Defence Research and Development Canada | Recherche et développement pour la défense Canada

RAP simulation environment characteristics

M. Allouche
P. Maupin
M. Bélanger
DRDC Valcartier

Collaborators:

J. Fitzback
Nurun

M. Ouellet
Cirrus Research Associates

D. Toussaint
Top Aces Consulting Inc.

** Authors listed in alphabetical order.*

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Authors

Mohamad Allouche, Micheline Bélanger, Patrick Maupin

Approved by

Éloi Bossé

Section Head, Decision Support Systems

Approved for release by

Christian Carrier

Chief Scientist

13dy05

Abstract

The Recognized Air Picture (RAP) is an important element of Air Force operations which can be associated with the Common Operational Picture (COP). With the Common Tactical Picture (CTP), they provide Air Force commanders with the necessary situation awareness (SA), indicating, in real time, the status of deployed friendly and enemy assets. In the 13dw project, DRDC Valcartier investigated concepts that could improve the implementation of a dynamic RAP and its exploitation for the management of Canadian Air Force resources in real-time operations. Such an implementation requires the definition of a reference scenario and the development of a simulation tool. On the one hand, an analysis of five existing scenarios led to the choice of the North Atlantis scenario, on top of which depicting a Combat Search and Rescue (CSAR) mission vignette was developed. On the other hand, the analysis of some existing simulation tools (two commercial tools and two R&D tools designed at DRDC Valcartier) led to recommendations for the development of a dynamic RAP tool.

Résumé

La Situation aérienne générale (SAG) est un élément important des opérations des forces aériennes qui peut être associé à l’Image Opérationnelle Commune (IOC). Utilisé conjointement avec l’Image Tactique Commune (ITC) l’ensemble fournit aux commandants des forces aériennes l’éveil situationnel nécessaire au suivi, en temps réel, de l’état du déploiement des forces amies et ennemies. Dans le cadre du projet 13dw, RDDC Valcartier a étudié différents concepts qui pourraient améliorer l’implantation d’une SAG dynamique ainsi que son exploitation pour la gestion en temps réel des ressources des Forces aériennes canadiennes. Cette implantation nécessite la définition d’un scénario de référence ainsi que le développement d’outils de simulation. D’une part, une analyse de cinq scénarios existants a conduit à sélectionner le scénario North Atlantis sur lequel a été développée une vignette décrivant une mission de Recherche Et Sauvetage au Combat (RESC). D’autre part, l’analyse de plusieurs outils de simulation (dont deux commerciaux et deux conçus à RDDC Valcartier) a permis de recommander la marche à suivre pour le développement d’un outil de compilation et d’exploitation d’une SAG dynamique.

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Executive summary

In the Canadian Air Force, commanders rely on two systems to provide them with the necessary situational awareness when conducting dynamic missions. The Common Tactical Picture (CTP) provides the tactical information required for the control of combat and combat support assets. It requires real-time or near-real time access to feeds from land, surface and airborne sensors. The Common Operational Picture (COP) provides all the necessary information for decision-making at the strategic and operational levels. The COP could be considered as a simplified view of the CTP, including a digitized representation of assets and tracks of interest.

The Recognized Air Picture (RAP) is associated with the Canadian Air Force COP. It is considered as a means for commanders to assess and understand a running situation and to monitor it as it develops.

DRDC conducted an R&D study to support the Canadian Air Force in improving the implementation of the dynamic RAP and its exploitation for the management of resources and assets in real-time operations. It was decided that in order to support this R&D effort, a reference scenario and simulation environment should be selected.

Five reference scenarios were analyzed:

- CF Security Support to the Winter Olympics 2010;
- Atlantic Littoral ISR Experiment (ALIX);
- Force Planning Scenario #4: Surveillance/Control of Canadian Territory and Approaches;
- Force Planning Scenario #10: Defence of North America;
- Joint Warrior Interoperability Demonstration (JWID);
- Exercise Final Lance: Atlantis.

The comparison of these was based on five aspects: (1) the richness of information, (2) the tactical realism from a conduct of operations point of view, (3) courses open to friendly and enemy assets, (4) the utility of the scenario for the compilation and exploitation of the RAP, and (5) the level of detail and the facility to develop vignettes. The Final Lance Atlantis scenario was considered the best and was selected for this study.

A Combat Search and Rescue (CSAR) vignette was then defined. The CSAR domain was chosen since it presents many challenges to the mission planner due to the highly dynamic and unpredictable nature of such operations.

Once the vignette was defined, it was necessary to identify the most suitable simulation tool for running the vignette and supporting the RAP R&D work.

Two commercial tools were analyzed: the Ship Air Defense Model (SADM) developed by British Aerospace (BAE) and the Integrated Anti-Ship Missile Defence Analysis and Simulation Software designed by Tactical Technologies Inc. (TTI). Two other R&D tools were also analyzed: the CASE_ATTI tool developed by the Decision Support Systems team at DRDC Valcartier, and the KARMA environment, also developed at DRDC Valcartier.

The analysis of these tools was based on two types of criteria: the first based purely on software engineering, and the second more oriented toward application needs in terms of RAP functionalities to conduct CSAR simulations. The output of this comparative analysis was in the form of recommendations for the selection and further development of a customized simulation tool.

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Sommaire

Les commandants des forces canadiennes comptent sur deux systèmes pour fournir l'éveil situationnel nécessaire lors de conduite de missions dynamiques. L'image tactique commune fournit les informations tactiques nécessaires pour le contrôle des ressources de combat et de support. Ceci requière un accès temps réel ou quasi temps réel aux données provenant de sources terrestres, de surface et aériennes. L'image opérationnelle commune fournit toutes les informations nécessaires pour la prise de décision aux niveaux opérationnel et stratégique. Elle peut être considérée comme une image simplifiée de la l'image tactique commune incluant une représentation digitalisée des ressources et des tracks d'intérêt.

La situation aérienne générale est associée à l'image opérationnelle commune des forces canadiennes. Elle est considérée comme un moyen permettant aux commandants d'estimer et d'interpréter une situation dynamique et de contrôler son évolution.

RDDC a conduit un effort de recherche et développement pour aider les forces aériennes canadiennes dans l'implantation d'une situation aérienne générale dynamique et son exploitation pour la gestion des ressources en temps réel dans les opérations. Il a été décidé qu'afin de supporter cet effort de recherche et développement, il est nécessaire de sélectionner un scénario de référence ainsi qu'un environnement de simulation.

Pour la sélection du scénario, cinq scénarios ont été analysés :

- CF Security Support to the Winter Olympics 2010;
- Atlantic Litoral ISR Experiment (ALIX);
- Force Planning Scenario #4: Surveillance/Control of Canadian Territory and Approaches;
- Force Planning Scenario #10: Defense of North America;
- Joint Warrior Interoperability Demonstration (JWID);
- Exercise Final Lance: Atlantis.

La comparaison entre ces scenarios était basée sur cinq aspects: (1) la richesse des informations, (2) le réalisme tactique du point de vue de la conduite d'opérations, (3) les capacités et possibilités des amis et des ennemies, (4) l'utilité du scénario pour la compilation et l'exploitation de la situation aérienne générale, (5) le niveau de détail pour développer des vignettes. Le scenario Final Lance : Atlantis a été sélectionné pour cette étude.

Une vignette de recherche et sauvetage militaire (CSAR) a été définie. Ce domaine d’application a été choisi car il présente d’importants défis aux planificateurs de missions à cause de la nature hautement dynamique et imprédictible des applications CSAR.

Une fois la vignette définie, il était nécessaire d’identifier un outil de simulation capable de dérouler la vignette et de supporter les travaux de recherche.

Deux outils commerciaux ont été analysés : SADM (Ship Air Defense Model) développé par British Aerospace (BAE) et Integrated Anti-Ship Missile Defence Analysis and Simulation Software développé par Tactical Technologies Inc. (TTI). Deux autres outils R&D ont été analysés : CASE_ATTI développé par la section de systèmes d’aide à la décision de RDDC-Valcartier et l’environnement KARMA également développé à RDDC-Valcartier.

L’analyse de ces outils a été basée sur deux types de critères : le premier est purement relié au génie logiciel et le second, est plus orienté vers les besoins des applications telles que les fonctionnalités relatives à la situation aérienne générale et la simulation CSAR. Le résultat de cette comparaison est fourni sous forme de recommandations pour la sélection et le développement d’outils de simulation bien adaptés.

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1. Introduction

In the Canadian Air Force, there are two types of situational awareness systems that "provide commanders at all levels the ability to see, at a glance, the true disposition of assets and tracks of interest": the Common Tactical Picture (CTP) and the Common Operational Picture (COP) [1].

The CTP is used at the tactical level. It represents the level of awareness needed for Air Defence Control as well as Tactical Control (TACON), which includes the control of combat and combat support assets. It requires real-time access to live feeds from land, surface and airborne sensors. However, since technology limitations preclude true real-time access, near-real time access involving a delay measured in milliseconds is considered acceptable. The pre-defined area of interest covered by the Canadian Air Defence Sector (CADS) has been identified as CADS CTP.

The COP is used at the operational and strategic level. It provides the level of SA that permits timely operational and strategic decision-making. The COP is a filtered and simplified representation of the CTP. A digitized representation of designated/relevant assets and tracks of interest (TOIs), delayed by a matter of seconds to minutes, is generated to augment strategic and operational levels of SA. This non-real time picture is variously termed, according to different areas of responsibility/interest, the CANR COP (Canadian NORAD Region COP), the NORAD COP or the CF (Canadian Forces) COP.

The notion of RAP is associated with the concept of Canadian Air Force COP and can be defined for any area of interest that is pertinent to Canadian Air Force operations. Accordingly, the RAP can be considered as the medium to monitor the situation and develop an understanding of what is going on in the field. To provide better SA for commanders, the RAP needs also to include Friendly Order of Battle, Enemy Order of Battle and anything else that can be considered as supporting or constraining air operations. In fact, the concept of RAP covers the identification of what to display (essential air data requirements), how to represent it, how often updates need to be sent, and their priority at the strategic, operational and tactical levels.

DRDC conducted an R&D activity in support of the Canadian Air Force by investigating concepts able to improve the implementation of a dynamic RAP and its exploitation for the management of Canadian Air Force resources in real-time operations. In order to support our R&D effort, the following were required:

- a scenario that could be used for reference and conceptual implementation purposes; and
- a simulation environment able to support the implementation of such scenario.

This report describes the scenario that was identified for our RAP project and characterizes the simulation environment able to support the selected scenario.

2. Identification of a case study

In order to develop and demonstrate the concepts of the RAP compilation and exploitation project, we needed a scenario supporting a type of operations that provides events leading to the compilation and exploitation of a RAP. Such scenario had to:

- be small enough to be handled during the project and complex enough to provide relevant RAP compilation and exploitation tasks;
- be flexible enough to allow the development of different realistic vignettes involving a broad diversity of friendly and opposing AF courses of action and/or AF missions;
- maintain a good tempo, be very dynamic in execution, and involve execution of planning tasks with the possibility of a high level of non-deterministic events.

This section describes the approach used to consider and compare existing scenarios and identify one that is appropriate to our needs. A vignette was developed and is presented in this section.

2.1 Scenarios analyzed

Five scenarios were analyzed to identify the most appropriate for our needs [2]. An overview of each scenario is given below.

