclassified data, a review of existing MDA policies and procedures, and current MDA initiatives. Data provided in this document is designed for maintenance at an unclassified level so that it could be shared among international partners. The authors of this thesis reviewed MDA policies and procedures to understand their parameters and to test a collaborative suite of tools for surveilling, collecting, and sharing data. This research also introduces new practices and operational concepts to enhance the current MDA initiatives. Lack of previous familiarity with the SNA tools, funding, and classification concerns all limited this research. This caused the authors to spend additional time on learning the importance of MDA, especially as it affects the littorals, social-economic issues, and international economic interests, as well as current policies and procedures. Historical data that encompasses past, present, and upcoming MDA programs were also reviewed for enhanced knowledge of the overall program and its way ahead. Lack of funding caused the thesis authors to rely on free web-based applications such as SeaVision, MyShipTracking, and MarineTraffic, and SNA tools such as Organizational Risk Analyzer (ORA) and UCINET analytic software. The authors were limited to utilizing websites and databases that provided access to non-classified data due to classification concerns. Finally, time constraints limited the number of possible strategies for analyzing the vast amount of data this research generated.

D. METHODOLOGY

This study uses a quantitative approach to examine the variables under research. It starts with locating the 59 sanctioned vessels designated by the UN Security Council on their webpage. The authors use the IMO number and Maritime Mobile Service Identity

(MMSI) for input into Seavision, MyShipTracking, and MarineTraffic to gather and analyze historical data on sanctioned vessels. The research also evaluates the consistency level of the data collection across the three applications. The data are input into Microsoft Excel to generate an output, which in turn is used to identify just how accurately and effectively SeaVision, MyShipTracking, and MarineTraffic perform in capturing vessel information. The authors also compare the existing capabilities of the three applications to determine how to improve the usability of SeaVision.

This thesis also gathered additional information from IMO and Lexis Advance Research Database on the 59 sanctioned vessels, their affiliated companies, and unsanctioned vessels related to these affiliated companies. Next, the authors utilized an SNA tool called ORA, developed by Carnegie Mellon University, to analyze the sanctioned vessels network, its affiliated companies, and their related unsanctioned vessels. In order to complete the dark network, the authors retrieved 271 affiliated companies and 67 non-sanctioned vessels from 2006 until present. For non-sanctioned vessels with changes of affiliated companies within the bounded timeframe, the authors added additional nodes to facilitate a more complete analysis. The authors believe that this would provide the appropriate "arbitrary" boundary of the complete dark network for a nominal SNA of the relational ties amongst the dark network.

E. ORGANIZATION OF THE RESEARCH

Chapter II provides a literature review outlining the research that highlights the importance of MDA as well as the social and economic issues that MDA aims to address. This section offers an overview of the current and future MDA policies and programs. It presents the research relative to the type of shipping data and shipping documents available in a non-classified platform for analysis. The subsequent section analyzes SNA and the common but unclassified computer tools employed to gather information on the maritime domain as well as analyze the data collected. The chapter also discusses why navies seek information on vessels, what tools are available, and how they might work to support the MDA mission. The chapter also presents the research on the definition of information strategy.

Chapter III explains in detail the methodology for gathering information sources, which ultimately led to exploring a different hypothesis. This chapter goes on to give a comprehensive breakdown on how the authors conducted the first experiment to evaluate the effectiveness of the three COP, SeaVision, MyShipTracking, and MarineTraffic. Next, Chapter III discusses how the authors conducted the second experiment by using SNA on the 59 sanctioned vessels, as well as 67 non-sanctioned vessels that are associated with any of the 271 companies affiliated with the sanctioned vessels, to uncover the dark network.

Chapter IV presents the results of using 59 sanctioned vessels designated by the UN Security Council for the DPRK under Resolution 1718 (2006), 2270 (2016), 2321 (2016) and 2375 (2017). Later in the chapter, the authors include an MDA information strategy useful for building an unclassified MDA approach for sharing with international partners.

Lastly, Chapter V documents the conclusion and recommendations through a comprehensive summary of the results from this research. The proposed information strategy aims to improve the partners' willingness to share information. Finally, this chapter also proposes ideas for future research.

II. LITERATURE REVIEW

This chapter first examines the research that highlights the importance of maritime domain awareness (MDA) as well as the social and economic issues that MDA aims to address. It also summarizes current and future MDA policies and programs.

The next section presents the research relative to the type of shipping data and shipping documents available in non-classified websites for analysis. The subsequent section analyzes social network analysis (SNA), and the common but unclassified computer tools for gathering information on the maritime domain as well as for analyzing and presenting the data gathered. The final section presents the research on the definition of information strategy and its purposes.

The overall approach of any navy is to monitor maritime activity and take appropriate actions to maintain the global commons. All these sources, properly analyzed, provide an ability to infer or deduce not only the position, direction, and identity, but also the intentions of the target. These pieces of information help navies to plan their activities, since in most cases international navies have limited resources. This chapter explains why navies seek this information, what tools are available to collect this information, and how they might work to support the MDA mission.

A. MARITIME DOMAIN AWARENESS

1. Importance of Maritime Domain Awareness

Admiral Mike Mullen, USN, approved the U.S. Navy's MDA Concept in May 2007 to "guide the Navy's efforts to improve MDA-related capabilities and develop related Fleet Concepts of Operations" (Mullen, 2007, p. 22). The maritime domain establishes a global common arena in which to exchange commodities between all nations to prosper and gain wealth. The United States and its allies share this arena with adversaries who threaten the security environment by engaging in criminal activities. Such activities are often associated with global socio-economic issues that plague the Pacific region in particular. The MDA Concept prepares the USN and its allies to confront and eliminate such threats successfully.

Effective decision making is possible with the establishment of a comprehensive common operating platform (COP) that displays real-time and trusted data. This provides the USN and its allies situational awareness of the entire maritime domain, especially in the "grey area" of the South China Sea (SCS) region (Greenway & Sipes, 2018).

When the USN introduced MDA in 2007, concepts such as network analysis were nascent and not considered ready for operational use. Current network analyses, however, can improve the COP by adding factors about vessel intent, including destination, Captain, insurance company, and connections to other businesses.

2. Importance of MDA for Littorals and Social-Economic Issues

Over time, the USN identified that incorporating the littorals widens the scope of operational focus and is necessary for illuminating challenges for modern navies. In particular, MDA is important in understanding ongoing disputes that have threatened the regional peace, stability, and unity of the Association of Southeast Asian Nations (ASEAN). Disputes have escalated over maintaining the SCS as international waters and contributed to the non-compliance of sharing data. Other key areas of interest within the disputed territories include the boundaries of the Gulf of Tonkin, Paracel Islands, Spratly Islands, and waters that surround the Natuna Islands (Etzioni, 2016). All parties making claims are pursuing rights to fishing locations, and examination or potential utilization of natural gas and crude oil from the seafloor of various areas throughout the SCS. They also want to obtain strategic control over valuable shipping trade routes (Etzioni, 2016).

"In July 2016, the United Nations Convention on the Law of the Sea (UNCLOS) arbitration tribunal, established under Annex VII, made a ruling against the maritime claims of Spratly Islands in Philippines v. People's Republic of China (PRC)" (Etzioni, 2016, p. 6). The ruling did not take into consideration the ownership of the islands that surround the maritime boundaries. The PRC and the Republic of China, on the other hand, did not agree with the tribunal and firmly maintained that bilateral negotiations among other claimants should determine matters (Keck, 2014). Overlapping exclusive economic zones (EEZ)—when countries disregard boundaries in the competition over vital resources—have exacerbated socio-economic issues, such as overfishing, piracy, and severe energy usage (Jakarta, 2016).

3. Importance of MDA to International Economic Interests

MDA is a crucial element in supporting international economic interests. The U.S. Energy Information Administration has profiled the SCS region with approximately 11 billion barrels of crude oil reserves (Fensom, Ayoob, Heydarian, & Goldstein, n.d.). “The state-owned China Offshore Exploration Corporation expects to spend nearly $30 billion in U.S. dollars over the next 20 years on the exploitation of oil in the [SCS] region (Marshall, 2014).” The United States has a stake in tracking non-cooperative VOIs within the Pacific region as approximately $5 trillion worth of global trade for the United States travels through the SCS (Fensom et al., n.d.). Non-cooperative VOIs are often related to illegal fishing, piracy, smuggling, and human trafficking all of which disrupt normal international trade.

B. CURRENT POLICIES AND PROCEDURES

Current policies and procedures for MDA provide a solid base for understanding both maritime threats and challenges by fostering positive conditions through the integration and sharing of unclassed information, intelligence, and recommendations for decision makers (White House, 2013). The “National Strategy for Maritime Security (NSMS)” contends that maritime security and safety depends entirely on systems and processes that create shared understanding of activity in the maritime domain for the United States and its allies (White House, 2013). Operational and tactical level commands have set goals for transparency throughout the littoral regions as well as the global commons, establishing a clearer picture of those environments and access to historical data, which is crucial for decision making. In 2005, President George W. Bush gave his approval for the NSMS and its eight supporting plans (Mullen, 2007). The eight supporting plans regulate the activities of the “U.S. government departments and agencies” that have claims in the maritime domain to maximize organic processes and procedures while removing barriers to shared “information to safeguard national security interests” (Mullen, 2007).

The USN initiated the forward-deployment of naval forces to gain intelligence and gather information. The Office of Naval Intelligence (ONI) is specifically structured to strengthen the Navy's traditional and non-traditional war fighting capabilities, and to stretch the USN's ability to explore new technologies, weapons, sensors, future platforms, C4ISR, and cyber ability (Mullen, 2007). U.S. strategic and interagency maritime stakeholders connect with operational headquarters and tactical units through the establishment of a global command, control, and communications network. This enables invaluable data-sharing relationships between commercial and international maritime allies, and engages a persistent Naval Criminal Investigative Service (NCIS) presence at a multitude of overseas ports. Military personnel exchange and training programs that focus on extensive unified training on maritime security are initiatives that have built a robust Theater Security Cooperation (TSC) (Mullen, 2007). U.S. government officials and the USN are strongly committed to the establishment of "a national maritime common operational picture (NMCOP)" (Mullen, 2007). The national plan to achieve MDA is the primary method that enables shared data through the government. The Department of Defense appoints system administrators to eliminate the possibility of manipulation or distortion of information (White House, 2013). The responsibility of making sure "that NMCOP is compatible with the burgeoning global framework of regional maritime situational awareness (RMSA) networks" falls to the USN (White House, 2013). To achieve this, the USN leverages its distinctive positioning to maximize growth, functionality, and content to provide situational awareness (SA) to Navy commanders in terms of national policies pertaining to MDA (White House, 2013).

C. MDA PROGRAMS

1. Current MDA Programs

Maritime domain significantly affects people's lives. As evidence, approximately 95 percent of telecommunications worldwide are conducted through cables that lie beneath the sea, 90 percent of commerce between nations is transported by sea, an estimated 84 percent of Arctic resources reside offshore, and there are seven vital chokepoints through which 50 percent of the global oil trade passes (White House, 2013). Moreover, shipping is the most carbon-friendly and fuel-efficient mode of transport compared to other forms of commercial transportation (White House, 2013). Thus, several MDA programs were developed with one goal in mind: to minimize or eliminate threats that could potentially influence the safety, security, environment, and economy of the United States and its partners abroad. These MDA programs provide integrated all-source intelligence and non-classified information from the private and public sectors and law enforcement agencies (White House, 2013).

There are various technologies and tools for planning, collecting, processing, exploiting, analyzing, and disseminating maritime information. Some MDA programs aim to identify small vessels, such as fishing or dredger vessels, while others focus on the larger shipping vessels. According to the National MDA Plan, “One of the more popular programs is the Automatic Identification System (AIS), which is a maritime navigation safety communications system” (White House, 2013, p. 3). The International Maritime Organization (IMO) adopted this system to provide voyage, static, and dynamic data, including a vessel’s type, identity, speed, course, position, and heading to shore stations, aircraft, and other ships (White House, 2013). International and U.S. law mandates that specific ships be equipped with AIS (White House, 2013). These vessels’ data are readily available for individuals that have AIS transponder capability and within range of an AIS signal (White House, 2013). Another popular program is the Maritime Safety and Security Information System (MSSIS), which provides a multilateral unclassified information sharing capability via the Internet. Accepted internationally as a maritime data-sharing standard, MSSIS is a system of choice for over 75 nations (White House, 2013). The third program is the Office of Naval Intelligence (ONI) Sealink Advanced Analysis (S2A), which supplies multi-Intelligence (multi-INT) data for global maritime domain situational awareness. This system provides tracking information that brings value to intelligence analysts, interagency offices of the SCI community, senior decision makers, and joint war fighters (White House, 2013). Nevertheless, information derived from S2A, because of its classification, is difficult to share with allied and coalition partners.

2. Upcoming MDA Programs

As mentioned earlier, AIS data provided on the open waters or even at the border of EEZs can appear scattered or "delayed due to low coverage or processing issues" at multiple levels (Claramunt, Ray, & Salmon, 2017). The lag in data processing, threat of manipulation, and poor movement quality presents a challenge to the design of information systems that support maritime situation awareness and surveillance (Claramunt et al., 2017). Researchers have realized a need for a solution to real-time data processing that can handle a large volume of information at high velocity such as "Long-Range Identification and Tracking (LRIT) and Vessel Monitoring Systems (VMS)," and synthetic aperture radar (SAR) imagery that can be used to authenticate the anomalies and emission of AIS (Claramunt et al., 2017). These initiatives are tested worldwide, including a collaborative project in development by "Ball Aerospace and Spire Global, Inc. on behalf of the National Geospatial-Intelligence Agency (NGA)" that will target the Arctic region (Spire Global, Inc., 2017). For now, the platform remains un-named, but NGA has indicated that it will increase awareness of VOI activities and behaviors (Spire Global, Inc., 2017).

D. USING SHIPPING DATA IN MDA

To gain situation awareness in the maritime domain, MDA programs need information such as where and what the threats are, before taking actionable decision to address them. Sharda (2016) said that only with the necessary information about a vessel could authorities enforce the appropriate maritime laws to uphold its sovereignty (para. 2). She added that information could be collected via multiple means, such as AIS, radars, or even long-range unmanned aerial vehicles (UAV). All these means help to provide real-time shipping information, and are employed to gain situation awareness on the maritime domain. In addition to real-time shipping data, shipping documentation, which contains information on the shipping company, the goods or materials that the vessel is carrying, and its port-of-calls, is also useful if not as timely. Combined effectively, this information can reveal any hidden relationships, which are easily missed.

1. Real-Time Shipping Data

Fournier (2015) has shown that "large database of maritime transportation could be better analyzed with the help of technology and could enable better visualization of real as well as unknown situations" (p. 88). Therefore, maritime transportation analysis has moved beyond studying historical data from maritime ports. Coupling the analysis now with real-time information, such as ship's location, movement, and traffic pattern, as well as the shipping company and its entities, provides a more holistic analysis. Although integrating real-time information into traditional maritime transportation analysis was always possible, it was dependent on ship tracking systems around the world to provide accurate input.

Etienne, Alincourt, and Devogele (2015) proposed "two general categories of ship tracking systems: cooperative and non-cooperative" (p. 191). Cooperative system refers to systems designed to receive information that ships volunteer to provide, such as their identity, location, planned intended movement, etc. Examples of cooperative systems include AIS, MSSIS, LRIT, and VMS. Non-cooperative system refers to systems designed to track and locate ships regardless of whether the ship was providing information. Examples of non-cooperative systems include radio detection and ranging (RADAR); optical sensors; and satellites. Continuous tracking of a VOI is possible by fusing a ship's data from both categories.

2. Company and Vessel Information

In order to export goods or materials via the international shipping routes, shipping companies need to provide standard documentation to the respective port authority, prior to allowing the vessel entry into the country's port. There are eight key documents related to international shipping: the pro forma invoice, commercial invoice, packing list, certificates of origin, shipper's letter of instruction, bills of lading, dangerous goods forms, and bank draft (Noah, 2018). These documents provide information on shipping company owners, customers, planned shipping routes, and types of goods and materials carried by the vessels. Such information, employed as a baseline to check against anomalies, might reveal whether the VOI was a threat.

