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A synthetic environment for the Arctic: applied research project 13oe final report

A. Taylor and P. Hubbard

Defence Research and Development Canada – Ottawa

Technical Report
DRDC Ottawa TR 2012-138
October 2013

Canada

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Abstract

The aim of Applied Research Project 13oe was to identify and address capability gaps for conducting simulated exercises and training in the Canadian Arctic. The Canadian Forces Air Warfare Centre (CFAWC) was the primary client, but guidance from other simulation communities was solicited through the Synthetic Environment Working Group. The project team instituted a phased plan for a contractor delivered Arctic simulation capability. In the first phase, a survey report was commissioned to identify capability gaps in Arctic simulation for DND. The report found that in the Arctic, the important effects (e.g. on vehicle mobility, human performance, and logistics) are caused by extreme terrain and weather. For the second phase, realistic simulation of weather and its effects on entities was selected for demonstration in a distributed synthetic environment. A weather server was commissioned to store and disseminate environmental conditions. The effects on entities were showcased in the serious game VBS2. VBS2 was modified to pull information from the weather server, and modify the behaviour and performance of entities in its synthetic environment accordingly. These final products were delivered in March 2012 and successfully demonstrated to CFAWC and other members of DND.

Résumé

Le projet de recherche appliquée (PRA) 13oe vise à développer un environnement synthétique pour l'Arctique. Notre client principal est le Centre de guerre aérienne des Forces canadiennes (CGAFC), mais nous avons aussi sollicité les commentaires d'autres groupes de simulation par l'intermédiaire du Groupe de travail sur les environnements synthétiques. L'équipe du projet a élaboré un plan en plusieurs phases qui vise à créer une capacité de simulation de l'Arctique qui serait fournie par un entrepreneur. Dans la première phase, on a commandé une étude afin de cerner les lacunes pour le MDN des simulations de l'Arctique. Cette étude a révélé que dans l'Arctique, les effets les plus importants (sur la mobilité des véhicules, le rendement humain et la logistique, par exemple), découlent du terrain et des conditions météo extrêmes. Pour la deuxième phase, nous avons voulu démontrer, dans un environnement synthétique réparti, une simulation réaliste du climat et de ses effets sur les entités évoluant dans cet environnement. Un serveur météo a été créé afin de stocker et de diffuser les conditions climatiques. Les effets sur les entités ont été démontrés dans le jeu réaliste VBS2, modifié afin d'interroger le serveur météo et de modifier en conséquence le comportement et le rendement des entités évoluant dans l'environnement synthétique réparti. Ces produits ont été livrés en mars 2012 et une démonstration a eu lieu en présence du CGAFC et d'autres membres du MDN.

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Executive summary

A synthetic environment for the Arctic: applied research project 13oe final report

A. Taylor, P. Hubbard; DRDC Ottawa TR 2012-138; Defence Research and Development Canada – Ottawa; October 2013.

Background: Synthetic environments have become indispensable tools for supporting training and concept development in the Canadian Forces, but simulators are limited by the lack of realistic environmental conditions. This is particularly significant for the Canadian Arctic. The Canadian Forces have committed to supporting Arctic operations for sovereignty and security. Improving Arctic environment support in synthetic environments would provide new capabilities to the CF in support of their Arctic priorities. Applied Research Project 13oe was approved to identify specific capability gaps in existing simulators for representing the Arctic, and demonstrate improvements addressing those gaps. Its main client was the Canadian Forces Air Warfare Centre (CFAWC). The project ran from 2009 to 2012, and was split into two phases. In the first phase a survey report was commissioned to help identify capability gaps for Arctic simulation. In the second phase improvements were made to an existing simulation tool to address those gaps.

Principal results: The survey report identified seven areas relevant for Arctic operations: terrain, weather, human performance, mobility, communications, logistics, and surveillance. The first two, terrain and weather, were identified as causes of the remaining five. Arctic weather and terrain is extreme, making operations difficult in ways specific to each domain. For example, low visibility in fog or storms lowers the safe speed of flying aircraft. Other effects, such as logistics and surveillance, are important but not as relevant to tactical-level synthetic environment scenarios. A subset of the causes and effects was selected for demonstration of new features in a distributed synthetic environment. First, a weather server was commissioned. In contrast with some other larger projects, particularly from the US, in which complete weather systems are simulated, the commissioned server is lightweight and generates simple weather patterns that are completely defined by the user. Weather information is distributed to multiple simulators using the Distributed Interactive Simulation specification. In order to demonstrate weather effects, a plug-in was created for VBS2, a commercial off-the-shelf serious game. The plug-in modified the VBS2 internal weather according to the conditions broadcast from the weather server, and adjusted some behaviours of entities in its simulation accordingly. Our focus was on the dissemination of weather conditions, so the specific effects in VBS2 are meant to be representational and are not complete or validated.

Significance of results: The weather server and VBS2 modifications were demonstrated to the client community in March 2012. The project was well-received by the community. CFAWC expressed interest in employing the weather server directly in some of their distributed flight simulators. In contrast to large all-encompassing weather solutions being

pursued by our foreign partners, the concept of a streamlined weather server is appealing for the Canadian Forces. It is simpler to support and deploy and can provide the capability to improve the range of weather conditions supported in distributed simulation.

Future work: The weather server is the first step in improving environmental fidelity in distributed simulation. However, to fully implement better weather, there remains the larger task of modifying all the simulators participating in a distributed simulation to support a standard weather dissemination protocol and to implement its effects on all entities. Additionally, there is a need to validate the effects of weather in each simulator. In 2012, DRDC Ottawa divested synthetic environment research, and therefore this work will need to be taken up elsewhere in DRDC or the Canadian Forces.