2.1.1 Scenario 1: CF Security Support to the Winter Olympics 2010

This scenario is concerned with the hosting of the 2010 Olympic Games in Vancouver. Such a large event may provide a venue for disruptive terrorist activities. To prevent such threats and ensure a secure environment, close cooperation between different governmental and non-governmental organizations is required. Event organizers must be able to respond in a timely and effective manner to a number of potential situations, such as aircraft infiltration, biological agent release, hidden explosives, etc. It is anticipated that DND will be responsible for several tasks such as perimeter defence, protection of vital points, surveillance, C2, communications and security.

2.1.2 Scenario 2: Atlantic Littoral ISR Experiment (ALIX)

This scenario is in fact three separate scenarios that provide different contexts but are related by similar types of assets (unmanned aerial vehicles or UAVs) and deployment of these assets.

Scenario 2a: Domestic Contingency Operations and Aid to Civil Power

The republic of Sakla has launched a satellite which failed to achieve orbit. It is expected that the satellite might re-enter and crash over the Nunavut Territory. The republic of Sakla has dispatched a research vessel with onboard helicopter to the area, and there are suspicions that it may attempt to recover the technologically sensitive sensor payload. In addition, local authorities have environmental concerns since the satellite may have a radioactive fuel cell on board. Public and media pressure forced the PM to direct the Minister of National Defence and CF to deploy elements and assert sovereignty in the North. The CF is to provide support to other government departments (OGDs) through a Joint Task Force led by Commander Canadian Forces Northern Area (CFNA).

Scenario 2b: Peace Support Operations

This scenario develops a conflict between two bordering states of Sakla and Granovia. Both parties agreed to a UN-brokered ceasefire and non-governmental organizations are intending to deploy into the area to provide humanitarian support. A UN force is to be deployed to conduct peace support operations. The Canadian government agreed to deploy CF personnel and to fund aid for reconstruction and assistance.

Scenario 2c: Maritime Security

This scenario illustrates a conflict in which the Sakla Republic intends to actively challenge international law by fishing inside the Canadian Exclusive Economic Zone. The event is expected to take place during the International Environmental Congress in St. John’s, Newfoundland, where discussions are to address natural resource conservation, biodiversity, and the establishment of world protected areas.

2.1.3 Scenario 3: Force Planning Scenario #4: Surveillance/Control of Canadian Territory and Approaches

This is a drug smuggling scenario. A narco-parastate known as El Diablo has been detected smuggling narcotics of all varieties. Its main market is North America, followed by Europe. Canada is part of its North American market and is also used as a conduit to the US market. Intelligence analysis revealed that a large quantity of drugs is expected to reach British Columbia from Hong Kong. At same time, a load of drugs is to arrive in Nova Scotia.

2.1.4 Scenario 4: Force Planning Scenario #10: Defence of North America

A new superpower has emerged and increasingly threatens the West for domination of the world stage. Over the years it has expanded its military capabilities to include submarines armed with ballistic missiles and nuclear weapons that target North America. It has also developed relationships with various regimes through economic ties. All diplomatic means have failed to solve the problem. The US and Canadian governments agreed that a joint Canada-US force has become necessary to eliminate this threat from the CANUS region and to establish conditions for democratic elections to be held there.

2.1.5 Scenario 5: Joint Warrior Interoperability Demonstration (JWID)

This is a US-hosted exercise based on fictitious nations in a real-world setting where the US and the NATO and AUSCANNZUKUS allies are seeing their national security and economic prosperity threatened by a coalition of terrorist groups.

2.1.6 Scenario 6: Exercise Final Lance: Atlantis

This scenario was used in 2000 as an exercise by the Canadian Forces Command and Staff College (CFCSC) to teach the Canadian Forces Operational Planning Process (CFOPP) and allow operational knowledge and expertise to be shared among CFCSC staff and students.

A crisis has developed over the past 10 days on the continent of Atlantis. It is the result of years of growing tensions since the fall of 1999, and has now erupted into armed conflict. Individual country studies are provided as well as a document entitled "The Manghalour Peninsula Crisis," to provide detailed background.

As a result of the critical situation between ORANGELAND/REDLAND and BLUELAND, the UN requested the Alliance Council to consider a military response to help resolve the crisis.

2.2 Comparison of existing scenarios

In order to identify the most appropriate scenario for our needs, different aspects need to be considered. First, we need a level of detail at the operational level similar to that required for real-world operations. Country briefings should be as comprehensive as possible to cover geographic, political, economic and social factors, and also an assessment of the location and strength of military forces, climate, topography, and transportation and communication systems. The more detailed the briefings, the more salient factors can be identified and the more deductions can be made to assist planning. The scenario should contain sufficient air force elements to allow the Air Component Commander to allot and employ those assets independently. The first aspect to consider is richness of information.

Although most of the elements of a scenario are fictitious, the technology and equipment should match those in current use in the CF for training and education purposes. Also, one should beara in mind that the next employment could be in a real-world operation. The second aspect to consider is tactical realism from a conduct of operations (tactical) point of view.

Richness and tactical realism are key to the development of COAs (for both friendly and enemy forces) at the operational level. Also required is sufficient detail at the strategic level (geopolitical, economic) and the tactical level (military forces, infrastructure). The third aspect to consider is friendly and enemy COAs.

An air picture is a dynamic (validated and correlated) display of tactical locations and tracks of airborne systems in a given area of operations (AOO). Due to the speed and manoeuvrability of aircraft, the air picture was normally theatre-specific and was usually dependent on one major radar or other sensors such as AWACS and/or long-range radars. With the advanced processing capabilities and portability of modern computing systems coupled with increased data transfer through data links, the AF has been increasing its capability to fuse real-time correlated data from a number of airborne, ground-based and space-based sensors into a RAP. This enhances reliability through system redundancy and expanded airspace coverage. But even with a range of sensors, the RAP is still affected by different natural impediments (clouds, fog, terrain, etc.). Enemy factors are also at play, including jamming and masking by terrain features, although masking is less relevant in high-altitude operations. Actually, the RAP is rendered more complex by elements like the number of air assets, mission complexity, airspace characteristics, unpredictable enemy air forces, sensor availability and natural impediments to forming the RAP. The fourth aspect to consider is the utility of the scenario for compiling and exploiting the RAP.

For the purposes of our R&D project, we needed vignettes that provide a written description of the execution of a specific tactical mission as part of the air campaign for a given scenario. The aim of developing vignettes is to map the conduct of the mission as planned and to identify alternate COAs at each stage based on emerging or changing factors. Examples of factors that may contribute to an unforecasted change are variable weather conditions, different topography or evolving air threats. Each would force the operational planner and, to a much greater extent, the tactical planner to develop contingencies to ensure mission accomplishment. The goal of vignette development is to model a tactical mission for simulation purposes based on a series or path of forecasted events and branched onto different paths to the same end by unforecasted events. Therefore, in analyzing each scenario for its ability to support vignette creation, emphasis must be placed on:

- The number of air assets involved for both friendly and non-friendly;
- The predictability of those assets based on the complexity of the tactical mission; and
- The effects of environmental factors like weather, light conditions and geography on the mission.

In essence, the more dynamic the scenario, the more event-altering factors are introduced and the greater the number of non-determinant paths that need to be created. The fifth aspect to consider is the level of detail in and the facility of developing vignettes.

Table 1 presents the compilation of the scenario analysis general ratings considering these five aspects:

- richness of information (called scenario details in Table 1);
- tactical realism;
- capability to support operational level COA development (called friendly/enemy COAs in Table 1);
- utility of the scenario for compiling and exploiting the RAP;
- level of detail in and the facility of developing vignettes (called suitability for vignettes in Table 1).

Table 1. *Scenario Evaluation Table [2]*

Scenario	Scenario Details	Tactical Realism	Friendly/Enemy COA Possibilities	Utility for RAP	Suitability for Vignettes
Olympics 2010	LOW	HIGH	LOW	MEDIUM	LOW
ALIX	MEDIUM	HIGH	LOW	LOW	MEDIUM
Surveillance / Control of Canadian Territory and Approaches	MEDIUM	HIGH	LOW	LOW	MEDIUM
Defense of North America	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH
JWID	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH
Atlantis	HIGH	MEDIUM	HIGH	HIGH	HIGH

Table 1 indicates that the Atlantis scenario provides the best possibilities for thorough operational level COAs. For RAP and vignette generation, the Atlantis, JWID or (to a lesser extent) Defence of Canada scenarios could be used to produce a complex RAP consisting of a variety of enemy and friendly aircraft plus a broad range of RAP-feeding sensors. Coupled with an equally wide range of geography and environmental options, the RAPs produced could permit the generation of multiple vignettes with varied levels of complexity. More details on the evaluation of the different aspects for each scenario can be found in [2].

2.3 Identification of a vignette

While we had determined that the North Atlantis scenario offered a good basis for developing a vignette that would be effective for RAP compilation and exploitation, we still needed to determine which vignette would meet our R&D needs.

The vignette had to be effective in RAP compilation by offering rich threat attributes, a dynamic environment, and resource/asset multiplicity and diversity. In terms of RAP exploitation, it had to be at an operational-tactical level, distributed, and dynamic. As mentioned earlier, the realism of the vignette is mandatory (likelihood, compliance with AF directions and policies). The area of operation needed to be in a region with a wide variety of geographical details.

From the different types of operations that may occur in such overall scenario, it was considered that a vignette of Combat Search and Rescue (CSAR) operation would be very appropriate for our needs. "Combat Search and Rescue (CSAR) is the detection, location, identification and rescue of downed aircrew in hostile territory (in crisis and in war, and when appropriate) isolated military personnel in distress, who are trained and equipped to receive CSAR support, throughout a theatre of operations." [3].

A CSAR mission presents many dynamic challenges for the mission planner in locating and extracting in a hostile environment. Various elements must be considered, which may be predictable such as the friendly elements of detect and rescue, or unpredictable such as the enemy elements of detect and destroy. Usually, mission planners use air and ground picture inputs to make their decisions.

It is important to mention that CSAR is different from SAR, although they are both considered as single missions. A SAR mission is usually conducted in peacetime and is composed of two distinct phases: the search phase and rescue phase. These two phases are virtually simultaneous. Once the person(s) is/are located, e.g., a disabled ship at sea, they are rescued immediately by a SAR-capable helicopter. In CASR missions, enemy threats are always a factor. Even if the lost person is located, the rescue must be carefully planned and may be executed several days after due to the presence of threats in enemy territory where the downed crews or lost persons are located. As expected, the technique of flying a predictable search pattern over enemy territory would be fraught with risk. Combat search techniques would include:

- Location by electronic means using emergency locator transmitter (ELT) signals emanating from downed aircraft. ELT signals can be triangulated by satellites like SARSAT or by aircraft flying in friendly territory.

- Location by radio/secure radio transmissions from the downed crew using escape and evasion radios. These transmissions can be voice, in which case the GPS location could be sent, or a homing signal could be triangulated. Again these search techniques could all occur over friendly territory.

- Fly tactically supported reconnaissance assets (UAVs or manned aircraft) through the suspected target location to visually spot the crew. This is normally not done to avoid the risk of losing another asset and also because the downed personnel do not know whether the search aircraft is friendly or not, and thus will try to avoid being seen.