Company and vessel information can be easily located on the Global Integrated Shipping Information System webpage, managed by the IMO. By providing the company's or vessel's name, IMO number or Maritime Mobile Service Identity (MMSI) number, anyone will be able to retrieve full information on the company or vessel such as the vessel's current and previous names, IMO number, registered owner, country of registration, and number of ships the company owns, operates, or manages. The Lexis Advance Research Database, which accesses IHS Jane's non-classified intelligence, provides additional information such as a vessel's registered owner, ship manager, technical manager, operator, and document of compliance company (LexisNexis, n.d.). These five roles can be performed by a single company or each role by a different company. For example, a vessel's owner may engage a ship management company to perform the role of a ship manager. The ship manager may operate and/or maintain the vessel, or the owner may choose to outsource the operation and maintenance to another ship management company (Marlow Navigation, n.d.). Other than management, operations, and maintenance, the owner will also need to ensure that his vessel's documents are compliant to the international standard stipulated by the IMO. The owner can hire a compliance company to perform this task.

E. COMMON OPERATING PLATFORMS

The following are some of the COP used to monitor and analyze maritime situations around the world.

1. SeaVision

SeaVision was created by "Brendon Providence of the U.S. Department of Transportation's John A. Volpe Center in Boston" (SeaVision, n.d.). It is a web-based maritime visualization and maritime information management tool that is shared freely amongst its users, providing unclassified data in almost real time through a data gathering and distribution network (SeaVision, n.d.). While used globally, SeaVision is legally restricted and reserved for the U.S. Department of Navy's use and approved coalition partners (U.S. Naval Forces, 2015). SeaVision leverages other detection systems such as coastal radar and satellite imaging, when available, to enable alerts regarding VOIs (SeaVision, n.d.). The system's flexibility allows the application to be compatible with other browsers including Firefox and Internet Explorer 11 (C6F Navy, 2016). SeaVision's visualization tool provides a user with the means to standardize a set of user-defined queries, automate rules for integration, and correlate data from different sources. These features are required to conduct risk assessments, generate automatic warnings and notifications, as well as emphasize anomalies (C6F Navy, 2016).

SeaVision uses data integrated from an array of government and commercial resources. The U.S. government and its partners can view and share content free of charge. The Maritime Safety and Security Information System (MSSIS) is one such government source that produces a near real-time information collection and distribution network that contains sharable unclassified information. Through sharing AIS position reports, it promotes information sharing between international partners (SeaVision, 2018). Visible Infrared Imaging Radiometer Suite is another government resource and is a project of both the "National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA)" (SeaVision, 2018). Its purpose is to provide nighttime visibility of man-made light sources produced by vessels at sea. Coastal radar can establish a reciprocal relationship with AIS movement and position reports of individual vessels from a SeaVision partner nation's shore-based radar network. Satellite Synthetic Aperture Radar (SAT-SAR) has the ability to correlate satellite imagery taken from Naval Research Laboratory (NRL) and integrate it with AIS positional reports (SeaVision, 2018).

Commercial data can also be purchased by Combatant Commanders or by government agencies to be integrated into SeaVision to support their missions (SeaVision, 2018). Satellite Terrestrial AIS is a commercial AIS system that provides data from various vendors. The data collected from this system can be displayed on a SeaVision map and also displayed in SeaVision vessel "baseball cards" (SeaVision, 2018). This system can provide a global picture that depicts vessel activity and includes specific information about each vessel. The Maritime Risk dataset provides around-the-clock monitoring updates along with alerts of piracy and other maritime security incidents. Additionally, the Port

Risk commercial dataset provides security intelligence on all international ports and terminals rated from medium- to high-risk. Lastly, SeaVision also has access to the dataset from Fairplay by IHS Markit. Fairplay takes an extensive amount of vessel information from the integrated World Registry of Ships. The data is analyzed for safety and security risk scores to produce warnings (SeaVision, 2018).

SeaVision also has the capability to monitor EEZs, port visits, and transits. In addition, this is an unclassified, non-Public Key Infrastructure (PKI) tool, so users can import and export data products as needed (C6F Navy, 2016). SeaVision's user guide covers a large scope of features for setting up rules, alerts, warnings, and vessel lists that are tailored to the user's operational mission requirements. The second section of the next chapter reveals SeaVision's capabilities and determines how other systems might synchronize with SeaVision's information to improve UN sanctioned vessel identification.

Naval Forces Africa employs SeaVision for MDA training to "increase maritime safety and security specifically in the waters of West Africa," as often as four times per annum (U.S. Naval Forces, 2015). SeaVision's advanced features, historical ship tracking data, and search capabilities are used by many agencies across the United States and the globe. In addition, there are also partner countries that contribute radar data to SeaVision to provide a better picture of the coastline on the Google-like map (U.S. Naval Forces, 2015).

2. MyShipTracking

MyShipTracking is another advanced search website that offers a worldwide real-time vessel positioning tracker on an active map. This website gives users the ability to monitor vessels and ports efficiently to analyze the marine traffic through AIS technology broadcasted by vessels via very high frequency "(VHF) channels from frequencies 161.975 MHz and 162.025 MHz" (MyShipTracking, n.d.). It uses a transceiver connected with a global positioning system to provide technical information and photos of more than 100,000 vessels daily (Marine Insight, 2018). MyShipTracking is a powerful tool for monitoring ship schedules, port arrivals, and fleet tracking or analyzing the ship trading patterns. It allows a user to save browser data and offers an assortment of services via applications downloadable to an iPhone or Android, which is also available at no cost (Marine Insight, 2018). MyShipTracking partners with multiple online vessel tracking providers such as "Marine Vessel Traffic, Ship Location, WikiShipia, MarineTraffic, Vessel Finder, Fleetmon, Ship Finder, Maritime Connector, Open Sea Map, and Cruise Mapper" to provide the most accurate and timely data on vessels (MyShipTracking, n.d.). Its website, however, provides minimum company information besides its privacy policy, and there is no evidence of partnerships outside of the aforementioned entities.

MyShipTracking website provides minimum information about the organization's processes for gathering accurate and real-time data. Its reputation is undefined, and its safety factors are not yet rated by any of its users. On the other hand, the website services are free, providing downloadable applications for the latest version of both iOS and Andriod mobile devices. MyShipTracking also has a social media webpage on Facebook, which allows messaging to request additional information if necessary. MyShipTracking uses satellite imagery collected by AIS signals to acknowledge vessel positioning, route, speed, and the vessel's type. "Its active map is processed through Google Earth which promises information of most ship's GPS location, speed over ground, course over ground, unique vessel identification and voyage information" (Myshiptracking, n.d.).

3. MarineTraffic

"MarineTraffic is an open source, community-based project, which provides real-time information on both the movements and current locations of vessels in harbors and ports" (McCabe, 2015). The platform was created in 2006 by Dimitris Lekkas, a self-proclaimed computer geek, radio enthusiast, and ship spotter. MarineTraffic was released on Live Map in 2007 and continued to enhance its services through major upgrades in 2013 to include notifications and fleet management (McCabe, 2015). The website offers a variety of services and products ranging from basic, at no cost, to a more extensive set of tools accessible through payment on the MarineTraffic web platform (MarineTraffic, n.d.d). The basic services include information on vessels such as origin, vessel dimensions, gross tonnage, and IMO number (MarineTraffic, n.d.c). The MarineTraffic community currently consists of over two million subscribers who include professionals, hobbyists, radio amateurs, photographers, translators, and AIS station owners (Ellison, 2014). Its AIS network of approximately 3,200 shore-based receivers is manned by enthusiasts who share a passion for ships and the maritime ecosystem (Ellison, 2014). MarineTraffic also collaborates with key global and regional project owners who use the company's vessel tracking data to share information, improve technology, and support the shipping industry (Ignatiou, 2017). MarineTraffic "signed a memorandum of understanding (MoU) with the United Nations Conference on Trade and Development (UNCTAD)" to provide members from more than 194 countries with analysis on trade globally and shipping trends (Ignatiou, 2017). MarineTraffic joined forces with the IMO on the establishment of energy efficiency measures for shipping (Ignatiou, 2017). They also worked with the "European Statistical Systems Network on Smart and Innovative Statistics, and Big Data Value Association on the European Big Data Value Innovation Strategy" (Ignatiou, 2017). MarineTraffic is currently active with the North Atlantic Treaty Organization Centre for Maritime Research on prescriptive shipping analytics and simulation (Ignatiou, 2017).

MarineTraffic is capable of gathering data from thousands of AIS volunteer stations from more than 140 countries worldwide (Stasinakis, 2015). AIS equipment on board vessels provides information, such as position, unique identification, speed, and course which is then transferred to the main MarineTraffic servers. The information and positional data is electronically shared between AIS stations. An AIS-receiving unit can accept AIS transponder-emitted AIS data given that it is within range (Stasinakis, 2015). This makes MarineTraffic essential to the research documented in this thesis as it gathers data from many AIS stations. Transmitted message packets (raw data) are encoded into a National Marine Electronics Association sentence in 64-bit plain text.

The MarineTraffic network can then decode the text to display dynamic information such as the vessel in question, location, status, speed, and rate of turn and course. "It also pulls static information such as, the vessel's name, IMO number, MMSI number, dimensions and voyage-specific information which consists of destination, ETA and draught" (MarineTraffic, n.d.c). MarineTraffic's central database receives large amounts of AIS data constantly and stores the most prominent part of it (MarineTraffic, n.d.c). The authors of this thesis extracted, analyzed, and measured this data against other tracking systems for the purpose of this research.

MarineTraffic's users can choose to pay either US$104.92 or US$190.75 per month, for an account to access extended services and advanced functions on its webpage (MarineTraffic, n.d.b). The $104.92 package covers access to satellite positions with a 12-hour delay for the global fleet. Users can track the global fleet wherever they sail, providing visibility of ships traveling beyond the reach of the terrestrial receiver network or ships making ocean crossings (MarineTraffic, n.d.b). The $190.75 package provides access to the most recent satellite positions of every ship that is in range or beyond the reach of the terrestrial receiver network (MarineTraffic, n.d.b). With a budget of US$100,000, an organization can sign up for at least 500 accounts for its member to access MarineTraffic's extended services and advanced functions..

European law protects MarineTraffic as intellectual property. The providers and partners of the web application possess exclusive intellectual property rights on the design, source code, and overall content of the website, including pictures, photos, text, graphics, designs, scientific presentations, articles, and services provided via the website (MarineTraffic, n.d.d). For the user, this means no copying, modifying, publishing, or distributing of any content on its page without the written permission of the provider (MarineTraffic, n.d.d). This means modification of the website's software is prohibited. MarineTraffic also prohibits users from posting to the website photos or images that users declare as their own if the material was copied from another online source (MarineTraffic, n.d.d).

4. Equasis

Equasis is a non-commercial database system developed by the European Commission and the French Maritime Administration. It provides an online platform, which encourages the "exchange of information and transparency amongst the shipping industry" (Wankhede, 2015, p. 4). A massive information system, it stores data on ship performance and maritime transportation companies from private, public, and maritime organizations (Wankhede, 2015). Although this online platform provides some transparency with vessels, it appears scattered. Accessing information is often difficult at times (Wankhede, 2015). Initiated in 2007, Equasis has approximately 43 million connections worldwide and by 2017 over 830,000 users (Wankhede, 2015). The primary goal of Equasis is to provide characteristics of vessels and ship management information, as well as collect and disseminate information (Wankhede, 2015). France and the Europe Commissions assume the bulk of the cost for the development and operation of Equasis, while other "financial support is provided through maritime authorities of Spain, Japan, Singapore, and United Kingdom" (Wankhede, 2015, p. 5).

5. Virtual Regional Maritime Traffic Centre

The Virtual Regional Maritime Traffic Centre (VRMTC) program, initiated by Italy, has a goal of sharing unclassified data of available historical records and information on vessels moving around the Mediterranean. This initiative links the operational centers of navies around the Mediterranean Sea, enabling them to work within a virtual network and share a recognized maritime picture across countries within the southern border of the Mediterranean, while participating in multi-cooperative exercises (Sabantini, n.d.). This program uses the Internet through a certified navy secured software and protocol that is user-friendly and economical (Sabantini, n.d.). The VRMTC reached full operational status in 2008 with ten active Marine Operations Center participants (Sabantini, n.d.). This program features email, chat, and forum capabilities, which increases the cooperative abilities amongst maritime centers of the member nations. In recent years, VRTMC has emerged as the "at home-based Computer Exercise" tool of choice as its technological evolution has targeted the improvement and speed of management of maritime traffic information from a number of heterogeneous sources (Sabantini, n.d.).

6. SafeSeaNet

U.S. foreign partners and allies have also created vessel monitoring tools to capture traffic in the maritime domain. SafeSeaNet is a European Maritime Safety Agency (EMSA) web interface developed to monitor vessel traffic to enhance maritime traffic and transport efficiency, marine environment protection, maritime and port security, and maritime safety (EMSA, n.d.). This system links together authorities across Europe and allows for the exchange of maritime data through a network. Iceland, Norway, and the European Union Member States are linked into information sharing on hazardous cargo, ship travel routes, and general ship data (EMSA, n.d.).

F. SURVEILLANCE, PERSISTENT OBSERVATION, AND TARGET RECOGNITION

The computer visioning tool surveillance, persistent observation, and target recognition (SPOTR) is designed by Progeny Systems and "is a comprehensive, intelligent video analytics processing application that helps to improve the surveillance capability by using target detection, recognition and soft biometric extraction" (Progeny Systems Corp., 2019). SPOTR is not specific to MDA but offers multiple ways to provide situational awareness for warfighters across the battlefield (Progeny Systems Corp., 2019). Its applications are capable of supporting various surveillance requirements, ranging from security and surveillance to forensic analysis and manufacturing, through an intelligent video analytics process. SPOTR allows for multi-sensor detection and monitoring from multiple cameras over long distance as well as facial detection and biometric extraction (Progeny Systems Corp., 2019). When used for MDA, SPOTR can provide automated VOI detection, classification, and identification, with appropriate preparation. SPOTR offers the possibility of using various optical sensors, whether aircraft or space-based, to identify and classify non-cooperative vessels, and input those tracks into any compatible MDA COP (Progeny Systems Corp., 2019).

G. SOCIAL NETWORK ANALYSIS

Wasserman and Faust (1994) discovered that researchers in the 1930s had started to use "social network analysis (SNA) to examine the relationships and linkages between human and social processes" (Farine & Whitehead, 2015, p. 1144). Together, these relationships and linkages form a collection of nodes and make up a network. Nodes can be people, organizations, companies, countries or ships. SNA can help to reveal known and hidden relationships, as well as to quantify the strength of each relationship (Farine & Whitehead, 2015, p. 1144). Advancements in computing power have made the use of SNA to analyze large databases of information much easier. SNA can uncover the dark network of companies or unsanctioned vessels conducting activities that contravene UN sanctions on the DPRK. Vast amounts of "non-classified data is obtained through one of three ways—through the conduct of surveys and questionnaires, via information taken from written records or interviews, or by means of direct observation or experience" (Everton, 2012, p. 87).

Ducruet and Lugo (2013) applied an agent-based model to examine inter- and intra-relationships between nodes such as ships. Bouveyron, Latouche, Zreik, and Ducruet (2015) used the stochastic block model and random subgraph model to discover hidden clusters as well as hidden relationships that might be dependent on those hidden clusters (p. 212).

There has also been growing interest in studying maritime transportation networks since increased globalization has resulted in 90 percent of the world's trade being transported via the maritime route (Bretagnolle, 2015, p. 32). Of note, there has been an increase in SNA usage by researchers to analyze maritime transportation networks instead of using traditional graph theory perspectives (Ducruet & Lugo, 2013, p. 348). Several techniques are applicable.

