

T.R.
TURKISH NAVAL ACADEMY
NAVAL SCIENCE AND ENGINEERING INSTITUTE
DEPARTMENT OF COMPUTER SCIENCE

**MODELING A PATROL MISSION WITH C-BML:
A CASE STUDY**

A MASTER THESIS

ÖMER ÜNAL

Advisor: Asst.Prof. Okan Topçu

İSTANBUL, 2011

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Submitted in partial fulfillment of the requirement for degree of

MASTER OF SCIENCE IN COMMAND, CONTROL, COMMUNICATIONS,
COMPUTER AND INTELLIGENCE (C4I)

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DEDICATION

Dedicated to my beloved wife Hilâl..

ACKNOWLEDGEMENT

I would like to render my special thanks to

My advisor, Asst.Prof. Okan TOPÇU, for giving me ultimate guidance and support,

My instructors, Assoc.Prof. Nafiz ARICA, Asst.Prof. Müjdat SOYTÜRK and Dr. Kadir A. DEMİR, for valuable contributions to my scientific development,

Institute director, Dr. Mustafa KARADENİZ, for his active collaboration,

Assoc.Prof. Halit OĞUZTÜZÜN, Dr. Kevin HEFFNER, Hakan SAVAŞAN and members of SISO C-BML Drafting Group for their feedbacks and supports.

DISCLAIMER STATEMENT

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Turkish Naval Forces, Turkish Naval Academy and Naval Science and Engineering Institute.

KARAKOL GÖREVİNİN C-BML İLE MODELLENMESİ: BİR DURUM ÇALIŞMASI

Ömer ÜNAL

Komuta, Kontrol, Muhabere, Bilgisayar ve İstihbarat Yüksek Lisans
Tezi, 2011

Danışman: Yrd.Doç.Dr. Okan TOPÇU

**Anahtar Kelimeler: C-BML, Alana Özel Modelleme, İnsansız
Suüstü Aracı**

ÖZETÇE

Günümüzde komuta kontrol sistemleri, askeri simülasyonlar, karar destek sistemleri gibi birçok sistem; operasyon planları, emirleri ve askeri konsept dokümanlarında bulunan bilgileri kullanmaktadır. Bu bilgiler genellikle uygulamaya özel bir şekilde sistemlere dâhil edilmektedir. Sistemler arası gün geçtikçe artan birlikte çalışabilirlik ihtiyacına istinaden, sistem girdi ve çıktılarını formalleştirerek makine tarafından anlaşılır bilgi elde etmek için, birçok alana özel dil ortaya çıkmıştır. Bu dillerden birisi halen geliştirilme aşamasında olan Koalisyon Harp Yönetim Dilidir (C-BML). Bu çalışmada, bir senaryo geliştirilerek, bünyesinde insansız suüstü araçları bulunduran ve korsanlıkla mücadele amacı güden bir organizasyon tanımlanmıştır. İnsansız suüstü araçları tarafından icra edilecek karakol vazifesine ilişkin emirler ve raporlar kurgulanmış ve C-BML ile modellenmiştir. Emirleri modellemek için, emirlerdeki faaliyetlerin fonksiyonel ve zamansal analizleri yapılmıştır. Senaryo kapsamında emirlerin, raporların ve görev taleplerinin C-BML’de temsil edilebilirliği incelenmiştir. Bir C-BML kullanıcısı bakış açısıyla C-BML’in ifade etme yeteneği hakkında bazı tartışmalar öne sürülmüştür. Ayrıca bu çalışmanın müteakip C-BML modelleme çalışmaları için bir kılavuz olarak kullanılabilmesi beklenmektedir.

MODELING A PATROL MISSION WITH C-BML: A CASE STUDY

Ömer ÜNAL

Command, Control, Communications, Computer and Intelligence
Master of Science Thesis, 2011

Advisor: Asst.Prof. Okan Topçu

**Key Words: C-BML, Domain Specific Modeling, Unmanned Surface
Vehicle**

ABSTRACT

Today, many military software-intensive systems such as command and control systems, military simulations, and decision support systems require the same military knowledge found in operation plans and orders, which are mostly imported to the system in an application specific form. Due to the increased need for interoperability among those systems, many domain specific languages arise in order to formalize the inputs and outputs to obtain machine-processable knowledge. A major domain-specific language is the Coalition Battle Management Language (C-BML), which is currently under development. In this work, a scenario is developed and a coalition combat organization that has unmanned surface vehicle (USV) units under command is created for fighting with piracy. The orders and reports related to the patrol mission for USVs are set up and modeled using C-BML. In order to model the orders, functional and temporal analyses of the actions in the orders are performed. Representability of the military orders, reports, and requests in the scope of the scenario domain in C-BML is examined. Discussions about expressiveness of C-BML are offered from C-BML adopter perspective. Furthermore, we anticipate that this study will serve as a guideline for further C-BML studies.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Today, Command, Control, Communications, Computer and Intelligence (C4I) systems, military simulations, decision support systems and other military software-specific systems need the same military knowledge found in concepts, operation plans, and operational orders. Currently, most military knowledge is in free text. They can be communicated in military messages or documents that can be understood by human readers, but not by simulations or robotic forces [1]. Such knowledge is mostly imported to the software systems in an application specific form, to function properly and in harmony.

The fact that C4I systems, simulations, and other similar military software-intensive systems require the same knowledge, dictates an increasing demand for interoperability among those systems, specifically among C2 systems and Modeling and Simulation (M&S) systems. Moreover, C2 and simulation systems generally exchange and share those military knowledge bases as inputs and outputs. As most military knowledge is in free text, the need for expressing that knowledge in a formal and common way arise in order to exchange them among systems. As a result, over a

number of years, many domain-specific languages arise in order to formalize these inputs and outputs to obtain machine processable knowledge. A major domain specific language is Coalition Battle Management Language (C-BML), which is in the process of standardization for C2 systems. C-BML is “a standard language for expressing and exchanging plans, orders, and reports across C2 systems, live, virtual and constructive M&S systems, and eventually also robotic systems participating in Coalition operations” [2].

C-BML is seen as a “standard representation of a digitized commander's intent to be used for real troops, for simulated troops, and for future robotic forces” [3,4]. It is used to command and control forces and to provide for a shared operational picture and situational awareness [3].

C-BML is being developed and is under standardization by Simulation Interoperability Standards Organization (SISO). SISO C-BML Draft Phase 1 Model [5] is developed mainly based on the MIP¹Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM) 3.0.2 May 2009 [6,7] products [8]. Because C-BML is under standardization, evaluations and comments from persons and organizations interested in Phase 1 C-BML products are welcome [8]. It is expected from users to experiment the usefulness and expressiveness of C-BML as a language and to make structural assessments [9].

¹Multilateral Interoperability Programme, <http://www.mip-site.org/>

1.2 Problem Definition, Research Questions and Objectives

The problem we work on this study is how to model a patrol mission with C-BML where unmanned surface vehicles are employed and to investigate representativeness of C-BML for the mission.

Basically, the study deals with two major research questions:

- How can a patrol mission order be modeled with C-BML?
- What are the representative capability and limitations of C-BML to model a patrol mission ordered to an organization that employs unmanned surface vehicles?

Thesis objectives are:

- To develop a case study with a sound scenario.
- To model the mission with C-BML.
- To examine representability of the military orders, reports, and requests in the scope of the scenario domain in C-BML.

Contributions of the thesis are:

- To develop a document that serves as a guideline for further C-BML studies.
- To contribute to C-BML development process.

1.3 Background

In [10], a Battle Management Language (BML) is defined: “BML is the

unambiguous language used to command and control forces and equipment conducting military operations and to provide for situational awareness and a shared, common operational picture.” The problem that commander’s intent and orders flow as “free text”, not as data, is emphasized. The need for using commander’s intent in simulations and robotic forces besides live forces is proposed to be solved by a battle management language [10]. The same BML is used whether the commanders are dealing with live subordinates, a simulation, or a future force robotic entity [1] (see Figure 1).

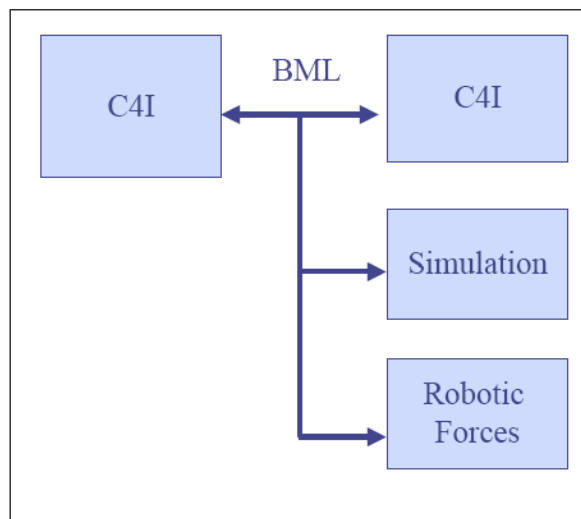


Figure 1. BML Scope [11]

In years, studies about C2 and M&S interoperability show that a standardized approach will be helpful that various coalition C2 and M&S systems will interoperate for decision support and training purposes [12, 13, 14].

Development of BML began when US Army chartered Simulation to C4I (SIMCI) Overarching Integrated Product Team (OIPT) who aimed improving

interoperability between the M&S and C4I domains [15]. Tasking and reporting related doctrinal manuals were analyzed by SIMCI OIPT [16]. Carey et al [10, 17] discuss required capabilities of an unambiguous language and its anticipated contributions in context of SIMCI OIPT's objectives such as achieving a seamless interoperability between M&S and C2 systems.

Extensible BML (XBML) project was founded on SIMCI OIPT's work. Being sponsored by US Defense Modeling and Simulation Office and the US Joint Forces Command, the project aimed using Command and Control Information Exchange Data Model (C2IEDM, former version of JC3IEDM) as basis and for information exchange, Service Oriented Architecture was used [15].

The Air Operations BML (AOBML) study was conducted to apply BML concepts to air operations [13]. Joint BML (JBML) included ground, air and maritime domains and urban warfare [18]. JBML contributes to C-BML with a revised Web Service schema [16]. In [19], US effort of JBML project is explained. JBML project goal is "to develop a standard Battle Management Language applicable to US Service and Joint Users as an input to the SISO C-BML process" [19].

Geospatial BML (geoBML) was developed by US Army Topographic Engineering Center that provides a framework for representing for actionable geo-environmental information [20].

In [21], it is pointed out that development of a formal BML grammar is

essential. An initial BML grammar for formalizing task representations and constructing valid BML sentences is presented.

It is stated in [22] that C-BML architecture must provide architectures to support diverse requirements, multiple standards, and overlapping and conflicting domain models. To manage such C-BML development challenges OWL (Web Ontology Language) [23] is proposed to be used [22].

International coalition initiatives are introduced in [24]. Coalition initiatives contribute to the development of a common understanding, and ease cooperation between nations.

1.3.1 C-BML

C-BML Study Group (SG) was formed in 2004. In Spring 2004 Simulation Interoperability Workshop (SIW), a paper survey for taking the carried out BML initiatives and developing a Coalition BML was decided. In 2006, based on SG final report C-BML Product Development Group was formed.

C-BML development and specification is conducted in three phases [2]: Phase I is Data Model description, Phase II is Grammar (syntax, semantics and vocabulary) specification and Phase III is Ontology (Formal Semantics) development.

C-BML uses the Joint Command, Control, and Consultation Information Exchange Data Model (JC3IEDM) as the basis for standards and implementations. JC3IEDM is shortly introduced in section 1.3.2. An information exchange structure

and content specification (IESCS) in extensible Markup Language (XML) format, and an information exchange mechanism as a Web Services Definition Language (WSDL) document is developed in context of C-BML standardization. Transfer of plans, orders, and reports is intended [2].

C-BML messaging architecture is provided in Figure 2. A C-BML expression is the payload of a C-BML message [9]. System A produces C-BML message and System B consumes the message. C-BML expression must comply with IESCS. An C-BML expression is defined as “A plan, order, or report stated using the C-BML information exchange content and structure” [2].

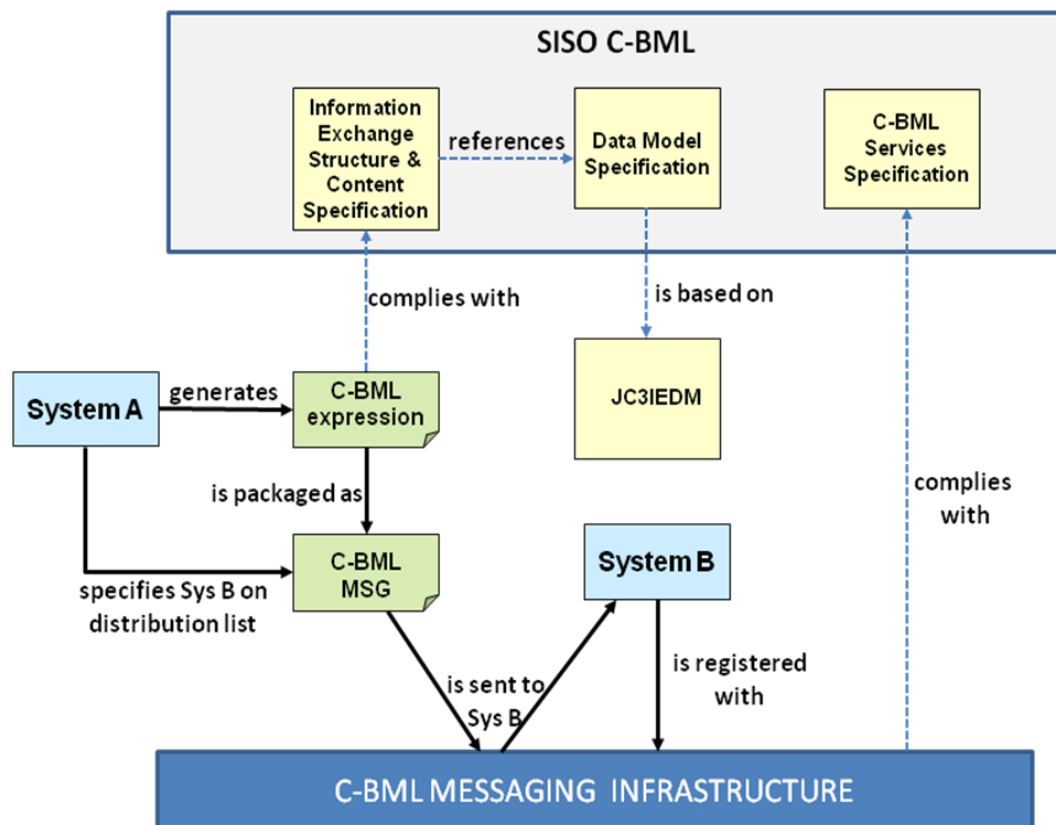


Figure 2. C-BML Messaging Architecture [9]

C-BML decomposes information in form of the 5Ws: Who, What, When, Where, and Why. Information structure and content is described in XML Schema language and the language is used to validate XML documents containing C-BML expressions encoded in XML. The expression of the 5Ws in C-BML XML schema provides information elements for use in expressing plans, orders, and reports that can be exchanged across systems through mechanisms [2].

Web Services provide a basic mechanism that can be used to exchange C-BML information. C-BML expressions can be “pushed” or “pulled” by a service. Users can also employ C-BML expression without Web Services [2].

1.3.2 JC3IEDM

NATO JC3IEDM is an information exchange model, which enables the military information to be defined in a common structure. Defining the objects and the events occurring in the operational field is a major goal of this model.

C-BML uses JC3IEDM as the reference model. International M&S and C2 communities have a widespread acceptance of the JC3IEDM as the standard for transferring C2 information. JC3IEDM is robust enough to handle the required data to be exchanged between C2, M&S and robotic systems. JC3IEDM is an independent data model, but it can describe the C2 information interchanged by systems that C-BML is intended for [2].

1.4 Thesis Overview and Outline

In this work, a particular kind of operations order, namely, a patrol mission (PM) for unmanned surface vehicles (USVs), and some orders derived from the operations order are set up and modeled using C-BML. A scenario is developed and a coalition combat organization that has USV units under command is created for fighting with piracy in the Gulf of Aden. In order to model the orders, functional and temporal analyses of the actions in the orders are made. Patrol mission is chosen because it is inherent in most naval operations and it is a part of the surveillance and reconnaissance operations, which is one of the basic naval operations. While it is intended to be comprehensive for naval operations, we anticipate that this study will serve as a guideline for further C-BML studies. Also, we explain and discuss some modeling issues to this end. Expressiveness of C-BML is discussed from C-BML adopter perspective.

The research process we followed for this study is depicted in Figure 3. A literature survey is conducted and C-BML is chosen to study on. Research questions in section 1.2 are developed, guideline document is reviewed, a scenario about fighting with piracy in Aden Gulf is set up and mission and related orders are derived, respectively. The following steps are executed several times in reaction to expanding the scenario, deriving and maturing orders: conceptual model and actions table creation, Where, Why, What, When, Who (5Ws) analysis, C-BML modeling and developing modeling issues and discussions. When the scenario and orders are mature enough and modeled totally, the C-BML model for patrol mission is

proposed. Feedback from SISO is taken and the study is evaluated and concluded.

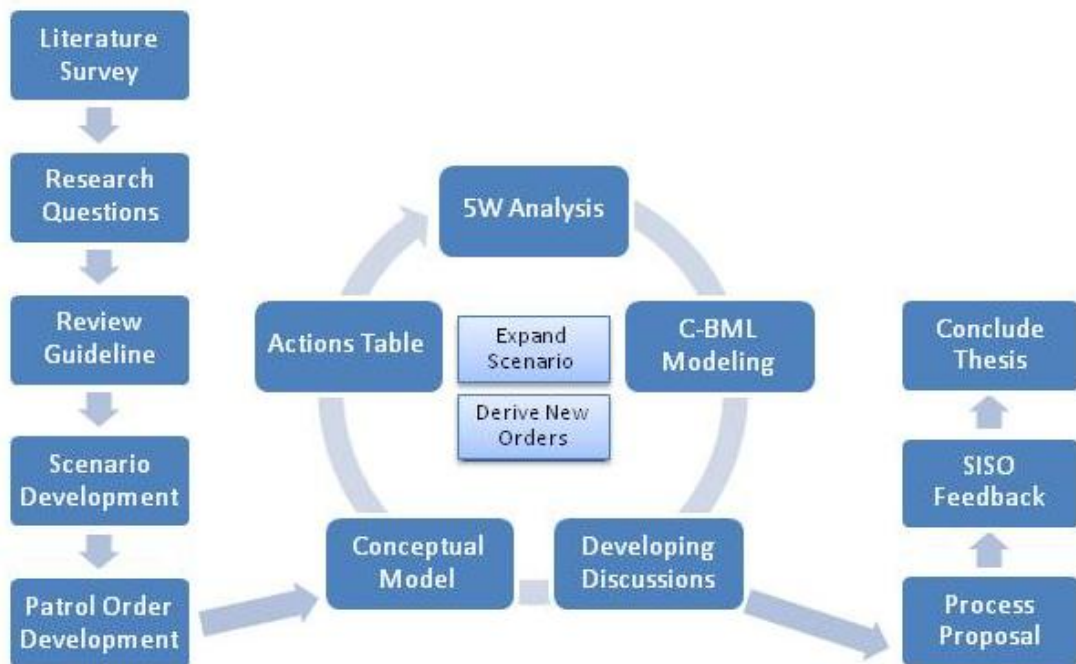


Figure 3. Research Process

As a byproduct, this work formalizes the patrol mission operations of an USV using C-BML. This case study is intentionally selected because it is believed that USVs are a rising research area for naval operations and for C2 systems, especially for patrol missions.

The structure of the thesis is as follows: Chapter 2 provides the scenario of our case study. Chapter 3 describes the C-BML model of the patrol mission. Chapter 4 discusses modeling issues and provides examples to each. Related work is presented in Chapter 5. Chapter 6 concludes the article and points to the future work. The appendixes hold the details about orders. Appendix B is the Operations Order from

Coalition Task Force to Patrol Task Group and Surface Warfare Task Group. Appendix C is the Patrol Order from Patrol Task Group to Patrol Task Units. Appendix D is the Patrol Order from Patrol Task Unit Country-A to Patrol Task Elements. Appendix E is the Patrol Order from Patrol Task Unit Country-B to Patrol Task Elements. Appendix F includes the Patrol Mission C-BML Model XML files.