Once the search locates the lost personnel, the rescue phase is planned. Usually, the CSAR will be conducted under the umbrella of an air campaign plan and will not be specifically assigned a large amount of support assets, unless the importance of rescue is high enough to warrant a separate mission with significant support assets, as in the case of the USAF F-16 pilot (Captain O'Grady) downed in Bosnia in 1995 [4].

The primary operational task of rescue is to locate, communicate with and recover downed aircrew and isolated personnel. This primary task can be broken down into three sub-tasks. Locate the aircrew or isolated personnel (survivor) by visual or electronic search methods to pinpoint the survivor's location and permit recovery. Communicate with the survivor by radio or visual signalling to authenticate. Recover the survivor and provide medical aid.

Other non-rescue specific operational tasks that must be completed to accomplish the primary rescue task include:

1. Provide personnel and equipment to train rescue mission-ready personnel;
2. Operate efficiently during peacetime;
3. Airdrop rescue personnel and equipment;
4. Configure rescue equipment for deployment;
5. Provide self-protection for rescue assets;
6. Conduct medical evacuation operations;
7. Provide intelligence support directly to the rescue aircrew;
8. Respond to and prepare for rescue mission execution;
9. Control alert and airborne rescue missions; and
10. Support rescue sortie production.

The threat environments in which rescue assets operate can be addressed by the use of supporting aircraft. Supporting aircraft providing air-to-air, air-to-ground and suppression of enemy air defence (SEAD) coverage can degrade the threat, either temporarily or permanently, permitting rescue assets to enter the area and execute the recovery. Rescue forces may be augmented by these supporting systems depending on the threat environment, distance to the survivor and availability of assets.

CSAR operations are known to be dangerous and complex. They normally take place in enemy territory or contested areas. Time is limited and knowledge of the situation is hard to find. Such operations require tailored assets, detailed coordination and timely execution. Irrespective of the quantity of resources available, the planning, coordination and control requirements for CSAR operations are considered complex.

CSAR seems to be an appropriate type of event for our vignette since it may involve many different types of operations, such as:

- Surveillance of a specific area, including RAP compilation and mission planning, monitoring and control to improve surveillance;
- Target detection, which includes planning, monitoring and control of missions to improve the search;
- Recovery, which includes planning, monitoring and control of missions to recover the target.

These operations will involve different types of AF missions, such as:

- Use of UAVs for improved search and surveillance;
- Combat air patrols (CAP);
- Air superiority;
- Electronic warfare;
- SEAD;
- Close air support (CAS);
- SAR;
- Search and extraction;
- Airborne command, control and communications (ABCCC).

These different operations and tasks are the same as may be involved in a domestic air defence and surveillance operation. So it is expected that the findings related to DSS for RAP compilation and exploitation in a CSAR will be directly relevant to a DSS for RAP compilation and exploitation in a domestic air defence and surveillance operation. For example:

- Capabilities developed for the surveillance of a specific area will be applicable to the surveillance of Canada (e.g., North Bay or Mac(P) Mac(A));
- Capabilities developed for selecting the missions to be executed in order to accomplish the CSAR will be applicable to COA management at a generic level;
- Capabilities developed for scheduling resources to execute the plan will be applicable to real-time scheduling of resources for AF transport missions and AF missions to support other environments;
- Capabilities developed to monitor execution and re-planning will be applicable to AF operations of emergency support.

Since CSAR operations take place in hostile territory, they provide the level of complexity and the time constraints needed to demonstrate our concepts for the compilation and exploitation of the RAP while dealing with an operation of suitable scale. Therefore, we will use a CSAR operation for our project in RAP compilation and exploitation for Dynamic Operations Management.

2.4 CSAR vignette

The aim of vignette development is to describe in detail the sequence of events for the development of a CSAR mission. The mission is placed into a fictional scenario – Final Lance - Atlantis, borrowed from the Canadian Forces Command and Staff College (CFCSC). The details of the mission include all methods and techniques used to compile the RAP and the Recognized Ground Picture (RGP) using airborne assets. Although they are separate elements of the same mission, many of the RGP assets are airborne and, as such, are part of the RAP [5, 6, 7].

The following paragraphs describe the CSAR vignette that was built up based on the Final Lance - Atlantis scenario [8].

On 12 June, the second day following the commencement of the Alliance joint operations to secure Blueland and expel Coalition invasion forces, a Royal Air Force (RAF) Tornado call-sign HAWK27, conducting an electronic countermeasures and reconnaissance (ECR) mission, was shot down over the Celtic Straits by a surface-to-air missile (SAM) at 1608 hours. The crew did not report any radar activity, so it was believed that the missile was either an SA-8 or SA-14. Both systems had been reported in the area as part of the Coalition Airborne Regiment that invaded the Blueland portion of the Camrien Peninsula at the onset of hostilities.

The Tornado’s wingman reported that both aircrew ejected safely and the downed crew reported no injuries via their secure survival radio. Shortly after the downed crew was located, a CH-124 Sea King helicopter from Wahhabe Airbase, with a crew of five, was sent to recover and evacuate the Tornado crew. At approximately 1800 hours, in the process of extracting the downed crew, the Sea King crashed. The crash was attributed to mechanical failure. Two members of the Sea King crew sustained non-life-threatening injuries that have limited their mobility on foot. The crash site is shown in Figure 1. The location of both crews is 5650N 2740W, which is approximately 60 nm north of the Brownland town of Amitava on the Camrien Peninsula.

The situation was forwarded from the Combined Air Operations Centre (CAOC) to the ACC for consideration in the Joint Force Commander’s (JFC) force allocation for the upcoming planning period. Following an initial assessment by the joint staff, the decision briefing resulted in the ACC issuing the following tasking:

Mission: Alliance AF will conduct a CSAR mission with a time on target (TOT) of NLT 13 June 1600 hrs. Mission will be part of ACC campaign plan, which for that period is to maintain air superiority over Blueland territory using IADS and AD fighters and to support MCC operations in the Atlantic.

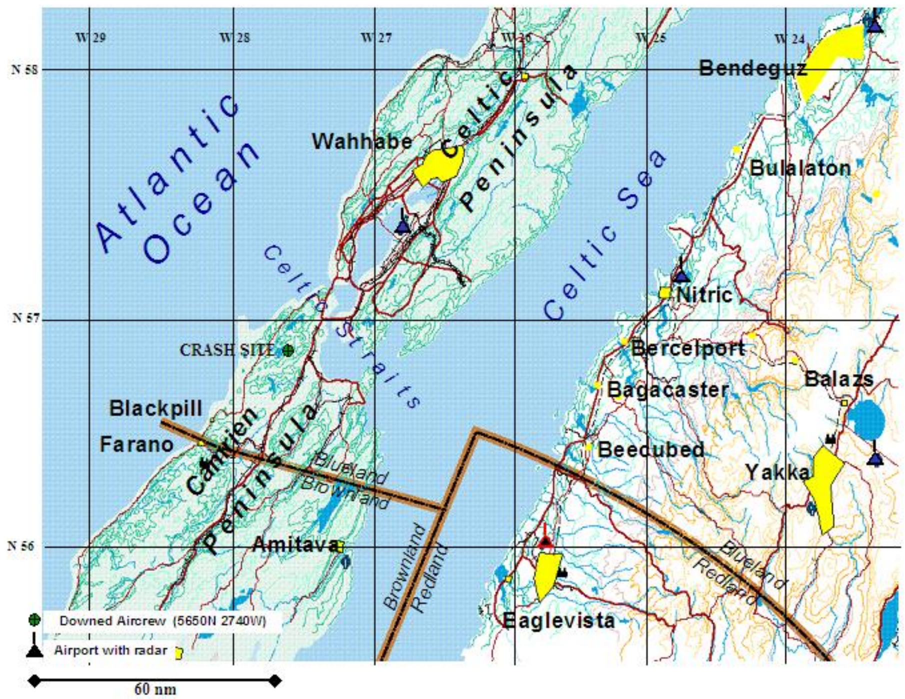

Figure 1. *Tornado and Sea King Crash Site*

In order to fulfill this mission, a CSAR Force and Joint Force were allocated. These forces include a number of aircraft, sensor and communication systems such as CF-18, Tornados, AC-130, CH-53, AWACS, KC-135, etc. (see Phase 4 report and Annex B for more details).

COA development started with a complete threat assessment by analyzing the enemy capabilities relevant to the mission. The analysis considers the ABR helicopter re-supply over the past weeks and its movement. Based on Redland doctrine and movement rates, it is possible to estimate the location of ABR in the next 24 hours and its impact on the extraction zone. Special assets (SEAD) should be dispatched to negate the threat and impede the ABR progress. Outside the extraction zone, threats posed by other enemy assets (MIG 31 CAP, SA-10 and SA-12 missile batteries) are identified and will have to be dealt with by dispatching Special Forces to counter the threats. At the end of the analysis, all enemy locations that threaten the mission conduct are identified and solutions are worked up.

Based on enemy states (ABR lead elements and associated SAM threats), the best method of reaching the goal of the mission (daylight CSAR extraction) is investigated. A CAS mission is necessary to deal with small groups of enemy troops and a BAI mission is also necessary to keep the ABR forces away from the extraction area.

To assure the safety of CSAR assets, local air superiority would need to be achieved by deploying SEAD and offensive counter-air missions to negate the threat of SAM systems during the extraction operation.

The PC designed a plan to meet the two critical mission requirements: air superiority and CSAR extraction. The plan includes tasks assignment to allocated assets to counter the enemy threat for “efficiency and safety” and to gain and maintain local air superiority. An example of a typical task of this plan is “4 x ECR Tornado – SEAD of Eaglevista SAMs from five (5) minutes before to five (5) minutes after mission aircraft enter AOO”.

Seven COAs were developed, three based on different routings for the CSAR package and four based on TOT relative to the sequenced availability of key mission assets. The potential routes considered are depicted in Figure 2.

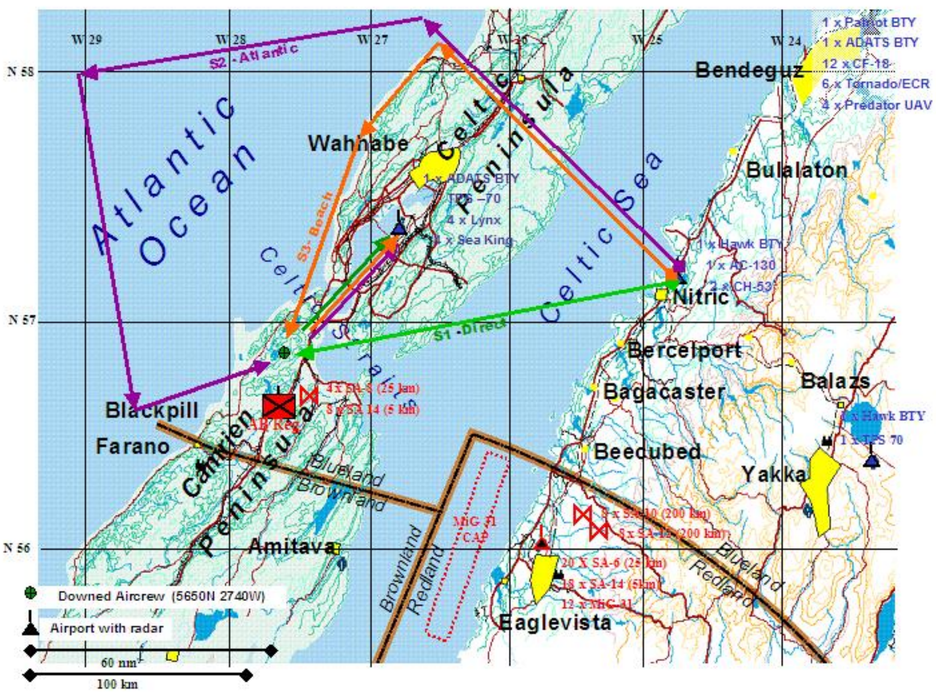

Figure 2. Route Options

The COA selected was code-named “Op Showdown/Beach” and was assigned the earliest TOT (1200 hours) that would ensure the availability of all necessary air assets. The PC and staff prepared a concept of operations (CONOPS) for the mission and briefed the mission and following COMAO flow plan and routings to the CSAR asset commanders and CAOC staff. An extract from the CSAR COMAO flow plan is shown below. The figure depicts the positions of CSAR and enemy assets at 1100 hours (see [7] for a full version of the plan and snapshots of the scene at 15-minute intervals).