1. Agent-Based Model

The agent-based model (ABM) is an evolutional model that allows flexible application as compared to other analytical models (Ducruet & Lugo, 2013). ABM simulates systems of autonomous components, called agents, and their inter- and intra-relationship, as well as their environment, based on a set of rules (Ducruet & Lugo, 2013). For this paper, the agents identified can be the sanctioned and non-sanctioned vessels, as well as the affiliated companies that might own, manage, operate, or maintain them. The thesis researchers can compile a database of these agents and use ABM to run a simulation that might reveal hidden relationships, as well as reveal the global patterns and structure of a network, without the influence of a central node. The central node, in this paper, could be the parent enterprise that operates multiple shell companies. ABM is conducted using either the generative or the degenerative method. The generative method starts with a graph of unconnected nodes and thereafter connects them based on a set of established related attributes. Also, connections can be based on the nodes' established relationship in the network derived from the degree of connectivity. The degenerative method starts from a complete network and subsequently breaks that down to smaller networks based on values and attributes. Relationships considered less valuable would imply lower importance, but may still support the critical path.

2. Stochastic Block Model

The stochastic block model (SBM) is also referred to as the "planted partition model in theoretical computer science, or as an inhomogeneous random graphs model in mathematics literature" (Abbe, 2017). SBM assumes that one network is related to one or more networks, and that relationship might be derived from one pair of actors within these two or more networks (Bouveyron et al., 2015, p. 211). Rohe, Chatterjee, and Yu (2011) proposed to use network spectral clustering under the SBM as it could discover clusters of highly connected actors, based on some empirical objective function, and yet "allow the number of clusters to grow with the number of actors" (Ducruet & Lugo, 2013). Clusters are established when there are two or more actors connected together. In this paper, a cluster is a network of shipping companies that share the same address, or a network of companies that own, manage, operate, or maintain a vessel. By studying these two different networks and aggregating them together, it is possible to find an edge between two or more actors in different clusters, which might uncover hidden relationships.

3. Random Subgraph Model

Jernite et al. (2014) proposed the random subgraph model (RSM) to analyze directed networks with typed edges for hidden relationships between two or more clusters. Each cluster of vertices would be divided into sub-clusters with homogenous connection profiles. Each sub-cluster also has its own mixing proportion, and its vertices are connected with a calculated probability. RSM is a model in which "its inference procedure would be able to provide an accurate estimation of the true clustering structure." Using the list of shareholders in the shipping company, it is possible to draw a direct link from each shareholder to the company. With a directed network of a company and its shareholders, RSM is used to analyze the network to reveal hidden relationships. RSM, however, would not be suitable if there were insufficient data.

4. Applying SNA in the Maritime Domain

Ducruet (2015) highlighted the lack of historic research on maritime transportation from a network perspective. He further explained that it was likely due to the "widespread geographical distribution, large data sets, and hard-to-obtain accurate maritime traffic statistics" (p. 27). Ducruet (2015) shared that with the advancement of analytical technologies, there was "increasing research on maritime transportation networks using historical data and real-time shipping data" (p. 40).

The Common Operational Research Environment (CORE) Lab under the Defense Analysis Department at the Naval Postgraduate School has conducted research in the maritime network, using SNA (Porter et al., 2017, p. 4). The research integrates SNA with geospatial track analysis to establish the relationship between agents-members (ships, owners/operators, port, types of cargoes), who might be involved in artificial reef construction and enhancement in the SCS. The researchers from the CORE Lab use ship-to-ship networks and company networks to determine which ship/company connections might be part of the core or have a significant relationship with the central core. The research concludes that SNA could help to enhance MDA by providing additional information on potential legal and illicit activities via the maritime grey/dark network. The research also determines that the analysis tool could be integrated into existing platforms, such as SeaVision, to enhance identification and tracking.

H. DATA VISUALIZATION

SNA software helps analysts to visualize large datasets for easier interpretation, analysis, and subsequent audience presentation. Many SNA software tools have built-in capabilities to analyze one-mode or two-mode data, as well as analytical tools such as centrality measure, multiple network analysis, sub-group identification, cohesion and clustering, and bridges and brokers (Cunningham, Everton, & Murphy, 2016). Commonly used software suites are UCINET, NetDraw, Pajek, Organization Risk Analyzer (ORA), and R Studio.

1. UCINET and NETDRAW

UCINET was "developed by Steve Borgatti, Martin Everett, and Lin Freeman" (Apostolato, 2013). UCINET requires the dataset to be in matrix-form and conducts analysis using various matrix algebra and multivariate statistics (Apostolato, 2013). To visualize the dataset, the analyst can use NetDraw, which is integrated in UCINET, to conduct similar analysis in UCINET. Analysts can also combine network data with attribute data, and differentiate the data by the color, shape, or size of the nodes (Everton, 2004).

2. Pajek

Pajek was developed by Vladimir Batagelj and Andrej Mrvar (Batagelj & Mrvar, 2016). This tool is designed to handle extremely large datasets and six data structures: network, permutation, vector, cluster, partition, and hierarchy (Apostolato, 2013). Batagelj and Mrvar (2016) highlight that in order for Pajek to analyze a large network, it will implement multiple sub-quadratic algorithms to dissect large datasets into a smaller size.

3. ORA

ORA was developed by Carnegie Mellon University and Netanomics (Carley, 2014). It can support large meta-network data and even analyze datasets that are in multi-mode form. According to the Center for Computational Analysis of Social and Organizational Systems (CASOS) at Carnegie Mellon University, ORA is an

> SNA tool that detects risks or vulnerabilities of an organization's design structure that uses a Java Interface for the ease of use and a C++ computational backend. … The design structure of an organization is the relationship among its personnel, knowledge, resources, and tasks entities. The entities and their relationships are represented by a Meta-Matrix which is input and used to analyze the structural properties of a potential risk that resides within an organization. (Carley, 2014)

Measurements are organized by the input requirements and by the output. ORA generates a formatted report in log files "in multiple data formats that are interoperable with existing network analysis packages" (Carley, n.d.). Researchers use ORA to show the relationships between company and sanctioned vessels, company, and parent company based on shared address, flags, and communication between multiple node types (Cable Telex, telephone, website, facsimile). Further, ORA identifies shell companies, normalizes data to reduce duplication, captures the identity of unknown vessels and companies, identifies transactional systems (ERP versus analytical systems), and generates different data views.

4. R Shiny

R code is a programming language developed by the R Foundation. It computes statistics and generates a graphic representation of the results (The R Foundation, n.d.). R allows its developer to define additional functions depending on his or her requirements, just like other programming languages such as C, C++, or S. The CORE Lab applied SNA to maritime networks by using a variety of R packages and writing code in R in order to perform the analysis. This was then implemented as an R Shiny application. The R Shiny application (developed by Shiny from R studio) has also been used as a maritime relations analysis tool that utilizes the modified R code. It analyzes historical maritime information provided within a specific timeframe, and generates a graphical display (world map and/or chord diagram of activity flow) for the researchers to conduct the maritime relations analysis (Porter et al., 2017, p. 6).

I. INFORMATION STRATEGY

An information strategy enables users or organizations to determine what information is critical for business functions and decision making. Often referred to as long-term planning, it is designed to achieve business objectives directly tied to management of knowledge, data, or information. Data can exist in a huge pool of other data indefinitely, never amounting to useful information. Information is the result of data transformed to meet the needs of its intended user. Data becomes useful when consumed in such a way that it becomes a part of the user's decision-making process. Hiltbrand (2017) asserts "information is to the digital revolution what oil was to the industrial revolution." Those who obtain the right information are set up to achieve their goal, while those who do not may struggle mightily (Hiltbrand, 2017, para. 3). Strategy is defined as "a shared organizational vision with ample resources applied to make it a reality" (Hiltbrand, 2017, para. 3). Creating a strategy can be difficult because it involves uncertainty and requires much more than just throwing ideas around or brainstorming. Developing a strategy with care is necessary to bring a desired state into fruition (Hanson, 2011).

Information strategy addresses horizontal issues, information management principles, and the governance arrangement (Hanson, 2011). Horizontal issues refer to the policy making that exists amongst departments and, in the case of MDA, partners across organizations of similar stature in a hierarchy who are working collaboratively toward a common outcome (Valentine, 1995). Information management principles allow authorized individuals to access information they need at the right place, the right time, and in the right form (Edge, 2016). The governance arrangement is simply the functions and accountability of departments. It is a critical element of any project, and an equivalent framework rarely exists to govern cooperative efforts across different countries (U.S. Department of State, 1999).

An information strategy is only as good as its sub-strategies. They include the fundamentals that are present throughout this entire thesis: the learning experience, teaching, and research process. The learning experience that the authors gain from this research will foster a deeper understanding of MDA and allow them to conduct a thorough examination of the findings. Once the authors conclude both experiments, it will become a teaching tool so that others can take the experiments even further. Finally, the research process will be conducted in steps to identify, locate, assess, and analyze the data collected to support their research questions.

J. SUMMARY

This chapter identifies the importance of MDA and the tools used to establish the situational awareness to support MDA. In addition, there are many data sources that include everything from ship’s registry and owners to manifests, port schedules, and other pertinent facts related to maritime activities. The situational awareness tools are all useful, but each has its own strengths and weaknesses. The usefulness of such situational awareness tools also depends also on how the user uses it to conduct MDA. MDA supports understanding of both lawful and unlawful maritime activities. Each of these sources provides lots of data and information, at varying costs. In the next chapters, the authors explore how leveraging all these sources might provide improved awareness and perhaps imply intent.

III. METHODOLOGY

The authors hypothesize that with enough vessel-related information it is possible to deduce considerable knowledge about a vessel's background and infer its intentions. Exploring this hypothesis requires gathering many information sources and employing the aforementioned tracking and network analytical tools. Specifically, the authors focused on what these data sources could tell about ships subject to United Nations (UN) sanctions, since those types of ships receive global attention. What follows is a description of the various data sources, many of the tactical picture tools and analytic tools that enable one to learn more about specific vessels of interest, and new ideas on how one might use emerging social network analysis (SNA) approaches to better use all this data. Finally, the authors also describe their approach in developing an information strategy through the experience gained from the two experiments.

A. LOCALIZING UNITED NATIONS SANCTIONED VESSELS

1. Types of UN Sanctioned Vessels

UN sanctioned vessels are separated into several categories of ship types, and can be found on the UN Security Council (UNSC) Subsidiary Organs website. The Security Council 1718 Sanctions Committee defined the following categories of vessels: (1) cargo (bulk carrier, refrigerated cargo); (2) patrol (coast guard, patrol boat, law enforcement); (3) tugboats (tugboats, pilot boat); (4) supply (offshore, supply, research vessel); (5) specialized (dredger, salvage vessel, barge, floating crane); (6) tankers (tanker, gas carrier); (7) fishing; and (8) other or unknown. As of 1 November 2018, the council committee designated 59 sanctioned vessels (UNSC, 2018). Most of these vessels are in the supply, cargo, tanker, or the other or unknown categories. The list of sanctioned vessels includes information such as the vessel's name, International Maritime Organisation (IMO) number, flag, call sign, Maritime Mobile Service Identity (MMSI) number, type of vessel, and other notes indicating source control (UNSC, 2018).

2. Concerns about UN Sanctioned Vessels in MDA

The UNSC has major concerns that these sanctioned vessels are engaging in or supporting illicit nuclear-related programs, weapons of mass destruction or ballistic missile related programs (IMO, 2017). Therefore, the UN desires the location and movement of these sanctioned vessels. Yet locating vessels is not an easy task, even though all vessels are required to carry the Maritime Automatic Identification System (MAIS), which broadcasts a vessel's information such as IMO number, flag, MMSI number, vessel type, and most importantly, its position. Although sanctioned vessels may be carrying the MAIS, they can easily mask their identity by broadcasting a fake IMO number or even refuse to switch on their MAIS, to avoid detection.

Currently, the MAIS is the single best way to track the history of a ship from the shipyard to the scrapyard (IMO, n.d.). Although additional ship information, such as the vessel owner company, is available through multiple Internet websites, it is not consistent.

3. Consolidating Information from Various Sources

The authors believe localizing UN sanctioned vessels is more effective when combining multiple sources of data to give an accurate position. UN members can then share information on any sanctioned vessels with each other, via an unclassified web browser or through their respective information sharing agreements. By using an unclassified web browser, a user has the ability to view and store data on any device on vessels that are physically positioned within borders of any specific country where the vessel's data was originally generated (Cory, 2017). It is also most cost effective, as it allows free flow of digital data collection on UN sanctioned vessels. In addition, this digital data can be physically stored on servers within the respective country's local database in order to meet the requirements of national law, as well as to comply with data protection regulations. Localizing data on UN sanctioned vessels serves as a foreign data storage solution because it prevents the loss of private information in case of a system breach (Cory, 2017). The first section of next chapter reveals the consolidated result on all the information that can be collected from unclassified sources, and recommends a centralized data point for vessel identification and tracking.

For this thesis, the authors consolidated information such as details on sanctioned and non-sanctioned vessels as well as their affiliated companies, from sources such as the UN's website, IMO's website, and the Lexis Advance Research Database.

a. Information on Sanctioned Vessels from the UN

The UN placed multiple sanction measures on the DPRK (UNSC, 2018). For this thesis, the authors focus on consolidating information about the sanctioned vessels designated for DPRK by the UNSC; this information can be found on the five lists shown in Figure 1.

Figure 1. List of Designated Vessels for DPRK. Source: UN Security Council Subsidiary Organs (n.d.).

b. Information from the IMO

The UN provides only basic information such as "vessel's name, IMO number and MMSI number," which was insufficient for the authors to determine the location of the sanctioned vessels. Therefore, the authors gathered more information such as flag of registration, call sign, type of vessel and registered owner, from 'Ships and Company Particulars' under the IMO's website (Figure 2).

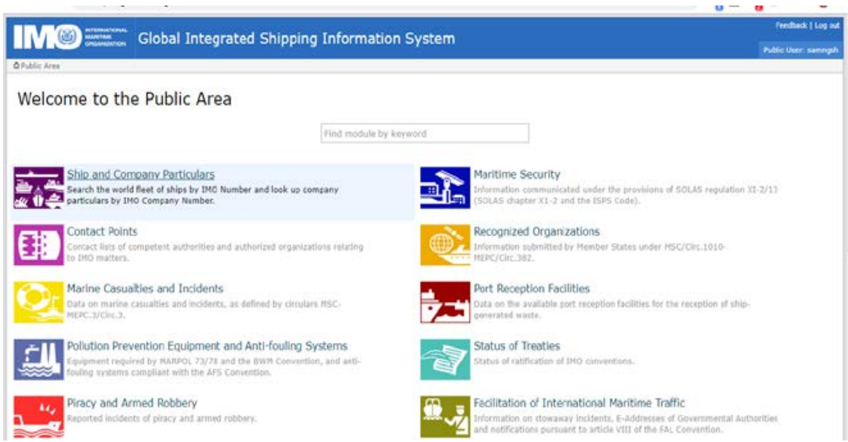

Figure 2. Ship and Company Particulars from IMO. Source: IMO Global Integrated Shipping Information System (2017).

c. Information from the Lexis Advance Research Database

In addition to the UN and IMO websites, the authors also utilized the Lexis Advance Research Database to verify the data collected. The Lexis Advance Research Database (Figure 3) collects data directly from the IHS maritime database, which is the largest maritime database in the world. The IHS maritime database provides additional information such as the vessel's operator, ship's manager, document of the compliance company, and the technical manager. This additional information was used in the second experiment on social network analysis.

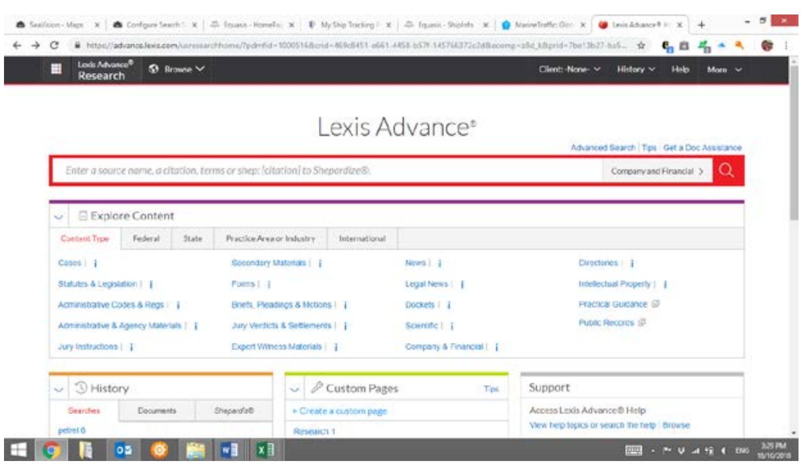

Figure 3. Lexis Advance Research Database. Source: LexisNexis (n.d.).