CHAPTER 2

SCENARIO

The hypothetical scenario used in this study is as follows.

The Gulf of Aden is a part of the important Suez Canal shipping route between the Mediterranean Sea and the Arabian Sea in the Indian Ocean. Because a number of acts of piracy occurred in the area in recent years, its waters are considered dangerous for water transport [25]. Pirates hijack ships in the area demanding ransoms. They usually attack ships with zodiac boats, carrying long-barreled weapons. They create threat for all ships passing through the area.

In order to deter piracy, a coalition task force (CTF 499) is constituted and is assigned a patrol mission in areas where piracy took place most frequently. USVs are employed for patrol mission. Due to the mechanical and tedious nature of patrolling, the USV units are used in the area. USVs are to detect suspicious and hostile vessels (i.e. pirate boats) and to report them instantly to their control station. If necessary, USVs make request from a manned warship to intervene a detected hostile vessel.

2.1 Mission and Organization Structure

For the purpose of fighting with piracy, the areas (Area Alpha and Area Bravo)

in the southeastern of the gulf are declared and CTF 499 is constituted to conduct surveillance and reconnaissance operations more effectively. It is established to monitor, inspect and interrupt suspect shipping. The structure of the task force organization is shown in Figure 4.

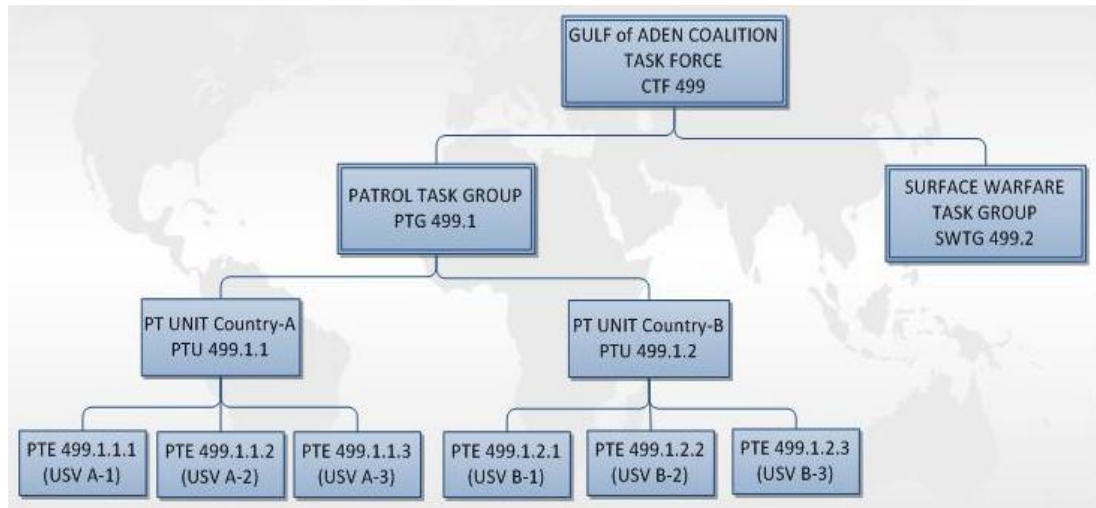


Figure 4. Organization Chart of the Coalition Task Force

CTF 499 has a Patrol Task Group (PTG 499.1) and Surface Warfare Task Group (SWTG 499.2) in command. CTF is responsible for establishing and maintaining the maritime tactical picture in its area of responsibility. In order to achieve its aim, all surface vessels in the area have to be monitored and identified continuously. Detection of suspicious vessels is highly important. Once detected, counteractions against such vessels have to be also conducted by the task force.

PTG 499.1 manages surveillance and reconnaissance operations in area of responsibility. It has two Patrol Task Units (PTUs) in command.

PTUs follow orders of Task Group and have USVs (i.e. Patrol Task Elements) in command for patrol and other missions. Each PTU is constituted by a country. PTUs are responsible for proper use and safely controlling of USVs. The organization takes advantage of USVs in strenuous and weary missions like patrolling.

PTEs are all USVs. They conduct patrol in given area. These vessels are to detect, locate, identify, monitor and inspect all surface contacts when used in patrolling. They do not use any weapons against suspected or hostile vessels. They request an armed intervention from SWTG 499.2 when necessary.

SWTG 499.2 has manned surface warships in command. It conducts maritime interdiction operations (MIO) and executes tasks of requests from PTG 499.1 units.

Countries presently contributing to CTF are Country A and Country B. The task force has logistics facilities at Caluula port of Somali.

There are two types USVs in this organization: Autonomous USVs and manually controlled USVs. The autonomous vehicles have intelligent agent systems and assumed as robotics systems. So that, they can navigate and operate autonomously based on the C-BML orders, and have the ability to make decisions without human intervention. The manually controlled USVs are operated and guided from a distant control station located at land. Caluula port is the operational base and moorage for USVs. Contact information sent by USVs is used in the construction of the tactical picture at control station. PTU Country A has manually controlled USVs and PTU Country B has autonomous USVs. It's assumed that an USV to be assigned

for patrol mission have the following characteristics:

- It has a mounted digital camera on board for taking photos and video.
- It has a surface radar, an infrared (IR) camera and a Laser Range Finder.
- It has navigational devices for positioning, course, speed and water depth information.

- It communicates encrypted with its control station.
- It can safely navigate in accordance with COLREG².
- It can detect any suspicious and hostile behavior of a surface vessel.
- It can work both day and night.
- An autonomous USV can also be controlled manually.
- USV sends all information to control station at near real-time.
- Autonomous USVs can automatically process C-BML expressions and act accordingly, but manually controlled USVs cannot.

2.2 C2 Systems in the Organization

The organization has C-BML enabled C2 systems where they exchange C-BML expressions. The conceptual view of systems in the organization is depicted in

²International Regulations for Preventing Collisions at Sea

Figure 5. C2 systems may be different from each other inside the organization and/or countries may have diverse systems. It is assumed that CTF, PTG and SWTG are permanent NATO units, so they use a common C2 system. Each country contributing the mission attends the CTF during a period and countries shift periodically. Different countries may have different C2 systems. So Country A and Country B have diverse national C2 systems but they can interoperate by the help of C-BML services. All C2 systems and the autonomous USVs (i.e. robotic systems) exchange C-BML expressions (in our case, USV patrol mission-BML model) among them. Web Service operations are used as a standard information exchange mechanism.

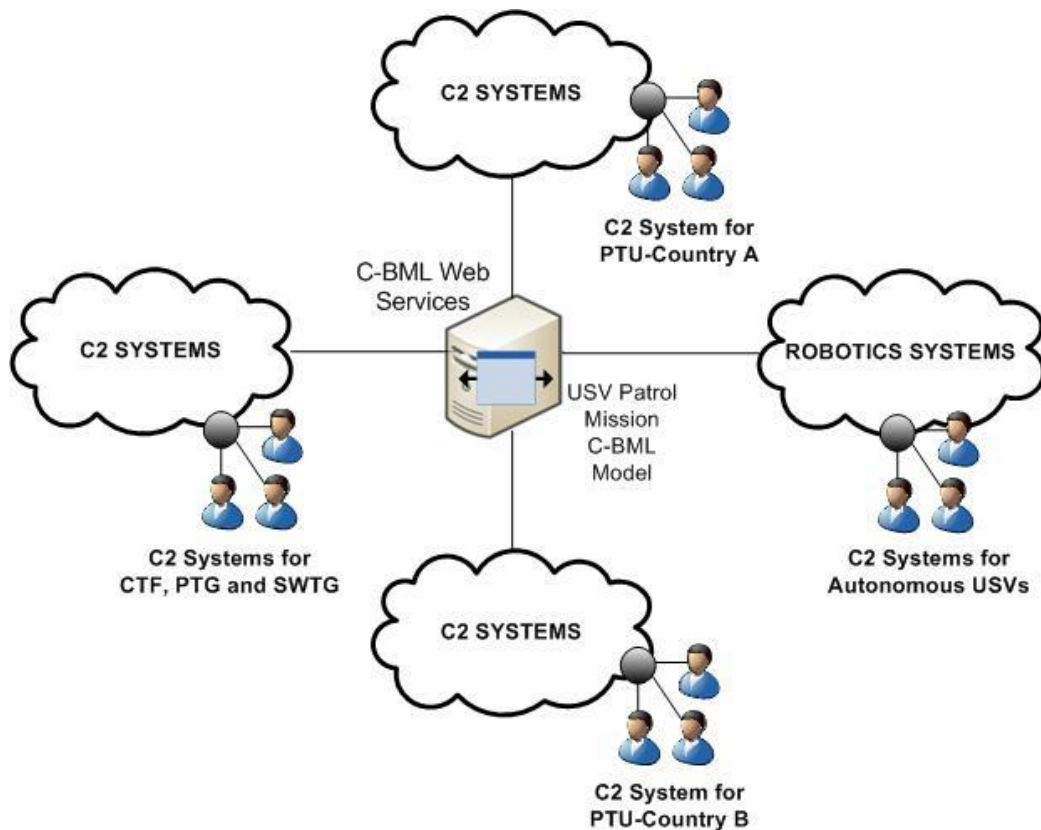


Figure 5. Conceptual View of Systems in the Case Study

Since there is a chain of command in this organization, orders flow from top-down and reports flow bottom-up. In order to assign USVs for a patrol mission the following orders are issued: Operations Order (OPORD 0001) from CTF to PTG and SWTG, ORDER 0002 from PTG to PTUs, ORDER 0003 from PTU Country-A to PTEs and ORDER 0004 from PTU Country-B to PTEs. The flow and general context of orders is illustrated in Figure 6.

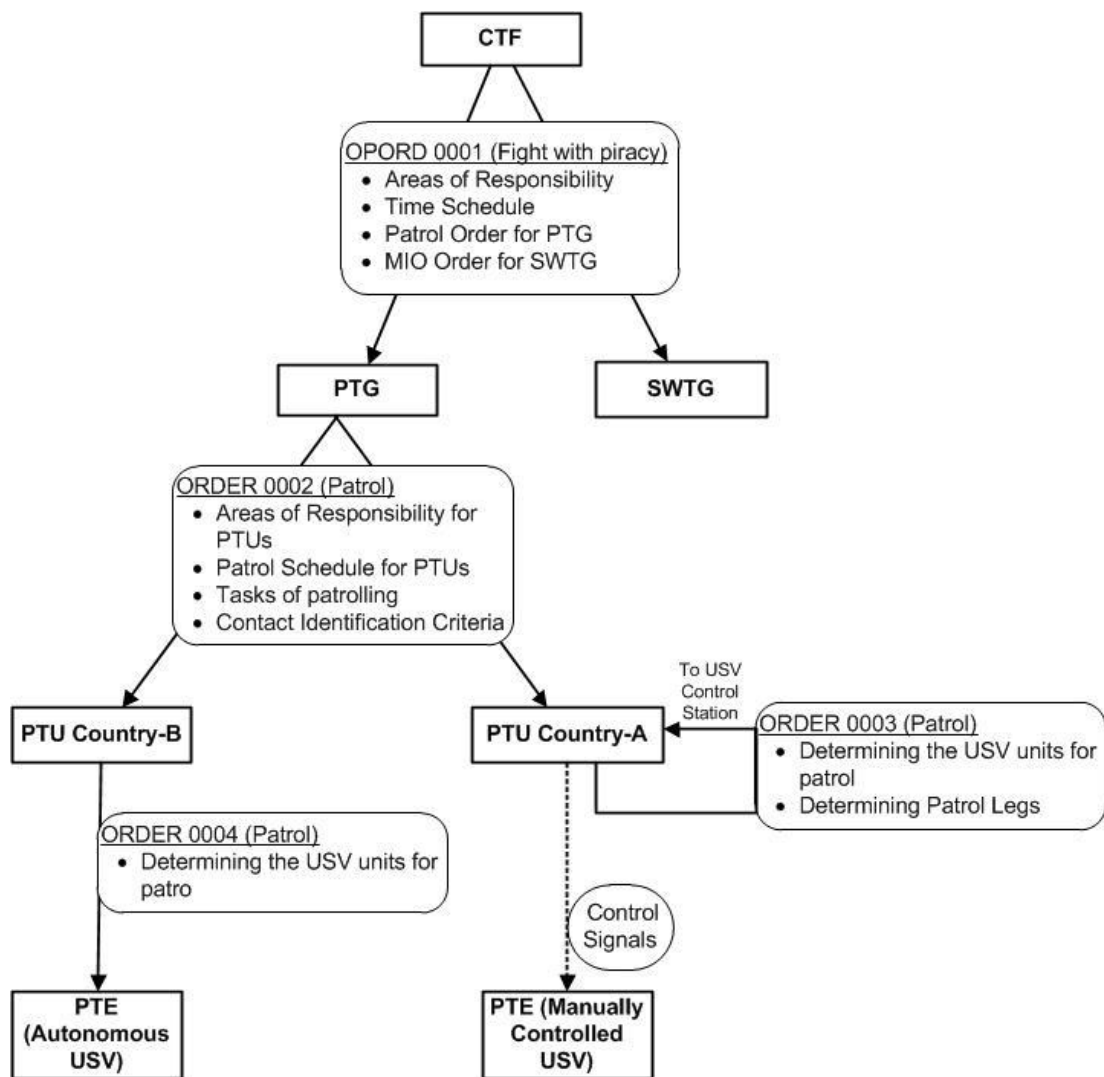


Figure 6. Order Flow

For simplicity, it is assumed that all USVs of PTU Country-A are manually controlled and all USVs of PTU Country-B are autonomous. As assumed, manually controlled USVs cannot process C-BML expressions automatically; therefore ORDER 0004 is to be given from PTU Command to the USV Control Station in PTU. The Control Station is expected to receive the C-BML expressions and control the USVs accordingly.

In this work, SWTG is considered as a black box and therefore its related orders are not detailed and modeled because it is a supporting unit and not directly related to patrol mission. The OPORD from CTF includes a patrol mission in the Gulf of Aden. The other orders detail the mission. CTF issues a general OPORD. Upon receiving the OPORD, PTG issues an order that specifies responsibility areas, patrol schedule, tasks of patrolling in detail and contact identification criteria for PTUs. Upon receipt of PTG's order, PTUs determine appropriate USVs for the mission and detail PTG's order.

Autonomous USVs will conduct area patrol that they will use a random traverse pattern in the area; manually controlled USVs will traverse over legs in the area. The course of actions that the USV will take in any given case is explained in the orders.

There are also some reports flowing in the organization as they are specified in the related orders. CTF sends the situation of friend and enemy forces to PTG and SWTG with the OPORD. PTG sends potential target list report network report to PTUs. PTEs send movement and arrival reports, contact reports, contact location

reports, contact type reports, contact hostility reports, contact location update reports, event reports, USV malfunction reports, USV fuel level reports and USV's location reports to PTUs. PTU and PTE also make requests from SWTG when necessary. Technically, reports and requests are different C-BML expressions; both are presented in Figure 7.

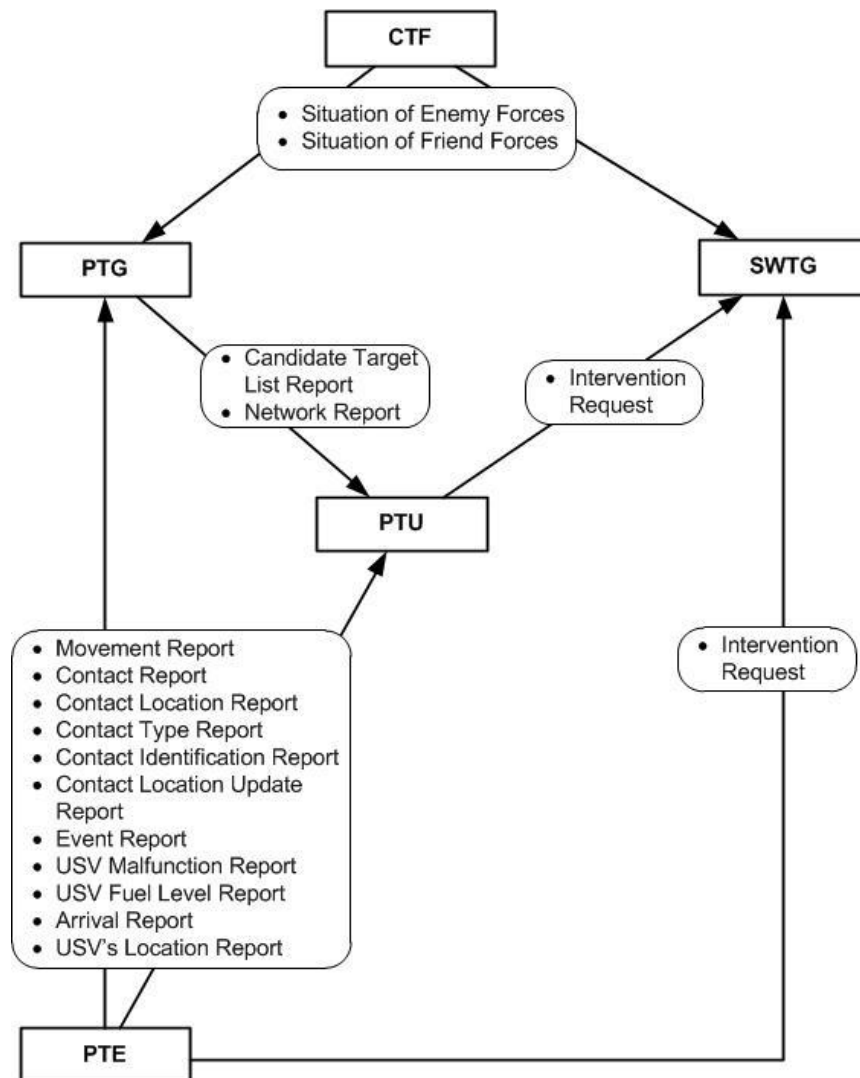


Figure 7. Reports

CHAPTER 3

THE C-BML MODEL

This section covers the C-BML model of the orders, reports and requests of the patrol mission. Section 3.1 introduces modeling process. In Section 3.2, the order from PTG to PTUs; in Section 3.3, the OPORD from CTF to PTG and SWTG; and in Section 3.4 the orders from PTUs to PTEs are analyzed and modeling details are presented. Modeling locations (areas, patrol legs, etc.), is explained in section 3.5, modeling reports is explained in section 3.6 and organization structure modeling is described in section 3.7. Section 3.8 defines the file structure of generated XML files.

Order from PTG to PTUs (ORDER 0002) is the most comprehensive one among orders in the patrol mission. This is why ORDER 0002 is explained first.

After developing the scenario and orders, we follow the process depicted in Figure 8 for modeling the orders with C-BML. The plain text of the order is taken and (1) the phases of the mission are extracted. (2) Using UML 2 Activity Diagrams [26], execution or occurrence sequence of actions is drawn. Creation of the conceptual model of an order is achieved with this step. (3) A C-BML actions table is created where all actions are assigned with an identification number. (4) Each

action in the actions table is analyzed in terms of 5Ws and action structure of C-BML and then (5) Using the XMLSpy [27] tool, orders are modeled accordingly. For organizations, reports, areas, locations and all objects in the orders, the appropriate C-BML structures to model with are determined, analyses are made and modeled with C-BML.

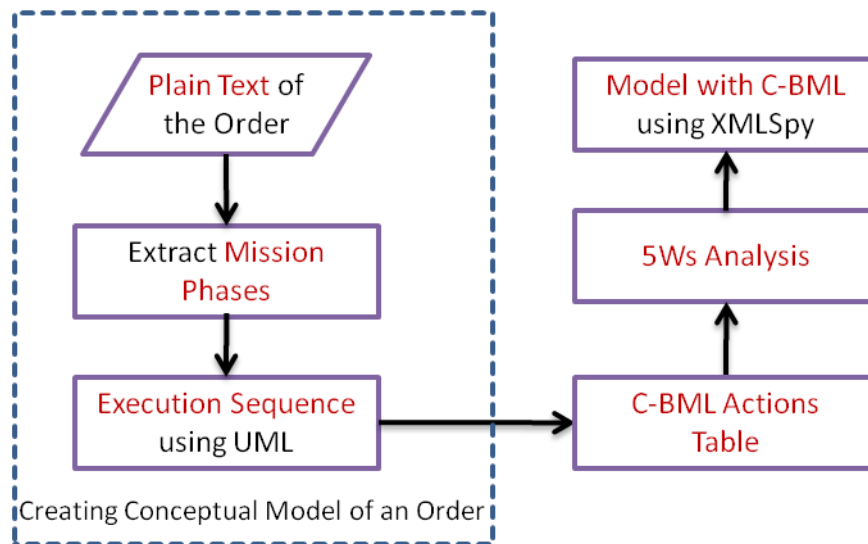


Figure 8. C-BML Modeling Process

3.1 Modeling the Order from PTG to PTUs

3.2.1 Conceptual Model of the Order

PTG issues ORDER 0002 that includes a patrol mission for PTUs. PTUs will conduct some tasks dictated in the order using the USVs under command and some tasks will be executed by PTUs. We start with the tasks to be performed using USVs.