1100

- Jammer 1-4 depart AAR
- Zap 1-2 join AAR Track A
- Sierra 1-4 (4 x CF-18) take off from Bendeguz
- Bomber 1-4 depart AAR Track B

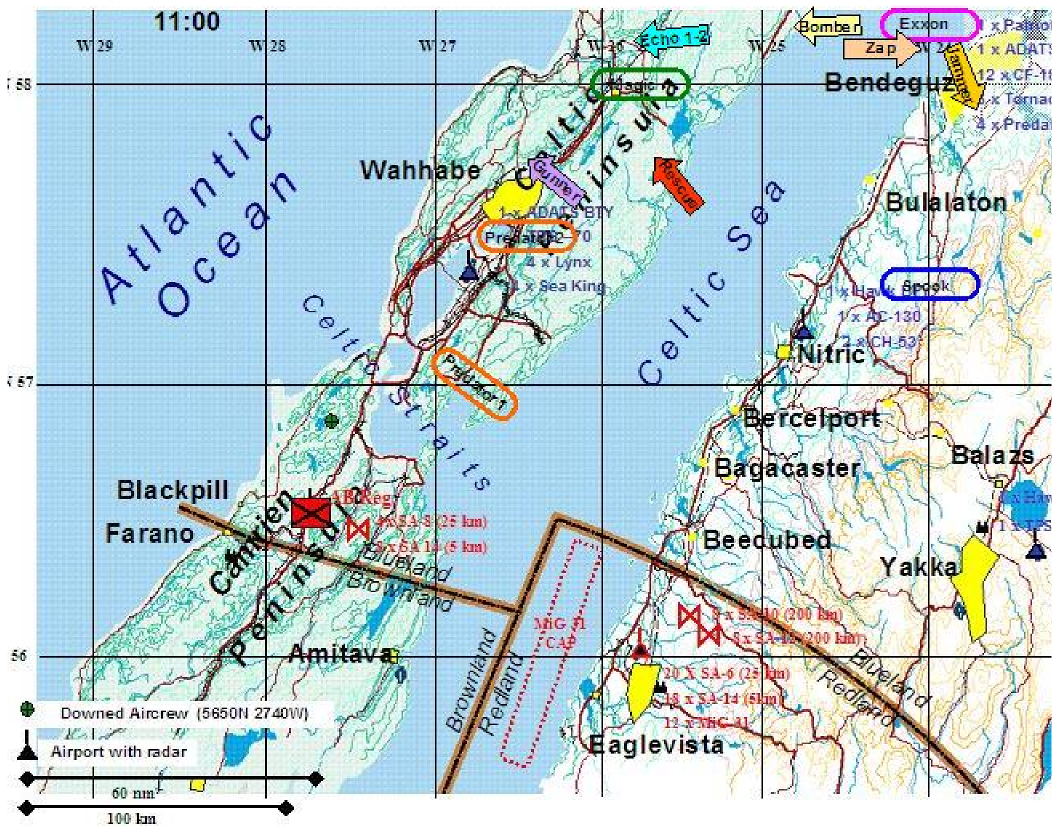

Figure 3. 1100 hours

In order to show all the information exchanged between mission assets and PC and CAOC, and also the data linked RAP and RGP from AWACS and JSTARS to the CAOC, a synchronization matrix has been proposed including all necessary information related to events that occur during scenario development. Each row of the matrix contains a description of the events and the times of occurrence. For example, Zap 1-2 (2 x Tornado ECR) take off from Bendeguz, mission: target area SEAD is considered as an occurred event. The matrix shows also the entity or entities that have caused the event to occur. In the example, Zap 1-2 are the entities that caused the event to occur. How this event has been perceived is also reported in the matrix. Usually, the perception corresponds to a message communicated by the mission assets including RAP, radio, secure phone, voice, and datalink communications. In the example, the take-off of the two Tornados was perceived as the two entities are on time. Once the information is received to ensure the perception of an event, it is important to report how this event is interpreted in relation to the mission requirements and execution. In the example, the perception and interpretation of the event are quite the same – the plan is on schedule. Finally, the matrix shows the decisions made based on the perceived events. In the example, any state/capability variances are reported to the PC and CAOC in order to ensure that the entities will always be on time and will not hinder mission completion.

An extract from the synchronization matrix is shown in Table 2.

Table 2. *Synchronisation Matrix (Example 1)*

Time	Event	Entity	Perception	Interpretation	Decision/Actions
1608	Crew of two eject from UK Tornado	E3 AWACS	ELT bailout tone picked up on UHF guard frequency. HAWK27 trackfile on air picture scope indicates emergency.	MC assesses tone to be legitimate and correlates to HAWK 27 mission number 2527.	Decision made to report to CAOC.
1612	Downed aircraft reported to CAOC	CAOC	Datalink message received, followed by secure radio call. RAP updated with distress signal from HAWK27.	Assess requirement to recover downed crew ASAP. Insufficient time before sunset to use CSAR resources at Nitric.	Decision made to utilize Sea King helicopter at Wahhabe due to proximity to crash site.
1628	Recovery tasking transmitted	Sea King Unit Ops	Tasking received via secure land-line phone.	Assess alert status and crew readiness.	Decision to launch Sea King 13.
1640	Sea King 13 launch ordered	Sea King 13	PA announcement received in Ready Room.	Requirement to launch ASAP.	Aircraft manned (crew of 5) and start-up initiated.
1705	Sea King 13 launches from Wahhabe	CAOC	RAP updated with Sea King take-off	Mission commencing.	Monitor routing and timing.

The event column describes the event, what is happening. The entity column describes the person or unit/sub-unit that is impacted by the event. The Ops Room is represented by the CAOC. The remaining entities are considered field or tactical level. The perception column describes the information received by the entity, how it is received and how it is displayed. The interpretation column describes how the information is interpreted by the entity. The decision/action column describes the decision or actions taken by the entity.

The synchronization matrix, which illustrates the execution of the mission, was first proposed in an ideal context, which means all occurred events were smoothly handled and the mission was executed successfully. However, in a real context forces need to consider unpredictable events resulting from enemy behaviour. The idea was to propose three events that were not supposed to occur as scheduled and to analyze their impact on mission execution. These events must be dealt with in near-real time since there is no time to stop or delay the mission. Re-tasking and re-planning are therefore necessary.

The three unexpected events are the following:

1. Inability to locate enemy ground positions due to cloud and terrain:

   The sensors used were affected by terrain and cloud, causing gaps in the RGP including critical positions. So a decision needs to be made to task other sensing means to cover the missing areas in the RGP;

2. Enemy attack helicopters appear in the CSAR area:

   Due to inaccurate information, enemy helicopters in the CSAR area were not reported. The presence of enemy aircraft endangers the CASR assets. A decision is needed to carefully devise a plan to counter the most threatening ECOA in the area;

3. Enemy SAM system in ABR rear area detects the CF-18 BAI mission:

   The routings of the mission were carefully planned based on enemy radar positions and ranges. An Atlantic routing was planned to attack enemy positions 10 minutes before the CSAR as a diversion. Unfortunately, enemy radar detected one of the bombers early and re-planning is needed to remedy the situation.

Adding unforecasted events to the scenario is a good way to test the robustness of the mission. The more robust the mission, the better it will handle new and unpredictable events. It is also important to see how the decision process was affected by such events, including retasking, rescheduling and resynchronization activities. In the synchronization matrix, a colour code was adopted to show all activities related to the unforecasted events. Table 3 presents two extracts from the synchronization matrix which show changes to the mission due to the three new events.

Table 3. Synchronization Matrix (Example 2)

Time	Event	Entity	Perception	Interpretation	Decision/Actions
1142	Magic confirms Jammer 2's call that MiGs are CAPing	Sierra 1	Voice reception on secure radio	MiGs still in CAP	Continue sweep mission. Confirms planned CAP point still appropriate
	Updated BAI targeting information passed to Bomber	Bomber	Received via datalink	Updated coordinates received	Weapon systems updated with new target information
	Updated CAS targeting information passed to Gunner	Gunner	Received via datalink	Updated coordinates received	Weapon systems updated with new target information
1143	Zap 1 picks up and calls SA-8 spike on the nose	Zap 2	Voice reception on secure radio	Within SAM detection range	Monitor own RWR. Commence visual look-out for possible SAM launches
	Bomber 2 reports RWR SAM search radar strobe from the southeast	Bomber 1	Voice reception on secure radio	Possible detection by enemy radar	Acknowledges call. Monitors own RWR
		Spook	Voice reception on secure radio	Need to correlate with the strobe with the RGP	Acknowledges call. Determines that strobe is emanating from the ABR rear area.
1144	Bomber 2 reports SA-8 tracking spike and performs defensive manoeuvring	Bomber 1	Voice reception on secure radio	Possible launch of SA-8 SAM against Bomber formation	Acknowledges call. Manoeuvres with Bomber 2 to provide mutual support
…	…	…	…	…	…
	AWACS detects unknown slow moving contacts	Magic	Surveillance scope highlights unidentified tracks moving forward from the ABR rear area	Need to make identification as soon as possible	Initiate electronic identification techniques
	Bomber 1 requests use of alternate IP (northern tip of Camrien Peninsula) for BAI	PC	Voice reception on secure radio	Concurs with request given importance of bombing run to delaying the ABR approach toward the extraction area	Grants request to proceed to alternate IP and calls for ROLEX of 10 minutes to both BAI and CSAR missions
1146	Spook updates downed aircrew location (received from Predator 1)	Spook	Receives Predator data link information from Predator	Conforms with ground mapping information and voice reports	Pass on updated RGP information to assets
	AWACS attempts to ID or correlate unknown tracks	Magic	Comparison of RAP with flow plan and enemy ORBAT	Able to determine targets are medium to heavy lift, single rotor transport or attack helicopters	Decision made that contacts are hostile due to lack of IFF combined with point of origin and track
	AWACS broadcasts position of "pop-up" targets				

Colour legend:

Black – Ideal planned events

Green – Event 1: Inability to locate the enemy ground positions due to cloud and terrain

Blue – Event 2: Enemy attack helicopters in target area

Red – Event 3: Enemy SAM system in ABR rear area detects the CF-18 BAI mission

3. Identifying simulation environment characteristics to support RAP R&D

Due to time and budget constraints, the evaluation of simulation tools to perform R&D on various RAP concepts was limited to two commercial products [9]:

- SADM, designed by British Aerospace, already used on several projects at DRDC Valcartier, and
- Integrated Anti-Ship Missile Defense Analysis and Simulation software, designed by Tactical Technologies Inc (TTI) of Ottawa.

and two R&D tools designed at DRDC Valcartier:

- CASE_ATTI, mainly developed by the Decision Support Systems team, and
- KARMA environment, developed also developed at DRDC Valcartier.