B. EVALUATING THE EFFECTIVENESS OF THE THREE COP

There are many ways to build and maintain maritime domain awareness (MDA). Before deciding what action to take on any vessel of interest, it is necessary first to observe that vessel and orient on its activities. Many methods exist to achieve such awareness, as well as many factors that determine the appropriate method. In the first experiment, the authors conducted a quantitative evaluation of the three COP by comparing how many sanctioned vessels each can track and how current the information is. Then the authors conducted a qualitative evaluation on the functionalities of the three COP.

1. Quantitative Evaluation

With the gathered information, the authors evaluated the effectiveness of SeaVision, MyShipTracking, and MarineTraffic in locating the sanctioned vessels. For this experiment, the authors used the IMO number of each vessel as the primary search selection. In the event that the IMO number of a sanctioned vessel is unavailable, the authors employed alternative information, such as MMSI or name and flag of registration, as the secondary search selection. The following paragraphs describe the search functions of the three COP.

a. SeaVision

Using the search function in SeaVision, the authors selected the type of search criteria that was deemed most appropriate. The authors could choose to use one or more of the following forms of vessel identification such as the flag of registration, name, call sign, MMSI number, or IMO number, as shown in Figure 4, to conduct the search.

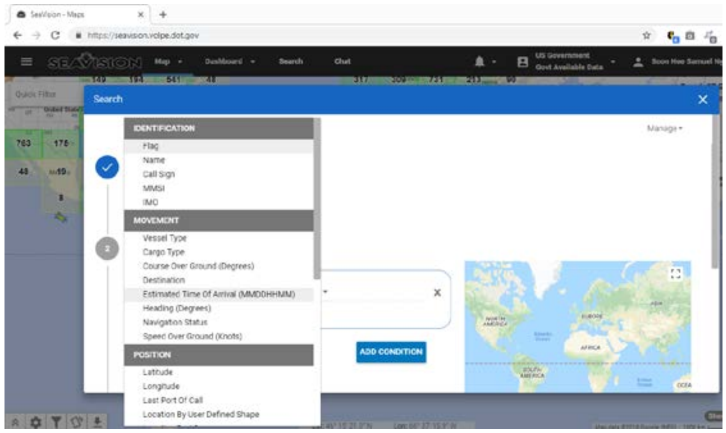

Figure 4. Search Parameters in SeaVision. Source: SeaVision (n.d.).

b. MyShipTracking

MyShipTracking maintains its own database for its users to track vessels. Similar to SeaVision, the authors can choose to enter the vessel's IMO, MMSI, name, or call sign, to search for a vessel, as shown in Figure 5.

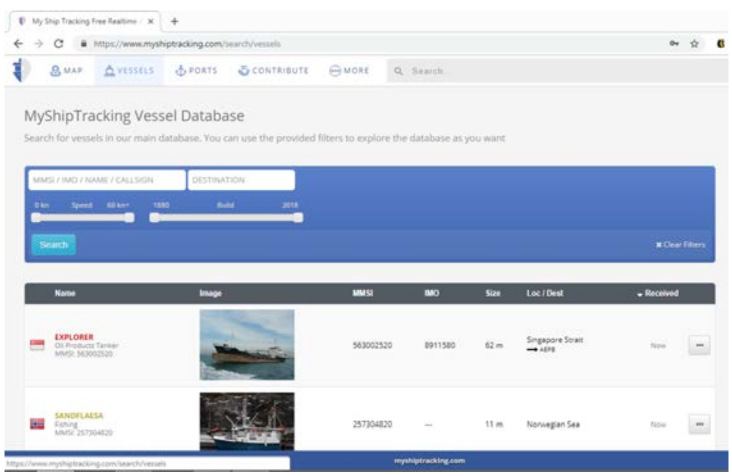

Figure 5. Search Parameters in MyShipTracking. Source: MyShipTracking (n.d.b).

c. MarineTraffic

MarineTraffic also has search function similar to that of SeaVision and MyShipTracking. The authors can search for a vessel using its IMO, MMSI, name, or call sign as shown in Figure 6.

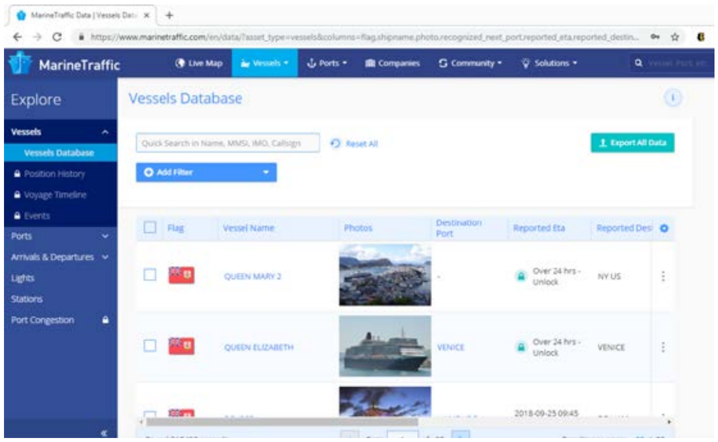

Figure 6. Search Parameters in MarineTraffic. Source: MarineTraffic (n.d.c).

2. Qualitative Evaluation

The qualitative evaluation considers the criteria shown in Table 1 to evaluate the functionalities of the three COP.

Table 1. COP Functionality Criteria

Criteria
Able to search for vessel via vessel’s name, IMO No. or MMSI No.
Able to track via AIS and Coastal Radar
Able to track via Satellite Imaging
Able to accept sighting report by member
Able to draw designated area to monitor vessel movement
Able to provide vessel’s company information
Able to be used on mobile application
Able to push alerts or notifications
Allow members to chat with each other

None of the three COP, however, offers analysis regarding what a vessel is doing and why. The authors believe that social network analysis can help with that challenge.

C. INCORPORATING SOCIAL NETWORK ANALYSIS INTO MDA

The social network analysis (SNA) toolkit can reveal possible hidden relationships that may go unnoticed by standard intelligence gathering. A dark network with hidden relationships might have common goals, such as conduct of illicit nuclear-related programs, weapons of mass destruction or ballistic missile-related programs.This research incorporates SNA into MDA to uncover the dark network that is hampering the UN's sanction efforts on DPRK.

For the second experiment, the authors focused on the UN sanctioned vessels for DPRK and their affiliated companies that are responsible for ownership, ship management, operation, documentation of compliance, or technical management. To uncover the dark network, the authors also included non-sanctioned vessels associated with any of the affiliated companies, as derived from the IMO and the Lexis Advance Research Database. The timeframe for this experiment spans from 2006, which was when the UN's sanction effort on DPRK commenced, to present. For the non-sanctioned vessels, additional nodes are included to reflect the change of companies within the stipulated timeframe. The authors assessed that this would provide the appropriate boundary of the dark network. All data was compiled using Microsoft Excel while analysis was conducted using ORA and UCINET.

1. Definition of SNA Relationships for the Network

To set up the boundary, it is necessary to define the relationships of the network prior to data collection (Cunningham et al., 2016). This experiment analyzed the dark network by using two relational networks. The first relational network was a two-mode network comprising vessels and their affiliated companies, and the second relational network was another two-mode network comprising companies and company addresses.

a. Relational Network of Vessels and Companies (Two-Mode, Two Actors)

A company (actor) is associated with a vessel (actor) through either its administrative or functional system. For the purpose of this analysis, the authors focused on companies responsible for ownership, ship management, operation, documentation of compliance, or technical management of a vessel. A two-mode relational tie is deemed to exist between a vessel and a company if the latter owns, manages, operates, or maintains the vessel. To account for the possibility that a company could play multiple roles, the authors weighted the ties: one for a single role, up to a maximum of five should all five roles be performed by the same company. All companies affiliated with a particular vessel earn a relational tie in their respective columns. For vessels with incomplete information on company affiliations, no weights were added to the ties to prevent unintended data skewing. The data was compiled in Microsoft Excel using the format shown in Table 2.

Table 2. Two-Mode Relational Network of Vessel and Company

Source Type	**Source ID**	**Relationship**	**Target Type**	**Target ID**
For all vessels Enter “Ship”	For sanctioned vessel Enter <*vessel’s name*> For non-sanctioned vessel Enter <*vessel’s name*> followed by start-year <*from*> to end-year (*till*>	For all vessels Enter either one of the following roles: - Registered Owner - Ship Manager - Document Compliance - Operator - Technical Manager	For all vessels Enter “Company”	For all vessels Enter <*company’s name*>

b. Relational Network of Companies and Addresses (Two-Mode, One Actor and One Affiliation)

A parent enterprise (actor) could be operating multiple actual and shell companies. To seek the parent enterprise, the authors analyzed the registered address (affiliation) for all companies. Companies affiliated with the same address received a two-mode relational tie. Companies with incomplete information on registered address did not register any relational tie on the network. The data was compiled in Microsoft Excel using the format shown in Table 3.

Table 3. Two-Mode Relational Network of Company and Address

Source Type	Source ID	Relationship	Target Type	Target ID
For all companies Enter "Company"	For all companies Enter <*company's name*>	For all companies Enter "Company Address"	For all addresses Enter "Address"	For all addresses Enter <*company's address*>

c. Attributes

The first attribute in this dark network was whether a vessel has been sanctioned. A vessel occupies one of two states, sanctioned or non-sanctioned. This status is governed by the UNSC under Resolutions 1718 (2006), 2270 (2016), 2321 (2016), and 2375 (2017). These data were compiled in Microsoft Excel using the format shown in Table 4.

Table 4. Attribute Data of Vessel's Sanctioned Status

Source Type	Source ID	Sanctioned or Not
For all vessels Enter "Ship"	For all vessels Enter <*vessel's name*>	For sanctioned vessel Enter "1" For non-sanctioned vessel Enter "0"

The second attribute in this dark network was the state of registration of each vessel. The flag state of a vessel is the jurisdiction under whose laws the vessel is registered or licensed. Vessels registered under the same flag state are deemed to have the same nationality, and be governed by the same set of affiliated laws. The data was compiled in Microsoft Excel using the format shown in Table 5, and each country was assigned a code shown in Table 6.

Table 5. Attribute Data of Vessel's State of Registration

Source Type	Source ID	Country Code
For all vessels Enter "Ship"	For all vessels Enter *<vessel's name>*	For all vessels Enter *<country code>*

Table 6. Country Code for State of Registration

Country	Code
Bahamas	1
Belize	2
Bolivia	3
Cambodia	4
Cayman Islands (British)	5
China	6
Comoros	7
Cook	8
Democratic People's Rep. of Korea	9
Dominica	10
Georgia	11
Japan	12
Kiribati	13
Liberia	14
Luxembourg	15
Malaysia	16
Mongolia	17
Palau	18
Panama	19
Philippines	20
Saint Kitts and Nevis	21
Sierra Leone	22
Singapore	23
South Korea	24
Taiwan	25
Tanzania	26
Thailand	27
Togo	28
Vanuatu	29

2. Using ORA and UCINET to Conduct Analysis

The authors used two SNA toolkits, ORA and UNCINET, to conduct analysis. First, they used ORA to display the two relational networks (Network of Vessels and Companies, and Network of Companies and Addresses). They also employed ORA to fold the network of companies and addresses to discover which companies share the same registered addresses, thus determining the parent enterprise. Next, they aggregated the folded network with the network of vessels and companies. This allowed them to discover which companies share an address and affiliate with any of the 59 sanctioned vessels.

Finally, the authors engaged the centrality measure function in ORA and UCINET to determine the key actors. First, they used ORA to convert the folded network (companies with shared addresses) into a one-mode network (parent enterprise). Thereafter, they employed UCINET and ORA to conduct centrality measure analysis on the one-mode network. The analysis revealed the dark network's topography, as well as identified key actors in the dark network.

D. FORMULATING THE INFORMATION STRATEGY

Finally, the authors formulated a cohesive information strategy through a collaborative effort of combining computer vision tools with MDA dark network analysis. An information strategy for this thesis includes the process from data creation, data governance and management, data integration, monetization of information assets, and finally to forming the information architecture (Hiltbrand, 2017, para. 4). They extracted and utilized the open source data illustrated earlier in this chapter. In creating an information strategy, there are a few major components that are defined, such as vision, impact, timeline, and cost (Hiltbrand, 2017, para. 4). The first step is to understand the vision of the USN and its partners, all of whom are creatively involved in improving the MDA data collecting and sharing process. The vision for this thesis derives from those organizations' visions. They aimed to complement and further improve upon existing data collecting and sharing objectives and processes. Next, they analyzed and determined the benefits or impacts that the strategy can achieve. Lastly, in the final section of the next chapter, the authors delve deeper into addressing the timelines required to gather and manage data, and costs associated with the implementation of this information strategy. The proposed information strategy presents information and data approaches that make collecting and tracking information simpler to gain better MDA.

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IV. EXPERIMENT AND RESULT

In this chapter, the authors compile a list of 59 sanctioned vessels designated "by the United Nations (UN) Security Council, for the Democratic People's Republic of Korea (DPRK)" under Resolution 1718 (2006), 2270 (2016), 2321 (2016), and 2375 (2017) as of 1 November 2018 (UN Security Council Subsidiary Organs, n.d.), and conduct two experiments.

In the first experiment, the authors compare the number of sanctioned vessels that the three common operating platforms (COP), SeaVision, MyShipTracking, and MarineTraffic, can locate. They also compare which COP had the latest information of each sanctioned vessel. Thereafter, they evaluate the functionalities of the three COP based on the criteria stated in Chapter III.

In the second experiment, the authors conduct social network analysis (SNA) on the list of 59 sanctioned vessels and the 271 affiliated companies that perform the role of owner, ship manager, operator, document of compliance, or technical manager. The period of the second experiment is from the commencement of sanctions, which is from 2006 until 1 November 2018. Further, using the IMO and the Lexis Advance Research Database, they retrieved an additional 67 non-sanctioned vessels associated with these 271 companies affiliated with the sanctioned vessels, to uncover the dark network.

Finally, using the experiences gained in the two experiments, the authors adapt the information strategy of Hiltbrand (2017) and lay down the approaches that will make collecting information and tracking vessels of interest simpler, and in turn, gain better maritime domain awareness (MDA).

A. EVALUATING THE EFFECTIVENESS OF THE THREE COP

With the comprehensive information gathered from the UN, IMO, and the Lexis Advance Research Database, the authors compiled a list of sanctioned vessels (available in Appendix A). Using the list, they compared the effectiveness of SeaVision, MyShipTracking, and MarineTraffic in locating the 59 sanctioned vessels. They also determined which COP had the latest information about these 59 sanctioned vessels.

Finally, they evaluated the functionalities of the three COP based on the criteria stated in Chapter III.

1. Locate Sanctioned Vessels

SeaVision located 53 percent of the UN sanctioned vessels, with the majority of the detected vessels' last known positions found within the last two years. Detailed results for SeaVision are found in Appendix B. MyShipTracking located 92 percent of the sanctioned vessels, but a high number of the detected vessels' last known positions were more than a year ago. Detailed results for MyShipTracking are provided in Appendix C. MarineTraffic located 57 out of the 59 sanctioned vessels, the highest as compared to the other two applications. Of the 59 detected, a high number of the detected vessels' last known positions were within the last two years. During the experiment, they even detected one of the sanctioned vessels (name: Koti) traveling in the Yellow Sea. Detailed results for MarineTraffic are provided in Appendix D.

2. Determine which COP has the Latest Information

The authors utilized the results gathered from previous step to determine which COP could provide the latest information. The results from Part A showed that MarineTraffic is the most capable COP as it was able to detect the highest number of sanctioned vessels as compared to the other COP. They compared the age of the information to determine which COP has the most up-to-date information. For this evaluation, they assigned one point to a COP when it had the latest information as compared to the other two. In the event that two or all three COP had the same date of information, both or all three were assigned one point. Figure 7 shows the respective results, and Figure 8 shows the comparison of all three COP. Detailed results are provided in Appendix E.