The order consists of both tasks and events. Although modeling with C-BML topics will be explained in the next section, we need to introduce two basic C-BML

structures here. In C-BML, tasks and events are considered as *actions*. A *task* defines the activity to be executed by the taskee, and an *event* defines a phenomena occurring. For example, a surface vessel changing speed greater than 5 knots (event-1141) is regarded as an event. That the USV must shadow that contact (task-1153) is regarded as a task. All tasks and events are given identification numbers and we specified the numbers in this section while explaining tasks and events.

We can divide this mission into the following three phases:

- Departing from port and ingress to operational area
- Activity on patrol line in operational area
- Egress from area and arrival to port.

Each three phases of the mission has sub-actions, and there are action-sub-action relations overall. We must specify action-sub-action relations and also specify the order of execution or occurrence of actions. All actions are temporally linked to each other. In C-BML, the start and the end times of actions can be defined as relative to other actions or as absolute times. Actions may occur sequentially or in parallel. Prior to modeling the order in C-BML, actions and relations among actions are extracted from the order. UML 2 Activity Diagrams are used for modeling the temporal process of the order.

In UML Activity Diagrams graphical notation, round-cornered rectangle represents an action. In our model, tasks of the order are represented with action notation. In UML, an accept event action is notated as a concave pentagon. Events in

the order are represented as concave pentagons. Time statements such as every minute, every 6 hours in the order are represented as a UML accept time event action, notated with an hourglass.

Top level actions of the order are illustrated in Figure 9. The vertical bar on the leftmost side of the figure is the fork node of UML notation, and it means parallel start of actions coming after it. Three main tasks (Move to Patrol Starting Point, Patrol in the Area, and Move to Port) of the order take place sequentially. Concurrently, USV sends its fuel status in every 6 hours. The dashed rectangle notates an interruptible activity region in UML. It means that if the event inside the region occurs, all actions inside the region are terminated and the action which is pointed with a lightning-bolt from the event is executed. In this context, when USV malfunctions it quits executing the all tasks and it sends a malfunction report.

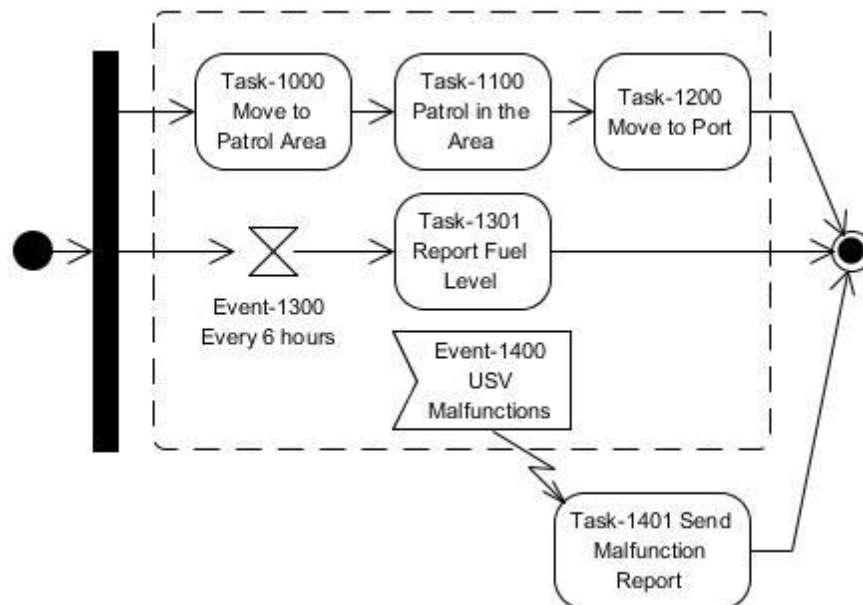


Figure 9. Top Level Actions of the Order

The decomposition of task-1100 is depicted in Figure 10; it has two parallel sub-tasks that start and end together. When USV starts to traverse over the patrol legs, it also starts to monitor all the vessels around. During the patrol in the area (task-1100), if a piracy event (event-1160) is detected, USV quits monitoring other vessels and takes pirate boat actions (task-1170). When USV accomplishes pirate boat tasks, it starts to monitor all vessels (task-1120) again. If any suspicious action of a vessel is detected (event-1140), USV quits traversing the patrol legs and quits monitoring vessels around and takes a series of actions (task-1150) for the suspect vessel. USV quits traversing the legs because it starts to shadow the suspect vessel. When USV finishes task-1150 it starts to traverse the patrol legs and monitor vessels around again.

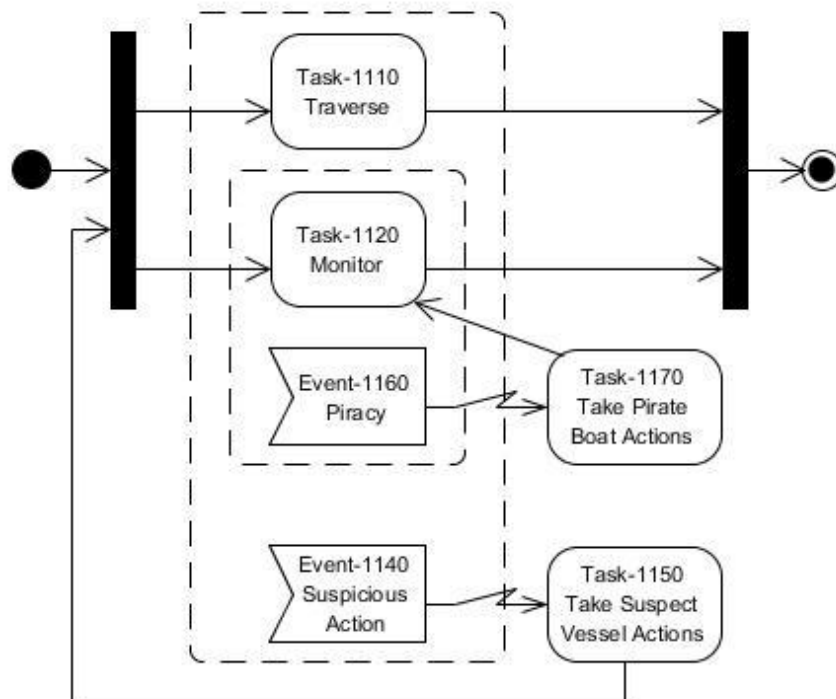


Figure 10. Subtasks of Task-1100

Actions to be performed by USVs in case of a piracy event are illustrated in Figure 11. USV will first identify and report the pirate boat as hostile, then make an intervention request from SWTG.

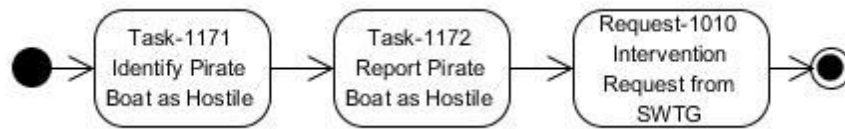


Figure 11. Pirate Boat Actions

Suspicious actions of a vessel (event-1140) are modeled as a set of events (i.e. criteria). When a contact changes speed greater than 5 knots, or it has no AIS info, or it is detected suspect based on its AIS info, or it is carrying weapons on board, or it is in drift position, or it is out of main shipping routes, or its distance to nearest land is less than 10 miles and USV detects any of these events, the vessel is considered suspect. These events are modeled as sub-actions of event-1140. Since any criterion may occur anytime, independently of other criteria, we modeled them as parallel (see Figure 12).

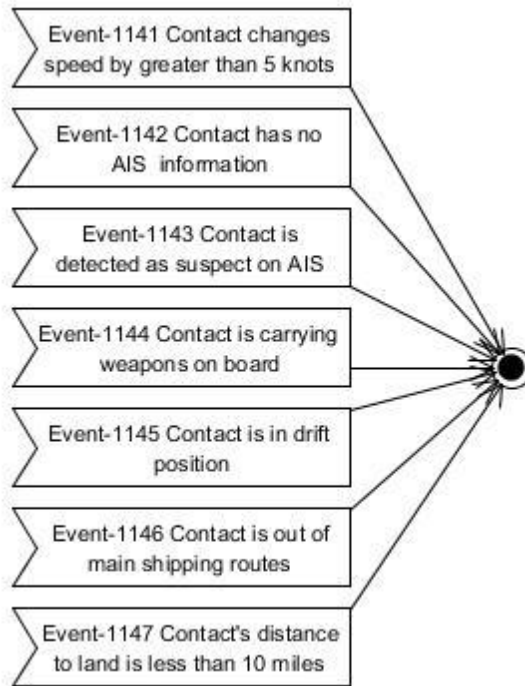


Figure 12. Suspicious Behavior (Event-1140)

USVs will execute the tasks shown in Figure 13 when a suspect vessel behavior is detected. USV will identify and report the vessel as suspect. Then, concurrently, it will start to shadow³ the vessel and take the vessel's pictures once in every 30 seconds. The vertical bars (called fork node and join node in UML) in the figure indicate parallel execution of the actions between bars. Meanwhile, PTU will evaluate the data coming from the USV and order the USV to quit shadowing and taking pictures after some time. When USV gets the quitting order from PTU, it turns back to traversing the legs and monitoring the vessels around (task-1100).

³Shadowing means to follow, especially in secret; to trail.

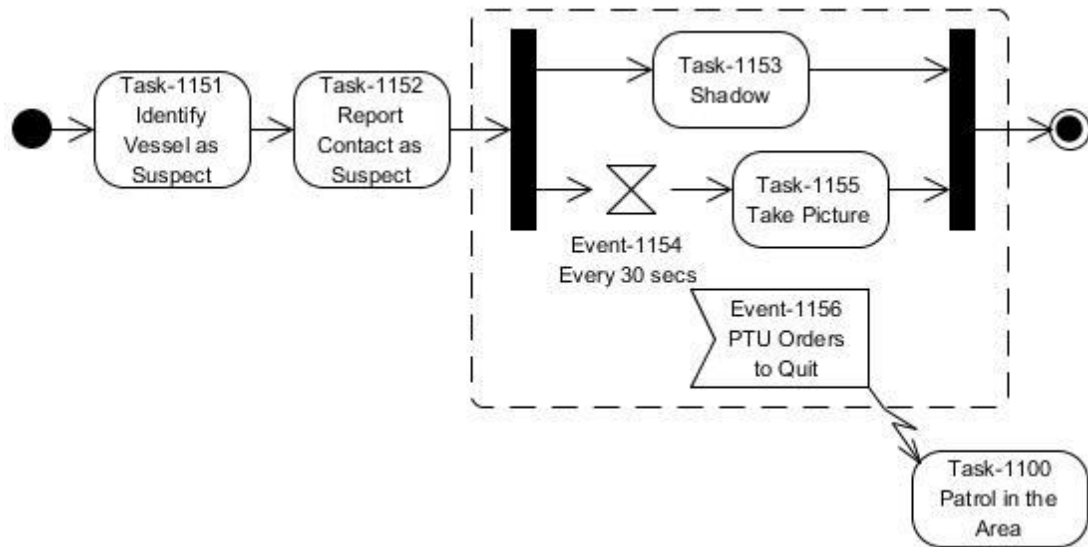


Figure 13. Suspect Vessel Actions

The monitor task (task-1120) has the sub-tasks shown in Figure 14. If any contact is detected (event-1121), USV will locate (task-1122) and report contact's location (task-1123), determine and report the type of contact (task-1125 and task-1126), and report the contact as neutral (task-1124). Detect means acquire a contact by radar or other sensors; locate means get the geographical position of a contact. After task-1124, a set of actions to be conducted by USV starts for that contact. The contact is added to USV's monitor list. The set of actions is shown in the *expansion region* (dashed rectangle on the right side of the figure) notation of the UML diagram. Note that set of actions are to be conducted in parallel for each of the contact on the monitor list. That means, if a new contact is added on the monitor list, while USV is performing the set of actions for a previously detected contact, USV starts to perform the same set of actions concurrently for the new contact.

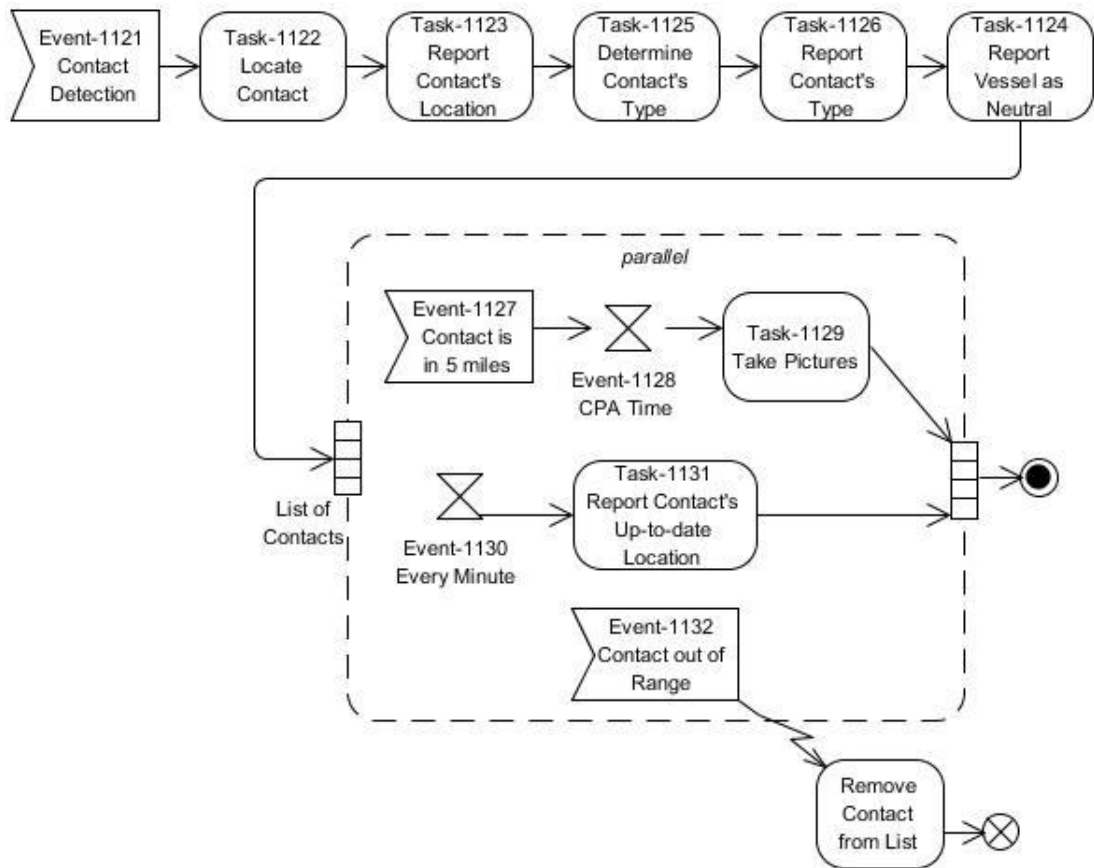


Figure 14. Activity Diagram of Task-1120

After reporting the contact as neutral, USV will wait for the event the contact gets in 5 miles of it (event-1127). If this event happens, USV waits the closest point of approach (CPA) time (event-1128) and takes pictures of the contact (task-1129) at CPA time. Also after reporting, USV will send contact location update reports (task-1131) once in every minute (event-1130). Taking pictures and location update reports must also be done after reporting as neutral task. The ordering of these tasks will not be the same for every contact, so these two tasks are considered independent in execution. USV continues to perform these two tasks until the contact gets out of its radar range. When the event of contact getting out of radar range

(event-1132) happens, reporting location updates and taking pictures tasks and related events are terminated, the contact is removed from USV's monitor list.

At the beginning of this section, we noted that some tasks will be executed by PTUs. PTU tasks are shown in Figure 15.

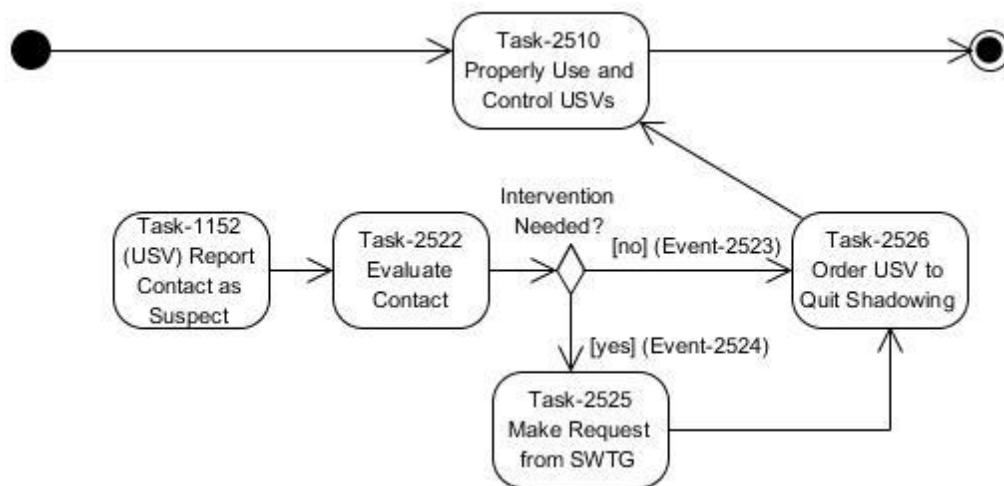


Figure 15. PTU Tasks

Main task of PTUs is to properly use and control USVs under command (task-2510). In addition, when a USV reports a suspicious contact (task-1152), PTU will evaluate (task-2522) the data (report and pictures) coming from USV. The diamond shape in the figure is a decision node in UML notation. When sufficient information is gathered about the vessel, PTU will decide if an intervention to the vessel is needed or not. If intervention is needed (event-2524), PTU will make an intervention request from SWTG (request-2525) and order USV to quit shadowing the vessel and taking pictures of it (task-2526). If PTU decides no intervention to the vessel (event-1123), it orders USV to quit. Note that decision nodes are modeled as events here.

3.2.2 C-BML Model of the Order

PTG sends ORDER 0002 to PTU Country-A and PTU Country-B. These two orders are the same except the responsibility areas, taskees and patrol type. Order2a.xml is the order sent to PTU Country-A and Order2b.xml is the order sent to PTU Country-B. XML files are available in Appendix F.

To model the order in C-BML, we construct a C-BML *actions* table, shown in Table 1, using the order presented in Appendix C and the UML activity diagrams we explained in section 3.2.2. We break down the mission into actions and number each with Object Identifier (OID). All actions are analyzed to in terms of 5Ws structure of C-BML.

Table 1. C-BML Actions Table of ORDER 0002

OID	Task/ Event	C-BML Action	Mission Phase
0900	Task	PTG orders PTU to conduct a patrol mission using USV units.	Mission
1000	Task	USV is to depart from the Caluula port and move to the patrol starting point.	Ingress
1100	Task	USV is to conduct patrol from 01 November 2010 0700Z to 01 November 2010 1900Z. Small boats are candidate targets for inspection.	Patrol Line Activity
1301 1300	Task Event	USV is to report fuel level every 6 hours (6 hour timer ticks)	

OID	Task/ Event	C-BML Action	Mission Phase
1401	Task	USV is to send malfunction report and quit patrol mission	
1400	Event	when USV malfunctions	
1160	Event	IF a piracy event is detected THEN	
1170	Task	USV is to take pirate boat actions, which are:	
1171	Task	USV is to identify pirate boat as hostile, AND	
1172	Task	USV is to report pirate boat as hostile, AND	
1010	Request (task)	USV is to make an intervention request from Surface Warfare Task Group (SWTG).	
1140	Event	IF a contact is considered suspect during identification, that is,	
1141	Event	If it changes speed by greater than 5 knots, OR	
1142	Event	It has no AIS ⁴ information OR	
1143	Event	It is detected as a suspected vessel based on its AIS info OR	
1144	Event	It is carrying weapons on board OR	
1145	Event	In drift position OR	
1146	Event	It is out of main shipping routes OR	
1147	Event	Its distance to land is closer than 10 miles THEN	
1150	Task	USV is to take suspect vessel actions, which are:	
1151	Task	USV is to identify vessel as suspect, AND	
1152	Task	USV is to report vessel as suspect, AND	
1153	Task	USV is to shadow the vessel at 4 miles, AND	
1155	Task	USV is to take pictures of the vessel	

⁴Automatic Identification System - an automated tracking system used on ships for identifying and locating vessels.