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A. Taylor, P. Hubbard ; DRDC Ottawa TR 2012-138 ; Recherche et développement pour la défense Canada – Ottawa ; octobre 2013.

Contexte : Les environnements synthétiques sont devenus des outils indispensables à l'instruction et au développement des concepts des Forces canadiennes. L'utilité des simulateurs est toutefois limitée, car les conditions environnementales n'y sont pas encore simulées de façon réaliste. Ce problème est particulièrement important dans le cas de l'Arctique. Les Forces canadiennes se sont engagées à défendre la securité et la souveraineté de l'Arctique. Améliorer le réalisme du climat arctique dans les environnements synthétiques permettrait aux FC de mieux appuyer leurs priorités en Arctique. Le projet de recherche appliquée 13oe a été approuvé dans le but de cerner les lacunes actuelles des simulateurs de l'Arctique et de démontrer certaines améliorations en ce sens. Son client principal était le Centre de guerre aérienne des Forces canadiennes (CGAFC) ; ses deux phases ont été échelonnées entre 2009 et 2012 inclusivement. Dans la première phase, nous avons commandé une étude afin de mieux cerner les lacunes des simulations de l'Arctique. Dans la deuxième phase, nous avons amélioré les simulateurs existants afin de combler les lacunes relevées.

Résultats principaux : L'étude a cerné sept aspects pertinents aux opérations en Arctique : le terrain, les conditions météorologiques, les performances humaines, la mobilité, les communications, la logistique et la surveillance. L'étude a aussi jugé que les deux premières, c'est-à-dire le terrain et les conditions météo, font partie des causes des cinq autres facteurs. Dans l'Arctique, les conditions météo et le terrain sont extrêmes, ce qui complique les opérations de façon propre à chaque facteur. La visibilité très basse en temps brumeux ou pendant les orages, par exemple, réduit la vitesse de vol sûre des aéronefs. D'autres répercussions, entres autres sur la logistique et la surveillance, restent importantes, mais ne sont pas pertinentes aux scénarios tactiques en environnement synthétique. Un sous-ensemble des causes et effets a été choisi afin de démontrer les améliorations apportées à l'environnement synthétique réparti. Un serveur météo a d'abord été créé. Contrairement à d'autres projets, qui simulent des systèmes climatiques complets, ce serveur léger génère des fronts météorologiques simples complètement définis par l'utilisateur. Ces données météorologiques sont diffusées aux simulateurs à l'aide de la norme des simulations interactives réparties (Distributed Interactive Simulation, ou DIS). Un module a été créé pour Virtual Battlespace 2 (VBS2), un jeu réaliste commercial, dans le but de démontrer les effets climatiques. La version adaptée de VBS2 modifie son climat en fonction des données diffusées par le serveur météo et adapte en conséquence le comportement des entités qui y sont simulées.

Portée des résultats : Le serveur météo et les modifications à VBS2 ont été démontrés à la communauté des clients en mars 2012, et ce projet a été bien reçu. Le CGAFC souhaite utiliser directement le serveur météo dans certains de ses simulateurs de vol répartis.

Contrairement aux vastes solutions climatiques qui intéressent nos partenaires étrangers, les Forces canadiennes préfèrent l'idée d'un serveur météo simplifié. Il est plus simple de déployer et d'assurer le soutien technique d'un tel serveur, qui rend possible l'amélioration de la gamme des conditions climatiques prises en charge par les simulations réparties.

Recherches futures : Le serveur météo constitue la première étape de l'amélioration du réalisme climatique dans les simulations réparties. Pour réellement simuler les conditions climatiques de façon plus réaliste, cependant, il faudra ajouter à tous les simulateurs d'une simulation répartie la prise en charge d'un protocole standard de diffusion des données météo. Il sera aussi nécessaire de valider les répercussions des conditions météorologiques dans chaque simulateur. Toutefois, comme RDDC Ottawa ne fait plus de recherches en environnements synthétiques répartis, d'autres au sein de RDDC ou des Forces canadiennes devront prendre la relève.

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1 Introduction

In 2012, the potential for synthetic environment-based training and experimentation is limited by the lack of realistic and varied environmental conditions. Simulated exercises and scenarios take place almost exclusively on sunny days with perfect visibility. This deficiency is particularly significant for the Canadian Arctic.

The Canadian Forces have committed to prioritizing Arctic operations in support of Canadian sovereignty and security [1, 2]. Because it is an extreme weather environment, the CF would doubly benefit from improved Arctic simulation to support missions with training and concept development. In 2009, DRDC Ottawa embarked on a project to address this deficiency: Applied Research Project 13oe: A Synthetic Environment for the Arctic (herein referred to as ARP 13oe). The goals of the project were to identify specific capability gaps in existing simulators for representing the Arctic, and demonstrate improvements. This final report for ARP 13oe gives an overview of the project history, describes its findings and outputs, and presents a way forward.

1.1 Project summary

ARP 13oe was a three year project aiming to identify and address capability gaps for the conduct of simulated exercises and training in the Canadian Arctic. The primary client and sponsor for the project was the Canadian Forces Air Warfare Centre (CFAWC). The project was intended to be delivered primarily through contract in order to capitalize on existing capability and grow future Canadian industry expertise that could respond to future Canadian Forces (CF) needs. During the first year of the project, DRDC Ottawa staff consulted with the client community to narrow the project scope and ensure its relevance to the Canadian Forces. A statement of work (SOW) was written based on this and other feedback obtained through the Synthetic Environment Working Group (SEWG)[1]. The SOW was designed to be comprehensive and include further scoping of the project.