These systems were evaluated based on two types of criteria: the first type being purely software engineering, the second type being less formal but more oriented toward application needs in terms of RAP functionalities to conduct CSAR simulations.

3.1 Software engineering criteria

The evaluation of these systems was done based on the classified evaluation criteria proposed by Nikoukaran, Vlatka and Ray [10]: vendor, model and input, execution, animation, testing and efficiency, output, and user.

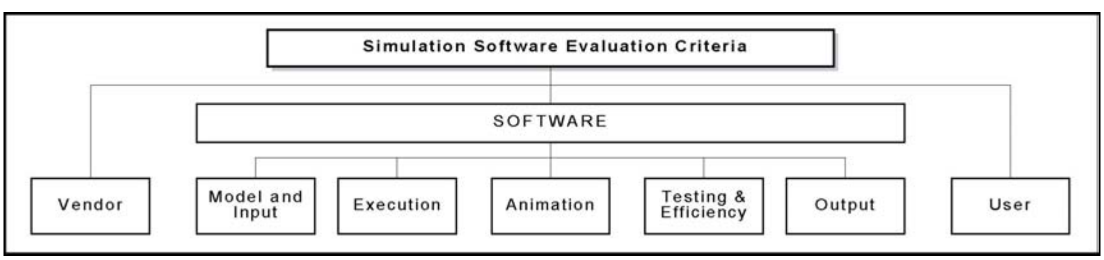

Figure 4. *Evaluation criteria for simulation software [10]*

The methodology proposed by Nikoukaran et al. is relatively detailed and proved to be efficient and easy to follow. An example of the items used for the evaluation under each criterion is given below. Not all items in the underlying hierarchy were used in this study. Scores were aggregated at the first level of the proposed hierarchy. As an example, for the model and input criterion, results were aggregated for the following items: library of reusable modules, model building, statistical distributions, coding aspects, queuing aspects and input, leaving aside conditional routing aspects that seemed irrelevant to our purpose.

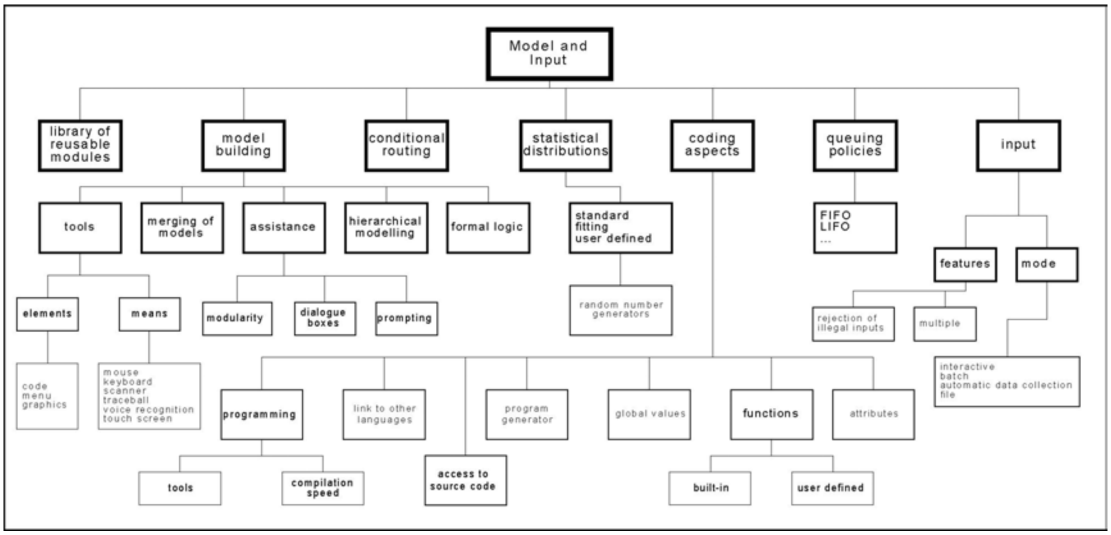

Figure 5. *Model and Input criterion (Nikoukaran et al. 1998)*

Details and scores obtained based on the fine-grained description of each of the seven criteria are given in the following table (more details can be found in [9]). It should be noted that the scores were attributed by one person and may not exactly reflect the opinions of a larger set of users.

Table 4. *Summary of the evaluation criteria*

Criterion	SADM	TTI	CASE_ATTI	KARMA
Vendor criteria	**39/43**	**37/43**	**21/43**	**18/43**
Pedigree	15/18	16/18	10/18	6/18
Documentation	10/10	9/10	5/10	4/10
Support	10/11	9/11	4/11	5/11

Pre-purchase	4/4	3/4	2/4	3/4
User Criteria	**7/14**	**11/14**	**12/14**	**10/14**
Simulation type	1/1	1/1	1/1	1/1
Orientation	Ship self defence	Simulation involving radar IR sensor and manoeuvring aircraft and ship with countermeasures	AWW in blue sea	Military electro-optically guided weapon engagements
Hardware	1/3	3/3	3/3	2/3
Security device	2/2	1/2	1/2	1/2
Operating system	1/2	2/2	2/2	1/2
Network version	1/2	2/2	2/2	1/2
Financial	Consult Peter Osbourne	1/3	2/3	3/3
Required experience	1/1	1/1	1/1	1/1
Software	**92/123**	**117/123**	**88/123**	**85/123**
Model and Input	***20/34***	***34/34***	***29/34***	***25/34***
Model building	7/14	14/14	11/14	11/14
Coding aspect	1/2	2/2	2/2	2/2
Queuing policies	1/2	2/2	2/2	1/2
Statistical distribution	8/11	11/11	10/11	7/11
Input	2/3	3/3	2/3	2/3
Library of reusable module	1/2	2/2	2/2	2/2
Execution	***14/17***	***17/17***	***9/17***	***14/17***
Speed control	2/2	2/2	1/2	2/2
Multiple runs	4/4	4/4	2/4	4/4
Automatic batch run	2/2	2/2	2/2	2/2
Warm-up period	1/2	2/2	1/2	1/2
Reset capability	1/2	2/2	1/2	1/2
Start in non-empty	1/1	1/1	1/1	1/1

state				
Parallel and distributed	3/4	4/4	3/4	3/4
Animation	***28/29***	***27/29***	***18/29***	***18/29***
Integrity	2/2	2/2	1/2	2/2
Icons	14/15	14/15	7/15	7/15
Running	4/4	3/4	4/4	4/4
Screen layout	6/6	6/6	4/6	3/6
Development	2/2	2/2	2/2	2/2
Testing and efficiency	***13/20***	***20/20***	***16/20***	***14/20***
Tracing	1/1	1/1	1/1	1/1
Snapshots	2/2	2/2	2/2	1/2
Step function	1/2	2/2	1/2	1/2
Breakpoint	1/2	2/2	1/2	1/2
Validation and verification	1/3	3/3	2/3	2/3
Backward clock	1/1	1/1	1/1	1/1
Interaction	1/2	2/2	1/2	1/2
Multitasking	2/2	2/2	2/2	1/2
Conceptual model generator	1/2	2/2	2/2	2/2
Limits	1/2	2/2	2/2	2/2
Display feature	1/1	1/1	1/1	1/1
Output	***17/23***	***19/23***	***16/23***	***14/23***
Delivery	5/6	5/6	2/6	4/6
Report	4/4	4/4	3/4	2/4
Database	1/3	2/3	3/3	1/3
Integration	2/2	2/2	1/2	1/2
Analysis	3/4	3/4	3/4	¾
Business graphics	2/4	3/4	4/4	¾

Total score	**138/180**	**165/180**	**121/180**	**113/180**

3.2 Criteria related to the CSAR scenario

Based on the vignette needs, the additional functionalities needed to adapt a published RAP system for the needs of DRDC Valcartier in combat search and rescue missions were defined as follows.

A. Database and data analysis system category

1. A database system for the registration of data received by the RAP;

2. A GIS link to georeference the RAP data, overlays for rivers, roads, commercial air routes and other items, and make some spatial RAP data requests;

3. A system of data analysis to identify, for example, significant correlations;

4. Statistical features that could be used to reproduce stochastic events;

5. An inference engine that may include additional expertise (e.g., reasoning applied by a soldier to avoid enemy contact).

B. Graphical user interface category

6. A graphic display to monitor the relevant RAP data;

7. A 3D animation system to visualize in real time the RAP data and a simulation scenario;

8. A simulation system to validate the efficacy of some scenarios as being a potential scenario of rescue.

C. Data fusion category

9. A tracking system to follow targets and other entities of interest;

10. A threat evaluation system to determine if a target is friendly, neutral or an adversary;

11. A projection system that could be used, for example, to anticipate where a target may go or how a situation may evolve;

12. A fusion system to aggregate, for example, the information coming from different sensors;

13. A planning system to assign and schedule the resources available for surveillance, search and rescue;

14. An optimization system to optimize the resource allocation.

D. Simulation system category

15. Features to improve the realism of a simulation as illumination model.

3.3 Evaluation of tools

In the following section, we briefly present software descriptions and comments on the strengths and weaknesses identified as far as RAP and CSAR simulation are concerned.

3.3.1 SADM

The following is a quotation from reference [11]. The "Ship Air Defence Model (SADM) is described as a software tool designed to simulate the defence of a task group against one or more attacking aircraft, cruise missiles, and/or surface targets. It simulates soft-kill, hard-kill, and the interactions between them.

This version of the model supports a task group of up to 10 ships. Each ship can have the following resources: a Command and Control System (C2), a Weapons Control System (WCS), up to three on-board ES (ESM) Receivers, up to five conventional or phased array Search Radars, an IFF System, an Infrared Search and Track (IRST) System, a Data Fusion engine, up to 16 Fire Control Radar channels, up to 16 illuminators, up to 6 types of hard-kill weapons (missiles, guns, and CIWS), up to 6 hard-kill weapon launchers, a Jammer (Electronic Attack System), offboard active and passive decoys, Mortar- or Rocket-launched Chaff, and up to 24 soft-kill weapon launchers.

The model supports up to three attacking aircraft, up to 34 sea-skimming or high-diving threat missiles, and up to 100 background air and surface targets, with the characteristics of each threat selected independently. Sixteen of the threat missiles are independent, and may be placed anywhere with respect to the ships under attack. The remaining threat missiles are associated with and launched by the threat aircraft or by other interacting models via an external HLA interface.

The model may be used in both the open-ocean and littoral environments. For littoral operations, the model will accept DTED® Level 0, 1, and 2 terrain elevation data, and modify RF sensor (radar and ESM) performance based on the resulting terrain height profiles. The optical obscuration effects of the terrain profile are also included in the IRST model."

It is interesting to note that the baseline SADM system can be extended to permit assessment of ground-based air defence systems and UAV system survivability.

SADM can be distinguished from the other simulation tools based on the following characteristics.

- **Support**: the support provided by the company that produces SADM is excellent because it was able to provide a response to our questions.

- **Documentation**: the documents provided with SADM are of high quality compared to the other tools, since in the user guide we found not only information on how to run the simulation tool and its options, but also on how the algorithms managed the model components.