OID	Task/ Event	C-BML Action	Mission Phase
1154	Event	once in every 30 seconds (30 seconds timer ticks).	
1156	Event	When PTU orders USV to quit, USV must quit shadowing and taking pictures and turns back to monitoring.	
1121	Event	During monitoring, IF any contact is detected by USV,	
1122	Task	USV is to locate all detected contacts in radar range.	
1123	Task	USV is to report contact's location.	
1125	Task	USV is to determine the type of contact (as merchant vessel, warship, submarine or fishing boat).	
1126	Task	USV is to report contact's type.	
1124	Task	USV is to report contact's identity as neutral.	
1127	Event	IF any contact is in 5 miles,	
1129	Task	USV is to take contact's pictures	
1128	Event	at CPA time.	
1131	Task	USV is to report contact's up-to-date location	
1130	Event	every minute (one minute timer ticks.)	
1132	Event	IF any contact gets out of radar range, USV quits location updates and taking picture actions.	
1200	Task	PTG orders USV to finish patrolling and move to Caluula port.	Egress and Move to Port
2510	Task	PTG orders PTU to properly use and control USVs	
2522	Task	PTG orders PTU to evaluate the contact.	
2524	Event	IF intervention needed for the contact THEN	
2525	Request (task)	PTU is to make intervention request from SWTG AND	

OID	Task/ Event	C-BML Action	Mission Phase
2526	Task	PTU is to order USV to quit shadowing.	
2523	Event	IF intervention not needed for the contact THEN	
2526	Task	PTU is to order USV to quit shadowing.	

A task is defined in the `Task` structure of the `Order` element. What to do during the execution of a task is specified in `Order.Task.What.ActionTask` element. The executor of the task is specified in `Order.Task.TaskeeWho` element, the one who is ordering the task is specified in `Order.Task.TaskerWho` element, the place that the action takes place is specified in `Order.Task.Where` element, and the start/end times are specified in `Order.Task.When` element. `Order.Task.Resource` element specifies the object that is used or required during the execution of the task [5]. C-BML code of task-1000, move to patrol starting point is shown in Figure 16. Note that the taskee is PTU, where USV type of vessel is modeled as resource. This is because the order is given to PTUs, and it will be conducted by PTUs using USVs.

```

<cbml:Task>                                <!--Ingress task-1000-->
  <cbml:Where>
    <cbml:SpecificLocation>                 <!--Patrol Starting Poing-->
      <cbml:Location xsi:type="cbml:GeographicPoint">
        <cbml:OID>1001</cbml:OID>
        <cbml:LatitudeCoordinate>12.059466</cbml:LatitudeCoordinate>
        <cbml:LongitudeCoordinate>050.519257</cbml:LongitudeCoordinate>
      </cbml:Location>
    </cbml:SpecificLocation>
  </cbml:Where>
  <cbml:Resource xsi:type="cbml:ActionResourceItem">
    <cbml:QualifierCode>AUTH</cbml:QualifierCode>
    <cbml:ObjectItemRef xsi:type="cbml:OtherControlFeatureRef">
      <cbml:OID>1002</cbml:OID>           <!--Berthing Port (Caluula)-->
    </cbml:ObjectItemRef>
  </cbml:Resource>

```

```

</cbml:Resource>
<cbml:Resource xsi:type="cbml:ActionResourceType">
  <cbml:QualifierCode>AUTH</cbml:QualifierCode>
  <cbml:ObjectTypeRef xsi:type="cbml:SurfaceVesselTypeRef">
    <cbml:OID>1944</cbml:OID>          <!--USV type-->
  </cbml:ObjectTypeRef>
</cbml:Resource>
<cbml:What>
  <cbml:ActionTask xsi:type="cbml:OtherActionTask">
    <cbml:OID>1000</cbml:OID>          <!--Ingress -->
    <cbml:NameText>move from port to Patrol Start Point</cbml:NameText>
    <cbml:ActivityCode>MOVE</cbml:ActivityCode>
  </cbml:ActionTask>
</cbml:What>
<cbml:When>
  <cbml:StartWhen>
    <cbml:AbsoluteTime>
      <cbml:SpecifiedTime>
        <cbml:Datetime>20101101070000.000</cbml:Datetime>
        <cbml:StartQualifierCode>BEF</cbml:StartQualifierCode>
      </cbml:SpecifiedTime>
    </cbml:AbsoluteTime>
  </cbml:StartWhen>
</cbml:When>
<cbml:TaskOrganisationRef>
  <cbml:OID>9100</cbml:OID>
</cbml:TaskOrganisationRef>
<cbml:TaskerWho>
  <cbml:OrganisationRef xsi:type="cbml:UnitRef">
    <cbml:OID>9100</cbml:OID>          <!--PTG -->
  </cbml:OrganisationRef>
</cbml:TaskerWho>
<cbml:TaskeeWho>
  <cbml:OrganisationRef xsi:type="cbml:UnitRef">
    <cbml:OID>9110</cbml:OID>          <!--PTU Country-A-->
  </cbml:OrganisationRef>
</cbml:TaskeeWho>
</cbml:Task>

```

Figure 16. Sample Task C-BML code

Some tasks in the mission order the reporting. For example, send malfunction report (task-1401), send location report (task-1123), etc. C-BML does not support reporting as order. The method to model reporting orders we follow is described in section 3.6.

The task in Figure 16 includes *objects*, namely, berthing port, USV type, PTG and PTU Country-A. JC3IEDM model design has two kinds of objects [7]:

individually identified objects having a call sign, private name and number, etc. (5th Battalion, USV A-1) and class objects (a ship, a battalion). Individually identified objects are named `object-items` and class objects are named `object-type`. An `object-type` is modeled in `Order/Report/Request.SupportingType` element. Code for USV type definition is provided in Figure 17. Once defined, the OID assigned to that class object can be used anywhere in the code as a reference to that class object.

```
<cbml:SupportingType xsi:type="cbml:SurfaceVesselType">
  <cbml:OID>1944</cbml:OID>
  <cbml:DecoyIndicatorCode>YES</cbml:DecoyIndicatorCode>
  <cbml:NameText>USV Type</cbml:NameText>
  <cbml:CategoryCode></cbml:CategoryCode>
</cbml:SupportingType>
```

Figure 17. USV Type Definition

An `object-item` is defined in two steps: (1) class definition and (2) instance creation. Item definition is detailed in section 3.7. The first two steps in the organization definition are item definition steps. See section 3.7 for more information.

Events are defined as reports in C-BML. Reports are detailed in section 3.6. Here event structure is introduced. An event is defined in `Order.CurrentState.Report.Report` `xsi:type="cbml:EventWhatLocationType"` element or `Order.Task.ActionCurrentState.Report` `xsi:type="cbml:EventWhatLocationType"` element. Event structure is similar to task structure. It has where, what, when, resource, executer who, and other sub-elements. Sample code of contact detection event (event-1121) is provided in Figure 18. In the code,

elements before `Event` element are related to report structure.

```

<cbml:ActionCurrentState>                                <!--contact detection event-->
  <cbml:Report xsi:type="cbml:EventWhatLocationType">
    <cbml:ReporterWho>
      <cbml:OrganisationRef xsi:type="cbml:UnitRef">
        <cbml:OID>9111</cbml:OID>                        <!--USV A-1-->
      </cbml:OrganisationRef>
    </cbml:ReporterWho>
    <cbml:ReportedWhen xsi:type="cbml:ReportedWhenRelativeTimingType">
      <cbml:ReportingDatetime>0000000000000.000</cbml:ReportingDatetime>
      <cbml:OffsetDuration>0</cbml:OffsetDuration>
      <cbml:ReferenceActionTaskRef xsi:type="cbml:OtherActionTaskRef">
        <cbml:OID>1120</cbml:OID>                        <!--monitor task-->
      </cbml:ReferenceActionTaskRef>
    </cbml:ReportedWhen>
    <cbml:ReportingData>
      <cbml:OID>0000</cbml:OID>
      <cbml:ReportingDataCategoryCode>PRDCTD</cbml:ReportingDataCategoryCode>
      <cbml:SourceTypeCode>RPV</cbml:SourceTypeCode>
    </cbml:ReportingData>
    <cbml:Event>                                         <!--detection of a contact. event 1121-->
      <cbml:Where>
        <cbml:SpecificLocation>
          <cbml:LocationRef xsi:type="cbml:PolygonAreaRef">
            <cbml:OID>1101</cbml:OID>                    <!--Area Alpha-->
          </cbml:LocationRef>
        </cbml:SpecificLocation>
      </cbml:Where>
      <cbml:What>
        <cbml:ActionEvent xsi:type="cbml:OtherActionEvent">
          <cbml:OID>1121</cbml:OID>
          <cbml:NameText>Any contact detection</cbml:NameText>
          <cbml:CategoryCode>NOS</cbml:CategoryCode>
        </cbml:ActionEvent>
      </cbml:What>
      <cbml:ExecuterWho>
        <cbml:OrganisationRef xsi:type="cbml:UnitRef">
          <cbml:OID>9111</cbml:OID>                        <!--USV A-1-->
        </cbml:OrganisationRef>
      </cbml:ExecuterWho>
    </cbml:Event>
  </cbml:Report>
</cbml:ActionCurrentState>

```

Figure 18. Code for Contact Detection Event

A *request* is an action and defined in `Request` structure of C-BML. It is modeled in the same way of modeling tasks, since request is composed of tasks.

As specified in the order, during patrolling, small boats are of more importance

for inspection. We modeled this phrase by using `Order.Task.CandidateTargetListRef` element. Patrol in the area task (task-1100) references a list of candidate targets for inspection. Candidate target list is created in a report. See section 3.6 for details.

The order also includes communication issues. They are modeled as reports using network related structures of C-BML. Network modeling is detailed in section 3.6.3.

Sections of the order and corresponding C-BML structures used for modeling are shown in Table 2. Modeling issues and related details are provided in the following sections.

Table 2. Order Sections Modeled with C-BML Structure

Order Section	C-BML Structure
Mission	<code>Order.Task</code>
Participating Units	Reference to <code>OrganisationStructureType</code> Report
Communication Issues	Report structures are used. See Section 3.6.3.
Patrol Schedule	Not modeled. No appropriate C-BML structure found. (See Section 4 for discussions)
Patrol Areas	<code>Order.Task.Where.DerivedLocationRef</code>
Patrol Details	<code>Order.Task</code> , <code>Event</code> , <code>Request</code> , <code>Report</code>
Berthing Place	<code>Order.Task.Resource</code>

All the orders have a security classification. In our scenario, security classification of all of the orders is unclassified. The classification is modeled in `Order.Context.SecurityClassification` element.

3.3 Modeling the Operations Order

The Operations Order has a mission of fighting with piracy. CTF assigns tasks and responsibilities for its subordinates. Tasks and sub-tasks of each task in OPORD are illustrated in Figure 19. In order to help readability, tasks are grouped according to their taskees. PTG sends OPORD to PTG and SWTG. `Opord1a.xml` is the order sent to PTG and includes tasks for PTG, PTUs, and PTEs. `Opord1b.xml` is the order sent to SWTG including only SWTG tasks. XML files are available in Appendix F.

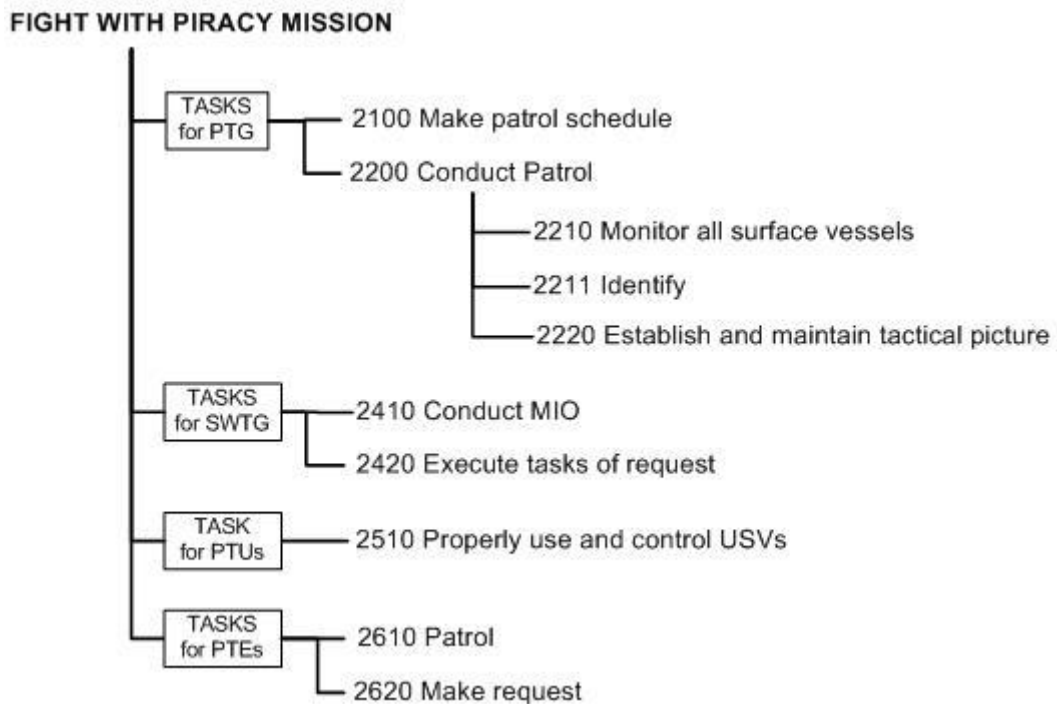


Figure 19. Tasks in OPORD

Temporal relationships of tasks for PTG in OPORD are illustrated in Figure 20. Task-2100 and task-2200 are sequential. Task-2200 has three sub tasks. Tasks 2210 and 2211 are sequential tasks, where task-2220 is parallel to those. The tasks for PTEs and SWTG are modeled as being parallel.

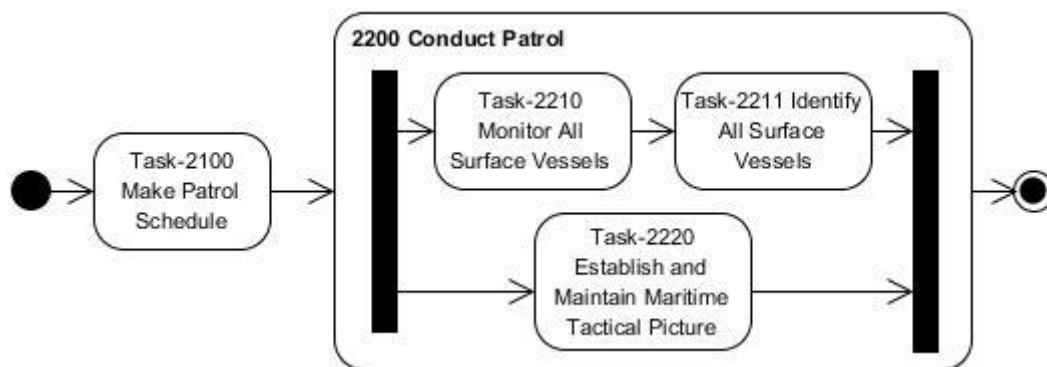


Figure 20. Tasks for PTG in OPORD

We construct a C-BML actions table for the OPORD. We break down the mission into actions shown in Table 3.

Table 3. C-BML Actions Table of the OPORD

OID	C-BML Action	Taskee
2000	CTF orders all its units fight with piracy in the Gulf of Aden with conducting patrol and maritime interdiction operations (MIO).	(Mission) All units of CTF
2100	CTF orders PTG to make a patrol schedule that enables a continuous patrolling of USVs in command.	PTG
2200	CTF orders PTG to conduct patrol in area of responsibility.	
2210	CTF orders PTG to monitor all surface vessels.	

OID	C-BML Action	Taskee
2211	CTF orders PTG to identify all surface vessels.	
2220	CTF orders PTG to establish and maintain the maritime tactical picture in the area.	
2410	CTF orders SWTG to conduct MIO.	SWTG
2420	CTF orders SWTG to execute tasks of request.	
2510	CTF orders PTUs to properly use and safely control of USVs.	PTU
2610	CTF orders PTEs to patrol in given area.	PTE
2620	CTF orders PTEs to request an armed intervention from SWTG 499.2 when piracy detected.	

Tasks in OPORD are all modeled in the same way as described in former sections. Sections of operations order and the corresponding C-BML structures are provided in Table 4.

Table 4. Order Sections modeled with C-BML Structure

Operations Order Section	C-BML Structure
Task Organization	OrganisationStructureType Report
Situation of Enemy Forces	CurrentState
Situation of Friendly Forces	CurrentState
Areas of responsibility	Order.Task.Where, AffectedWho (See section 3.5)
Mission	Order.Task

Operations Order Section	C-BML Structure
Commander's Intent	Order.Task.Why
Concept of Operations	Partly modeled in Tasks
Tasks for Major Subordinate Commands	Order.Task
Patrol Schedule	Not modeled. No appropriate C-BML structure exists. (See Section 4 for discussions)
Command and signal	Report structures are used. See Section 3.6.

Different from the order from PTG to PTUs, OPORD has Situation of Enemy Forces, Situation of Friendly Forces and Commander's Intent sections. Situations of Enemy/Friend Forces are modeled as reports, and described in section 3.6. Commander's intent is modeled in Order.Task.Why.ExpectedEndState as a report, XML code is given in Figure 21. The report specifies that task of fighting with piracy (task-2000) will have an effect of neutralizing Aden Pirate Group (OID 9301) totally.

```

<cbml:Why>
  <cbml:ExpectedEndState>                                <!--Aden Pirate Group will be neutralized totally-->
  <cbml:Report xsi:type="cbml:WhatEffectType">
    <cbml:ReporterWho>
      <cbml:OrganisationRef xsi:type="cbml:UnitRef">
        <cbml:OID>9001</cbml:OID>                                <!--CTF-->
      </cbml:OrganisationRef>
    </cbml:ReporterWho>
    <cbml:ReportedWhen xsi:type="cbml:ReportedWhenAbsoluteTimingType">
      <cbml:ReportingDatetime>20101001000000.000</cbml:ReportingDatetime>
    </cbml:ReportedWhen>
    <cbml:ReportingData>
      <cbml:OID>0000</cbml:OID>
      <cbml:ReportingDataCategoryCode>REP</cbml:ReportingDataCategoryCode>
    </cbml:ReportingData>
  </cbml:WhatRef>

```

```

        <cbml:ActionRef xsi:type="cbml:OtherActionTaskRef">
            <cbml:OID>2000</cbml:OID>          <!--Fight with piracy mission-->
        </cbml:ActionRef>
    </cbml:WhatRef>
    <cbml:ActionEffect xsi:type="cbml:ActionEffectItem">
        <cbml:DescriptionCode>NUTRLD</cbml:DescriptionCode><!--neutralized-->
        <cbml:Ratio>1</cbml:Ratio>          <!--totally-->
        <cbml:ObjectItemRef xsi:type="cbml:OtherOrganisationRef">
            <cbml:OID>9301</cbml:OID>          <!--Aden Pirate Group-->
        </cbml:ObjectItemRef>
    </cbml:ActionEffect>
</cbml:Report>
</cbml:ExpectedEndState>
</cbml:Why>

```

Figure 21. Code for Commander's Intent

CTF determines responsibility areas of its subordinate units for fighting with piracy mission also in OPORD. The location that a task takes place is specified in `Order.Task.Where` element. But only one location can be defined using this structure. In other words, using where structure, a task can be defined to take place in only one location. To overcome this, we specified responsibility areas in `Order.Task.AffectedWho` element. Location definitions are described in section xx. In `Order.Task.AffectedWho` element, references to areas are used. In OPORD, conduct patrol task (task-2200) includes responsibility areas. XML code part of task-2200 showing responsibility area assignment is provided in Figure 22.

```

<cbml:Where>
    <cbml:DerivedLocationRef xsi:type="cbml:GeographicFeatureRef">
        <cbml:OID>2902</cbml:OID>          <!--Gulf of Aden-->
    </cbml:DerivedLocationRef>
</cbml:Where>
<cbml:AffectedWho>
    <cbml:ActionObjective xsi:type="cbml:OtherActionObjectiveItem">
        <cbml:OID>0</cbml:OID>
        <cbml:ObjectItemRef xsi:type="cbml:OtherControlFeatureRef">
            <cbml:OID>1101</cbml:OID>          <!--Area Alpha-->
        </cbml:ObjectItemRef>
    </cbml:ActionObjective>
</cbml:AffectedWho>
<cbml:AffectedWho>
    <cbml:ActionObjective xsi:type="cbml:OtherActionObjectiveItem">
        <cbml:OID>0</cbml:OID>

```

```
<cbml:ObjectItemRef xsi:type="cbml:OtherControlFeatureRef">
  <cbml:OID>1101</cbml:OID> <!--Area Bravo-->
</cbml:ObjectItemRef>
</cbml:ActionObjective>
</cbml:AffectedWho>
```

Figure 22. Responsibility Area Assignment

3.4 Modeling Orders from PTUs to PTEs

Orders from PTUs to PTEs are ORDER 0003 and ORDER 0004. These orders are modeled in the same way as the order from PTG to PTUs. As for difference, patrol legs are defined in ORDER 0003. We explain modeling areas and legs in section 3.5.