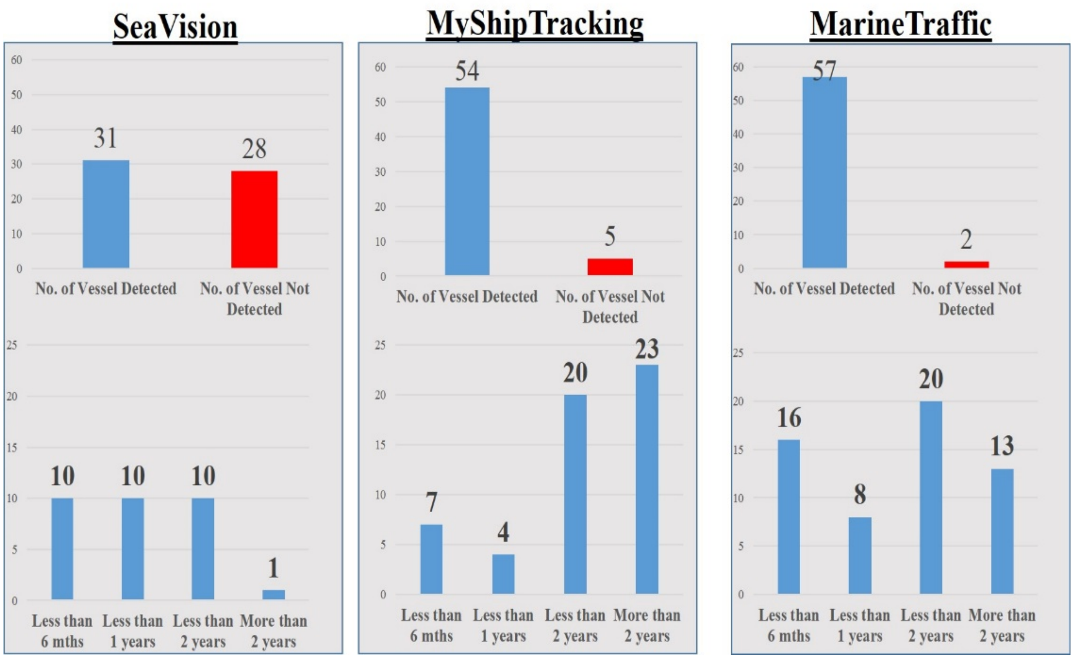

Figure 7. Detailed Results from Each Application

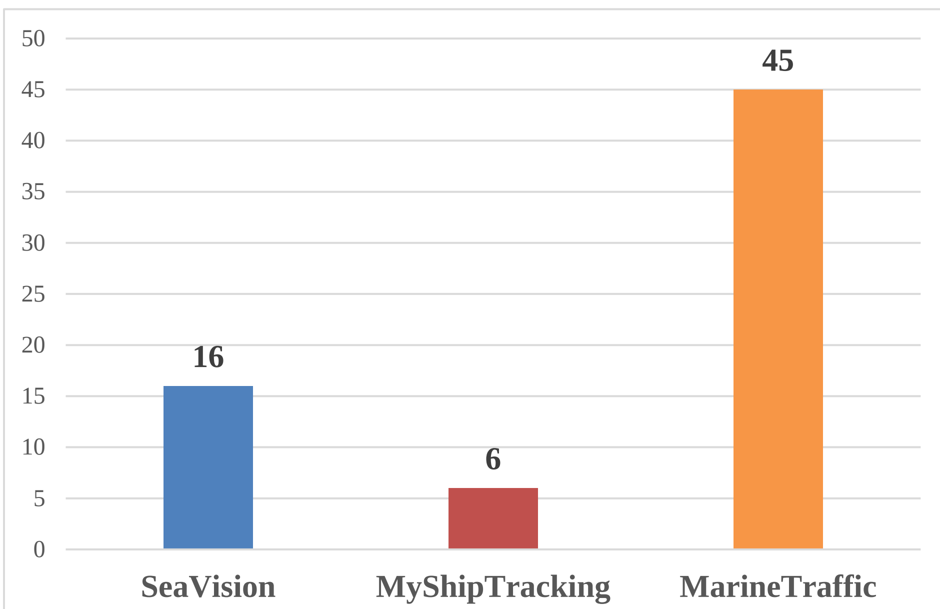

Figure 8. Comparison Result for Age of Information

In the earlier experiment, SeaVision detected 31 out of 59 sanctioned vessels and 16 of these 31 vessels (54%) had the latest information as compared to MyShipTracking and MarineTraffic. Even though MyShipTracking detected 54 out of 59 sanctioned vessels, only 6 of these 54 vessels (11%) had the latest information as compared to the other two applications. MarineTraffic had the highest percentage of latest information. MarineTraffic detected 57 out of 59 sanctioned vessels, and 45 of these 57 vessels (82%) had the most up-to-date information as compared to other two applications.

3. Evaluation of the Functions of Each COP

Using the experience gained from operating SeaVision, MyShipTracking, and MarineTraffic in the first part of the experiment, the authors evaluated the COP functionalities based on the criteria stated in Chapter III. It should be noted that these evaluations were conducted prior to 1 November 2018 and capabilities of these COP may have changed or improved thereafter.

All three COP enable individual vessel and fleet tracking on a live map via advanced filtering, notification services, and customizable mapping. Data can be split into two distinctive channels, Application Program Interface Data Services and Archive Data, provided by AIS and coastal radar.

Both SeaVision and MarineTraffic allow their users to draw a designated area such as an EEZ or territorial water on the map. Users can then set up alerts on the type of vessels or specific vessel's name, IMO number, or MMSI number, whenever it enters the designated area. Once the VOI has entered, it will send an alert to the user via email or as determined by the user.

All three COP promote sighting reports from its users. Users are encouraged to submit photos of vessels to be uploaded to each site's directory allowing other users to rate them.

Both MyShipTracking and MarineTraffic have downloadable mobile applications (apps) that integrate with the web services to support boaters, and these apps are available from iOS, Android, Windows, and Amazon app stores. MyShipTracking's app is downloadable at no cost while MarineTraffic's can be purchased through various online app stores at $4.99. SeaVision does not offer motion satellite imagery and primarily uses various types of AIS combined with radar that gives minimum overhead and multi-browser support to provide near real-time data displayed onto the maps (Foughty, 2016). SeaVision is powered by Google Maps, which offers satellite, aerial, 3D, and street view images. Stationary images are collected over time from multiple providers and platforms, so images are not real-time (Finch, 2018).

In addition to vessel information, MarineTraffic also provides information on a vessel's registered company. This information, however, is only available as part of the extended service and advanced functions to which users must subscribe. This feature does give users the ability to trace a sanctioned vessel back to its company.

All three COP also provided basis alerts or notifications that their users specify, "such as a vessel's name, IMO number, MMSI number, or call-sign" (Finch, 2018). Users can also specify under what conditions there be an alert or notification, such as when the vessel reaches or departs a port, or when the vessel starts to move or stop, or when there is a change in the vessel's AIS status.

Finally, SeaVision is the only platform that offers a group chat feature by clicking on a tab located at the top of the webpage. Once a user clicks on the tab, he or she is immediately redirected to the chat location whereby users of the same working group communicate with each other. Table 7 summarizes these evaluations.

Table 7. Comparison on Functions and Capabilities of Each COP

	SeaVision	**MyShipTracking**	**MarineTraffic**
Search Vessel via Name, IMO No. or MMSI No.	✓	✓	✓
Track via AIS and Coastal Radar	✓	✓	✓
Track via Satellite Imaging	X	X	✓
Draw Designated Area to Monitor Vessel Movement	✓	X	✓
Accept Sighting Report by Member	✓	✓	✓
Mobile App	X	✓	✓
Provide Vessel's Company Information	X	X	✓

	SeaVision	MyShipTracking	MarineTraffic
Alerts or Notifications	✓	✓	✓
Chat Function	✓	X	X

B. SNA OF UN SANCTION EFFORT ON DPRK

Using data collected from UN, IMO, and the Lexis Advance Research Database, the authors gathered additional information on 271 companies affiliated with any of the 59 sanctioned vessels. The affiliations were identified because these companies had performed the role of owner, ship manager, operator, document of compliance, or technical manager, of at least one sanctioned vessel. To uncover the dark network, they also retrieved an additional 67 non-sanctioned vessels which are associated with any of the earlier 271 companies. For the 67 non-sanctioned vessels, an additional 108 nodes were added to reflect the change of companies within the stipulated timeframe. This provided the appropriate boundary for the dark network.

1. Relational Networks

Two networks, which are a relational network of vessels and companies and a relational network of companies and addresses, were developed from the data collected. The first relational network of vessels and companies is a two-mode network that comprised 234 vessels and 271 companies. The second relational network of companies and addresses is a two-mode that comprised 271 companies and 142 addresses.

2. Analysis of Aggregated Relationships and Attributes

The authors folded the network of companies by common addresses in an attempt to reveal the parent enterprise. Figure 9 shows the top six addresses that were registered by a number of companies. They found:

- Sixteen companies shared the same registered address at Room 1, 4th Floor, 380, Minquan 2nd Road, Qianzhen District, Kaohsiung City, Republic of China (Taiwan);

- Eleven companies shared the same registered address at 8th Floor, 12, Fuxing 4th Road, Qianzhen District, Kaohsiung City, 80661, Republic of China (Taiwan);

- Nine companies shared the same registered address at Tonghung-dong, Chung-guyok, Pyongyang, North Korea;

- Five companies shared the same registered address at Room 2105 Trend Centre, 29–31 Cheung Lee Street, Chai Wan Hong Kong, Hong Kong, China 999077;

- Four companies shared the same registered address at Room 19, 11th Floor, 2, Nanjing E Road, Section 3, Songshan District, Taipei City, 10457, Republic of China (Taiwan); and

- Four companies shared the same registered address at Unit 503, 5th Floor, Silvercord Tower 2, 30, Canton Road, Tsim Sha Tsui, Kowloon, Hong Kong, China. 999077.

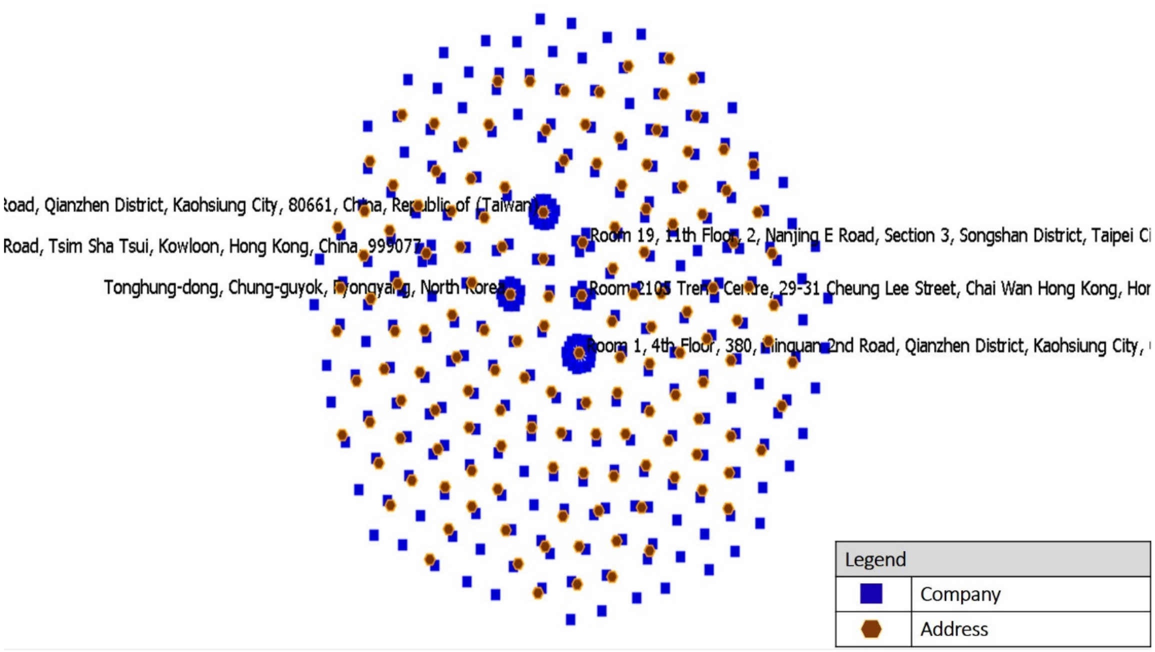

Figure 9. Companies with Same Address

The authors aggregated the vessels by companies' network with the folded network of the parent enterprise as shown in Figure 10. In this aggregated network, the authors discovered three sets of companies that shared the same address, and these three sets were affiliated with at least two or more sanctioned vessels (Figure 11). This showed that *birds of the same feather flock together*.

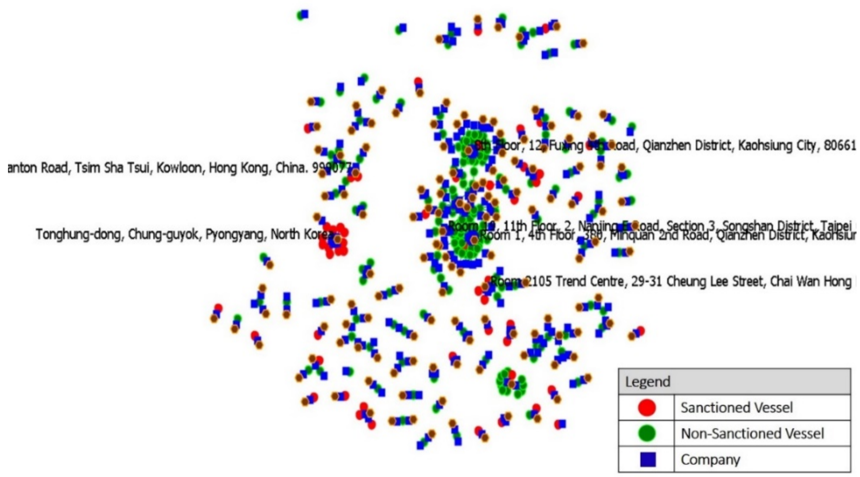

Figure 10. Network Comprising Ships and Companies with Same Address

The authors assessed that UN sanctions effectively remove some of the enterprises from the network and these three addresses might no longer be viable for the parent enterprises to continue their illicit activities, as all these vessels were sanctioned. Thus, it is likely that the DPRK regime will not engage the services of these enterprises or their vessels for future shipments and the dark network might have shifted its illicit operation to other parent enterprises.

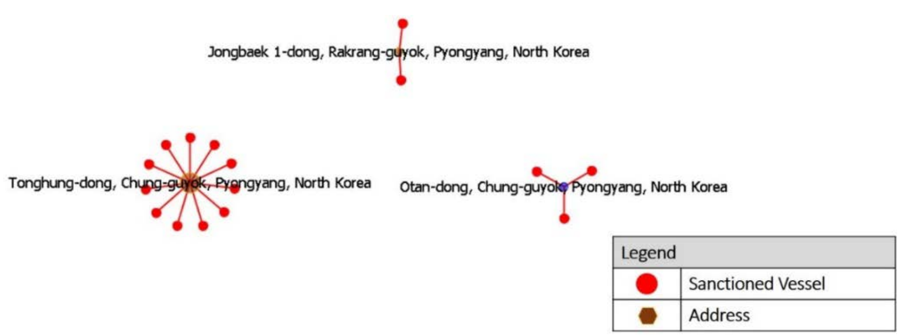

Figure 11. Sanctioned Vessels from Companies with Same Address

Next, the authors discovered some parent enterprises that had two or more sanctioned vessels, as well as at least one non-sanctioned vessel, as shown in Figure 12. These parent enterprises might continue their illicit operations via the non-sanctioned vessels under their charge. Hence, investigators should focus their efforts on the following eight non-sanctioned vessels: Asia Bridge, Hai Fu, Hao Fan 3, Lucky Star, Nam San 6, Xin Tian Xie, Xin Yang 7, and Xin Yang 688.