- **Training**: this company provided good training. The cost of a SADM licence included two training courses: three days on site, and two more days at a later date (i.e., 3 to 6 months after the purchase). This training helps users learn the product quickly.

- **Communication** with other simulation tools: like KARMA, SADM is compatible with HLA simulation.

- **Simulation**:

    - Monte-Carlo Simulation: As with TTI, a Monte-Carlo can be done with SADM.

    - 3D structure: The I/Q RCS profile that can be associated with a simulation entity permits indirect consideration of the 3D structure of a simulation entity.

    - Command and Control models: This model mimics the operation of a Command and Control System/Weapon Control System for both area defence and self-defence operations. The model interfaces directly or indirectly (through the Track Management System) with all the sensor and weapon systems on the ship. It implements the Threat Evaluation and Weapons Assignment (TEWA) process for both hard-kill and soft-kill weapons.

    - Data link: With SADM it is possible to define a data link between ships or between aircraft.

    - Topography: SADM considers topography: missiles and aircraft can fly over mountainous terrain, and terrain affects RF signal propagation and IR visibility.

    - Survivability and lethality model: Like TTI**,** SADM has a direct survivability model as well. SADM incorporates the SLAMS V/L model developed at DRDC-V. The user specifies a vulnerability model for each threat missile, aircraft and background target, and the lethality model for each weapon, and SADM calculates the results of each engagement based on endgame geometry and the V/L files. In addition, SADM supports a Lethality Range Factor for all threat missiles, which assesses the probability of a ship being hit by debris from a destroyed missile.

For the extension of SADM tools toward a RAP application, the following needs must be addressed.

- Improve SADM extensibility: Because SADM is not an open-source software, to implement a novel function in this tool the company BAE should code it or develop an interface allowing plug-ins for our functions. This option is essential because the development of a new generation of RAP requires the addition of several functions. Consequently, this aspect should be mentioned in the negotiations with BAE to authorize access to the code. The contact manager has already confirmed the possibility of such a deal with the company.

- Improve the debug functionalities: Because the SADM codes are not accessible, it is not possible to debug a simulation scenario written in SADM. If access to the code cannot be negotiated with BAE, the company should add functionalities in SADM that will allow users to debug simulations in order to develop it into a RAP application.

- Improve model building: The interface of SADM can define simulation scenarios from predefined models in SADM, but it is not possible to define new models. However, for some functionalities an interface is provided that allows models defined by the user to be plugged in. Again, if access to the code cannot be negotiated with BAE, the company should add functionalities in SADM allowing new models to be built in order to develop it into a RAP application.

- Improve input validation: Currently, a minimal validation exercise of the input parameters used in SADM can be done, as with the other tools selected in the present study. Each simulation tool checks if the input parameters are within a predefined range, but does not verify if they are coherent in the group of parameters. Consequently, if users are unaware of this they can easily crash the simulation tool.

- Simulation: Improve the command and control model simulation: since SADM is a tool dedicated only to naval attacks, the command and control model is present on a ship. Consequently, it may not be located on another entity (e.g., aircraft). For simulating the scenarios selected by the DRDC, it is important to extend the command and control model to other simulation entities.

- Improve the IFF model: The IFF model is currently very simple. It receives interrogations from the command and control system and returns responses after a brief delay. The user specifies the average delay, with a Gaussian random component added. Since all emitters in the model except ships are currently threats, the IFF always returns a “hostile” result. This behaviour will change as the model is expanded. However, a more sophisticated IFF model is essential to develop a RAP application.

- Improve the data link: Simulating the scenario presented in the previous chapter requires functionalities for establishing communication between different entities of simulation. In other words, the SADM data link is too restricted (ship to ship, aircraft to aircraft) for our needs, and should be improved.

- To develop new environmental effect model: Entity simulation runs can be affected not only by the atmosphere, but also by other environmental phenomena like waves. Improving the realism of the simulations necessitates the development of other effective environmental models.

- To develop a new kind of illumination modelling: Simulating the scenario selected by the DRDC requires the capability to reproduce solar and lunar illumination. For example, the plan for a daylight rescue operation will be very different from the plan for a night rescue. For example, personal camouflage is not the same during the day and at night. Therefore, an illumination model must be developed.

- To develop new entities: The selected scenario demands the development of new SADM simulation entities like soldiers, tanks, etc.

- To develop facilities that include different layers: For simulating the scenario by the DRDC, different layers such as road and land-use should be considered. It is important to develop new facilities that permit the display and consideration of these layers during the simulation.

- To develop facilities for zone characterization: For simulating the selected scenario, the characterization of specific areas such as commercial air routes and other high-risk areas should be considered. So it is important to develop new facilities that permit the display and consideration of these zones during the simulation.

- To improve the 3D aspect of the simulation: SADM indirectly considers 3D structure via the I/Q RCS. It would be important to have functionalities that allow a three-dimensional structure to be associated with each simulation entity. It is also essential that the different models consider that structure.

- To eliminate limitations on the number of entities: SADM permits the simulation of a limited number of simulation entities. For DRDC needs, it is important to eliminate this limitation.

3.3.2 TTI

On the TTI web site [12], the products are described as follows.

“The Tactical Engagement Simulation Suite (TESS) is a family of dynamic simulations of one-on-one, three-dimensional tactical engagements. Engagement types include guided missiles or radar-controlled guns and target platforms that employ manoeuvres and combinations of electronic countermeasures for self-protection and survival.

The TESS software product line includes simulations of engagements involving various types of Surface-To-Air Missile (SAM), Air-to-Air Missile (AAM), Anti-Ship Cruise Missile (ASCM) and radar controlled Anti-Aircraft Artillery (AAA) weapons. Target platforms include manoeuvring ships and aircraft. Each TESS product allows the user to select the type of threat weapon angle tracking technique from a menu of various angle tracking types. It also allows the user to select electronic countermeasures from a menu of techniques, including chaff clouds, decoys, and on-board jamming techniques that include noise, range gate pull off, multiple range targets, velocity gate pull off, swept amplitude modulation, countdown, cross-eye and cross-polar techniques. Most combinations of countermeasure techniques can be used individually, simultaneously or sequentially. Models of specific weapon and countermeasure systems are established through the user's selection of the simulation's configuration and the input parameter values."

TTI can be differentiated from other simulation tools based on the following characteristics.

- **Input data**: In addition to reading input data interactively or reading a file, it is also possible to download those data from other databases through an SQL link. Also, continuous data entry by Ethernet for hardware-in-the-loop application has been delivered in custom orders.

- **Model building**: TTI products are available in the form of an open-source code of the MathWorks fifth-generation languages of Matlab/Simulink. So the simulation models are developed via graphical programming, and the program makes it easy to re-use each model developed.

- **Debug option**: Simulink has an integrated debugging environment that allows the user to debug the simulation model along with the process of development.

- **Distributed and parallel application**: TTI is the sole application that offers parallelization and distribution of applications.

- **Simulation**:

    - Monte-Carlo: Like SADM, Monte-Carlo simulations can be performed with TTI.

    - Tank and jeep simulation entities: TTI is the sole application that offers simulation of tanks and jeeps.

    - Satellite simulation entities: TTI is the only application that may also propose the simulation of satellite entities.

    - Movement model: With TTI it is possible to associate movement models not only with ships, as with SADM, but also aircraft, chaff, flares and decoys.

- Wave model: TTI includes RF scattering and multi-path effects from waves. In the IR domain, atmospheric events such as attenuation by weather are user-enterable.

- Geometry: As with SADM, it is possible to associate a 3D structure with a simulation entity. It is possible to link CAD 3D geometric models with TTI sensor models in a Simulink framework. However, code should be developed to automate the extraction of features.

- Lethality and survivability model: As with SADM, the TTI lethality model is relatively simple, since the primary objective is to determine the conditions under which the missile can be launched to miss its target by a distance such that the warhead fuse is not triggered. Hence, lethality is an issue only if this primary objective is not achieved. The concept of survivability appears through the computation of missile miss distance and probability of platform survival based on step-by-step computation of missile fly-out, including all linear and non-linear interactions between the missile and its fire control system, as well as the target platform with its manoeuvres and self-defence measures.

For the extension of TTI tools toward a RAP application, the following needs must be addressed.

- Improve the TTI performance: Since TTI simulation executes interpreted code, the execution of the simulation is relatively slow. To improve simulation performance, conversion of the code into C language using the Matlab/Simulink Real Time Workshop is essential. This induces a duplication of the code (C and Simulink versions), which may be difficult to manage. For the needs of DRDC, it will be appreciated if TTI performance can be improved directly within Simulink.

- Improve the TTI documentation: Understanding the TTI documentation requires the ability to program graphically. A brief introduction to graphic programming is essential for a better understanding of the documentation provided.

- Simulation: Improve the command and control model simulation: As with SADM, the command and control model is present only on a ship. To simulate the scenarios selected by DRDC, it is important to extend the command and control model to other simulation entities.

- Develop the IFF model: TTI does not contain an IFF model, which is necessary to meet DRDC needs.

- Develop the data link: TTI does not have a data link model. For simulating the selected scenario, it is important to develop this model.

- Develop simulation model considering topography: Presently in TTI, topography is not taken into account. For instance, when simulating the scenario selected by

DRDC, topography is an important parameter to consider when simulating the landing of an airplane. Topography should therefore be considered.

- Develop new environmental effects model: As observed for SADM, improving the realism of simulations necessitates the development of other effective environmental models (e.g., ice storm).

3.3.3 CASE_ATTI

The documentation on CASE_ATTI [13] describes this tool as follows: “The designer/developer/user/operator of Level-One Data Fusion (L1DF) systems need capabilities that allow them to quantitatively assess if the algorithms and techniques of a proposed L1DF system are suitably working. In that respect, a highly modular, structured, and flexible test bed, called CASE_ATTI (Concept Analysis and Simulation Environment for Automatic Target Tracking and Identification), has been developed at DRDC Valcartier as a proof-of-concept demonstrator to achieve the continuing exploration of L1DF.

Besides the possibility of using real data, CASE_ATTI has a high-fidelity stimulator that emulates the behaviour of real targets, sensor systems and the meteorological environment, allowing the user to create and edit test scenarios with multiple ships/sensors/targets. The ships can be stationary or moving along user-predefined paths. One or several sensors can be assigned to each ship (currently, the stimulation module supports surveillance radar, IFF, ESM and IR sensor and link simulations). Targets are created with user-predefined 3D trajectories and attributes.

One of the main requirements of the CASE_ATTI test bed has also been to provide the algorithm-level test and replacement capability (required to study and compare the technical feasibility, applicability and performance of advanced, state-of-the-art L1DF techniques) where the user can switch between all available algorithms in the CASE_ATTI library without re-coding and/or re-compiling. The L1DF system module supports a wide variety of L1DF architecture types, varying from a simple single sensor tracker to an arbitrary complex multiple sensor topology (including contact-level, track-level or hybrid fusion architecture types).

A performance analysis database retains archives of all manipulated data. A performance evaluation module provides tools to assist the quantitative assessment of L1DF systems performance. A user interface module supports all interactions with the users/operators.”

It is possible to distinguish CASE_ATTI compared to the other simulation tools from the following characteristics:

- **Developer guide**: CASE_ATTI contains a good developer guide. This guide can be useful if it is decided to extend CASE_ATTI toward a RAP application.