In our scenario, PTG sends a patrol order that specifies a patrol schedule. Since task periods cannot be defined in C-BML, we assumed that PTUs in our organization will, based on the order from PTG, send the patrol orders to PTEs daily, each order including one period (one day). As a note, in ORDER 0003 and ORDER 0004, all periods are included. Daily orders will be the same of ORDER 0003 and ORDER 0004, except that daily orders will use one period in the schedule table.

Moreover, in ORDER 0003, two USVs are employed in Area Alpha between 15 November 2010 and 30 November 2010. But only one taskee can be assigned for a task in C-BML. So we modeled tasks twice for each USV.

Order3a.xml is the order sent from PTU Country-A to USV A-1, which is the daily order of November the 1st, 2010. USV A-1 will conduct patrol using Patrol Track No.1. Order3ba.xml is the order sent from PTU Country-A to USV A-2 and

Order3bb.xml is the order sent from PTU Country-A to USV A-3. Order3ba.xml and Order3bb.xml are daily patrol orders of November the 17th, 2010 in Area Alpha. USV A-2 is ordered to conduct patrol using Patrol Track No.2 and USV A-3 will use Patrol Track No.3 on the same day in Area Alpha. XML files are available in Appendix F.

Order4a.xml is the order sent from PTU Country-B to USV B-1, which is the daily order of November the 1st, 2010, ordering patrol in Area Bravo. This order and other daily orders refer to the tasks in Order2b.xml. To model referenced tasks in these orders, we created a task named “Execute the task and its subtasks stated in ref” and we referenced patrol mission for PTU Country-B (task-0800) using Order.Task.Why element. XML code showing the reference is provided in Figure 23.

```

<cbml:Why>
  <cbml:ActionFunctionalAssociationInSubjectAction>
    <cbml:ObjectActionRef xsi:type="cbml:OtherActionTaskRef">
      <cbml:OID>0800</cbml:OID>          <!--patrol mission for USVs-->
    </cbml:ObjectActionRef>
    <cbml:FunctionalAssociationCategoryCode> UAR          <!--uses as reference-->
    </cbml:FunctionalAssociationCategoryCode>
  </cbml:ActionFunctionalAssociationInSubjectAction>
</cbml:Why>
<cbml:What>
  <cbml:ActionTask xsi:type="cbml:OtherActionTask">
    <cbml:OID>0801</cbml:OID>
    <cbml:NameText>Execute the task and its subtasks stated in ref
  </cbml:NameText>
    <cbml:ActionCode>PATROL</cbml:ActionCode>
  </cbml:ActionTask>
</cbml:What>

```

Figure 23. Task using other task as reference

3.5 Modeling Patrol Area, Traverse Legs and Other Locations

The location that a task or event takes place is specified in `Order.Task.Where/RouteWhere` element or `Event.Where/RouteWhere` element. Where element has two alternative sub-elements: `SpecificLocation` and `DerivedLocationRef`.

`SpecificLocation` has alternative sub-elements named `Location` and `LocationRef`. Using `Location`, a line, point, polygon-area, orbit-area, ellipse, track-area, surface volume and so on can be defined in terms of absolute or relative points. `LocationRef` references to a previously defined location using its OID.

`DerivedLocationRef` specifies the location in terms of an object-item's location.

`RouteWhere` element has `StartWhere`, `Via` and `EndWhere` sub-elements. Each sub-element has `SpecificLocation` and `DerivedLocationRef` as alternative sub-elements. In our model, patrol legs are defined using `RouteWhere`.

Responsibility Areas (Area Alpha, Area Bravo) and Aden Gulf are modeled as object-items. Patrol Areas correspond to control-features⁵: in C-BML. To model Area Alpha, for example, first its type is defined and instance is created. Then its

⁵Control Feature is a term in JC3IEDM and is used to represent abstract objects created or assigned by military authorities for the purposes of planning and coordination, especially in operational areas. It is a non-permanent point (e.g., start point for a road move), line (e.g., a Main supply route), area (e.g., a Slow-go area), or volume (e.g., an air corridor) [28].

location is defined as a PolygonArea in a report it is referenced in Order.Task.Where.DerivedLocationRef. The steps to model an area or other control-feature are elaborated below:

(i) Type Definition: First, the control feature's type must be defined in Order.SupportingType structure. In Figure 24, a new type, namely Area of Responsibility is defined and the type's OID is 1103.

```
<cbml:SupportingType xsi:type="cbml:OtherControlFeatureType">
  <cbml:OID>1103</cbml:OID>
  <cbml:DecoyIndicatorCode>NO</cbml:DecoyIndicatorCode>
  <cbml:NameText>Area of Responsibility</cbml:NameText>
  <cbml:CategoryCode>AOR</cbml:CategoryCode>
</cbml:SupportingType>
```

Figure 24. Area of Responsibility Type Definition

(ii) Instance Creation: After defining the type of control feature, an instance of the type is created using WhoTypeType Report. Figure 25 shows the code that defines Patrol Area Alpha (OID 1101) as an Area of Responsibility.

```
<Report xsi:type="WhoTypeType">
  <!-- there is omitted code here -->
  <Who>
    <ObjectItem xsi:type="OtherControlFeature">
      <OID>1101</OID>
      <NameText>Patrol Area Alpha</NameText>
    </ObjectItem>
  </Who>
  <ObjectTypeRef xsi:type="OtherControlFeatureTypeRef">
    <OID>1103</OID> <!--Area of Responsibility Type-->
  </ObjectTypeRef>
</Report>
```

Figure 25. Type Report for Area Alpha

(iii) Location Definition: Location of the control feature is then defined in WhoLocationType Report. In Figure 26, location of Patrol Area Alpha is

specified using a several geographic points.

```

<cbml:Report xsi:type="cbml:WhoLocationType">
  <!-- there is omitted code here -->
  <cbml:WhoRef>
    <cbml:ObjectItemRef xsi:type="cbml:OtherControlFeatureRef">
      <cbml:OID>5002</cbml:OID>          <!--Patrol Area Alpha-->
    </cbml:ObjectItemRef>
  </cbml:WhoRef>
  <cbml:Location xsi:type="cbml:PolygonArea"> <!--Coordinates are defined here-->
    <cbml:OID>0000</cbml:OID>
    <cbml:BoundingLine>
      <cbml:OID>0000</cbml:OID>
      <cbml:Point xsi:type="cbml:GeographicPoint">
        <cbml:OID>0000</cbml:OID>
        <cbml:LatitudeCoordinate>12.059466N</cbml:LatitudeCoordinate>
        <cbml:LongitudeCoordinate>50.519257E</cbml:LongitudeCoordinate>
      </cbml:Point>
      <cbml:Point xsi:type="cbml:GeographicPoint">
        <cbml:OID>0000</cbml:OID>
        <cbml:LatitudeCoordinate>12.098410N</cbml:LatitudeCoordinate>
        <cbml:LongitudeCoordinate>50.865326E</cbml:LongitudeCoordinate>
      </cbml:Point>
    <!-- there is omitted code here defining other points -->
    </cbml:BoundingLine>
  </cbml:Location>
</cbml:Report>

```

Figure 26. Location Definition of Area Alpha

(iv) **Referencing the location inside the Task.Where:** Lastly, a previously defined control feature's OID is entered in Task.Where.DerivedLocationRef element. Figure 27 provides the code for a task specifying that its location is Patrol Area Alpha.

```

<cbml:Where>
  <cbml:DerivedLocationRef xsi:type="cbml:OtherControlFeatureRef">
    <cbml:OID>1101</cbml:OID>          <!--Patrol Area Alpha-->
  </cbml:DerivedLocationRef>
</cbml:Where>

```

Figure 27. Referencing Area Alpha in Task.Where

Patrol traverse legs are modeled using RouteWhere element. XML code defining Patrol Track1 is provided in Figure 28.

```

<cbml:RouteWhere>
  <cbml:StartWhere>
    <cbml:SpecificLocation>
      <cbml:Location xsi:type="cbml:GeographicPoint">
        <cbml:OID>1111</cbml:OID>
        <cbml:LatitudeCoordinate>12.095724</cbml:LatitudeCoordinate>
        <cbml:LongitudeCoordinate>50.754089</cbml:LongitudeCoordinate>
      </cbml:Location>
    </cbml:SpecificLocation>
  </cbml:StartWhere>
  <cbml:Via>
    <cbml:SpecificLocation>
      <cbml:Location xsi:type="cbml:Line"          <!--Patrol Legs-->
        <cbml:OID>1102</cbml:OID>
        <cbml:Point xsi:type="cbml:GeographicPoint">
          <cbml:OID>1112</cbml:OID>
          <cbml:LatitudeCoordinate>12.089010</cbml:LatitudeCoordinate>
          <cbml:LongitudeCoordinate>50.565948</cbml:LongitudeCoordinate>
        </cbml:Point>
        <cbml:Point xsi:type="cbml:GeographicPoint">
          <cbml:OID>1113</cbml:OID>
          <cbml:LatitudeCoordinate>12.199100</cbml:LatitudeCoordinate>
          <cbml:LongitudeCoordinate>50.880432</cbml:LongitudeCoordinate>
        </cbml:Point>
      </cbml:Location>
    <!-- there is omitted code here defining other points -->
  </cbml:SpecificLocation>
</cbml:Via>
  <cbml:EndWhere>
    <cbml:SpecificLocation><!--the same point of starting-->
      <cbml:Location xsi:type="cbml:GeographicPoint">
        <cbml:OID>1111</cbml:OID>
        <cbml:LatitudeCoordinate>12.095724</cbml:LatitudeCoordinate>
        <cbml:LongitudeCoordinate>50.754089</cbml:LongitudeCoordinate>
      </cbml:Location>
    </cbml:SpecificLocation>
  </cbml:EndWhere>
</cbml:RouteWhere>

```

Figure 28. RouteWhere Example

In the Order from PTG to PTE's, event-1146 is that a contact is detected to be out of main shipping routes. Main shipping routes are modeled as `CorridorArea` in `Report.Event.Where.SpecificLocation` structure. A `CorridorArea` has a width dimension and a center line consisting several points. Event-1127 is that a contact is detected to be in 5 miles range of USV. The range is modeled using `Ellipse` structure. Event-1156 is that contact distance to land is closer than 10 miles. The location for that event could not be modeled using a

location structure because no appropriate C-BML structure is found; so it is modeled as a free text.

3.6 Modeling Reports

Reports are modeled in the `Report` structure of C-BML. In our scenario, we assumed that some reports will be sent from USVs in prescribed periods. The reports and corresponding C-BML structures for modeling are provided in Table 5.

Table 5. Reports Table

Report Name	Period	Explanation	Type of Report in C-BML Structure
Contact Report	Once	When a surface contact is acquired, it will be reported as an unknown surface vessel.	<code>WhoTypeType</code>
Contact Location Report	Once	When a contact is acquired.	<code>WhoLocationType</code>
Contact Type Report	Once	When the type of a contact is determined as merchant vessel, fishing boat, warship or submarine.	<code>WhoTypeType</code>
Contact Identification Report	Once	When a contact is identified as friend, hostile or suspected. And also when identity of a contact changes.	<code>WhoHostilityType</code>

Report Name	Period	Explanation	Type of Report in C-BML Structure
Contact Location Update Report	1 minute	Up-to-date location information of all contacts being tracked.	WhoLocationType
Event Report	Once	When an event such as piracy is detected by USV.	EventWhatLocationType
USV Malfunction Report	Once	When a USV malfunctions.	WhoStatusType
USV Fuel Level Report	6 hours	Remaining fuel level of USV will be reported.	WhoHoldingType
Movement Report	Once	Before departing from port for a naval operation.	TaskWhatStatusType
Arrival Report	Once	After arrival to port from a naval operation.	TaskWhatStatusType
Situation of Friend/Enemy Forces	Once	Reported with the OPOD.	WhoTypeType, WhoAffiliationType, WhoAssociationType, WhoHoldingType, WhoStatusType
USV's Location Report	Every minute	USV sends its location.	WhoLocationType

Report Name	Period	Explanation	Type of Report in C-BML Structure
Network Report	Once	Defines communication network between USV and PTUs.	WhoTypeType, NetworkService StatusType, WhoAddressType
Candidate Target List Report	Once	Defines objects that are potentially target for inspection.	CandidateTarget ListType

To model conditional statements (e.g. contact is detected (event-1121), contact is in 5 miles (event-1125)) that initiate performing tasks, `event` structure under `Order.CurrentState.Report` is used. In other words, events as conditional statements are modeled in `report` structure. Besides, events can also be modeled in an independent report.

A sample Contact Type Report full XML code is provided in Figure 29. USV A-1 reports that the surface vessel (OID 1935) is a merchant ship (OID 1940). It is assumed that vessel-1935 was reported and being tracked by the C2 system as a surface vessel.

```

<cbml:Report>
  <cbml:Context xsi:type="cbml:OtherContext">
    <cbml:OID>0000</cbml:OID>
    <cbml:NameText>Contact Type Report after Location Report</cbml:NameText>
    <cbml:CategoryCode>NOS</cbml:CategoryCode>
  </cbml:Context>
  <cbml:Report xsi:type="cbml:WhoTypeType">
    <cbml:ReporterWho>
      <cbml:OrganisationRef xsi:type="cbml:UnitRef">
        <cbml:OID>9111</cbml:OID>          <!--USV A-1-->
      </cbml:OrganisationRef>
    </cbml:ReporterWho>
    <cbml:ReportedWhen xsi:type="cbml:ReportedWhenAbsoluteTimingType">

```

```

        <cbml:ReportingDatetime>0000000000000.000</cbml:ReportingDatetime>
    </cbml:ReportedWhen>
    <cbml:ReportingData>
        <cbml:OID>1912</cbml:OID>
        <cbml:ReportingDataCategoryCode>REP
    </cbml:ReportingDataCategoryCode>
        <cbml:SourceTypeCode>RPV</cbml:SourceTypeCode>
    </cbml:ReportingData>
    <cbml:WhoRef>
        <cbml:ObjectItemRef xsi:type="cbml:OtherObjectItemRef">
            <cbml:OID>1935</cbml:OID>          <!--Any surface vessel item-->
        </cbml:ObjectItemRef>
    </cbml:WhoRef>
    <cbml:ObjectType xsi:type="cbml:SurfaceVesselType ">
        <cbml:OID>1940</cbml:OID>
        <cbml:DecoyIndicatorCode>NO</cbml:DecoyIndicatorCode>
        <cbml:NameText>Merchant Ship Type</cbml:NameText>
        <cbml:CategoryCode>TM</cbml:CategoryCode><!--Merchant ship, general-->
    </cbml:ObjectType>
    </cbml:Report>
</cbml:Report>

```

Figure 29. Sample Contact Type Report

In C-BML, report and order are two disparate elements. Due to the nature of our scenario, some tasks in the mission order the reporting. For example, send malfunction report (task-1401) and send location report (task-1123) tasks order to report information. C-BML does not support reporting as order. In our study, we modeled such reports in Report structure and specified the reporting time of the report relative to the task. So that, when the task is executed, the related report would be send. Sample part of XML code of the ContactLocationReport.xml indication the reporting time as reference to Task-1123 is shown in Figure 30.

```

<C_BML:ReportedWhen xsi:type="C_BML:ReportedWhenRelativeTiming">
    <C_BML:ReportingDatetime>20101101070000.000</C_BML:ReportingDatetime>
    <C_BML:OffsetDuration>0</C_BML:OffsetDuration>
    <C_BML:ReferenceActionTaskRef>
        <C_BML:OID>1123</C_BML:OID>
    </C_BML:ReferenceActionTaskRef>
</C_BML:ReportedWhen>

```

Figure 30. Sample Report Referring to a Task

3.6.1 Modeling Candidate Target List

The orders state that small boats must be given more importance for inspection during patrolling. We modeled this phrase by using `Order.Task.CandidateTargetListRef` element. Patrol in the area task (task-1100) references a list of candidate targets for inspection. Candidate target list is created in a report named `CandidateTargetListType`. The report provided in Figure 31 announces small boats with high speeds as candidate items for observation. First, the type of small, speedy boats is defined in `SupportingType`. Then, in the report, this type of objects is defined as potential targets for observation. A reference is given to the defined target list in `Task.CandidateTargetListRef` element.

```
<cbml:SupportingType xsi:type="cbml:SurfaceVesselType">
  <cbml:OID>1924</cbml:OID>
  <cbml:DecoyIndicatorCode>NO</cbml:DecoyIndicatorCode>
  <cbml:NameText>Small boat capable of high speeds</cbml:NameText>
  <cbml:CategoryCode>SPDBAT</cbml:CategoryCode><!--JC3IEDM-codes definition:
Speedboat=Small, sleek boat capable of high speeds with or without outboard engines.-->
</cbml:SupportingType>

<cbml:Report xsi:type="cbml:CandidateTargetListType">
  <cbml:ReporterWho>
    <cbml:OrganisationRef xsi:type="cbml:UnitRef">
      <cbml:OID>9001</cbml:OID><!--CTF-->
    </cbml:OrganisationRef>
  </cbml:ReporterWho>
  <cbml:ReportedWhen xsi:type="cbml:ReportedWhenAbsoluteTimingType">
    <cbml:ReportingDatetime>20101101000000.000</cbml:ReportingDatetime>
  </cbml:ReportedWhen>
  <cbml:ReportingData>
    <cbml:OID>1922</cbml:OID>
    <cbml:ReportingDataCategoryCode>REP</cbml:ReportingDataCategoryCode>
  </cbml:ReportingData>
  <cbml:CandidateTargetList>
    <cbml:OID>1923</cbml:OID>
    <cbml:NameText>Small boats are candidate targets for
observation</cbml:NameText>
    <cbml:CandidateTargetDetail xsi:type="cbml:CandidateTargetDetailType">
      <cbml:OID>0000</cbml:OID>
      <cbml:FocusTypeCode>OBSRV</cbml:FocusTypeCode><!--JC3IEDM-codes
```

```

definition: To provide continuous view, and the potential for reports on the activity of an objective.-->
      <cbml:ObjectTypeRef xsi:type="cbml:SurfaceVesselTypeRef">
        <cbml:OID>1924</cbml:OID><!--type of small boat capable of high
speeds-->
      </cbml:ObjectTypeRef>
    </cbml:CandidateTargetDetail>
  </cbml:CandidateTargetList>
</cbml:Report>

```

Figure 31. Candidate Target List Report

3.6.2 Modeling Situation of Enemy and Friendly Forces

Circumstances and conditions for a situation are defined as reports. CTF sends current situation of friendly and enemy forces to its subordinates. The phrases regarding to current situations are modeled with the corresponding report types shown in Table 6.