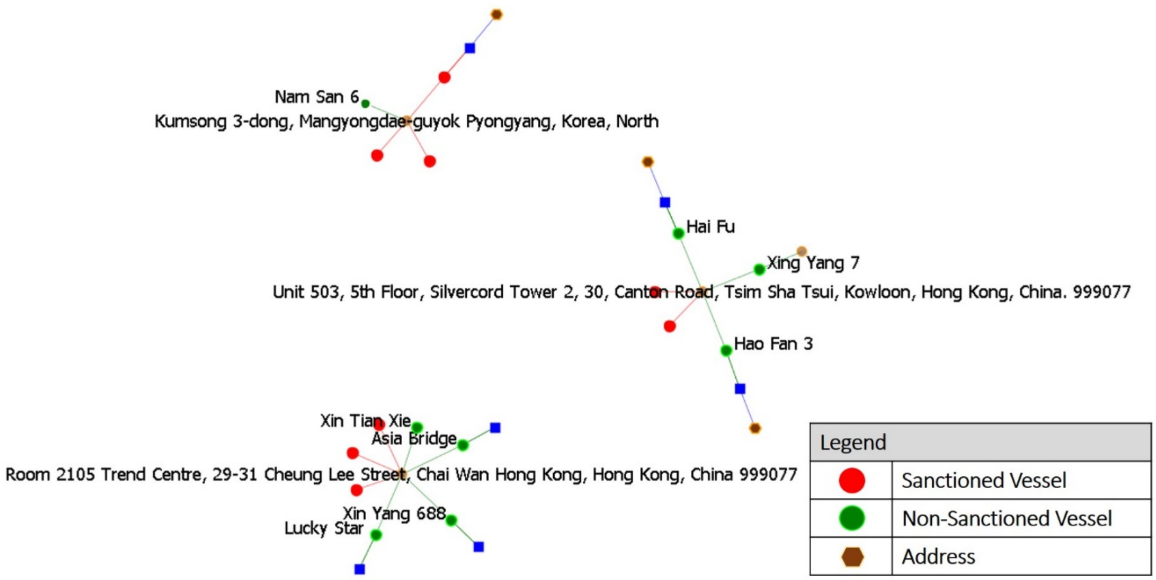

Figure 12. Parent Enterprises with Sanctioned and Non-sanctioned Vessels

Lastly, the authors also discovered a very densely connected network within the aggregated network, shown in Figure 10. They used ORA to fold the two-mode network (companies with the same address and ships) into a one-mode (parent enterprises), as shown in Figure 13. Using the newly folded one-mode network, they used UCINET and ORA to conduct centrality measure analysis (degree centrality, closeness centrality, and betweenness centrality), and the result is shown in Table 8. The result shows four parent enterprises—Ocean Grow International Shipment, Vanguard Shipping Safety Management, Shinhan Capital Co Ltd, and Natzutec Maritime Ltd—consistently ranked in the top ten central actors in this one-mode network. Ocean Grow International Shipment scored the highest and is considered the most central actor in the whole network. The authors assessed that these top four parent enterprises were in the position to serve as brokers between groups, and bring to bear the influence of one group onto another. These parent enterprises could easily dispatch the remaining non-sanctioned vessels to continue with illicit shipments to DPRK, should they choose to do so. Coupled with the fact that each of these parent enterprises resides in a broker position, it could collaborate with other like-minded enterprises to use the latter's vessel in lieu of its own, and continue to support DPRK's illicit activities. In this network, investigators should focus on these four top parent enterprises and vessels under their charge.

Figure 13. One Mode Network (Parent Enterprise)

Table 8. Centrality Measures for Densely Connected Network

Degree	Closeness	Betweenness
Ocean Grow Intl Shipmgmt (0.109)	**Ocean Grow Intl Shipmgmt (0.213)**	**Ocean Grow Intl Shipmgmt (0.121)**
Vanguard Shipping Safety Mgmt (0.109)	**Vanguard Shipping Safety Mgmt (0.192)**	**Vanguard Shipping Safety Mgmt (0.074)**
Shinhan Capital Co Ltd (0.076)	Chang Soon Shipping Corp (0.169)	Chang Soon Shipping Corp (0.063)
Natzutec Maritime Ltd (0.043)	**Natzutec Maritime Ltd (0.167)**	Keoyoung Shipping Co Ltd (0.055)
Dalian Grand Ocean Shipping Mg (0.043)	**Shinhan Capital Co Ltd (0.162)**	**Shinhan Capital Co Ltd (0.054)**
Lauritzen Bulkers A/S (0.043)	Keoyoung Shipping Co Ltd (0.161)	**Natzutec Maritime Ltd (0.043)**
Shen Zhong International Shipping (0.033)	Gold Advance Corp (0.153)	Dalian Grand Ocean Shipping Mg (0.018)
HongKong XingXiang Co Ltd (0.033)	Jacksoon Shipping Safety Mgmt (0.149)	Silverline Maritime Sdn Bhd (0.017)
Stove Rederi AS (0.033)	Zhejiang Wanheng Shipping Co (0.145)	Li Quan Shipping Co Ltd (0.017)
Bidsted & Co A/S (0.033)	Win Trend Transportation Ltd (0.142)	Jacksoon Shipping Safety Mgmt (0.010)

C. MDA INFORMATION STRATEGY

The current problem of an information silo mentality among international partners who are not willing to share information may be due to a lack of trust or a lack of understanding of each other’s technical intelligence limitations (GPO INTELLIGENCE, 1996). Nevertheless, critical information, when shared appropriately, could help involved parties focus their efforts, instead of working individually, and therefore reap higher returns on their time invested. Decision makers need timely and accurate information to effectively counter threats such as overfishing; weapons, drugs, and contraband smuggling; terrorism; illegal immigration; and military actions (MarineTraffic, n.d.a).

Aiming to address this problem, the authors consolidated the results of the two experiments conducted in this thesis. They adapted the information strategy by Hiltbrand (2017) to propose an information strategy for an unclassified MDA, for use and sharing by international partners. This MDA information strategy has the following major components: vision, data to be collected, information to be processed, time required to collect data and process information, information sharing, and the benefits and impacts of strategy.

The vision of the information strategy is aligned to the vision of the USN and its partners involved in the MDA data collecting and sharing process. This will ensure that all efforts focus on improving MDA and sharing critical information.

Collected data should be drawn from multiple sources that are non-classified and publicly available, such as the UN website, IMO website, or the online Lexis Advance Research Database. There can also be established rules, procedures, and boundaries for all members to follow. This will serve as the guideline on what, when, and how to collect the data.

After data collection, the users need to analyze the raw data and extract useful information from it. By using SNA tools like ORA and UCINET, users can analyze large amounts of raw data and reveal possible concealed relationships in the dark network. Thereafter, users can focus their attention on the key actors revealed by ORA and UCINET, and conduct further analysis on those actors.

Data collection times vary from days to months, depending on the dataset size. For the two sets of experiments for this thesis, the authors took five days to collect the requisite data from the three sources. It took one week to clean up the data before processing it with ORA and UCINET. Another two weeks passed while analyzing the data in ORA and UCINET and finalizing the results.

With the results, the user can decide with whom and how to share information. The authors think it will be easier to share this information since it was derived from publicly available sources. Nonetheless, in order to encourage members to share information, it is important to be transparent in the sharing process. The transparency of well-established rules, procedures, and boundaries will be a critical success factor for this strategy. Transparency will help to bridge the gap between different members and to address possible concerns related to sharing information with multiple countries.

The benefits and impacts of the strategy can be a matter of life and death. With critical information shared timely, decision makers can take pre-emptive measures or make critical decisions to thwart a dangerous situation instead of reacting to it only after it happens.

V. CONCLUSION

This chapter provides a comprehensive summary of results from the experiments. Also included is the developed information strategy for MDA, to gather necessary information from various sources in order to build up an unclassified MDA and its dark network, all of which are shareable with international partners. The information strategy should also improve the partners' willingness to subsequently share information. Finally, this chapter also proposes ideas for future research.

A. SUMMARY OF RESULTS

The following sections summarize the results from the two experiments described in Chapter IV.

1. Evaluation of COP

MarineTraffic stood out compared to the other two applications (SeaVision and MyShipTracking) during the evaluation phase of the first experiment. MarineTraffic scored highest in detecting the highest number of sanctioned vessels, as well as providing the most up-to-date information on the sanctioned vessels. MarineTraffic also had almost all the same functions and capabilities as SeaVision and MyShipTracking, except for the chat function that SeaVision offers. It is worth noting that MarineTraffic users are required to pay a monthly subscription of US$190.75 for an account to access the advanced functions and capabilities (MarineTraffic, n.d.a).

2. SNA of UN Sanctions on DPRK

In the second experiment, the authors focused on the 59 sanctioned vessels and the 271 affiliated companies that were responsible for ownership, ship management, operation, documentation compliance, or technical management, as well as 67 non-sanctioned vessels that are associated with any of the affiliates.

The authors subsequently aggregated the vessels' network with the network of companies by common addresses in an effort to reveal the parent enterprise. They discovered companies that shared the same addresses and affiliations with at least one sanctioned vessel. For example, there was one registered address in North Korea associated with 11 sanctioned vessels. Next, they learned that three parent enterprises had two or more sanctioned vessels, as well as at least one non-sanctioned vessel. The authors assessed that these parent enterprises might continue to operate their illicit operations via those non-sanctioned vessels under their charge.

Lastly, the authors also realized that there was a very densely connected network within the folded network. In this folded network, four parent enterprises were totally connected to other vessels or companies. They assessed that these four parent enterprises were in the position to serve as brokers between groups and bring to bear the influence of one group onto another. Similarly, there was at least one sanctioned vessel linked to each one of these four parent enterprises.

3. MDA Information Strategy

The authors recommend aligning the vision of the information strategy to that of the USN and its partners involved in the MDA data collecting and sharing process. Data was collected from multiple sources that are non-classified and publicly available. Thereafter, using SNA tools, they analyzed the raw data and revealed key actors within the dark network. This process allows investigators to focus their effort on these key actors revealed by the SNA tools, and conduct further analysis on them. The time required for collection and processing will depend on the size of the dataset to be collected. For the two sets of experiments documented in this thesis, the authors took a month to finalize the results. As the final results are generated from publicly available sources, these results can be shared freely among MDA members. Moreover, transparency in the sharing processing will be a critical success factor for this strategy.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

1. Consider Changing from SeaVision to MarineTraffic

As shown in the evaluation of the three applications, there are still many areas in which SeaVision can improve. A key feature lacking in SeaVision is the ability to track vessels via satellite imagery, which MarineTraffic can do. As compared to paying a hefty sum to maintain and upgrade SeaVision, it is only a fraction of that cost to subscribe to MarineTraffic's advanced functions.

2. Integrate SNA with MDA

As shown in the second experiment of this thesis, SNA can help cue intelligence investigators to focus on a smaller selective group of targets, as compared to a large group of non-sensitive vessels and companies. Thus, coupling MDA with an SNA capability for a particular group of vessels might enable investigators to discover potential dark networks and stop illicit activities before they even happen. Since SNA uses unclassified data, results can be rapidly and easily shared with partners.

3. Analyze Other Sources of Information on the Current List of SNA Data

The SNA experiment conducted in this thesis used vessels, their affiliated companies, and each company's registered address. Including more data sources, such as shareholders, longitudinal data of vessels changing affiliated companies, and telephone and fax numbers used by these companies might reveal more hidden relationships of the dark network.

4. Research How the New MQ-4C Triton Unmanned Aerial Vehicle Might Support USN MDA

The USN recently began operations using the MQ-4C Triton Unmanned Aerial Vehicle (AV), which is a long ranged UAV. Designed to augment the ISR component of the manned P-8 missions, the MQ-4C Triton UAV contains an advanced surface search radar that might have use in MDA support. One wonders whether adding an AIS receiver, visible light, or IR cameras would enhance its MDA capabilities.

C. CONCLUSION

The first experiment evaluated the capabilities of SeaVision as compared to the other two applications, MyShipTracking and MarineTraffic. It provided evidence to show that SeaVision still has much room for improvement and for the USN to consider changing over to MarineTraffic. As proposed under the information strategy, the COP needs to have multiple functions and capabilities, as well as be easy to use and flexible. This will then encourage international partners to be willing to use the COP first, and promote possible information sharing later.

The second experiment showed the capability of SNA in discovering a possible dark network of a group of actors connected through common links such as company and registered address. Multiple sources of information are critical in order for SNA to build up a more credible network. This can be achieved through increased information sharing by international partners, in addition to the non-classified means discussed in this thesis.

Finally, the proposed information strategy for MDA is envisaged to help in building an unclassified MDA so that it can be used and shared by international partners. The strategy also aims to address the concerns of partners' unwillingness to share information, and turn them into advocates who help to promote the benefits of sharing MDA.

APPENDIX A. LIST OF SANCTIONED VESSELS

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
1	An San 1	445018000	7303803	Chemical Tanker	Democratic People's Rep. of Korea	HMYD7	Korea Ansan Shipping Co	5676084	Korea, North
2	Asia Bridge 1	677092100	8916580	General Cargo Ship	Tanzania, United Republic of	5IM721	WORLD-SHIPPING MARING LTD	5799201	Hong Kong, China
3	Chol Ryong	445144000	8606173	General Cargo Ship	Democratic People's Rep. of Korea	HMBR	CHOLRYONG SHIPPING CO LTD	5814870	Korea, North
4	Chon Ma San	445082000	8660313	Oil Products Tanker	Democratic People's Rep. of Korea	HMYA2	KOREA ACHIM SHIPPING CO	5936312	Korea, North
5	Chon Myong 1	445564000	8712362	Oil Products Tanker	Democratic People's Rep. of Korea	HMZD2	CONMYONG SHIPPING CO	5571322	Korea, North

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
6	Chong Bong	445528000	8909575	General Cargo Ship	Democratic People's Rep. of Korea	HMXW	CHONGBONG SHIPPING CO LTD	5878589	Korea, North
7	Chong Rim 2	445175000	8916293	Chemical Tanker	Democratic People's Rep. of Korea	HMYF7	Ocean Bunkering JV Co	4199470	Korea, North
8	Dong Feng 6	677093100	9008201	General Cargo Ship	Tanzania, United Republic of	5IM731	SHANGHAI DONGFENG SHIPPING CO LTD	5721069	China, People's Republic of
9	Fan Ke	667077000	8914934	General Cargo Ship	Panama	9LY266	Pantech Shipping Ltd	5901171	Hong Kong, China
10	Hao Fan 2	341988000	8747604	General Cargo Ship	Saint Kitts and Nevis	V4PM3	Advance Superstar Hong Kong	5975408	Hong Kong, China
11	Hao Fan 6	341985000	8628597	Bulk Carrier	Saint Kitts and Nevis	V4PL3	TRENDY SUNSHINE HONG KONG LTD	5975385	Hong Kong, China
12	Hap Jang Gang 6	445045000	9066540	General Cargo Ship	Democratic People's Rep. of Korea	HMPI	HAPJANGGANG SHIPPING CORP	5787684	Korea, North

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
13	Hoe Ryong	445150000	9041552	General Cargo Ship	Democratic People's Rep. of Korea	HMBF	HOERYONG SHIPPING CO LTD	5817786	Korea, North
14	Hua Fu	353715000	9020003	General Cargo Ship	Panama	FH6	CHANG AN SHIPPING & TECHNOLOGY	5938411	Hong Kong, China
15	Hui Chon	445113000	8405270	General Cargo Ship	Democratic People's Rep. of Korea	HMZI	HUICHON SHIPPING CO LTD	5817812	Korea, North
16	Ji Hye San	445128000	8018900	Bulk Carrier	Democratic People's Rep. of Korea	HMBN	JIHYESAN SHIPPING CO LTD	NA	Korea, North
17	Ji Song 6	445195000	8898740	Bunkering Tanker	Democratic People's Rep. of Korea	HMYL3	PHYONGCHON SHIPPING & MARINE	5878561	Korea, North
18	Jie Shun	514569000	8518780	General Cargo Ship	Cambodia	XUTS3	VAST WIN TRADING LTD	5824187	Hong Kong, China
19	Jin Hye	667025000	8518572	Oil Products Tanker	Sierra Leone	9LC2009	S&P;LLC	5774618	Liberia
20	Kal Ma	445392000	8503228	General Cargo Ship	Democratic People's Rep. of Korea	HMYW8	Korea Surim Trading Co	6037771	Korea, North