Contract work was divided into three phases. The first phase required the delivery of a detailed survey of challenges specific to Arctic operations. The survey was to identify the impact of these challenges to simulation in synthetic environments, and propose methods of addressing those gaps. The final report for the first phase was to include a detailed specification for a synthetic environment for the Arctic. In the second phase, the contractor was tasked with the creation of the synthetic environment specified in the first phase after consultation and modification with the DRDC project team. The third phase of the contract provided a call-up vehicle for follow-on work to exploit the new synthetic environment by adding additional features or building new scenarios. The third phase began after the end of ARP 13oe, and was provided to simplify the delivery of additional related work funded by the CF or a project extension within DRDC.

The project was delivered on schedule. The main contract was awarded to Acron Capability

[1] A community of groups within the Canadian Forces and DRDC who meet twice annually to discuss issues related to the use of synthetic environments.

Engineering midway through the project's second year. Phase I was delivered early in the project's third year, leading to a compressed schedule for the delivery of the synthetic environment specified in Phase II. The project also underwent a reduction in funds in its second year due to budget restrictions. Because the contract was already delayed, this was absorbed with minor impact. The final products were demonstrated to the client community in March 2012. The outputs of phase I and phase II are described in detail in Section 2. DRDC Ottawa divested its synthetic environment research in April 2012 and the project was not extended.

1.2 How the project developed from its initial vision

ARP 13oe was originally formulated as described in its quad chart (Figure 1). The initial plan had four major steps:

1. Establish requirements.
2. Develop a synthetic environment.
3. Run war-game scenarios.
4. Deliver a persistent distributed simulation

Detailed requirements identified in step one would inform the development of the synthetic environment in step two. War-gaming in step 3 would provide feedback to iterate the synthetic environment design. The war-gaming was planned to be based on three scenarios: civilian major air disaster (MAJAID), a sovereignty challenge [3, 4], and a terrorist attack. The final deliverable was to be a persistent multi-simulator distributed simulation (step four).

The project's chief client was the Canadian Forces Air Warfare Centre. Its initial champion was posted shortly after the project award, leading to a succession of clients with varying interest in the project. Requirements were ultimately driven by the synthetic environment community consensus, arrived at following progress presentations at SEWG meetings.

A number of changes were made from the original concept and the four steps became the three phases in the contract. Step one: establish requirements was fulfilled in Phase I, and step two: develop a synthetic environment was fulfilled in Phase II. Step three: war gaming became an optional follow-on phase of the contract, due to scheduling constraints. Step four: delivery of a persistent distributed simulation, while a noble goal in the context of the Air Force CASE project [5], was overly ambitious. Moreover, the wider SEWG community remains undecided as to which architecture and toolset will be adopted and persist in each service environment. Instead, the scope of the work was reduced to focus on weather information dissemination in a distributed simulation environment, as described below.

The three scenarios were down-selected to one, the major air disaster. The major air disaster was the most relevant and timely scenario for the RCAF, and the down-selection was in line with a natural right-sizing and re-focusing of the project scope.

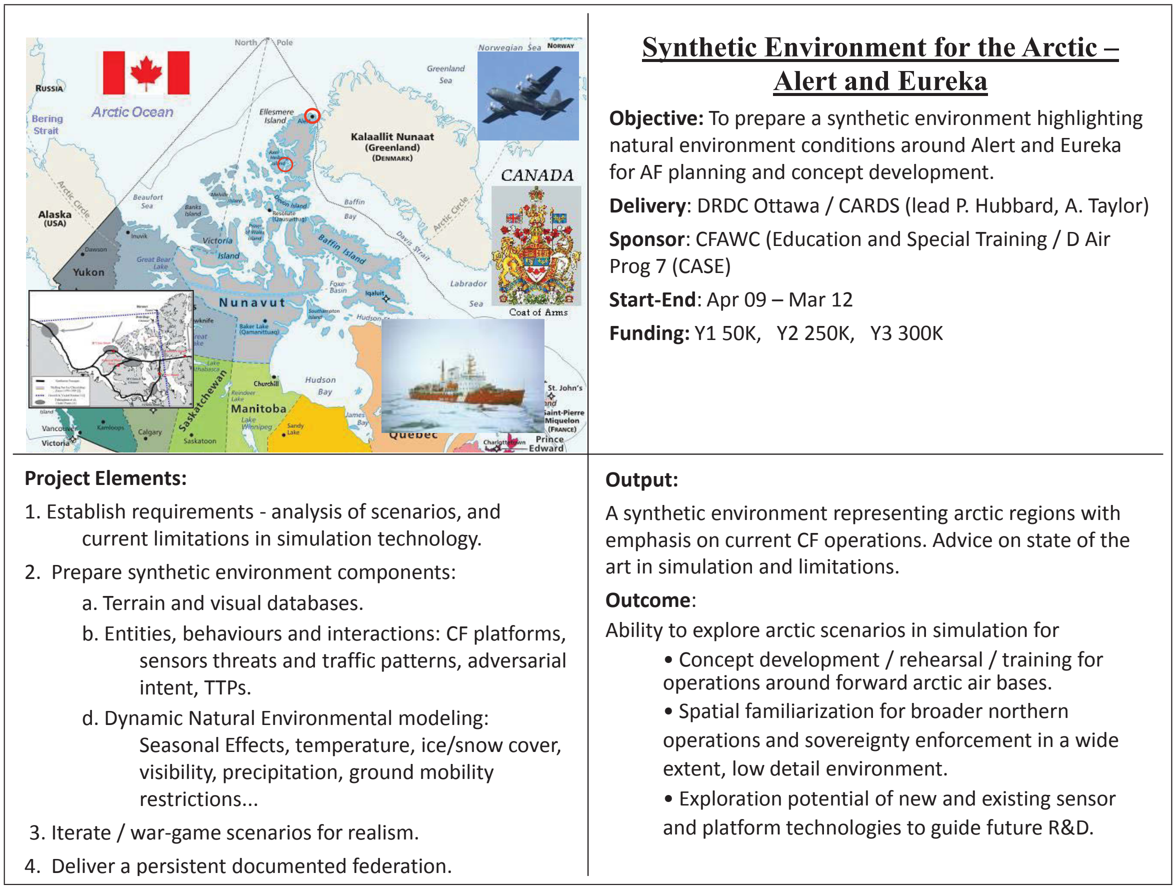

Figure 1: The original 13oe quad slide.