Table 6. Situation of Enemy & Friendly Forces

Phrase about Situation	Report type
Aden Pirate Group is a pirate group.	WhoTypeType
Pirate Boat-1 is a small boat capable of high speeds.	WhoTypeType
Pirate Boat-2 is a small boat capable of high speeds.	WhoTypeType
Aden Pirate Group is affiliated with the criminal piracy group.	WhoAffiliationType
Aden Pirate Group is situated in Aden Gulf.	WhoAssociationType
Pirate Boat-2 is situated in Aden Gulf.	WhoAssociationType
Pirate Boat-1 is situated in Aden Gulf.	WhoAssociationType
Aden Pirate Group uses Pirate Boat-1.	WhoAssociationType
Aden Pirate Group uses Pirate Boat-2.	WhoAssociationType

Phrase about Situation	Report type
Aden Pirate Group holds assault guns.	WhoHoldingType
PTG is situated in Caluula Port.	WhoAssociationType
SWTG is situated in Caluula Port.	WhoAssociationType
SWTG's status is operational (ready for mission).	WhoStatusType
PTG's status is operational (ready for mission).	WhoStatusType

Part of an affiliation report is given in Figure 32. A criminal group named piracy is defined and Aden Pirate Group is reported to be in affiliation with that group.

```

<cbml:WhoRef>
  <cbml:ObjectItemRef xsi:type="cbml:OtherOrganisationRef">
    <cbml:OID>9301</cbml:OID><!--Aden Pirate Group-->
  </cbml:ObjectItemRef>
</cbml:WhoRef>
<cbml:Affiliation xsi:type="cbml:AffiliationFunctionalGroup">
  <cbml:OID>0</cbml:OID>
  <cbml:Code>CRIMIN</cbml:Code>
  <cbml:NameText>Piracy</cbml:NameText>
</cbml:Affiliation>

```

Figure 32. Affiliation Report

An association report example is provided in Figure 33. In the report, Aden Pirate Group is associated with Aden Gulf. The association category is “is situated in” and the report states that Aden Pirate Group is situated in Aden Gulf.

```

<cbml:WhoRef>
  <cbml:ObjectItemRef xsi:type="cbml:OtherOrganisationRef">
    <cbml:OID>9301</cbml:OID><!--Aden Pirate Group-->
  </cbml:ObjectItemRef>
</cbml:WhoRef>
<cbml:ObjectObjectItemRef xsi:type="cbml:GeographicFeatureRef">
  <cbml:OID>2902</cbml:OID><!--Aden Gulf-->
</cbml:ObjectObjectItemRef>
<cbml:ObjectItemAssociation>
  <cbml:OID>0</cbml:OID>
  <cbml:CategoryCode> ISSITU</cbml:CategoryCode><!--Is situated in: Aden Pirate Group is
located within Aden Gulf-->
  <cbml>Status>
    <cbml:CategoryCode>START</cbml:CategoryCode>
  </cbml>Status>
</cbml:ObjectItemAssociation>

```

Figure 33. Association Report

3.6.3 Modeling Communications as Network

PTG assigns some frequencies to be used for data transfer communications between PTUs and USVs. There are six links assigned each having a discrete frequency:

- a. Network between USV A-1 and PTU 499.1.1
- b. Network between USV A-2 and PTU 499.1.1
- c. Network between USV A-3 and PTU 499.1.1
- d. Network between USV B-1 and PTU 499.1.2
- e. Network between USV B-2 and PTU 499.1.2
- f. Network between USV B-1 and PTU 499.1.2

Each link is assigned to be used only between specified units. In order to model each link in C-BML, the phrases in Table 7 are modeled with the corresponding structures.

Table 7. Creating a Network

Phrase about Network	Report type
Data Transfer Network-1 between USV A-1 and PTU Country-A is a point-to-point, wireless, data link network having a data transfer network service and the network's frequency is 10500 KHz.	WhoTypeType
Previously defined data transfer network service is active.	NetworkServiceStatusType
Electronic address of USV A-1 is the previously defined data transfer network service and USV A-1 uses this electronic address for both transmit and receive.	WhoAddressType
Electronic address of PTU Country-A is the previously defined data transfer network service and PTU Country-A uses this electronic address for both transmit and receive.	WhoAddressType

3.7 Modeling the Organization Structure

We model the organization described in Section 2.1 in the `OrganizationStructureType` structure of C-BML which is under the `Report` element. Before modeling an organization structure in C-BML, each unit in the organization must be defined. There are four steps to model an organization: (i) type definition, (ii) instance creation, (iii) association definition, and (iv) organization structure definition.

(i) Type Definition: To model a unit or any other object in C-BML, first, its type must be declared in `SupportingType` structure of the `Order/Report` element. For instance, there are task units (e.g. PTUs) in our organization. The definition of Task Unit as a type (i.e. Task Unit Type) is provided in Figure 34.

```
<cbml:SupportingType xsi:type="cbml:UnitType" <!--Task Unit Type definition-->
  <cbml:OID>1932</cbml:OID>
  <cbml:DecoyIndicatorCode>NO</cbml:DecoyIndicatorCode>
  <cbml:NameText>Task Unit Type</cbml:NameText>
  <cbml:CommandFunctionIndicatorCode>YES</cbml:CommandFunctionIndicatorCode>
  <cbml:ServiceCode>NAVY</cbml:ServiceCode>
  <cbml:CategoryCode>COMBAT</cbml:CategoryCode>
  <cbml:ArmCategoryCode>ADMIN</cbml:ArmCategoryCode>
  <cbml:SizeCode>NTU</cbml:SizeCode>
</cbml:SupportingType>
```

Figure 34. Task Unit Type Definition

(ii) Instance Creation: Instances of a previously defined type are defined in `WhoTypeType` structure of the `Report` element. Sample code for defining that PTU-Country A is a Task Unit (i.e. PTU-Country A (OID 9111) is an instance of Task Unit Type (OID 1932)) is in Figure 35. Note that for referencing Task Unit Type, OID of Task Unit Type, determined before in type definition, is used.

```
<cbml:Report xsi:type="cbml:WhoTypeType" <!--Type report for PTU Country-A (9110)-->
<!--there is omitted code here -->
  <cbml:Who>
    <cbml:ObjectItem xsi:type="cbml:Unit">
      <cbml:OID>9110</cbml:OID>
      <cbml:NameText>Patrol Task Unit Country-A</cbml:NameText>
      <cbml:FormalAbbreviatedNameText>PTU 499.1.1
      </cbml:FormalAbbreviatedNameText>
    </cbml:ObjectItem>
  </cbml:Who>
  <cbml:ObjectTypeRef xsi:type="cbml:UnitTypeRef">
    <cbml:OID>1932</cbml:OID> <!--Task Unit Type-->
  </cbml:ObjectTypeRef>
</cbml:Report>
```

Figure 35. Type Report for a PTU

(iii) Association Definition: An object's (unit's) association to its supervisor must be declared using `WhoAssociationType` structure of the `Report` element. In this structure, there are enumerated category codes for specifying the association type such as `CMDCTL` (command and control), `ADMINS` (administrators), `COORDN` (coordinates use of), `EMPLOY` (Employs), etc. The appropriate enumeration is to be selected for association. For example, PTU Country-A (OID 9111) reports that it is under command and control of PTG (OID 9101). XML code for this `WhoAssociationType` report is in Figure 36.

```

<!--Association Report of PTU Country-A-->
<cbml:Report xsi:type="cbml:WhoAssociationType">
<!--there is omitted code here -->
  <cbml:WhoRef>
    <cbml:ObjectItemRef xsi:type="cbml:UnitRef">
      <cbml:OID>9110</cbml:OID>      <!--PTU Country-A-->
    </cbml:ObjectItemRef>
  </cbml:WhoRef>
  <cbml:ObjectObjectItemRef xsi:type="cbml:UnitRef">
    <cbml:OID>9100</cbml:OID>      <!--PTG-->
  </cbml:ObjectObjectItemRef>
  <cbml:ObjectItemAssociation>
    <cbml:OID>0000</cbml:OID>
    <cbml:CategoryCode>CMDCTL</cbml:CategoryCode>
    <cbml:Status>
      <cbml:CategoryCode>START</cbml:CategoryCode>
    </cbml:Status>
  </cbml:ObjectItemAssociation>
</cbml:Report>

```

Figure 36. Association Report of PTU Country-A

(iv) Organization Structure Definition: `OrganizationStructureType` report structure is used for definition. The root of the organization is indicated using the root's OID. The organization structure is defined using the associations described in the previous step. All associations have an OID. Organization structure report is made up with OIDs of these associations. A sample portion of the XML

code for the organization structure report of PTG 499.1 is presented in Figure 37. Note that the root is PTG (OID 9101) and the OIDs from 1970 to 1973 are of associations.

```

<!--Gulf of Aden Coalition Task Force Org. (9000) Report-->
<cbml:Report xsi:type="cbml:OrganisationStructureType">
<!--there is omitted code here -->
  <cbml:RootOrganisationRef xsi:type="cbml:UnitRef">
    <cbml:OID>9001</cbml:OID>          <!--CTF-->
  </cbml:RootOrganisationRef>
  <cbml:OrganisationStructure>
    <cbml:OID>9000</cbml:OID>          <!--Gulf of Aden Coalition Task Force Org.-->
    <cbml:NameText>Gulf of Aden Coalition Task Force Organisation</cbml:NameText>
    <cbml:ObjectItemAssociationRef>
      <cbml:OID>1980</cbml:OID>          <!--Association ref of USV A-1-->
    </cbml:ObjectItemAssociationRef>
<!--there is omitted code here -->
    <cbml:ObjectItemAssociationRef>
      <cbml:OID>1986</cbml:OID>          <!--Association ref of PTU Country-A-->
    </cbml:ObjectItemAssociationRef>
    <cbml:ObjectItemAssociationRef>
      <cbml:OID>1987</cbml:OID>          <!--Association ref of PTU Country-B-->
    </cbml:ObjectItemAssociationRef>
    <cbml:ObjectItemAssociationRef>
      <cbml:OID>1988</cbml:OID>          <!--Association ref of PTG-->
    </cbml:ObjectItemAssociationRef>
    <cbml:ObjectItemAssociationRef>
      <cbml:OID>1989</cbml:OID>          <!--Association ref of SWTG-->
    </cbml:ObjectItemAssociationRef>
  </cbml:OrganisationStructure>
</cbml:Report>

```

Figure 37. Organization Structure Report of PTG 499.1

3.8 File Structure

The patrol mission is modeled using multiple files in order to increase the usability. There are four folders: Orders, Reports, Organizations and Requests. Opord1a.xml, Opord1b.xml, Order2a.xml, Order2b.xml, Order3a.xml, Order3ba.xml, Order3bb.xml and Order4a.xml files are in Orders folder. Reports folder includes xml files of all reports described in previous sections. OrgReport.xml (defines the CTF 499 structure) is in Organizations folder.

Request_of_USV_of_PTU_CountryA.xml (USV's intervention request from SWTG), Request_of_USV_of_PTU_CountryB.xml, Request_of_PTU_CountryA.xml (PTU's intervention request from SWTG) and Request_of_PTU_CountryB.xml is in Requests folder. The file structure is shown in Figure 38.

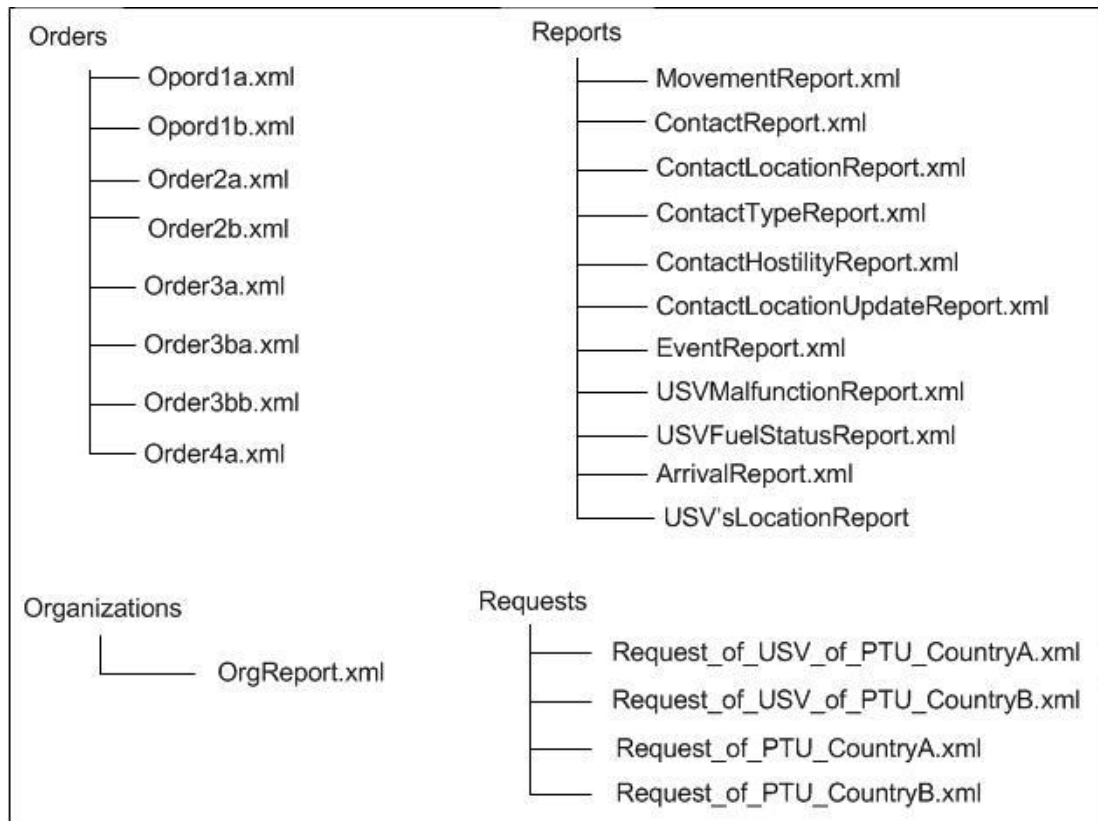


Figure 38. File Structure for the Patrol Mission

In Table 8, source lines of code (SLOC) each XML model file of patrol mission we created and the total SLOC is provided in order to give a rough estimate about the size of modeling.

Table 8. Source Lines of Code

<i>XML Model</i>	<i>SLOC</i>	<i>XML Model</i>	<i>SLOC</i>
Opord1a.xml	917	ContactLocationUpdateReport.xml	47
Opord1b.xml	511	HostilityReport_Neutral.xml	38
Order2a.xml	2808	HostilityReport_Suspect.xml	38
Order2b.xml	2803	HostilityReport_PirateBoat.xml	38
Order3a.xml	2373	NetworkReport1_for_PTU-A.xml	142
Order3ba.xml	2358	NetworkReport1_for_PTU-B.xml	135
Order3bb.xml	2363	NetworkReport2_for_PTU-A.xml	135
Order4a.xml	69	NetworkReport2_for_PTU-B.xml	135
ContactLocationReport.xml	47	NetworkReport3_for_PTU-A.xml	135
ContactTypeReport.xml	61	NetworkReport3_for_PTU-B.xml	135
HijackingEventReport.xml	52	CandidateTargetListReport.xml	43
USVFuelLevelReport.xml	52	Request_of_USV_of_PTU_A.xml	116
MovementReport.xml	39	Request_of_USV_of_PTU_B.xml	115
ArrivalReport.xml	35	Request_of_PTU_CountryA.xml	60
USV'sLocationReport.xml	43	Request_of_PTU_CountryB.xml	59
OrgReport.xml	726	USVMalfunctionReport.xml	43
SituationOfEnemy.xml	310	SituationOfFriendlyForces.xml	122
Total SLOC			17103

CHAPTER 4

MODELING DECISIONS AND DISCUSSIONS

4.1 Functional Association of Actions

When expressing the functional relations, we first generalized and categorized the relations as (1) decomposition of actions, (2) sequential, (3) parallel, (4) alternate execution of actions and (5) selection of actions to be executed. The following subsections discuss some modeling decisions for each.

4.1.1 Decomposition of Actions

In the orders, some actions include sub-actions. We model this sub-action relation in `Why` structure of `Task/Event` element. The enumerated value `HSA` of the functional association of the action specifies that the subject action has the object action as a sub-action. For example, task-1100 (patrol) has sub-tasks of 1110 (traverse) and 1120 (monitor). The XML code defining that task-1100 has task-1110 as a sub-action is presented in Figure 39.

```
<cbml:Why>
  <cbml:ActionFunctionalAssociationInSubjectAction>
    <cbml:ObjectActionRef xsi:type="cbml:OtherActionTaskRef">
      <cbml:OID>1110</cbml:OID>      <!--traverse task -->
    </cbml:ObjectActionRef>
    <cbml:FunctionalAssociationCategoryCode>HSA
    </cbml:FunctionalAssociationCategoryCode>
  </cbml:ActionFunctionalAssociationInSubjectAction>
</cbml:Why>
```

Figure 39. Sample Sub-action Definition

4.1.2 Sequential Execution of Actions

Sequential execution of actions are defined in When structure of Task/Event element. The start and end times of actions can be specified as relative to other actions or as an absolute time. Enumerated categories like “starts after end of (category code is STREND)” “starts after start of (category code is STRSTR)”, “ends after end of (category code is ENDEND)”, starts no later than after start of (category code is STRSNL) are used. For example, task-1122 (locate) must be done after event-1121 (detection) and must finish as soon as possible. See Figure 40 for a sequential execution structure.

```
<cbml:When>
  <cbml:StartWhen>
    <cbml:RelativeTime>
      <cbml:ObjectActionRef xsi:type="cbml:OtherActionEventRef">
        <cbml:OID>1121</cbml:OID>          <!--contact detection event-->
      </cbml:ObjectActionRef>
      <cbml:TemporalAssociationCategoryCode>STREND
    </cbml:RelativeTime>
  </cbml:StartWhen>
  <cbml:EndWhen>
    <cbml:AbsoluteTime>
      <cbml:UnspecifiedTime>
        <cbml:EndQualifierCode>ASAP</cbml:EndQualifierCode>
      </cbml:UnspecifiedTime>
    </cbml:AbsoluteTime>
  </cbml:EndWhen>
</cbml:When>
```

Figure 40. Sample Sequential Execution Code

4.1.3 Concurrency of Actions

In the orders, some actions are to be done concurrently. There is no enumerated category meaning that two actions start and end together. We used STRSNL and ENDENL in conjunction to indicate that: When execution of some actions is to be

started together, we use the enumerated category of STRSNL, meaning that the subject action starts no later than after start of the object action. Furthermore, when execution of some actions is to be completed together, we use the enumerated category of ENDENL, meaning that the subject action ends no later than end of the object action. For illustration, assuming task-9001 and task-9002 start together, sample code indicating that start time of task-9002, which is no later than after start of task-9001 is shown in Figure 41.

```

<cbml:StartWhen>
  <cbml:RelativeTime>
    <cbml:ObjectActionRef xsi:type="cbml:OtherActionEventRef">
      <cbml:OID>9001</cbml:OID>          <!--contact detection event-->
    </cbml:ObjectActionRef>
    <cbml:TemporalAssociationCategoryCode>STRSNL
  </cbml:RelativeTime>
</cbml:StartWhen>

```

Figure 41. Code for Start Time of a Concurrent Task

However, when two tasks start after execution of the same task, start times of both are specified as the end of the previous task. For instance, task-1153 and event-1154 start together after task-1152. The xml code of task-1153 and event-1154 indicating their start times is provided in Figure 42.

```

<cbml:StartWhen>
  <cbml:RelativeTime>
    <cbml:ObjectActionRef xsi:type="cbml:OtherActionTaskRef">
      <cbml:OID>1152</cbml:OID>          <!--report vessel as suspect task-->
    </cbml:ObjectActionRef>
    <cbml:TemporalAssociationCategoryCode>STREND
  </cbml:RelativeTime>
</cbml:StartWhen>

```

Figure 42. Sample Code Showing Start Times of Parallel Tasks

4.1.4 Alternative Execution of Actions

To define the alternatives of an action (OR statement), we use the `Why` structure of the `Task/Event` element. If two actions are alternative to each other, this is specified with the enumerated category of `ALT`, meaning that the subject action is an alternative to the object action. This must be done in each of the alternative actions. For example, events 1150 (suspicious behavior) and 1160 (piracy event) are alternatives. The xml code of event-1150 declaring event-1160 as its alternative is reproduced in Figure 43.