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
21	Kang Gye	445122000	8829593	General Cargo Ship	Democratic People's Rep. of Korea	HMAK	Kanggye Shipping Co Ltd	5822804	Korea, North
22	Kingsway	511647000	9191773	Chemical oil products tanker	Palau	T8A2736	COSMOS OIL TRADE CO LTD	6019523	Marshall Islands
23	Koti	372095000	9417115	Oil Products Tanker	Togo	3EXU4	KOTI CORP	5982254	Panama
24	Kum Un San 3	445537000	8705539	Products Tanker	Democratic People's Rep. of Korea	HMHP	KOREA MIHYANG SHIPPING & TRDG	6041527	Korea, North
25	Mi Rim	445498000	8713471	General Cargo Ship	Democratic People's Rep. of Korea	HMMS	MIRIM SHIPPING CO LTD	5647684	Korea, North
26	Mi Rim 2	445716000	9361407	General Cargo Ship	Democratic People's Rep. of Korea	HMLP	MIRIM SHIPPING CO LTD	5647684	Korea, North
27	MIN NING DE YOU 078	NA	NA	NA	NA	NA	NA	NA	NA

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
28	Nam San 8	445145000	8122347	Crude Oil Tanker	Democratic People's Rep. of Korea	HMAW	HAPJANGANG SHIPPING CORP	5787684	Korea, North
29	New Regent	355976000	8312497	Crude Oil Tanker	Panama	3FCR5	MEGA GLORY HOLDINGS LTD	5625186	Hong Kong, China
30	O Rang	445142000	8829555	General Cargo Ship	Democratic People's Rep. of Korea	HMBW	ORANG SHIPPING CO LTD	5821443	Korea, North
31	O Un Chong Nyon Ho	445112000	8330815	General Cargo Ship	Democratic People's Rep. of Korea	HMAD	NA	NA	NA
32	Paek Ma	445207000	9066978	Oil Products Tanker	Democratic People's Rep. of Korea	HMYG5	PAEKMA SHIPPING CO	5999479	Korea, North
33	Paek Yang San	445759000	9020534	General Cargo Ship	Democratic People's Rep. of Korea	HMHV	PAEKYANGSAM SHIPPING CO LTD	6029462	Korea, North

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
34	Petrel 8	620233000	9562233	Bulk Carrier	Comoros	D6A2233	LI QUAN SHIPPING CO LTD	5838827	Hong Kong, China
35	Ra Nam 2	445470000	8625545	General Cargo Ship	Democratic People's Rep. of Korea	HMMG	KOREA SAMILPO SHIPPING CO	1701459	Korea, North
36	Ra Nam 3	445024000	9314650	General Cargo Ship	Democratic People's Rep. of Korea	HMPQ	KOREA SAMILPO SHIPPING CO	1701459	Korea, North
37	Rak Won 2:	445140000	8819017	General Cargo Ship	Democratic People's Rep. of Korea	HMBC	NA	NA	Korea, North
38	Rye Song Gang 1	445038000	7389704	Oil Products Tanker	Democratic People's Rep. of Korea	HMKU	KOREA KUMBYOL TRADING CO	5614028	Korea, North
39	Ryo Myong	445023000	8987333	General Cargo Ship	Democratic People's Rep. of Korea	HMPP	KOREAN POLISH SHIPPING CO LTD	1267131	Korea, North

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
40	RYONG GANG 2	445135000	7640378	General Cargo Ship	Democratic People's Rep. of Korea	HMAI	NA	NA	NA
41	Ryong Rim	445110000	8018912	Bulk Carrier	Democratic People's Rep. of Korea	HMZB2	RYONGRIM SHIPPING CO LTD	5817772	Korea, North
42	Sam Jong 1	445184000	8405311	Crude Oil Tanker	Democratic People's Rep. of Korea	HMYC3	KOREA SAMJONG SHIPPING CO	5954061	Korea, North
43	Sam Jong 2	445078000	7408873	Chemical oil products tanker	Democratic People's Rep. of Korea	HMBE	CHINA DANCONG XIANGHE	5800748	China, People's Republic of
44	Sam Ma 2	445220000	8106496	Oil Products Tanker	Democratic People's Rep. of Korea	HMYO5	KOREA SAMMA SHIPPING CO	5145892	Korea, North
45	Shang Yuan Bao	374287000	8126070	Products Tanker	Panama	3EED4	JUI CHENG SHIPPING CO LTD	5499198	Hong Kong, China

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
46	Songjin	445366000	8133530	Bulk Carrier	Democratic People's Rep. of Korea	HMZE	SONGJIN SHIPPING CO LTD	5821430	Korea, North
47	South Hill 2	667003342	8412467	Bulk Carrier	Sierra Leone	9LY2253 9	NA	NA	NA
48	Thae Pyong San	445527000	9009085	General Cargo Ship	Democratic People's Rep. of Korea	HMXQ	THAEPHYONGS AN SHIPPING CO LTD	5878575	Korea, North
49	Tong Hung 1	445141000	8661575	General Cargo Ship	Democratic People's Rep. of Korea	HMYI	TONGHUNG SHIPPING & TRADING CO	1991835	Korea, North
50	Tong Hung San	445114000	7937317	General Cargo Ship	Democratic People's Rep. of Korea	HMZF	TONGHUNGSAN SHIPPING CO LTD	5826665	Korea, North
51	Tong San 2	445539000	8937675	Bulk Dry	Democratic People's Rep. of Korea	P7LY	NAMPO FISHERY STATION	1845244	Nampo, North Korea

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
52	Ul Ji Bong 6	445276000	9114555	General Cargo Ship	Democratic People's Rep. of Korea	HMUG	CK INTERNATIONAL LTD	5980332	Hong Kong, China
53	Wan Heng 11	445815000	8791667	Oil Products Tanker	Democratic People's Rep. of Korea	HMYZ3	ZHEJIANG WANHENG SHIPPING CO	4221559	China, People's Republic of
54	Woory Star	445393000	8408595	General Cargo Ship	Democratic People's Rep. of Korea	HMYW9	PHYONGCHON SHIPPING & MARINE	5878561	Korea, North
55	Xin Guang Hai	NA	9004700	General Cargo Ship	NA	NA	Ascending Enterprise Ltd	5957636	United Kingdom
56	Yu Jong 2	445190000	8604917	Oil Products Tanker	Democratic People's Rep. of Korea	HMYC6	KOREA YUJONG SHIPPING CO LTD	5434358	Korea, North

No.	Name of Vessel	MMSI No.	IMO No.	Type of Vessel	Flag	Call Sign	Registered Owner	Comp IMO No.	Nationality of Registration
57	Yu Phyong 5	445372000	8605026	Oil Products Tanker	Democratic People's Rep. of Korea	HMYQ	KOREA MYONGDOK SHIPPING CO	5985863	Korea, North
58	Yu Son	511329000	8691702	Oil Products Tanker	Democratic People's Rep. of Korea	HMZE9	JINMYONG JOINT VENTURE CO	6005921	Korea, North
59	Yuk Tung	325823000	9030591	Crude Oil Tanker	Dominica	J7DN3	YUK TUNG ENERGY INC	5988222	Cook Islands

APPENDIX B. DETAILED RESULT FROM SEAVISION

No.	Name of Vessel	IMO No.	Destination	Latitude	Longitude	Timestamp	Age of info
1	An San 1	7303803	Unknown	30.202552	122.343703	02-Aug-18	Less than 6 months
2	Asia Bridge 1	8916580	No result				
3	Chol Ryong	8606173	No result				
4	Chon Ma San	8660313	Wsb	34.82271	122.712385	14-Sep-17	Less than 2 years
5	Chon Myong 1	8712362	Unknown	41.846132	130.033853	30-Jan-18	Less than 1 year
6	Chong Bong	8909575	Unknown	33.884837	129.338197	18-Oct-17	Less than 1 year
7	Chong Rim 2	8916293	Chong Jin	32.445543	127.933905	25-Sep-17	Less than 2 years
8	Dong Feng 6	9008201	Unknown	33.905277	126.930743	17-Jul-17	Less than 2 years
9	Fan Ke	8914934	Unknown	26.74495	121.131782	27-Sep-17	Less than 2 years
10	Hao Fan 2	8747604	Xzm	33.047783	126.75235	26-Oct-17	Less than 1 year
11	Hao Fan 6	8628597	No result				
12	Hap Jang Gang 6	9066540	No result				
13	Hoe Ryong	9041552	No result				
14	Hua Fu	9020003	Dandong	34.324217	123.133213	11-Oct-16	Less than 2 years
15	Hui Chon	8405270	No result				
16	JI HYE SAN	8018900	No result				
17	Ji Song 6	8898740	No result				
18	Jie Shun	8518780	No result				
19	Jin Hye	8518572	Kaohsiung	22.585092	120.230305	08-May-17	Less than 2 years
20	Kal Ma	8503228	Wsb	32.819467	127.982867	20-Sep-17	Less than 2 years
21	Kang Gye	8829593	No result				
22	Kingsway	9191773	Kaohsiung	22.590067	120.232033	21-Jan-18	Less than 1 year
23	Koti	9417115	Pyeongtaek	34.046077	127.798852	07-Dec-17	Less than 1 year
24	Kum Un San 3	8705539	Unknown	33.5242	129.1719	16-Feb-18	Less than 1 year
25	Mi Rim	8713471	No result				
26	Mi Rim 2	9361407	No result				
27	Min Ning De You 078	NA	No result				
28	Nam San 8	8122347	No result				

No.	Name of Vessel	IMO No.	Destination	Latitude	Longitude	Timestamp	Age of info
29	New Regent	8312497	Unknown	25.1054	121.1248	12-Jul-18	Less than 6 months
30	O Rang	8829555	No result				
31	O Un Chong Nyon Ho	8330815	Won San	34.663493	130.28345	16-Apr-18	Less than 6 months
32	Paek Ma	9066978	C. J.k	37.525518	122.532715	31-Jul-18	Less than 6 months
33	Paek Yang San	9020534	Nam Pho	37.347917	123.04295	16-Jul-18	Less than 6 months
34	Petrel 8	9562233	Byq	34.118673	125.936642	31-Oct-17	Less than 1 year
35	Ra Nam 2	8625545	No result				
36	Ra Nam 3	9314650	No result				
37	Rak Won 2:	8819017	No result				
38	Rye Song Gang 1	7389704	No result				
39	Ryo Myong	8987333	No result				
40	RYONG GANG 2	7640378	No result				
41	Ryong Rim	8018912	No result				
42	Sam Jong 1	8405311	Dalian	38.584718	123.18407	07-Mar-18	Less than 1 year
43	Sam Jong 2	7408873	Chong Jin	34.190527	129.76703	12-Dec-17	Less than 1 year
44	Sam Ma 2	8106496	Chongjin	38.63333	132.982718	04-Aug-18	Less than 6 months
45	Shang Yuan Bao	8126070	Unknown	22.462755	119.702595	24-Jun-18	Less than 6 months
46	Songjin	8133530	No result				
47	SOUTH HILL 2	8412467	No result				
48	Thae Pyong San	9009085	No result				
49	Tong Hung 1	8661575	No result				
50	Tong Hung San	7937317	No result				
51	Tong San 2	8937675	Unknown	38.212933	123.614762	19-Mar-18	Less than 1 year
52	Ul Ji Bong 6	9114555	Kholmsk/russia	33.217452	128.498083	05-Sep-17	Less than 2 years
53	Wan Heng 11	8791667	Nampho	34.909933	130.961018	21-Jun-18	Less than 6 months
54	Woory Star	8408595	No result				
55	Xin Guang Hai	9004700	Wei Hai	32.479952	130.503118	03-Sep-16	More than 2 years
56	Yu Jong 2	8604917	Unknown	38.673748	125.02964	06-Dec-18	Less than 6 months
57	Yu Phyong 5	8605026	Nampho	32.696147	128.090397	25-Sep-17	Less than 2 years

No.	Name of Vessel	IMO No.	Destination	Latitude	Longitude	Timestamp	Age of info
58	Yu Son	8691702	Chongjin	33.105413	128.331347	12-Jul-18	Less than 6 months
59	Yuk Tung	9030591	Unknown	25.0867	120.092507	21-Sep-17	Less than 2 years

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APPENDIX C. DETAILED RESULT FROM MYSHIPTRACKING

No.	Name of Vessel	IMO No.	Destination	Latitude	Longitude	Timestamp	Age of info
1	An San 1	7303803	Ch_Dandong	33.20117	128.35437	04-May-17	Less than 2 years
2	Asia Bridge 1	8916580	Cn Wei	37.442	122.27412	07-Aug-16	More than 2 years
3	Chol Ryong	8606173	Chang Jiang Kou	31.12118	121.93253	19-Feb-16	More than 2 years
4	Chon Ma San	8660313	Zhoushan	30.26714	121.92829	04-Jun-17	Less than 2 years
5	Chon Myong 1	8712362	Hung Nam	34.52112	130.28983	02-Dec-16	Less than 2 years
6	Chong Bong	8909575	Haeju	34.73872	130.74433	28-Mar-17	Less than 2 years
7	Chong Rim 2	8916293	Taichung, Taiwan	38.95335	121.6782	30-Dec-15	More than 2 years
8	Dong Feng 6	9008201	CN Foc	26.29417	119.85135	15-Aug-17	Less than 2 years
9	Fan Ke	8914934	Vanino	37.35475	122.78187	22-Feb-16	More than 2 years
10	Hao Fan 2	8747604	LY	29.82093	122..45940	26-Dec-17	Less than 1 year
11	Hao Fan 6	8628597	Unknown	33.82997	127.11249	30-Aug-17	Less than 2 years
12	Hap Jang Gang 6	9066540	Namph O	38.81608	122.16825	08-Feb-15	More than 2 years
13	Hoe Ryong	9041552	Lan Shan	36.73187	123.0447	18-Jun-16	More than 2 years
14	Hua Fu	9020003	Jingtang	38.89167	121.98413	16-May-17	Less than 2 years
15	Hui Chon	8405270	Dong Jiakou, China	37.24528	122.94357	25-Nov-14	More than 2 years
16	Ji Hye San	8018900	Dan Dong, China	37.55157	123.0362	16-Jun-16	More than 2 years
17	Ji Song 6	8898740	No Result				
18	Jie Shun	8518780	Bombay	32.44332	29.62992	18-Aug-16	More than 2 years
19	Jin Hye	8518572	Kaohsiung	22.58509	120.23031	07-May-17	Less than 2 years
20	Kal Ma	8503228	WSB	40.30063	121.95248	28-Sep-17	Less than 2 years
21	Kang Gye	8829593	Nam Po	32.14065	123.10353	15-Jun-15	More than 2 years
22	Kingsway	9191773	Kaohsiung	22.59007	120.23193	08-Dec-17	Less than 1 years
23	Koti	9417115	Pyeongtaek	37.00624	126..75086	21-Apr-18	Less than 6 months
24	Kum Un San 3	8705539	Yellow Sea	38.01925	123.3809	26-Jul-17	Less than 2 years