The scope of the synthetic environment was reduced. Initially designed to be a complete representation of the Arctic theatre, it was simplified to showcase the new features identified as an output of Phase I. The original concept for the synthetic environment included high-resolution inserts for key geographic areas (Alert and Eureka), with low-resolution areas covering the rest of the Arctic territory. The contractor ultimately developed a prototype of a tool to define and distribute weather patterns across a low-resolution representation of full Arctic terrain. The new features such as reduced visibility and mobility due to real-time weather were implemented as modifications to Virtual Battlespace 2 (VBS2)[2], and are discussed in more detail in Section 3.2.2. VBS2 is designed for tactical encounters, and the version used in this research has limitations on map size (50 KM X 50 KM) and modifiability, that limited the scope of proposed changes. The region modelled in VBS2 was moved from Alert and Eureka Gascoyne Inlet on Devon Island, west of Resolute to support a land and water crash site and indirectly support the 2012 Joint Arctic Experiment lead by the CF Warfare Centre. These decisions are discussed in more detail in Section 3.

[2]VBS2 is a commercial serious game by Bohemia Interactive Studios. It is an adaptation of an entertainment focused product, specialized for military training and concept development. It is used extensively by the Canadian army.

1.3 The Arctic major air disaster scenario

The major air disaster scenario was fleshed out with information gathered during a visit to the Joint Rescue Coordination Centre (JRCC) in Trenton, ON. The project team met with Search And Rescue (SAR) office commanders and technicians, and were given a tour of the command center and description of its operation. As a result of international agreements, Canada has a responsibility to respond to any civilian aircraft crash in the Canadian Arctic. The rescue effort would be launched from the air base in Trenton, but additional local assets would also be tasked. These are mainly volunteer pilots based out of the Canadian north.

In SAR emergencies, the first task is often to locate the crash site. However as large commercial aircraft are very likely to have a transponder, its location is likely to be known. Thus the first task in the air disaster scenario is to determine the condition of the wreckage and any survivors. If possible, local pilots would also provide assistance, but a more likely scenario is for a C-130 Hercules aircraft from Trenton to airdrop SAR techs and a rescue package (containing shelter, food, heat, etc.). In some cases, a crash may occur near an airport, as with the disaster in Resolute during Op Nanook in 2011 [6]. In that case ground-based help may be available to provide help more quickly.

As a result of this analysis, the project team decided to use the basic idea of a crash with survivors and air reconnaissance as the basis of the main scenario to showcase the synthetic environment developed in Phase II.

2 Phase I: Survey

The Arctic was considered in terms of seven fundamental factors: terrain, weather, human performance, mobility, communications, logistics, and surveillance. These were reviewed in general, then again for impact on synthetic environments. They may also be sorted into two categories: causes and effects. In the extreme austere environment of the Arctic, weather and terrain are causes. These produce effects in the other five areas of human performance, mobility, communications, logistics and surveillance. Here we review both categories in turn.

2.1 Causes: terrain and weather

The Arctic is vast and largely uninhabited. The isolation means operations must bring everything they will need with them, creating logistical difficulties. The terrain itself is difficult to traverse, alternately rugged, icy, or composed of uncertain permafrost. Snow covers the ground in winter months. There are few roads, making air travel a necessity for covering long distances. Water in the Arctic is also problematic, as it can be covered with ice, preventing ship traffic, or choked with icebergs, making water travel perilous.

Arctic weather is notorious and undoubtedly the root cause of almost all factors considered here. Seasonal changes in the Arctic are severe. In the winter, days are very short and the temperature is very low. Snow and ice cover land and water. In the spring the days grow longer but conditions would qualify as winter in more southern regions. Only in summer does the snow and ice retreat; with this come very long days and short nights. By autumn the days grow short again and snow returns. Wind also varies with the seasons, with very windy conditions in the winter and only moderate wind in the summer months. Planned (i.e. not emergency) operations in the Arctic normally take place in the summer because of the difficulty in operating in the extreme weather in the other months [7].

2.2 Terrain and weather in synthetic environments

In distributed synthetic environments, terrain is usually sourced from a common terrain database. Different federates have their own internal terrain representation, so the common database information is usually converted ahead of time to each consumer's format. Conversion to different formats with varying fidelity leads to problems in consistency when simulators are networked together[3]. Industry standards such as SEDRIS [4] and the Common Database (CDB) [5] are helping to overcome this problem. But fundamental issues remain because different types of simulators have different terrain requirements. For example, fast air simulators need to represent large areas with low resolution, while tactical ground simulators need to represent smaller areas with higher detail. The vastness of the

[3] Often termed the fair-fight problem

[4] `http://www.sedris.org/`

[5] `http://www.presagis.com/products_services/standards/cdb/`

Arctic exacerbates the problem, as does the paucity of source data. The problem of consistency in distributed simulators is also exacerbated by the need to represent varying terrain conditions similarly across the distributed simulation. This is an open problem.