There can be three or more actions that each one is alternative to other all. In this case, in `Why` structure of each action, the action should be specified as alternative to every other action. Let task-A, task-B and task-C be alternatives. Task-A must be specified as alternative to task-B and task-C, task-B must be specified as alternative to task-A and task-C, task-C must be specified as alternative to task-A and task-B.

```
<cbml:Why>
  <cbml:ActionFunctionalAssociationInSubjectAction>
    <cbml:ObjectActionRef xsi:type="cbml:OtherActionEventRef">
      <cbml:OID>1160</cbml:OID>      <!--piracy event-->
    </cbml:ObjectActionRef>
    <cbml:FunctionalAssociationCategoryCode>ALT
    </cbml:FunctionalAssociationCategoryCode>
  </cbml:ActionFunctionalAssociationInSubjectAction>
</cbml:Why>
```

Figure 43. Sample Alternative Action Definition

4.1.5 Selection of Task to be executed

When certain actions must take place to initiate a task, in other words, when there is a conditional statement (IF statement), we used the enumerated category of

INRSTO (the enumerated category code for “in response to”), meaning that the subject action is to be carried out in reaction to the object action in the Why structure of Task element. In other words, a choice of tasks in a conditional statement is made. When there is a statement like *IF X THEN Y*, we modeled *X* as an event and *Y* as a task. For instance, task-1150 (take suspect vessel actions) must be done in response to event-1140 (suspicious action of a vessel) if the event takes place. A part of xml code of Why structure of task-1150 is provided in Figure 44.

```

<cbml:Why>
  <cbml:ActionFunctionalAssociationInSubjectAction>
    <cbml:ObjectActionRef xsi:type="cbml:OtherActionEventRef">
      <cbml:OID>1140</cbml:OID>          <!--suspicious action of a vessel-->
    </cbml:ObjectActionRef>
    <cbml:FunctionalAssociationCategoryCode>INRSTO
    </cbml:FunctionalAssociationCategoryCode>
  </cbml:ActionFunctionalAssociationInSubjectAction>
</cbml:Why>

```

Figure 44. Sample IF Statement

We should also emphasize that C-BML lacks an *ELSE* structure. If event-1150 and event-1160 do not occur, the contact should be reported as neutral. Suspicious and hostile behaviors can be represented as events, but ‘no event’ cannot be represented in C-BML. We modeled the report contact as neutral task (task-1124) that it will be executed for every contact detected, but if piracy or suspect action of a vessel events occur, that vessels will be reported as hostile or suspect.

4.2 Organization Definition

In general, the combat organizations in military like task forces use a hierarchical numbering system for naming their units. An organization has positions

under command. A portion of the CTF organization is shown in Figure 45. Each box in the figure represents a position of the organization. A position name (e.g. PTU 499.1.1) indicates its hierarchical place inside the organization. When such an organization is constructed, units are assigned to positions. For example, PTE 499.1.1.1, PTE 499.1.1.2 and PTE 499.1.1.3 are all USVs. When Country-A leaves from the CTF, new ships from the new country attending the mission will be assigned for these PTE positions.

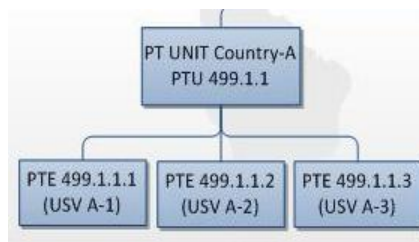


Figure 45. A Portion of the CTF Organization

In our case, we need to assign a USV (as a surface vessel) to a position (as a unit) in the organization. USVs possess both unit properties and surface vessel properties. Taking these into consideration, the USV (physical platform) is modeled as a Surface Vessel and PTE (organization) is modeled as Unit in C-BML. These two items then is linked by an association, in our case using *Establishes* (the subject organization sets up the function or physical presence of the object OBJECT-ITEM) category code. The association states that PTE establishes USV. Portion of sample association report declaring that PTE 499.1.1.1 establishes USV A-1 in presented in Figure 46.

```
<cbml:Report xsi:type="cbml:WhoAssociationType">
  ...
  <cbml:WhoRef>
    <cbml:ObjectItemRef xsi:type="cbml:UnitRef">
      <cbml:OID>9990</cbml:OID>          <!--PTE 499.1.1.1-->
    </cbml:ObjectItemRef>
  </cbml:WhoRef>
  <cbml:ObjectObjectItemRef xsi:type="cbml:OtherObjectItemRef">
    <cbml:OID>9991</cbml:OID>          <!--USV A-1-->
  </cbml:ObjectObjectItemRef>
  <cbml:ObjectItemAssociation>
    <cbml:OID>9992</cbml:OID>
    <cbml:CategoryCode>ESTA</cbml:CategoryCode>  <!--establishes-->
    <cbml>Status>
      <cbml:CategoryCode>START</cbml:CategoryCode>
    </cbml>Status>
  </cbml:ObjectItemAssociation>
</cbml:Report>
```

Figure 46. Sample Unit-USV Association Code

Another important issue in organization definition is about specifying the mandatory type of vessel to be assigned to a position. An organization structure may require that some of its positions will be composed of a certain vessel type. In our example, PTE 499.1.1.1 is a position of the organization that has to be an USV according to a superior order/plan. A frigate, for instance, should not be assigned for PTE 499.1.1.1 position. The modeling approach we followed in C-BML is as follows: In JC3IEDM, there is a link from EQUIPMENT-TYPE to UNIT-TYPE that allows the identification of the major type of equipment that can be associated with a unit. In C-BML, there is a corresponding attribute, namely `PrincipalEquipment-TypeRef`, for defining a `UnitType`. We interpreted this structure that a surface vessel type can be the major type of equipment of a position (unit type), and modeled in this way.

4.3 Orders and Relationships between Orders

(i) **Consistency:** While military documents reference each other, an order may refer, may detail or simply may repeat some information that exists in the other order that it references. The information in such orders has to be consistent with each other. For example, a PTG sends a patrol order to PTUs. In that order, PTG states the number of vessels and related patrol areas for the mission (see Table 9). PTU-Country A will then send an order to its PTEs in which PTU should assign the same number of vessels in the same area that are specified in PTG’s patrol order (see

Table 10). As specified in the superior order, PTU assigns two USV’s in 4th and 5th of January. The automatic checking of consistency among C-BML orders is left to C2 systems.

Table 9. Part of Order from PTG

Date	Patrol Area	Number of Vessels	Assigned Unit
01-03 January 2011	Area Alpha	1 USV	PTU-Country A
	Area Bravo	1 USV	PTU-Country B
04-05 January 2011	Area Alpha	2 USVs	PTU-Country A
	Area Bravo	1 USV	PTU--Country B

Table 10. Part of Order from PTU-Country A

Date	Patrol Area	Assigned Units
01 January 2011	Area Alpha	USV A-1 (Z-601)
02 January 2011	Area Alpha	USV A-2 (Z-602)
03 January 2011	Area Alpha	USV A-3 (Z-603)
04 January 2011	Area Alpha	USV A-1 (Z-601), USV A-2 (Z-602)
05 January 2011	Area Alpha	USV A-3 (Z-602), USV A-1 (Z-601)

(iii) Specifying Order Types: In real life, the orders are categorized as Administrative/Logistics orders, Fragmentary orders, Operations Orders, Warning Orders, etc. [29]. While modeling an order in C-BML, the type of an order cannot be specified. However these enumerations exist in `OrderCategoryCode` of `JC3IEDM-3.0.2-Codes-20090514.xsd` schema. Specifying the order type may be helpful such that C2 systems can classify orders; archives can be constructed; various analyses can be made in after action reviews (e.g. the number of orders issued during an operation in each type can be determined).

(iv) Specifying an Order Issuing Time: The orders have date and time group (DTG) indicating their time of issuing. The DTG of orders cannot be defined in C-BML. Therefore, C-BML must provide a way to specify order issuing time.

4.4 Tasks

(i) **Defining Recurrent Tasks:** Schedules that indicate periods of a task or mission are usually used in missions like patrol. There is one start time and one end time for each task in C-BML. However, some tasks may be ordered to execute in two or more time slices. That means these tasks have two or more start and end times. For example, an USV may be ordered to conduct a patrol mission in these periods:

From 1 Jan 2011, 0001GMT to 1 January 2011 2359 GMT

From 3 Jan 2011, 0001GMT to 3 January 2011 2359 GMT

From 7 Jan 2011, 0001GMT to 7 January 2011 2359 GMT

In the current version of C-BML, the order above can be issued as three orders each including one period. It is assumed that orders are send one by one, being handled and managed by the C2 system.

(ii) **Multiple Taskees for a Task:** It is possible that a task may be required to be performed by two or more units in coordination. In our case, two USVs can be ordered for the same patrol mission. However, only one taskee can be assigned for a task in the current C-BML specification. The taskee of a task cannot be more than one. In order to overcome this restriction, the same task is defined twice, each for one USV. C-BML should be able to assign more than one item as taskee for tasks.

4.5 When will a C-BML enabled C2 system send an order?

In our scenario, PTG sends a patrol order that specifies a patrol schedule. Since

task periods cannot be defined in C-BML, we assumed that PTUs in our organization will, based on the order from PTG, send the patrol orders to PTEs daily, each order including one period (one day). C-BML does not establish when or how the information will be sent; C-BML only establishes the content of what information is transferred. This decision is totally left to C2 system.

4.6 Is it possible to feed tactical picture with C-BML expressions?

Robotics system (USV) sends contact reports to PTU that contacts will be displayed in PTU's tactical picture. PTU's tactical picture may be fed by a data fusion center and the question is that is it possible to feed tactical picture with C-BML expressions? In which format will data flow among data fusion center and tactical pictures?

4.7 Other

(i) The location that a task takes place is specified in `Order.Task.Where` element. Only one location can be specified using this structure. In other words, using where structure, a task can be defined to take place in only one location. But, it is possible to order a task to be executed in more than one location. For example, CTF orders PTG to conduct patrol both in Area Alpha and Area Bravo. We modeled that task using `AffectedWho` element, see section 3.3 for details. We think that permitting multiple `Where` for a task should be discussed.

(ii) To model conditional statements , e.g. contact is detected (event-1121), that

initiate performing tasks, event structure under `Order.CurrentState.Report` is used. In other words, events as conditional statements are modeled in `report` structure. When events are modeled as reports, `ReportingDateTime` element of event report must be filled. While we intended that such events represent conditional statements, specifying `ReportingDateTime` is problematic that what value will be entered in `ReportingDateTime` element. Will we enter zero or a specific time in this element?

(iii) In our scenario, some tasks in the mission order the reporting. For example, send malfunction report (task-1401), send location report (task-1123) tasks order to report information. C-BML does not support reporting as order. In our study, we modeled such reports in `Report` structure and specified the reporting time of the report relative to the task. So that, when the task is executed, the related report would be send. However, when we select reporting time as relative, `ReportingDateTime` element is problematic again that what value will be entered in this element, zero or a specific time? This solution is open to discussion. C-BML shall support reporting as order explicitly.

(iv) In our study, there are statements like “Report your location every minute” inside orders. This is a task having a repetition time. The repetition time (every minute) is modeled as an event, named “one minute timer ticks”. There should be explicit structures within task element to support repetitions.

(v) While modeling events in C-BML, almost all `ActionEventCategoryCodes` in `Event`.What is selected as `NOS=Not` ootherwise specified. `ActionEventCategoryCodes` seems to be insufficient.

(vi) While modeling tasks in C-BML, for the following activities, we could not find any appropriate `ActionTaskActivityCode` that matches with the activity: intervene, make patrol schedule, establish and maintain the maritime tactical picture, properly use and control USVs, make a request, take suspect vessel actions.

(vii) There is no enumerated category meaning that two actions start and end together. We used `STRSNL` (starts no later than after start of) and `ENDENL` (ends no later than after end of) in conjunction to indicate that.

CHAPTER 5

RELATED WORK

C-BML is under development since 2004. As a part the development process, SISO C-BML Drafting Group prepares guideline and tutorial documents for adopters. There are multiple examples in the C-BML tutorial [9] that presents how to use the C-BML Phase 1 schema [5]. Various combat reports, orders, and a few requests are provided in this document. Compared to these examples, our study involves orders, reports and request in one scenario. In the tutorial orders, functional relationships among tasks are not as complicated as in our study. Tutorial orders are simple in that all are given from the same unit in each example. However, we model orders in layers: First an OPORD and then other orders derived from this OPORD is modeled.

There is an UAV (unmanned aerial vehicle) mission in the tutorial [9]. In this example, UAV is not modeled individually, instead a UAV Platoon exists. Orders are given to this platoon. It reports about contacts, events, etc. For example, UAV Platoon is ordered to do a Tactical Air Reconnaissance Task, it reports an arms trade. However, in our case study we modeled USVs as individual units in order to emphasize robotics systems as one of the main aims of C-BML is to provide the interoperability between the C2 Systems and Robotics Systems. Actually, in ORDER

0003, tasks are given from PTU to autonomous USVs, and reports are sent by USVs. However, in ORDER 0004, the same tasks in ORDER 0003 are given from PTU to its USV Control Station. This is because we assumed that manually controlled USVs cannot process C-BML expressions automatically.

As far as we know, our study is the first one in the Naval Operations domain and therefore the first one that involves unmanned surface vehicles, both autonomous and manually controlled. C-BML expressions flow between C2 systems and C2 systems, C2 systems and robotic forces.

JC3IEDM can express a great variety of facts about military situations but JC3IEDM does not have sufficiently rich modeling constructs to express reasoning arguments [30]. This observation explains the difficulty we encountered in modeling functional association of tasks.

Ulicny et al. studied the representability of METT-TC factors (mission, enemy, terrain & weather, troops, time available and civil considerations) in JC3IEDM [28]. They state that in JC3IEDM, it is not possible to assign a mission-intent to a set of action-tasks grouped together. In addition, they emphasize that specifics of the rules of engagement, enemy doctrine and enemy's possible course of actions are not defined in JC3IEDM. It is pointed out that action-event entity is insufficient for representing recurring event types and man-made facilities can be represented at only a crude level of detail.

Matheus et al. have observed that JC3IEDM has an insufficient vocabulary for

irregular warfare; it cannot deal with quantification, and cannot represent the absence of something occurring now or in the future [31].

In [32], expressiveness of NATO JC3IEDM for modeling a patrol mission given to an USV is examined and some extension points for the model are proposed. Concepts about USV operations are found to be absent in JC3IEDM information exchange requirements. Considering the increase in the use of unmanned surface vehicles for military purposes, it is evaluated that JC3IEDM should meet USV related requirements. Following paragraphs elaborate the study in [32].

A hypothetical patrol order is set up. The order includes a patrol mission around a peninsula on which a facility that needs to be protected exists. Patrol is to be executed by USVs on specified times, in specified patrol areas using the specified patrol patterns. USVs are controlled by a station on land. In Figure 47, functional relationships among actions in the order are illustrated. Rectangles represent tasks, ellipses represent events or conditions. A line drawn downward from an action points a sub-action of that action. A USV moves to patrol area, conducts patrol in the area and finally moves to port. During patrolling, if any contact is acquired, USV takes picture and video of the contact at CPA time and reports the contact. If the contact is en route to the Restricted Area, USV warns the contact, if the contact does not move away, USV makes evasive maneuvers and alarms the control station.

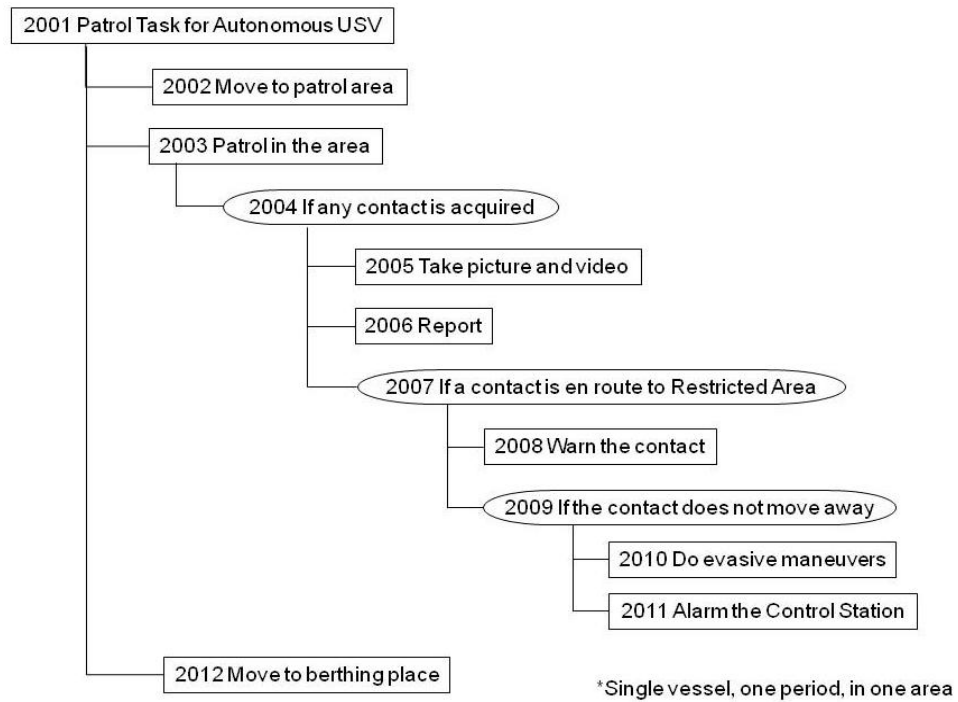


Figure 47. Functional Relations of Actions [32]

Each action is modeled with action entity of JC3IEDM, in addition to action entity, tasks are modeled with action-task entity and conditional events are modeled with action-event entity. Details of actions are described using action-task and action-event-detail entities.

The subject or executor of an action is modeled with action-resource entity. In addition to action-resource entity, if the subject of an action is an object-item, action-resource-item is used; if the subject of an action is an object-type, action-resource-type entity is used. The object that is affected by the execution of an action is modeled with action-objective, action-objective-item and action-objective-type entities in the same way.

Functional relations among actions, such as an action is the sub-action of the other, an action is conducted in response to another action, are modeled with action-functional-association entity. Temporal relations among actions or execution sequence of actions are modeled with action-temporal-association entity.

Difficulty was encountered in modeling reasoning arguments. For modeling conditional statements that occurrence of an event triggers the execution of an action, action-event and action-functional-association entities are used.

Because a USV is regarded as a robotic system, the surface vessel entity in JC3IEDM is evaluated to be insufficient to model USVs. Attributes of a USV such as autonomy level (autonomous, semi-autonomous, manually-controlled, etc.), operational range, maximum total operating time in a period, main operational function cannot be described with current surface vessel entity of JC3IEDM. To meet this requirement, unmanned-surface-vessel-type entity is proposed as a subcategory of surface-vessel-type entity.

Only one start and one end time for an action can be specified using action-task entity, but there are recurrent tasks in the order having multiple start and end times. In the study, period and action-task-period entities are proposed for extension to model recurrent tasks. Recurrent tasks can be defined separately for each time period, so this extension must not be regarded as mandatory. It just brings simplicity for modeling.

In general, JC3IEDM provides the required data for modeling such a patrol mission employing USVs. However, because of the previously explained reasons, unmanned-surface-vessel-type and period extensions are proposed. When the use of USVs increases and becomes widespread, it is evaluated that more extensions will be taken into consideration. Also, it is clear that JC3IEDM should support definition of reasoning statements explicitly.

C-BML extends the JC3IEDM by abstracting the actions focusing on the plans, orders, and the reports that will be exchanged among C2 systems. Therefore, the C-BML becomes more powerful in order to model a patrol mission.

CHAPTER 6

CONCLUSIONS AND FUTURE WORK

In this study, first we developed a scenario and created an organization for surveillance and reconnaissance operations in the Gulf of Aden that has USVs under a coalition command. We set up an operations order for a patrol mission in the area and some other orders derived from the operations order. Then in order to model the mission in C-BML; we constructed C-BML action tables, made the functional breakdown of the orders and draw temporal relationships between actions. Then, organization structure, reports and orders related to the patrol mission were modeled accordingly. Modeling issues and discussions about expressiveness of C-BML are provided.

Patrol mission was chosen because it is inherent in most naval operations and it is a part of the surveillance and reconnaissance operations, which is one of the basic naval operations. While it is intended to be comprehensive for naval operations, we anticipate that this study will serve as reference for further C-BML studies. It can be considered as a guideline for modeling missions in which both unmanned and manned naval units participate. Expressiveness of C-BML is discussed from C-BML adopter perspective.