No.	Name of Vessel	IMO No.	Destination	Latitude	Longitude	Timestamp	Age of info
25	Mi Rim	8713471	Nampho	38.49276	121.53471	29-Feb-16	More than 2 years
26	Mi Rim 2	9361407	Wonsan	36.66561	122.91302	10-May-16	More than 2 years
27	MIN NING DE YOU 078	NA	No Result				
28	Nam San 8	8122347	Dalian	38.4837	122.09393	27-Apr-17	Less than 2 years
29	New Regent	8312497	Unknown	26.49524	119.87504	30-Jul-18	Less than 6 months
30	O Rang	8829555	Unknown	30.98954	122.51933	09-Sep-14	More than 2 years
31	O Un Chong Nyon Ho	8330815	Wonsan	37.29038	122.96794	22-Sep-15	More than 2 years
32	Paek Ma	9066978	No Result				
33	Paek Yang San	9020534	Nam Pho	33.56321	128.90178	12-Jul-18	Less than 6 months
34	Petrel 8	9562233	KR TGH	37.98705	121.52208	16-Oct-17	Less than 1 year
35	Ra Nam 2	8625545	Nan Pho	38.49718	122.24981	03-Mar-16	More than 2 years
36	Ra Nam 3	9314650	WSB	38.52215	122.35779	06-Mar-16	More than 2 years
37	Rak Won 2:	8819017	Nam Pho	36.75214	122.99932	15-Jul-15	More than 2 years
38	Rye Song Gang 1	7389704	Shiadao, China	36.80117	122.43748	03-Dec-16	Less than 2 years
39	Ryo Myong	8987333	Lk, China	37.68114	120.18454	11-Mar-16	More than 2 years
40	RYONG GANG 2	7640378	Dalian	38.58774	123.30977	21-Aug-14	More than 2 years
41	Ryong Rim	8018912	Nam Pho	37.02777	122.90244	24-Sep-14	More than 2 years
42	Sam Jong 1	8405311	Chong Jin	34.72442	130.45794	29-Aug-17	Less than 2 years
43	Sam Jong 2	7408873	Unknown	38.16876	123.91033	18-Oct-16	Less than 2 years
44	Sam Ma 2	8106496	Nam Pho	33.53929	128.90112	25-Jul-18	Less than 6 months
45	Shang Yuan Bao	8126070	South China Sea	22.46317	119.70299	24-Jun-18	Less than 6 months
46	Songjin	8133530	Lanqiao	36.88924	122.9318	11-Nov-16	Less than 2 years
47	SOUTH HILL 2	8412467	Jiangin	31.9215	120.1911	20-Jan-16	More than 2 years
48	Thae Pyong San	9009085	HongKong	34.51397	130.08743	16-Apr-18	Less than 6 months
49	Tong Hung 1	8661575	Taean	37.8885	120.08933	02-Mar-16	More than 2 years
50	Tong Hung San	7937317	No Result				

No.	Name of Vessel	IMO No.	Destination	Latitude	Longitude	Timestamp	Age of info
51	Tong San 2	8937675	Daean	38.69682	125.11834	26-Aug-17	Less than 2 years
52	Ul Ji Bong 6	9114555	Dalian	38.79048	121.86982	21-Jul-17	Less than 2 years
53	Wan Heng 11	8791667	Chongjin	34.73426	130.75001	21-Jun-18	Less than 6 months
54	Woory Star	8408595	Nampo	38.74542	123.61795	23-Sep-17	Less than 2 years
55	Xin Guang Hai	9004700	Wei Hao	37.44336	122.27329	23-Jan-17	Less than 2 years
56	Yu Jong 2	8604917	No Result				
57	Yu Phyong 5	8605026	Chong Jin	34.02043	129.55395	24-Sep-17	Less than 2 years
58	Yu Son	8691702	Shiadao, China	36.86238	122.38136	23-Aug-16	More than 2 years
59	Yuk Tung	9030591	Kr Pus	25.43915	121.99984	02-Jan-18	Less than 1 year

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APPENDIX D. DETAILED RESULT FROM MARINETRAFFIC

No.	Name of Vessel	IMO No.	Destination	Latitude	Longitude	Timestamp	Age of info
1	An San 1	7303803	East China Sea	30.20256	122.3437	02-Aug-18	Less than 6 months
2	Asia Bridge 1	8916580	No Result				
3	Chol Ryong	8606173	Yellow Sea	28.32983	124.2438	21-Nov-16	Less than 2 years
4	Chon Ma San	8660313	East China Sea	31.13916	122.7292	06-Jun-17	Less than 2 years
5	Chon Myong 1	8712362	Japan Coast	35.17123	131.3031	01-Oct-17	Less than 2 years
6	Chong Bong	8909575	North China	39.88593	128.5297	03-Aug-18	Less than 6 months
7	Chong Rim 2	8916293	Yellow Sea	36.73779	122.7419	21-Nov-17	Less than 1 year
8	Dong Feng 6	9008201	East China Sea	26.29417	119.8513	15-Aug-17	Less than 2 years
9	Fan Ke	8914934	East China Sea	27.72992	121.854	15-Jul-18	Less than 6 months
10	Hao Fan 2	8747604	East China Sea	29.8228	122.4581	27-Jan-18	Less than 1 year
11	Hao Fan 6	8628597	East China Sea	29.92597	122.2898	18-Dec-17	Less than 1 year
12	Hap Jang Gang 6	9066540	Yellow Sea	38.71588	125.369	18-Oct-16	Less than 2 years
13	Hoe Ryong	9041552	North China	41.47255	129.7754	05-Mar-17	Less than 2 years
14	Hua Fu	9020003	East China Sea	26.78352	121.6911	29-Jul-18	Less than 6 months
15	Hui Chon	8405270	North China	40.90295	129.9034	21-Sep-16	More than 2 years
16	Ji Hye San	8018900	Yellow Sea	38.70871	125.4031	03-Nov-16	Less than 2 years
17	Ji Song 6	8898740	Yellow Sea	37.21639	122.9594	13-Nov-17	Less than 1 year
18	Jie Shun	8518780	Red Sea	29.8743	32.47725	28-Feb-16	More than 2 years
19	Jin Hye	8518572	East China Sea	24.71716	120.2181	26-Apr-18	Less than 6 months
20	Kal Ma	8503228	Bohai Sea, North China	40.10017	121.5748	28-Sep-17	Less than 2 years
21	Kang Gye	8829593	North China	41.33577	129.8511	23-Oct-16	Less than 2 years
22	Kingsway	9191773	South China	22.27498	120.0808	21-Jan-18	Less than 1 year
23	Koti	9417115	Yellow Sea	37.00571	126.7509	21-Oct-18	Less than 6 months
24	Kum Un San 3	8705539	Yellow Sea	37.78679	123.2529	26-Jul-17	Less than 2 years

No.	Name of Vessel	IMO No.	Destination	Latitude	Longitude	Timestamp	Age of info
25	Mi Rim	8713471	Yellow Sea	38.70413	125.3273	23-Mar-17	Less than 2 years
26	Mi Rim 2	9361407	North China	39.00777	130.2066	17-May-16	More than 2 years
27	MIN NING DE YOU 078	NA	No Result				
28	Nam San 8	8122347	Yellow Sea	38.68819	124.9904	07-Sep-17	Less than 2 years
29	New Regent	8312497	East China Sea	29.82621	122.3621	09-Oct-18	Less than 6 months
30	O Rang	8829555	CIS Pacific	42.40579	132.6974	11-Mar-16	More than 2 years
31	O Un Chong Nyon Ho	8330815	Yellow Sea	37.29038	122.9679	28-Jun-16	More than 2 years
32	Paek Ma	9066978	Yellow Sea	37.51803	122.5289	30-Jul-18	Less than 6 months
33	Paek Yang San	9020534	Yellow Sea	37.05275	122.8942	16-Jul-18	Less than 6 months
34	Petrel 8	9562233	Bohai Sea, North China	40.34578	121.9493	31-Oct-17	Less than 1 year
35	Ra Nam 2	8625545	Yellow Sea	38.49747	122.2608	28-Jun-16	More than 2 years
36	Ra Nam 3	9314650	Yellow Sea	38.68492	125.2134	25-Sep-16	More than 2 years
37	Rak Won 2:	8819017	Yellow Sea	38.67962	125.2329	24-Sep-16	More than 2 years
38	Rye Song Gang 1	7389704	CIS Pacific	42.53726	131.604	10-Jun-17	Less than 2 years
39	Ryo Myong	8987333	Bohai Sea, North China	37.68542	120.1852	26-Jun-16	More than 2 years
40	RYONG GANG 2	7640378	North China	41.42919	129.711	17-May-16	More than 2 years
41	Ryong Rim	8018912	Japan Coast	34.30147	129.9315	11-Oct-18	Less than 6 months
42	Sam Jong 1	8405311	Japan Coast	34.72442	139.4579	29-Aug-17	Less than 2 years
43	Sam Jong 2	7408873	Yellow Sea	39.00494	121.8706	04-Jul-17	Less than 2 years
44	Sam Ma 2	8106496	North China	38.64077	132.9761	04-Aug-18	Less than 6 months
45	Shang Yuan Bao	8126070	South China	22.46276	119.7026	24-Jun-18	Less than 6 months
46	Songjin	8133530	Yellow Sea	37.59892	123.1099	09-Jan-17	Less than 2 years
47	SOUTH HILL 2	8412467	East China Sea	31.9215	120.1911	20-Jan-16	More than 2 years
48	Thae Pyong San	9009085	North China	38.80886	131.7135	19-Apr-18	Less than 6 months
49	Tong Hung 1	8661575	Bohai Sea, North China	37.8885	120.0893	23-Jun-16	More than 2 years

No.	Name of Vessel	IMO No.	Destination	Latitude	Longitude	Timestamp	Age of info
50	Tong Hung San	7937317	Japan Coast	34.22758	129.9158	03-May-16	More than 2 years
51	Tong San 2	8937675	East China Sea	29.7988	122.6925	15-Oct-18	Less than 6 months
52	Ul Ji Bong 6	9114555	Okhotsk Sea	47.04856	142.044	05-Sep-17	Less than 2 years
53	Wan Heng 11	8791667	North China	38.73571	132.9179	23-Jun-18	Less than 6 months
54	Woory Star	8408595	Yellow Sea	38.83026	122.4154	14-Oct-17	Less than 1 year
55	Xin Guang Hai	9004700	South China	20.22072	110.4639	09-Feb-18	Less than 1 year
56	Yu Jong 2	8604917	CIS Pacific	42.92116	131.6245	16-Jun-17	Less than 2 years
57	Yu Phyong 5	8605026	Japan Coast	34.02043	129.5539	24-Sep-17	Less than 2 years
58	Yu Son	8691702	CIS Pacific	42.93507	131.6278	22-Jun-17	Less than 2 years
59	Yuk Tung	9030591	East China Sea	26.4949	120.3661	17-May-18	Less than 6 months

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APPENDIX E. COMPARISON MATRIX

No.	Name of Vessel	TimeStamp			Comparison Matrix		
		SeaVision	MyShipTracking	MarineTraffic	SeaVision	MyShipTracking	MarineTraffic
1	An San 1	02-Aug-18	04-May-17	02-Aug-18	1	0	1
2	Asia Bridge 1	No Info	07-Aug-16	No Info	0	1	0
3	Chol Ryong	No Info	19-Feb-16	21-Nov-16	0	0	1
4	Chon Ma San	14-Sep-17	04-Jun-17	06-Jun-17	1	0	0
5	Chon Myong 1	30-Jan-18	02-Dec-16	01-Oct-17	1	0	0
6	Chong Bong	18-Oct-17	28-Mar-17	03-Aug-18	0	0	1
7	Chong Rim 2	25-Sep-17	30-Dec-15	21-Nov-17	0	0	1
8	Dong Feng 6	17-Jul-17	15-Aug-17	15-Aug-17	0	1	1
9	Fan Ke	27-Sep-17	22-Feb-16	15-Jul-18	0	0	1
10	Hao Fan 2	26-Oct-17	26-Dec-17	27-Jan-18	0	0	1
11	Hao Fan 6	No Info	30-Aug-17	18-Dec-17	0	0	1
12	Hap Jang Gang 6	No Info	08-Feb-15	18-Oct-16	0	0	1
13	Hoe Ryong	No Info	18-Jun-16	05-Mar-17	0	0	1
14	Hua Fu	11-Oct-16	16-May-17	29-Jul-18	0	0	1
15	Hui Chon	No Info	25-Nov-14	21-Sep-16	0	0	1
16	Ji Hye San	No Info	16-Jun-16	03-Nov-16	0	0	1
17	Ji Song 6	No Info	No Info	13-Nov-17	0	0	1
18	Jie Shun	No Info	18-Aug-16	28-Feb-16	0	1	0
19	Jin Hye	08-May-17	07-May-17	26-Apr-18	0	0	1
20	Kal Ma	20-Sep-17	28-Sep-17	28-Sep-17	0	1	1
21	Kang Gye	No Info	15-Jun-15	23-Oct-16	0	0	1

No.	Name of Vessel	TimeStamp			Comparison Matrix		
		SeaVision	MyShipTracking	MarineTraffic	SeaVision	MyShipTracking	MarineTraffic
22	Kingsway	21-Jan-18	08-Dec-17	21-Jan-18	1	0	1
23	Koti	07-Dec-17	21-Apr-18	21-Oct-18	0	0	1
24	Kum Un San 3	16-Feb-18	26-Jul-17	26-Jul-17	1	0	0
25	Mi Rim	No Info	29-Feb-16	23-Mar-17	0	0	1
26	Mi Rim 2	No Info	10-May-16	17-May-16	0	0	1
27	MIN NING DE YOU 078	No Info	No Info	No Info	0	0	0
28	Nam San 8	No Info	27-Apr-17	07-Sep-17	0	0	1
29	New Regent	12-Jul-18	30-Jul-18	09-Oct-18	0	0	1
30	O Rang	No Info	09-Sep-14	11-Mar-16	0	0	1
31	O Un Chong Nyon Ho	16-Apr-18	22-Sep-15	28-Jun-16	1	0	0
32	Paek Ma	31-Jul-18	No Info	30-Jul-18	0	0	0
33	Paek Yang San	16-Jul-18	12-Jul-18	16-Jul-18	1	0	1
34	Petrel 8	31-Oct-17	16-Oct-17	31-Oct-17	1	0	1
35	Ra Nam 2	No Info	03-Mar-16	28-Jun-16	0	0	1
36	Ra Nam 3	No Info	06-Mar-16	25-Sep-16	0	0	1
37	Rak Won 2:	No Info	15-Jul-15	24-Sep-16	0	0	1
38	Rye Song Gang 1	No Info	03-Dec-16	10-Jun-17	0	0	1
39	Ryo Myong	No Info	11-Mar-16	26-Jun-16	0	0	1
40	RYONG GANG 2	No Info	21-Aug-14	17-May-16	0	0	1
41	Ryong Rim	No Info	24-Sep-14	11-Oct-18	0	0	1
42	Sam Jong 1	07-Mar-18	29-Aug-17	29-Aug-17	1	0	0
43	Sam Jong 2	12-Dec-17	18-Oct-16	04-Jul-17	1	0	0

No.	Name of Vessel	TimeStamp			Comparison Matrix		
		SeaVision	MyShipTracking	MarineTraffic	SeaVision	MyShipTracking	MarineTraffic
44	Sam Ma 2	04-Aug-18	25-Jul-18	04-Aug-18	1	0	1
45	Shang Yuan Bao	24-Jun-18	24-Jun-18	24-Jun-18	1	1	1
46	Songjin	No Info	11-Nov-16	09-Jan-17	0	0	1
47	SOUTH HILL 2	No Info	20-Jan-16	20-Jan-16	0	1	1
48	Thae Pyong San	No Info	16-Apr-18	19-Apr-18	0	0	1
49	Tong Hung 1	No Info	02-Mar-16	23-Jun-16	0	0	1
50	Tong Hung San	No Info	No Info	03-May-16	0	0	1
51	Tong San 2	19-Mar-18	26-Aug-17	15-Oct-18	0	0	1
52	Ul Ji Bong 6	05-Sep-17	21-Jul-17	05-Sep-17	1	0	1
53	Wan Heng 11	21-Jun-18	21-Jun-18	23-Jun-18	0	0	1
54	Woory Star	No Info	23-Sep-17	14-Oct-17	0	0	1
55	Xin Guang Hai	03-Sep-16	23-Jan-17	09-Feb-18	0	0	1
56	Yu Jong 2	06-Dec-18	No Info	16-Jun-17	1	0	0
57	Yu Phyong 5	25-Sep-17	24-Sep-17	24-Sep-17	1	0	0
58	Yu Son	12-Jul-18	23-Aug-16	22-Jun-17	1	0	0
59	Yuk Tung	21-Sep-17	02-Jan-18	17-May-18	0	0	1
				Total	16	6	45

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   Naval Postgraduate School
   Monterey, California