Weather simulation has similar challenges. Standard communication protocols such as Distributed Interactive Simulation (DIS) do not contain sufficient detail about weather conditions to provide for consistent results in different simulators. For example, in air combat each participant should see the same cloud volumes, but there is no standard way of representing this level of detail in DIS. Each simulator is free to represent weather and its effects differently. So the full scope of providing weather in synthetic environments has two aspects: the accurate and precise distribution of weather conditions to the distributed simulation, and the validation of the resulting effects in each simulator. The distribution problem is the simpler of the two from a technical perspective. However it requires the community to agree on a standard representation. Modelling and validating consistent effects in each simulator is the topic of the next few sections.

Generation of weather can be the result of a robust simulation, as is the case with the U.S. Government Off The Shelf (GOTS) Ocean, Atmosphere, and Space Environmental Services (OASES) system. However OASES is difficult to configure and use. The US Department of Defence has more recently developed a product called the Environmental Data Cube Support System (EDCSS) that aims to address all needs for weather in distributed simulation. It does not simulate weather, but does distribute pre-programmed weather conditions. It is also a complex product, and as of this writing is not freely available to Canadian government due to export restrictions. Realistic simulation of weather was ultimately deemed to be outside the scope of ARP 13oe.

2.3 Effects: Consequences of terrain and weather on human performance, mobility, communications, logistics, and surveillance

The performance of humans varies with environmental conditions. In the Arctic, the cold temperature is the main source of problems. Heavy clothing encumbers movement and reduces dexterity; cold, gloved fingers are clumsy. Icy and snowy terrain slows movement, snow and rain impair vision and prolonged exposure leads to hypothermia and impaired decision-making. These effects present different implementation challenges depending on who is controlling a human entity in a simulation. An artificial intelligence controller would need to interpret environmental conditions and modify its performance accordingly. A human controller would need to be presented with appropriate effects via the interface. For example, animations could be slowed for actions requiring dexterity (e.g. reloading a rifle). Properly rendered visual effects would produce the correct result naturally, e.g. slower movement in whiteout conditions.

Vehicle mobility is impacted by both terrain and weather. Air movement is impacted by icing, visibility, and wind. Extreme cold also stresses aircraft and can require remedial measures (alternate lubricants, more frequent maintenance, etc.). Sea movement is impacted by ice flow, fog, and surface water conditions. Land movement is impacted by ground conditions; tundra and crevasses or ice build-up may be impassable or necessitate the use of specialized vehicles. Implementation of these effects depends on the domain. Ground effects rely on the interaction between the movement simulation model, the terrain database and the received weather. Similarly, air effects rely on the flight model and atmospheric conditions. All effects may depend on the AI responding realistically to the environment conditions, or on a human perceiving or being constrained by realistic rendering or changes in vehicle and animation speeds as with human performance effects.

Communications links cannot be assumed in the Arctic. With little infrastructure, flights over the Arctic may be isolated from the rest of the world. Operations in theatre will need to bring their own communications infrastructure. In simulation, this requires consideration of available radio links when designing scenarios, and possibly realistic propagation modelling if this is an important factor for the scenario.

Logistics includes aspects such as moving and housing troops or storing supplies. This is challenging in the Arctic because of its isolation – troops must either bring everything they need or be re-supplied by air drops. However such aspects are rarely modelled in a synthetic environment exercises; they are more frequently explored in operational research studies. Logistics would come into play in the planning phase of a large exercise, but for small scale simulations, they are often assumed.

Surveillance of the Arctic is a pressing issue for the Canadian Forces. The Arctic is a vast area with little infrastructure, making it difficult to maintain situational awareness. However the larger surveillance issues are less relevant here as the focus of this project is on small-scale simulations and scenarios.

2.4 Capability gaps for synthetic environments for the Arctic

As a result of the survey, capability gaps were identified in COTS and GOTS synthetic environments for representing the seven factors described above. The causes, terrain and weather, are generally produced by dedicated servers because they affect all participants in a distributed simulation. Whether this happens at simulation run-time or in advance depends on the situation; terrain usually does not change over the course of a simulation event and is generated and shared ahead of time, while weather simulation is more valuable if it can change and be shared at run-time. Of course, representation of weather must be modelled in each simulator in a manner appropriate to its own scope and consistent across the network. The challenge is to establish a communication protocol or interoperability standard between the weather server and its consumers. All simulators must understand the same messages. Practically, this means each simulator must be modified to accept messages from the server. The five effects (human performance, mobility, communications, logistics and surveillance) must be validated in each simulator to ensure a fair fight and common environment.

There is no single approach to addressing this gap: a communication protocol must be agreed upon, servers must be created, and effects in each simulator must be modelled and validated. Effects may be simple, e.g. limiting maximum vehicle speeds or changing AI behaviour decision thresholds, or more involved, e.g. complex interactions between precipitation types, different terrain and vehicle tracks, effects of icing on wing shape or nonlinear degradation in sensors and decision-making. Specific capability gaps were discussed for inclusion in the synthetic environment created in Phase II. These are discussed in the next section.

3 Phase II: Creating an Arctic Synthetic Environment

3.1 Phase II planning

The contractor produced a proposal for potential work in Phase II in the survey report [8]. The proposal made several recommendations for Phase II development. In the analysis, several options were considered:

- A weather server, based on the GOTS OASES software, or custom-developed;
- A terrain conditions server;
- A communications server, based on the Asti hardware and software system currently used by the CF;
- An ice cover and ice flow server, based on a modification of the OASES software;
- A satellite server, based on STK®[6] or the open source GPredict[7];
- An arctic environment implemented in VBS2;
- The creation of Arctic terrain databases;
- The creation of entities and their customization for particular simulators.