- **Good extensibility**: Like KARMA, CASE_ATTI is available in the form of an open object-oriented source code. This facilitates the extension of this tool toward a RAP application. Because CASE_ATTI is compiled code, performance should be better than TTI.

- **Database connection**: CASE_ATTI possesses a link to ORACLE database. This database provides many facilities for data storage and retrieving and manipulating output, input and other data concerning the model. Furthermore, for the majority of GIS, it is possible to make a connection to this database.

- **Statistical features**: Like TTI, CASE_ATTI provides good statistical features. This tool supplies some standard statistical distributions such as normal and exponential, which facilitate the acceptance of input data modelled according to a statistical distribution. It also supplies functionalities to fit data into a distribution. Furthermore, CASE_ATTI provides different random number streams. It is also possible to define our own random generator. Finally, in CASE_ATTI, all functionalities needed for the implementation of Monte-Carlo simulation are available.

- **Business graphics**: CASE_ATTI offers the best possibilities for graphic management (i.e., a graphic may be changed at each change of a model run).

- **Simulation**:

  - Track management: As described in the preceding section, CASE_ATTI provides the algorithm-level test and replacement capability (required to study and compare the technical feasibility, applicability and performance of advanced, state-of-the-art L1DF techniques), where the user can switch between all available algorithms in the CASE_ATTI library without re-coding and/or re-compiling. The L1DF system module supports a wide variety of L1DF architecture types, varying from a simple single-sensor tracker to an arbitrary complex multiple-sensor topology (including contact-level, track-level or hybrid fusion architecture types).

  - Wave model: As with TTI, some sensor models take into account a wave effect.

For the extension of CASE_ATTI tools toward a RAP application, the following needs must be addressed.

- Improve documentation: The CASE_ATTI documentation describes how to use the CASE_ATTI interface, but a description of the different algorithms that can be selected is not available. To extend this application toward a RAP application it would be important to make this possible.

- Improve support: CASE_ATTI has no specific support department. It is the developer who should answer questions from users. Because developers are often busy with other work, a quick answer may not always be provided. In the eventuality that this tool is extended toward a RAP application, it would be essential to improve user support.

- Improve communication with other simulation tools: CASE_ATTI is not compatible with HLA simulations. Since RAP application may involve several types of simulation, it is essential to develop this option.

- Improve animation: In CASE_ATTI, a simulation entity is modelled as a cylinder. The size of the cylinder can be defined, but during animation, simulation entities are represented only by single points. Accurate reproduction of the DRDC scenario will require the development of functionalities for 3D animation.

- Simulation:

  - Develop Monte-Carlo simulation: Too validate the performance of the selected scenario, it would be important to implement Monte-Carlo simulations.

  - Improve the simulation of each entity: In CASE_ATTI it is possible to simulate a generic platform. This type of generic approach is used to reproduce the common properties of the different platforms, e.g., displacement. However, more specific properties such as aircraft turbulence may not be simulated. The improvement of simulation realism necessitates the development of those specific properties.

  - Add a movement model: In CASE_ATTI no movement model is available. For simulating the scenario selected by DRDC, the movement model may influence the planning of rescue operations. A movement model should therefore be developed.

  - Add a survivability and lethality model: CASE_ATTI does not contain survivability and lethality models. The realism of the DRDC scenario simulation may be enhanced by the development of a survivability and lethality model.

  - Improve the command and control model: CASE_ATTI implements only a part of the command and control system (i.e., track management, data fusion, etc.). However, there are no weapon control models that permit, for example, the launch of a missile according to threat. An improvement would consist of taking into account this aspect.

  - Improve the 3D structure management: In CASE_ATTI, only some sensors may consider the cylinder associated with a simulation entity. It would be important to develop functionalities for associating a cylinder and especially a three-dimensional structure with each simulation entity. Furthermore, it would be essential to consider this 3D structure in the different models.

3.3.4 KARMA

According to reference [14], "KARMA is a process for carrying out engagement-level modelling and simulation of weapon systems. The main objective of this process, named KARMA, is to provide a method and software architecture to model and simulate weapon system engagements. The envisioned mission of KARMA products is to support the improvement of the military platforms self-protection. The main features of the KARMA process are the incorporation of a structured method for modeling the simulation actors; a component-based modeling strategy allowing various levels of detail; an autonomous simulation environment which shall include planning, scripting and analyzing capabilities; a component-based simulation architecture permitting various levels of detail; and a simulation architecture flexible enough to ensure component interoperability and reusability. Although KARMA has a very broad reach, its extent was limited, to engagements between IR guided weapon systems, aircraft and countermeasures."

It is possible to differentiate KARMA from the other simulation tools based on the following characteristics.

- **Development process documentation**: KARMA is the sole application for which the development process is documented in the reference [15]. This documentation could be useful if we decide to extend KARMA toward a RAP application.

- **Developer guide**: KARMA contains a developer guide which is less comprehensive than CASE_ATTI, but it could be useful if it is decided to extend KARMA towards a RAP application.

- **Good architecture**: KARMA possesses a very good architecture to which new functionalities can be added easily.

- **Extensibility**: Like CASE_ATTI, KARMA is available in the form of an open object-oriented source code. Therefore, it is easier to extend this tool toward a RAP application. Since KARMA is compiled code, its performance should be better than that of TTI.

- **Communication with other simulation tools**: Like SADM, KARMA is compatible with HLA simulations.

- **XML input and output files**: KARMA input and output files are saved in XML format.

- **Support**: The KARMA team has no support department, although they provide high-quality service and answer questions promptly.

For the extension of KARMA tools toward a RAP application, the following needs must be addressed.

- Documentation: As with CASE-ATTI, the documentation on KARMA describes the utilities of the KARMA interface but not the model.

- Tests: The unit tests of KARMA are not complete. Only the interface (KARMA studio) was tested. Also, this tool has no integration system and acceptance tests. It would be important to improve this aspect to demonstrate the robustness of KARMA. Test for portability: special care was taken to develop code that is platform-independent, but portability has not yet been tested. Again, it would be important to validate this aspect before selecting this tool.

- Screen layout: KARMA doesn't provide an editor to create screen layout. Therefore, it is not possible to generate multiple screen layouts and switch between screens as well as their printout. To facilitate analyzing the simulation of the selected scenario, the development of an editor would be appreciated.

- Simulation:

    - Improve the 3D structure management: In KARMA, it is possible to associate a sphere or cube with a simulation entity. These structures are considered by the collision model only, and not by the sensor model. In this case, the sensors may perceive only a single point. It would be important to provide functionalities permitting the association of a cylinder, a sphere and a three-dimensional structure for each simulation entity. Also, it would be essential that the different models consider the 3D structure.

    - Platform command and control: In KARMA, there is no command and control model. For simulating the scenarios selected by DRDC, it would be important to develop a command and control model.

    - Improve trajectory management: The simulation entities for which a trajectory is pre-defined are not yet implemented in KARMA. For DRDC needs, it is essential to implement this feature.

3.4 Comparison/discussion

The simulation tools that were evaluated can be grouped in two main categories: commercial products (SADM and TTI) and DRDC developments (CASE_ATTI and KARMA). In the commercial category, these are the main points that have been observed. Being the product of greater input resources, the commercial tools clearly achieve higher scores. Documentation, support and animation features are better in the commercial simulation tools than in the DRDC tools. A comparison of the two commercial simulation tools yielded the following observations. Unlike TTI, SADM is able to take topography into account, it contains an IFF model, and it can simulate the data link. On the other hand, SADM has the following limitations. The number of simulation entities is limited; SADM is essentially dedicated to naval attacks, so the IFF model is relatively simple (ship = friend, other platform =hostile); and the command and control model can be associated only with a ship. Unlike SADM, TTI is an open-source software. Therefore, a simulation can easily be debugged. The TTI development environment (Simulink) permits easy building of other simulation models. TTI can supply more simulation entities (tank, jeep and soldier) than SADM. TTI is able to take wave effects into account. TTI is a portable application. With TTI, it is possible to associate a movement model with threats. On the other hand, TTI has certain limitations. As with SADM, the current command and control model is implemented only for the ship. And because TTI is interpreted code, its simulation performance does not equal that of SADM.

Both tools developed by DRDC are open object-oriented source. Their object-oriented technology ensures good extensibility and reusability of the code. The source code is registered according to the DRDC programming standard, so it is easier to understand, read and use in conjunction with other DRDC tools. A comparison of these two DRDC tools yielded the following observations. Unlike KARMA, the portability of CASE_ATTI has been tested. CASE_ATTI contains the required functionalities in the source code to implement Monte-Carlo simulation. In CASE_ATTI, it is possible to modify a scenario while another is running. CASE_ATTI contains a database link. Some sensor models of CASE_ATTI can consider the cylinder that may be associated with a simulation entity. CASE_ATTI contains an IFF model and supplies a track management system. CASE_ATTI is able to consider the curvature of the earth. In CASE_ATTI it is possible to assign a pre-defined trajectory to a simulation entity. As for KARMA, the development team answered requests more promptly. The development process of KARMA is documented. KARMA is compatible with HLA simulation. In KARMA, it is possible to control the speed of each run. KARMA contains a collision model that is able to take into account the sphere or the cube associated with a simulation entity. KARMA supplies various weapon systems and contains a motion model.

Now, the two main questions are:

1. Could the development of a new-generation RAP system be assured by extending existing command and control simulation tools?
2. If yes, which of the tools examined here would be preferable?

The following are the essential elements to help answer question 1:

RAP functionalities 1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13 and 15 (see list in section 3.2) needed by DRDC can be partially or totally fulfilled by the simulation tools examined in the present study. However, the following functionalities are not fulfilled. Number 14 concerns the need for an optimization module. To simulate the scenario selected by DRDC, it is important to find a solution to this problem. In fact, this scenario involves a lot of constraints that we should consider during the planning operation, for example, limited flying time. To achieve a high degree of success in planning, an optimization model capable of taking these different constraints into account is needed. *So it is recommended that this aspect be resolved*. Functionality 5 concerns the inclusion of an inference engine in the RAP application. This option is important when DRDC decides to include a reasoning aspect in the RAP application (e.g., reasoning applied by a soldier to avoid enemy contact). *Again, it is recommended that consideration be* *given to how this functionality can be added*. Functionality 2 concerns the possibility of having a GIS link in the RAP application to allow the following major operations: georefencing RAP data, displaying different overlays like roads and rivers, assigning some characteristic to commercial air routes, making space-time requests (e.g., in a rescue operation, finding the nearest bridge).

To simulate the scenario selected by the DRDC, further study is recommended to answer the following questions:

3. Which GIS could be used to support the RAP development?
4. Which simulation tool would be compatible with this GIS?

As the treatment of spatial data is central to the RAP application, it is essential that questions 3 and 4 be answered before question 1. But even without further study it is already clear that ***the simulation tools examined here fulfil many of the functionalities needed for the RAP application***. One of the purposes of this study was to answer question 2. The following are the most important software properties for which the selection of a simulation tool was performed. The simulation tool selected should provide as many as possible of the 15 RAP functionalities listed earlier. And as the new-generation RAP necessitates the development of several new functionalities, it would be preferable to get open-source code for the simulation tool selected. Eventually, the RAP application will probably become a real-time application. It is therefore important that the simulation tool selected offer excellent performance and robustness. Because the scenario selected by DRDC involves many simulation entities, the tool selected should not be limited in the number of simulation entities it can process.