As far as we know, our study is the first one in the Naval Operations domain and therefore the first one that involves unmanned surface vehicles, both autonomous and manually controlled.

This study is considered as formalization and modeling for unmanned surface vehicle (USV) patrol operations by employing the Coalition Battle Management Language (C-BML), which is expected to be a dominating standard in the military domain for the interoperability of C2 systems, M&S systems, and robotics.

As C-BML is intended for enabling communication between C2, M&S, and robotic forces, the author take the position that C-BML should support all the tasks (including the low level ones), that take place in the mission, if a full automation and interoperability among systems is required. So this case study is prepared including all the low level orders and reports that provide completeness of a USV patrol mission.

It is a known fact that, in naval operations, the operations of the USVs must be tightly integrated to the C2 systems. We envision, in the near future, that all the unmanned systems will be capable to produce and consume C-BML orders, plans, and reports. In this respect, we believe that our study presents a complete case study including all the stages of a patrol mission, where USVs are involved. And, it lays the groundwork where the model developed will enable future studies such as the interactions among C2 system and unmanned systems.

In general, the current version of C-BML has substantially rich modeling

constructs. But, there are some points in modeling of the order where we had difficulty deciding the appropriate construct in C-BML. To specify the *OR* statement between actions, we used `ALT` (alternative) enumerated category between them. To specify the *IF* clause between actions, we used the `IRSTO` (in response to) enumerated category between them. When there is a statement like *IF X THEN Y*, we modeled *X* as an event and *Y* as a task. Considering such relationships between actions, we think that there should be explicit structures to facilitate modeling. Moreover, we could not find out how to model a statement like *IF X AND Y THEN Z* yet. Additionally, there is no enumerated category meaning that two actions start and end together. We used `STRSNL` (starts no later than after start of) and `ENDENL` (ends no later than after end of) in conjunction to indicate that.

We also made evaluations about insufficiency of C-BML about defining periods, multiple taskees for a task, specifying order type and order issuing time. Discussions about organization structure definition, consistency between documents and feeding tactical picture with C-BML expressions are presented.

As a result of the current work, it is obvious that the C-BML needs explicit modeling elements for logical task structuring (e.g. conditional task execution in the same vein as dynamic workflow modeling [33]) due to the complicated nature of battle management.

As a future work, the (battle) plans, when the C-BML evolves, can also be included in the model. Moreover, modeling in other domains may be conducted to

evaluate C-BML capability.

The C-BML model of USV mission is planned to be used in the study of C-BML enabled intelligent agents and in transferring data among C2-M&S-Robotic Systems. That work aims to achieve and test interoperability of C2-M&S-Robotic Systems, where our model will be exchanged across these systems. Furthermore, constructing a tactical picture from C-BML reports is an ongoing work and the case study presented here is the scenario selected.

Since all C-BML modeling is performed manually in this work, a modeling interface can be developed for automatic generation of C-BML expressions from orders. Reversely, generation of a human readable textual order from a C-BML expression is another future work.

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APPENDIX A

TABLE OF ABBREVIATIONS

5Ws	Who, What, Where, When, Why
AI	Artificial Intelligence
AIS	Automatic Identification System
ALT	Alternative
AOBML	Air Operations Battle Management Language
ASUW	Anti Surface Warfare
BML	Battle Management Language
C2	Command and Control
C2IEDM	Command and Control Information Exchange Data Model
C4I	Command, Control, Communications, Computer and Intelligence
C-BML	Coalition Battle Management Language
CMDCTL	Command and Control
COLREG	International Regulations for Preventing Collisions at Sea
CPA	Closest Point of Approach
CS	Control Station
CTF	Coalition Task Force
DTG	Date and Time Group

ENDENL	Ends No Later than End of
GeoBML	Geospatial Battle Management Language
GMT	Greenwich Mean Time
HF	High frequency
HSA	Has as a Sub Action
IESCS	Information Exchange Structure and Content Specification
INRSTO	In Response to
JBML	Joint Battle Management Language
JC3IEDM	Joint Command, Control and Consultation Information Exchange Data Model
M&S	Modeling and Simulation
MIO	Maritime Interdiction Operations
MIP	Multilateral Interoperability Programme
NATO	North Atlantic Treaty Organization
OID	Object Identifier
OIPT	Overarching Integrated Product Team
OPORD	Operations Order
OWL	Web Ontology Language
PM	Patrol Mission
PTE	Patrol Task Element
PTG	Patrol Task Group

PTU	Patrol Task Unit
SG	Study Group
SIMCI	Simulation to C4I
SISO	Simulation Interoperability Standards Organization
SLOC	Source Lines of Code
STRSNL	Starts No Later than Start of
SWTG	Surface Warfare Task Group
UAV	Unmanned Aerial Vehicle
USV	Unmanned Surface Vehicle
WSDL	Web Services Definition Language
XBML	Extensible Battle Management Language
XML	Extensible Markup Language

APPENDIX B

OPERATIONS ORDER FROM CTF

OPORD 0001

References: Maps, charts, and other documents

Task Organization:

Coalition Task Force CTF 499

 Patrol Task Group PTG 499.1

 Patrol Task Unit Country-A PTU 499.1.1

 Patrol Task Element-1 (USV) PTE 499.1.1.1

 Patrol Task Element-2 (USV) PTE 499.1.1.2

 Patrol Task Element-3 (USV) PTE 499.1.1.3

 Patrol Task Unit Country-B PTU 499.1.2

 Patrol Task Element-1 (USV) PTE 499.1.2.1

 Patrol Task Element-2 (USV) PTE 499.1.2.2

 Patrol Task Element-3 (USV) PTE 499.1.2.3

 Surface Warfare Task Group SWTG 499.2

1. SITUATION.

a. Enemy Forces. The Gulf of Aden (Figure 48), a part of the important Suez Canal shipping route between the Mediterranean Sea and the Arabian Sea in the Indian Ocean, became dangerous for water transport because a number of acts of

piracy occurred in the area in recent years. Pirates hijack ships in the area, and demand ransoms for them. They usually attack ships with zodiac boats, carrying long-barreled weapons. They create threat for all ships passing through the area.

b. Friendly Forces. PTG 499.1 and SWTG 499.2 are located in Caluula port of Somali. They are ready for orders of fighting with piracy.

c. Areas of responsibility.

PTG 499.1 is responsible for Area Alpha and Area Bravo.

SWTG 499.2 is responsible for Area Alpha and Area Bravo.

2. MISSION. Fight with piracy in the Gulf of Aden with conducting patrol and maritime interdiction operations (MIO).

3. EXECUTION.

a. Commander's Intent. Area of responsibility will be secured against piracy with minimum loss of friendly forces and merchant ships.

b. Concept of Operations. Fighting with piracy will be conducted as two major operations: Patrol and MIO. PTG 499.1 is responsible for patrol and SWTG is responsible for MIO. PTG 499.1 will conduct patrol with unmanned surface vehicles (USV) in the area. Detection of suspicious vessels is highly important. It will not use any weapons against any suspected or hostile vessels. It will request an armed intervention from SWTG 499.2 if necessary.

c. Tasks for Major Subordinate Commands.

(1) PTG 499.1. Conduct patrol in area of responsibility. It is responsible for

establishing and maintaining the maritime tactical picture in the area. Monitor and identify all surface vessels in the area continuously. PTG 499.1 will make a patrol schedule that enables a continuous patrolling of USVs in command.

(2) **PTU 499.1.1 and PTU 499.1.2** are responsible for proper use and safely controlling of USVs.

(3) **PTE 499.1.1.1, PTE 499.1.1.2, PTE 499.1.2.1, PTE 499.1.2.2.** These are all USVs. They conduct patrol in given area. They will request an armed intervention from SWTG 499.2 when necessary.

(4) **SWTG 499.2.** Conduct MIO. Execute tasks of requests from PTG 499.1.

d. Patrol Schedule.

Date	Area
01 – 15 November 2010	Area Alpha
	Area Bravo
16 – 30 November 2010	Area Alpha
	Area Bravo

4. SUPPORT.

5. COMMAND AND SIGNAL.

a. Command.

b. Signal. During operations, these communication lines must be established at minimum: Data Link Main (Data)(HF)

6. AREA COORDINATES



Figure 48. Gulf of Aden

Area Alpha (Figure 49): 12.059466N-50.519257E, 12.098410N-50.865326E,
11.950662N-51.267700E, 12.093039N-51.345978E, 12.223260N-50.901031E,
12.229971N-50.585175E



Figure 49. Area Alpha

Area Bravo (Figure 50): 11.956036N-50.344849E, 12.286334N-50.372314E,

12.106466N-49.801025E, 11.835094N-49.803772E



Figure 50. Area Bravo

[SECURITY CLASSIFICATION]

APPENDIX C

PATROL ORDER FROM PTG

ORDER 0002

References: (a) OPORD 0001

1. MISSION:

In order to support establishing the maritime tactical picture, patrol mission will be conducted by USV (unmanned surface vehicle) units, as a part of surveillance operations in the Gulf of Aden.

2. PARTICIPATING UNITS:

a. PTU 499.1.1 (USV A-1 (Z-601), USV A-2 (Z-602), USV A-3 (Z-603))

b. PTU 499.1.2 (USV B-1 (T-701), USV B-2 (T-702), USV B-3 (T-703))

3. COMMUNICATION ISSUES:

a. Frequency of Data Transfer Network between USV A-1 and PTU 499.1.1
(HF): 10500 KHz

b. Frequency of Data Transfer Network between USV A-2 and PTU 499.1.1
(HF): 11500 KHz

c. Frequency of Data Transfer Network between USV A-3 and PTU 499.1.1
(HF): 12500 KHz

d. Frequency of Data Transfer Network between USV B-1 and PTU 499.1.2
(HF): 14500 KHz

e. Frequency of Data Transfer Network between USV B-2 and PTU 499.1.2

(HF): 15500 KHz

f. Frequency of Data Transfer Network between USV B-1 and PTU 499.1.2

(HF): 16500 KHz

4. PATROL SCHEDULE:

Date	Patrol Area	Number of Vessels	Assigned Unit
01 – 15 November 2010	Area Alpha	1 USV	PTU 499.1.1
	Area Bravo	1 USV	PTU 499.1.2
16 – 30 November 2010	Area Alpha	2 USVs	PTU 499.1.1
	Area Bravo	1 USV	PTU 499.1.2

Manually controlled USVs must be on the first point in the line at patrol start time and autonomous USVs must enter the patrol area at patrol start time.

PTU 499.1.1 and PTU 499.1.2 will maintain patrol for 24 hours a day with the number of USVs indicated.

5. PATROL LOCATION:

a. Patrol Areas:

Patrol will be conducted in Area Alpha and Area Bravo where their coordinates are specified in ref. (a).

6. PATROL DETAILS:

a. Patrol Speed: 12 kts.

b. Patrol Type: Multi linear patrol for manually controlled USVs, random area patrol for autonomous USVs. USVs assigned for patrol will conduct the following tasks during patrol periods.

c. Detect, locate and report all contacts acquired in radar range.

d. Take pictures at CPA time of all contacts acquired in 5 miles range. Send them to Control Station.

e. Determine and report the type of contact (merchant vessel, warship, submarine or fishing boat).

f. Identify all contacts acquired, if possible.

IF a contact changes speed greater than 5 knots, OR

has no AIS information OR

detected as a suspected vessel based on its AIS info OR

carrying weapons on board OR

in drift position OR

out of main shipping lines OR

distance to land is closer than 10 miles THEN

report the vessel as suspect AND

begin shadowing at 4 miles AND

take and send photos once in every 30 seconds until PTU orders to quit.

IF a piracy event is detected THEN

Report pirate boat as hostile AND

make intervention request from SWTG

c. PTUs will properly use and control USVs,

IF any USV reports suspect vessel THEN

Evaluate the pictures of vessel sent from USV AND

Make an intervention request from SWTG if needed,

Order USV to quit shadowing.

7. BERTHING PLACE:

CALUULA port is the berthing place for all USVs during this operation.

APPENDIX D

PATROL ORDER FROM PTU COUNTRY-A

ORDER 0003

References: (a) OPORD 0001

(b) ORDER 0002

1. MISSION:

In order to support establishing the maritime tactical picture, patrol mission will be conducted by USV (unmanned surface vehicle) units, as a part of surveillance operations in the Gulf of Aden.

2. PARTICIPATING UNITS:

a. USV A-1 (Z-601)

b. USV A-2 (Z-602)

c. USV A-3 (Z-603)

3. COMMUNICATION ISSUES:

See ref (b).

4. PATROL SCHEDULE:

Date	Patrol Area	Assigned Units	Patrol Track Number
01 November 2010	Area Alpha	USV A-1 (Z-601)	No.1
02 November 2010	Area Alpha	USV A-2 (Z-602)	No.1

03 November 2010	Area Alpha	USV A-3 (Z-603)	No.1
04 November 2010	Area Alpha	USV A-1 (Z-601)	No.1
05 November 2010	Area Alpha	USV A-2 (Z-602)	No.1
06 November 2010	Area Alpha	USV A-3 (Z-603)	No.1
07 November 2010	Area Alpha	USV A-1 (Z-601)	No.1
08 November 2010	Area Alpha	USV A-2 (Z-602)	No.1
09 November 2010	Area Alpha	USV A-3 (Z-603)	No.1
10 November 2010	Area Alpha	USV A-1 (Z-601)	No.1
11 November 2010	Area Alpha	USV A-2 (Z-602)	No.1
12 November 2010	Area Alpha	USV A-3 (Z-603)	No.1
13 November 2010	Area Alpha	USV A-1 (Z-601)	No.1
14 November 2010	Area Alpha	USV A-2 (Z-602)	No.1
15 November 2010	Area Alpha	USV A-3 (Z-603)	No.1
16 November 2010	Area Alpha	USV A-1 (Z-601)	No.2
		USV A-2 (Z-602)	No.3
17 November 2010	Area Alpha	USV A-2 (Z-602)	No.2
		USV A-3 (Z-603)	No.3
18 November 2010	Area Alpha	USV A-3 (Z-603)	No.2
		USV A-1 (Z-601)	No.3
19 November 2010	Area Alpha	USV A-1 (Z-601)	No.2

		USV A-2 (Z-602)	No.3
20 November 2010	Area Alpha	USV A-2 (Z-602)	No.2
		USV A-3 (Z-603)	No.3
21 November 2010	Area Alpha	USV A-3 (Z-603)	No.2
		USV A-1 (Z-601)	No.3
22 November 2010	Area Alpha	USV A-1 (Z-601)	No.2
		USV A-2 (Z-602)	No.3
23 November 2010	Area Alpha	USV A-2 (Z-602)	No.2
		USV A-3 (Z-603)	No.3
24 November 2010	Area Alpha	USV A-3 (Z-603)	No.2
		USV A-1 (Z-601)	No.3
25 November 2010	Area Alpha	USV A-1 (Z-601)	No.2
		USV A-2 (Z-602)	No.3
26 November 2010	Area Alpha	USV A-2 (Z-602)	No.2
		USV A-3 (Z-603)	No.3
27 November 2010	Area Alpha	USV A-3 (Z-603)	No.2
		USV A-1 (Z-601)	No.3
28 November 2010	Area Alpha	USV A-1 (Z-601)	No.2
		USV A-2 (Z-602)	No.3
29 November 2010	Area Alpha	USV A-2 (Z-602)	No.2

		USV A-3 (Z-603)	No.3
30 November 2010	Area Alpha	USV A-3 (Z-603)	No.2
		USV A-1 (Z-601)	No.3

USVs must be on the first point in the line at patrol start time.

Patrol starts at 07h00 and ends at 19h00 local time for each given day.

5. PATROL LOCATION:

a. Patrol Areas

Patrol will be conducted in Area Alpha where its coordinates are specified in ref. (a).

b. Patrol Legs

USVs will move over the tracks which are formed by the connection of points.

Track No.1 Coordinates: 12.095724N-50.754089E, 12.089010N-50.565948E, 12.199100N-50.880432E, 12.050065N-51.045227E, 12.086324N-51.307526E, 11.997682N-51.234741E, 12.211180N-50.597534E and 12.098410N-50.760956E.



Figure 51. Patrol Track No.1 for Area Alpha

Track No.2 Coordinates: 12.095724N-50.754089E, 12.089010N-50.565948E,
12.199100N-50.880432E, 12.211180N-50.597534E, 12.095724N-50.754089E



Figure 52. Patrol Track No.2

Track No.3 Coordinates: 12.059466N-50.519257E, 12.098410N-50.865326E,
11.950662N-51.267700E, 12.093039N-51.345978E, 12.223260N-50.901031E,
12.229971N-50.585175E, 12.059466N-50.519257E



Figure 53. Patrol Track No.3

6. PATROL DETAILS:

a. Patrol Type: Multi Linear Patrol

b. Patrol Speed: 12 kts

c. USVs assigned for patrol will conduct the tasks indicated in item 6 of ref (b) during patrol periods.

7. BERTHING PLACE:

CALUULA port is the berthing place for all USVs during this operation.

APPENDIX E

PATROL ORDER FROM PTU COUNTRY-B

ORDER 0004

References: (a) OPORD 0001

(b) ORDER 0002

1. MISSION:

In order to support establishing the maritime tactical picture, patrol mission will be conducted by USV (unmanned surface vehicle) units, as a part of surveillance operations in the Gulf of Aden.

2. PARTICIPATING UNITS:

a. USV B-1 (T-701)

b. USV B-2 (T-702)

c. USV B-3 (T-703)

3. COMMUNICATION ISSUES:

See ref (b).

4. PATROL SCHEDULE:

Date	Patrol Area	Assigned Units
01 November 2010	Area Bravo	USV B-1 (T-701)
02 November 2010	Area Bravo	USV B-2 (T-702)
03 November 2010	Area Bravo	USV B-3 (T-703)

04 November 2010	Area Bravo	USV B-1 (T-701)
05 November 2010	Area Bravo	USV B-2 (T-702)
06 November 2010	Area Bravo	USV B-3 (T-703)
07 November 2010	Area Bravo	USV B-1 (T-701)
08 November 2010	Area Bravo	USV B-2 (T-702)
09 November 2010	Area Bravo	USV B-3 (T-703)
10 November 2010	Area Bravo	USV B-1 (T-701)
11 November 2010	Area Bravo	USV B-2 (T-702)
12 November 2010	Area Bravo	USV B-3 (T-703)
13 November 2010	Area Bravo	USV B-1 (T-701)
14 November 2010	Area Bravo	USV B-2 (T-702)
15 November 2010	Area Bravo	USV B-3 (T-703)
16 November 2010	Area Bravo	USV B-1 (T-701)
17 November 2010	Area Bravo	USV B-2 (T-702)
18 November 2010	Area Bravo	USV B-3 (T-703)
19 November 2010	Area Bravo	USV B-1 (T-701)
20 November 2010	Area Bravo	USV B-2 (T-702)
21 November 2010	Area Bravo	USV B-3 (T-703)
22 November 2010	Area Bravo	USV B-1 (T-701)
23 November 2010	Area Bravo	USV B-2 (T-702)
24 November 2010	Area Bravo	USV B-3 (T-703)

25 November 2010	Area Bravo	USV B-1 (T-701)
26 November 2010	Area Bravo	USV B-2 (T-702)
27 November 2010	Area Bravo	USV B-3 (T-703)
28 November 2010	Area Bravo	USV B-1 (T-701)
29 November 2010	Area Bravo	USV B-2 (T-702)
30 November 2010	Area Bravo	USV B-3 (T-703)

USVs must enter the patrol area at patrol start time.

Patrol starts at 07h00 and ends at 19h00 local time for each given day.

5. PATROL LOCATION:

a. Patrol Areas

Patrol will be conducted in Area Bravo where its coordinates are specified in ref. (a).

6. PATROL DETAILS:

a. Patrol Type: Random Area Patrol

b. Patrol Speed: 12 kts

c. USVs assigned for patrol will conduct the tasks indicated in item 6 of ref (b) during patrol periods.

7. BERTHING PLACE:

CALUULA port is the berthing place for all USVs during this operation.

APPENDIX F

PATROL MISSION C-BML MODEL XML FILES

Patrol Mission C-BML Model XML files can be obtained at
<http://www.ceng.metu.edu.tr/~otopcu/cbml/>.