The project team discussed these options with Acron, considering the available time and budget. It was determined that the most value for money, in terms of demonstrating new features within a synthetic environment, could be attained by exploring a weather server to demonstrate the distribution of a *cause* (see Section 2) and customizing a specific host to demonstrate the *effects* on entities. This was also identified at a SEWG meeting as a high priority for the CF Air Warfare Centre. Thus, a low-complexity weather server was commissioned. To showcase the real-time effects of the distributed weather conditions, the creation of an Arctic environment and scenario in VBS2 was also commissioned. This would allow for demonstration of weather effects, and provide a reusable environment for the CF. Finally, because VBS2 has some limitations on visualization, the team commissioned an additional demonstration of the weather server effects in a dedicated image generator. Based on this direction, Acron prepared a detailed specification and work plan for Phase II [9].

3.2 Phase II deliverables

In March 2012, Acron delivered the work commissioned for Phase II, including the weather server, VBS2 modifications (a weather plug-in, scenario, and models), and a final report [10]. The deliverables were demonstrated at DRDC Ottawa to the local SE community in April, 2012. The deliverables and demonstration are described and summarized below.

[6] `https://www.agi.com/products/stk/Default.aspx`

[7] `http://gpredict.oz9aec.net/`

3.2.1 Weather Server

The weather server software is designed to store and disseminate information about regions of weather anywhere on the Earth. It is documented in detail in the contractor's final report [10] and summarized here. The weather server has three functional parts: (i) a graphical user interface (GUI) that allows the user to define weather patterns, (ii) a database of weather patterns, and (iii) a set of methods to communicate information from the database to entities in a distributed simulation. We describe first the database of weather patterns, then the GUI and communication methods.

The weather server database contains a background (default) weather condition, and the collection of weather patterns in the database. Weather patterns are represented by rectangular three-dimensional volumes that can move across the world. This approach is based on weather representation in the Common Image Generator Interface (CIGI) standard. Each weather pattern has a list of parameters (including weather conditions such as precipitation, temperature, and wind speed, and volume definitions such as size, position, and movement vectors). Weather patterns also have a user-set transition zone allowing gradual changes at their borders. The weather server tracks these volumes using XML-formatted text files.

As a single weather pattern passes over a specific location (in the air or on the surface), the weather at that location goes through a series of changes. Initially the location will have the default background weather conditions. As the transition zone moves over the location its conditions will gradually change to match those defined inside the volume. As the volume leaves the location, there is a reverse transition to the default conditions. At a location that is inside two or more volumes simultaneously, their conditions are averaged or combined as needed.

The weather patterns are created using the weather server's GUI, shown in Figure 2. The user is presented with a three-dimensional model of the earth, and can enter new volumes by providing all the necessary parameters. The GUI allows the user to see the volumes move over the world as time plays out in a simulation and update them in real-time.

Weather conditions are communicated to simulators by either pull or push mechanisms using the DIS standard. The core functionality offered by the weather server is this set of methods for computing or interpolating weather at specific locations. The weather data is embedded in a custom Protocol Data Unit (PDU) message. For example, by sending a particular request, the weather server will update weather conditions at a particular location at specified intervals. Alternatively a simulator can ask for a one-time report at a location. Simulators can also ask for the complete weather volume information, a useful feature if the consumer has a CIGI-compliant image generator capable of rendering the weather based on the raw volume information. A complete set of information requests is detailed in the documentation [10]. The weather server is in principle compatible with any DIS-compatible simulator; however those simulators must be modified to read the custom PDU message, and change their own internal weather conditions appropriately.

The weather server ensures consistent weather (a *cause*) is available across the distributed