4. Conclusion

To develop and demonstrate the concepts of RAP compilation and exploitation, a scenario able to support a type of operation that provides events leading to the compilation and exploitation of a RAP was needed. Six military scenarios were analyzed.

- Scenario 1: CF Security Support to the Winter Olympics 2010;
- Scenario 2: Atlantic Littoral ISR Experiment (ALIX);
- Scenario 3: Force Planning Scenario #4: Surveillance/Control of Canadian Territory and Approaches;
- Scenario 4: Force Planning Scenario 10: Defence of North America;
- Scenario 5: Joint Warrior Interoperability Demonstration (JWID);
- Scenario 6: Exercise Final Lance: Atlantis.

These five aspects were considered.

- Scenario details and richness of information;
- Realism from a conduct of operations (tactical) point of view;
- Possible friendly or enemy COAs;
- Utility for the compilation and exploitation of the RAP; and
- Level of detail available and facility of developing vignettes.

The North Atlantis scenario was identified as the one offering the best basis for developing a vignette which would be of interest for the compilation and exploitation of a RAP. Once selected, a vignette appropriate for RAP compilation/exploitation was developed. The vignette needed to be at the operational-tactical level, distributed, with rich threat attributes, a dynamic environment, resource/asset multiplicity and diversity. It was determined that a vignette of a CSAR operation would be appropriate. Accordingly, the vignette was developed with a good level of detail and including three realistic unforecasted events:

- Inability to locate enemy ground positions due to cloud and terrain;
- Enemy attack helicopters appear in the CSAR area;
- Enemy SAM system in ABR rear area detects the CF-18 BAI mission.

Once the vignette was developed, four simultation tools were evaluated considering purely software engineering criteria and the application requirements in terms of RAP functionalities needed for CSAR simulations. Although the commercial tools (SADM and Integrated Anti-Ship Missile Defence Analysis and Simulation software) seemed to be more refined, the analysis showed that none of the tools emerged as dominant, i.e., none outperformed the others on all counts.

- SADM is not open-source and simulates only a limited number of entities. But it can fulfill the greatest number of RAP functionalities and takes topography into account, a feature that we consider essential. *Therefore, it is recommended that the company be approached to see if SADM's limitations can be addressed (e.g., source code access and limited number of simulation entities).*

- TTI is an open-source product with no limitation on the number of simulation entities. But its source code is interpreted, and that may seriously hinder performance. *If DRDC plans to implement a real-time RAP application, it is recommended that the performance of TTI be analyzed before it is selected.*

- CASE-ATTI is open-source but fulfills fewer RAP functionalities than either TTI or SADM. Still, CASE-ATTI offers the best track management model. *This model should be included in the new-generation RAP. In doing this, the following actions are recommended: a) isolate the track management model from the CASE-ATTI interface, and. b) improve the robustness of this model by introducing a software verification and validation plan and executing the tests documented in the plan.*

- KARMA is open-source, but like CASE-ATT, it fulfills fewer RAP functionalities than either TTI or SADM. Still, KARMA supplies different simulation entities such as logic fuse, which are not present in the other simulation tools. These simulation entities should be included in the new-generation RAP. *In including these entities, the following actions are recommended: a) isolate these simulation entities from the KARMA interface, and b) improve the robustness of these simulation entities by introducing a software verification and validation plan and performing the tests documented in the plan.* Furthermore, KARMA contains an excellent documented development process and a software architecture that facilitates the integration of different models. *It is recommended that this process be adopted to develop the new-generation RAP.* Also, the RAP architecture could be based on the same architecture.

All things considered, SADM would be one of the best tools if topography were not an important factor for simulating DRDC scenarios. Owing to this factor, TTI is a good option. If DRDC plans to develop a real-time RAP application, it would be imprudent to choose TTI before thoroughly analyzing its performance. If that analysis is not performed, the only choices would be KARMA and CASE_ATTI. As previously mentioned, KARMA is an attractive choice because the development process is documented and the architecture allows different models to be integrated. On the other hand, CASE_ATTI has the best track management model and an acceptable developer guide. To take full advantage of the strengths of these two teams, it is suggested that one member of each team participate in the architectural phase of RAP development. The RAP architects could draw inspiration from the integrative aspect of the KARMA architecture.

A promising avenue for the development of RAP simulation and analysis tools would integrate GIS tools for analyzing terrain features and integration of typical layers of information such as bodies of water, elevation, obstacles, roads and airfields take can be found in the North Atlantis vignette database. It is clear that promising GIS solutions for the rapid development and testing of concepts would use either a COTS GIS environment such as that marketed by ESRI or a GIS library allowing the development of tailored display and analysis tools. *Consistent with the underpinnings of the KARMA architecture, it was concluded that instead of trying to develop RAP extensions starting with the fundamentals of programs like TTI, SADM or CASE_ATTI, it would be easier and more efficient to extract the minimum required functionalities such as basic sensor shells and detection, tracking and identification algorithms from these programs.*

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List of symbols/abbreviations/acronyms/initialisms

Acronym	Description
AAA	Anti-Aircraft Artillery
AAM	Air-to-Air Missile
AAT	ATO/ACO Tool
ABCCC	Airborne Command, Control and Communications
ABR	Airborne Regiment
ACC	Air Component Commander
ACO	Airspace Control Order
AD	Airspace Deconfliction**,** Air Defence
ADRG	Arc Digitized Raster Graphics
ADSI	Air Defense System Integrator
AFATDS	Advanced Field Artillery Tactical Data System
AODB	Air Operations Database
AOI	Area of Interest
AOO	Area Of Operation
API	Application Programming Interface
ASCM	Anti-Ship Cruise Missile
ATO	Air Tasking Order
ATOX	ATO Exchange
AUTODIN	Automatic Digital Network
AWACS	Airborne Warning and Control System

BAI	Battlefield Air Interdiction
C2/IE	Command and Control and Information Exchange
C4I	Command, Control, Communications, Computers and Intelligence
CADRG	Compressed Arc Digitized Raster Graphics
CADS	Canadian Air Defence Sector
CAOC	Combined Air Operations Centre
CAP	Combat Air Patrol
CAS	Close Air Support
CBT	Computer-based Training
CFC	Canadian Forces Command
CFCSC	Canadian Forces Command and Staff College
CFNA	Canadian Forces Northern Area
CFOPP	Canadian Forces Operational Planning Process
CIWS	Close-In Weapon System
COA	Course of Action
COMAO	Combined Air Operation
CONOPS	Concept of Operations
COP	Common Operational Picture
CSAR	Combat Search And Rescue
CST	Common Operating Picture (COP) Synchronization Tool
CTP	Common Tactical Picture
DBMS	Database Management System
DII-COE	Defence Infrastructure Information-Common Operating Environment.
DISA	Defense Information Systems Agency

DMS	Degrees/Minutes/Seconds
DND	Department of National Defence (Canada)
DoD	Department of Defense (USA)
DSS	Decision Support System
DTED	Digital Terrain Elevation Data
ECR	Electronic Countermeasures and Reconnaissance
ECOA	Enemy COA
ELINT	Electronic Intelligence
ELT	Emergency Locator Transmitter
EM	Execution Management
EMC	Execution Management Control
EMR	Execution Management Replanning
ESM	Electronic Support Measures
FrOB	Friendly Order of Battle
GCCS	Global Command and Control System
GIS	Geographical Information System
GMIDB	General Military Intelligence Database
GOTS	Government Off-the-Shelf.
GUI	Graphical User Interface.
I3	Integrated Intelligence and Imagery
IADS	Integrated Air Defense System
IBIS	Integrated Battlespace Intelligence Server
IDM	Intelligence Data Management
IFF	Identification Friend or Foe

IR	Infrared
IRIS	USMTF message processing application that performs message parsing validation, reformatting, and dissemination functions
IRST	Infrared Search and Track
J2RE	Java 2 Runtime Environment
JANAP	Joint Army, Navy, Air Force Publication
JDP	Joint Defensive Planner
JFC	Joint Force Commander
JMTK	Joint Mapping Toolkit
JPT	JFACC Planning Tool
L1DF	Level One Data Fusion
Lat/Long	Latitude/Longitude
LPD	Location Probability Distribution
MAOP	Master Air Operations Planner
MCC	Maritime Component Commander
MGRS	Military Grid Reference System
MIDB	Modernized Intelligence Database
MTC	Multi-TADIL Capability
MTF	Message Text Format
NATO	North Atlantic Treaty Organization
NIMA	National Imagery and Mapping Agency
NRT	Near-Real Time
OGD	Other Government Departments
ORBAT	Order of Battle

OTH-T Gold	Over-The-Horizon Targeting GOLD
PC	Package Commander
PM	Prime Minister
PDF	Portable Document Format (Adobe)
PMTLS	Process Management Tools
RAF	(UK) Royal Air Force
RAP	Recognized Air Picture
RBC	Remote Briefing Capability
RCS	Radar Cross Section
RF	Radio Frequency
SA	System Administrator
SAA	Situation Awareness and Assessment
SAAAC	SAA Augmented Communications
SAAFD	SAA Friendly Order of Battle Display
SAAHLP	SAA On-Line Help
SAATD	SAA Terrain Delimitation
SAM	Surface-to-Air Missile
SAR	Search And Rescue
SATDCD	SAATD Classified Data
SEAD	Suppression of Enemy Air Defenses
SLAM	Simulation Language for Alternative Modelling
SUM	Software User's Manual
TACELINT	Tactical Electronic Intelligence
TACREP	Tactical Report

TADIL	Tactical Digital Information Link
TAP	Theater Air Planning
TBMCS	Theater Battle Management Core Systems
TBMWD	Theater Ballistic Missile Warning and Display
Tdbm	Track Database Manager
TEL	Transporter-erector-launchers
TESS	Tactical Engagement Simulation Suite
TEWA	Threat Evaluation and Weapon Assignment
TOI	Tracks of Interest
TOT	Time on Target
UAV	Unmanned Aerial Vehicle
UB	Unified Build
UM	User Manual
USMTF	United States Message Text Format
UTM	Universal Transverse Mercator
WAN	Wide Area Network
WCS	Weapon Control System
WebAD	Web Airspace Deconfliction system
WVS	World Vector Shoreline
WX	Weather Briefing

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RAP simulation environment characteristics

4. AUTEURS (Nom de famille, prénom et initiales. Indiquer les grades militaires, ex.: Bleau, Maj. Louis E.)
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14. The Recognized Air Picture (RAP) is an important element of Air Force Operations that can be associated to the Common Operational Picture (COP). With the Common Tactical Picture (CTP), they provide the Air Force Commanders with the necessary situation awareness (SAW) giving, in real-time, the states of deployed friendly and enemy assets. In the 13dw project, DRDC Valcartier investigated concepts that could improve the implementation of a dynamic RAP and its exploitation for the management of Canadian Air Forces resources in real-time operations. Such an implementation requires the definition of a reference scenario and the development of a simulation tool. On the one hand, an analysis of five existing scenarios led to the choice of the North Atlantis scenario, on top of which depicting a Combat Search and Rescue (CSAR) mission vignette was developed. On the other hand, the analysis of some existing simulation tools (two commercial tools and two R&D tools designed at DRDC Valcartier) led to recommendations for the development of a dynamic RAP tool..

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Recognized air picture

RAP

COP

CSAR

simulation environment

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