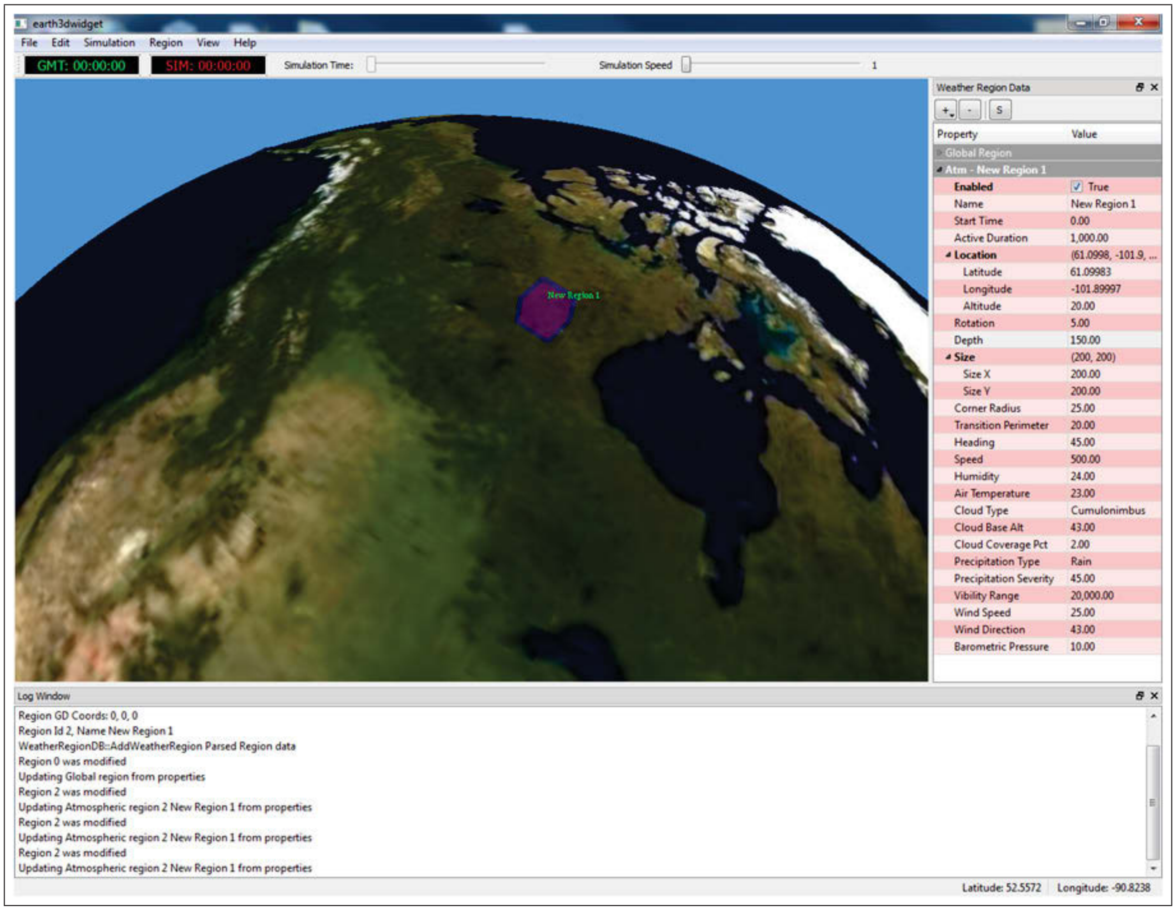

Figure 2: Screen capture of weather server interface.

simulation. But the behaviour of each simulator once it receives the weather information is not under the control of the weather server. It must be agreed and validated through a different mechanism, for example by agreement through the Distributed Simulation Engineering and Execution Process (DSEEP).

3.2.2 VBS2 Modifications

The project team selected VBS2 software to demonstrate the weather server's operation, and show how weather conditions can change the behaviour of entities in a scenario. The contractor developed a software plug-in for VBS2 to receive data from the weather server and apply the conditions to the scenario. The plug-in queries the weather server for conditions at the location of a particular entity. The plug-in then modifies behaviours and simulation effects (e.g. visualization effects) within VBS2 accordingly. A similar plug-in could be created for any host software such as a computer-generated forces tool.

A scenario with a crashed airplane and several ground and air units was also developed in VBS2, situated in Gascoyne Inlet. The scenario demonstrates the effects of weather by contrasting the behaviour of units within a fast-moving weather pattern of precipitation, cold and fog, with the behaviour of units completely outside any weather pattern. In this demonstration the effects are simple and not validated; the plug-in somewhat arbitrarily modifies entity behaviour variables in VBS2, affecting speed, fuel consumption, and fatigue. These effects and the scenario are described in more detail in the next section.

3.2.3 Client Demonstration

DRDC hosted a demonstration of the developed software and synthetic environment in March 2012. Attendees included representatives from the primary client at the CF Air Warfare Centre, as well as representatives from the CF Warfare Centre, and the CASE project. The agenda included:

- Project overview;
- Review of the survey report;
- Overview of the weather server;
- Demonstration of the synthetic environment in VBS2.

The VBS2 demonstration showcased the complete output of this project. A vignette was designed for VBS2 simulating a major air disaster. The scenario took place on a 50x50 km map, created for VBS2 using open-source elevation data, and centered on Gascoyne Inlet. The contractor prepared models for a downed aircraft, icebergs, vehicles, and winter-gear soldiers, and arranged them in the scenario. Figure 3a shows a view of the site in VBS2. The weather server generated a storm that passed through the map over a short time. VBS2 received environmental conditions from the weather server via its custom plug-in. Three effects were demonstrated over the scenario. In each case two entities were prepared, with one affected by weather, and the second unaffected by weather, allowing for visual comparison by the audience.

In the first demonstration, two helicopters fly a circuit around the map, as if doing low-level reconnaissance over the crash site (Figure 3b). As the weather pattern moves through the area, the visibility is reduced and precipitation increases. The plug-in modifies the visualization of the scenario with increased fog, rain, and winds. The plug-in also modifies entity behaviour in three demonstrates. First, the speed of the helicopter is reduced to simulate the effect of reduced visibility on a human pilot. The second demonstration shows the effect on fuel consumption in land vehicles. Two BV206 land vehicles move in a straight track (Figure 3c). As the weather pattern passes through the region, fuel consumption for the vehicle can be seen to increase appropriately when it is within the weather volume. The third demonstration shows human effects. Two soldiers move in a straight track and the affected one's fatigue attributes are increased as the weather worsens (Figure 3d).

In addition to these three demonstrations, a CIG-compliant image generator, Genesis RTX, was used to show visibility and precipitation effects as a weather pattern for a storm passes through the scenario. In the demonstrated implementation, the imagery characteristics

(a) The crash site.

(b) A helicopter reconnoitering the crash site.

(c) BV206

(d) Dismounted soldiers

Figure 3: VBS2 screen captures from the demonstration scenario.

are affected only by the weather at the current location. Weather patterns with volumes that do not contain the current location do not affect the image, i.e. the IG cannot show approaching fog banks; it can only show the effect of reduced visibility as the fog arrives.

The demonstration was well-received by the audience. CFAWC expressed interest in employing the weather server immediately in their CF-18 simulators.

4 Conclusions

4.1 Lessons learned

The model of delivering ARP 13oe primarily through contractors was a success. The RFP attracted a contractor with direct Arctic and CF experience, who delivered high quality work with a relatively small budget. The contract was designed with flexibility in mind. Phase II and III were both optional, and flexible enough to leave their full specification to the completion of the previous phase. The third phase was not optioned by DRDC Ottawa due to the divestment of its synthetic environment research mandate. Had this continued it would have been valuable for transitioning the work and tailoring it to CFAWC's applications. However the third phase was leveraged by DRDC Toronto and the CF for further development in VBS2.

Some aspects of the project execution could have been improved. While the contract competition was successful, only one bidder responded. Reasons for this may simply be that Canada has a small industrial base for performing synthetic environment development, especially given the budget. Because Phases II and III were optional, only the first phase was listed as funded, despite the fact that sizeable funding was approved in the ARP for Phase II. Failing to communicate this to bidders may have made the contract appear risky. Finally, the project plan suffered initially from a lack of focus. The potential scope of uses for synthetic environments is very large. Had the SOW been linked to an existing CF project such as CASE, the requirements for the research output could have been more focused and the resulting product more relevant in the nearer term.

4.2 Overall Evaluation

The project was a success: ARP 13oe successfully anticipated the client desire for improvements in Arctic simulation, and it was completed on time and on-scope. Due to contracting delays in its second year, it was under-budget in FY10/11, and over-budget in FY11/12. ARP 13oe impacted the CARDS SE program at a fundamental level by expanding the potential uses of synthetic environments for the CF. It met S&T challenges [11] 4.2 (Capability based planning) and 10.5 (Distributed, adaptable, and on-demand learning, training and rehearsal) by providing increased realism in simulation for Arctic operations. The project also directly addressed CF priority areas of arctic operations and synthetic training.

The use of modelling and simulation in the CF is growing, as is the importance of the Arctic. This project provided support for realistic Arctic simulation for future concept development, war-gaming, and training activities that leverage synthetic environments. In particular, by focusing on the weather, ARP 13oe addressed a capability gap recognized by CFAWC, at SEWG, and within the general SE community for consistent distributed, weather modelling. The weather server developed in this project provides one potential solution that can be immediately applied to provide a new capability for CFAWC. It provides an alternative to more complex weather solutions that may be expensive and cumbersome to manage. The VBS2 modifications can also be directly used by Directorate Land Synthetic Environments, an extensive user of VBS2 in the CF.

Despite weak interest in the first year of the project from the SE community, the survey report summarized in Section 2 was widely circulated and enthusiastically received by that same community [8]. The project's eventual focus on a simple weather server and use of an existing standard were key decisions that make the results better positioned to be exploited by the CF.

4.3 Future work

The causes, weather and terrain, are factors that are fundamental not just for Arctic simulation but also for many other regions. Representation of weather, in particular, is a major barrier to achieving realistic simulation. The weather server prototype produced in this project is ready for use: it currently supports the DIS standard for distributing information, and the CIGI standard for representing weather. Any DIS-compatible simulator can communicate with the weather server if it can be modified to parse the weather information such as was demonstrated here with a VBS2 plug-in. However for serious simulation, a next step would be the development and validation of specific weather effects in each individual simulator.

A natural next step is the use of the weather server in a distributed exercise within the CF infrastructure, at the CFWC or through CASE or another CF client. Further development on weather and terrain will then solve not just problems for Arctic simulation but also for improving realism of other simulation conditions. Large projects such as the US DoD Environment DataCube Support System aims to address this, but access to this tool is not guaranteed. Another approach would be the development of a Canadian tool, as was performed here with the weather server. A simpler, more focused approach could provide all the weather and terrain that is required for small-scale federations for Canadian use.

Follow-on research would focus on continued development of weather dissemination and representation, interfacing and maintaining consistent effects in popular synthetic environment platforms (addressing the fair-fight problem), and the extension of weather effects to terrain and other features such as weapons effects. However, as DRDC Ottawa has divested synthetic environment research, this work will need to be taken up elsewhere in DRDC or the Canadian Forces.

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The aim of Applied Research Project 13oe was to identify and address capability gaps for conduct-ing simulated exercises and training in the Canadian Arctic. The Canadian Forces Air Warfare Centre (CFAWC) was the primary client, but guidance from other simulation communities was so-licited through the Synthetic Environment Working Group. The project team instituted a phased plan for a contractor delivered Arctic simulation capability. In the first phase, a survey report was commissioned to identify capability gaps in Arctic simulation for DND. The report found that in the Arctic, the important effects (e.g. on vehicle mobility, human performance, and logistics) are caused by extreme terrain and weather. For the second phase, realistic simulation of weather and its effects on entities was selected for demonstration in a distributed synthetic environment. A weather server was commissioned to store and disseminate environmental conditions. The effects on entities were showcased in the serious game VBS2. VBS2 was modified to pull information from the weather server, and modify the behaviour and performance of entities in its synthetic environment accordingly. These final products were delivered in March 2012 and successfully demonstrated to CFAWC and other members of DND.

Le projet de recherche appliquée (PRA) 13oe vise à développer un environnement synthétique pour l'Arctique. Notre client principal est le Centre de guerre aérienne des Forces canadiennes (CGAFC), mais nous avons aussi sollicité les commentaires d'autres groupes de simulation par l'intermédiaire du Groupe de travail sur les environnements synthétiques. L'équipe du projet a élaboré un plan en plusieurs phases qui vise à créer une capacité de simulation de l'Arctique qui serait fournie par un entrepreneur. Dans la première phase, on a commandé une étude afin de cerner les lacunes pour le MDN des simulations de l'Arctique. Cette étude a révélé que dans l'Arctique, les effets les plus importants (sur la mobilité des véhicules, le rendement humain et la logistique, par exemple), découlent du terrain et des conditions météo extrêmes. Pour la deuxième phase, nous avons voulu démontrer, dans un environnement synthétique réparti, une simulation réaliste du climat et de ses effets sur les entités évoluant dans cet environnement. Un serveur météo a été créé afin de stocker et de diffuser les conditions climatiques. Les effets sur les entités ont été démontrés dans le jeu réaliste VBS2, modifié afin d'interroger le serveur météo et de modifier en conséquence le comportement et le rendement des entités évoluant dans l'environnement synthétique réparti. Ces produits ont été livrés en mars 2012 et une démonstration a eu lieu en présence du CGAFC et d'autres membres du MDN.

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