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Selection Criteria for the Complex Scenarios used in the IMAGE Project

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Technical Memorandum
DRDC Valcartier TM 2007-561
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Abstract

The objective of the present document is to describe the criteria to be considered in selecting scenarios deemed to be appropriate for the Technical Investment Fund IMAGE. Five selection criteria were identified to be critical: completeness, complexity, relevance, feasibility, and innovation demonstrator. To be considered complete, an IMAGE scenario must include a suitable description, the presence of relevant metrics, an explicit intent, and sufficient background material. To be of adequate complexity, the nature of the interactions, the situation dynamics and the uncertainty present in the scenarios should show characteristics of a complex situation. To be relevant to the CAF, the scenarios should be related to CAF issues, be realistic with regard to CAF operations and involve cooperative users. The feasibility of the scenarios is defined by the quality and maturity of the material, and the ability to implement it in IMAGE. The innovation demonstrator is the capacity of the scenarios to demonstrate the plus-value of the proposed technical tools in IMAGE, namely the simulation, exploration and knowledge representation concepts. An evaluation grid is proposed for each of the selection criteria.

Résumé

L'objectif de ce document est de décrire les critères à prendre en considération dans le choix des scénarios jugés appropriés pour le Fonds d'investissement technologique IMAGE. Cinq critères de sélection ont été identifiés comme étant critiques : exhaustivité, complexité, pertinence, faisabilité et démonstrateur d'innovation. Pour être considéré comme complet, un scénario employé dans IMAGE doit inclure une description appropriée, des paramètres pertinents, une intention explicite, et des documents de support suffisant. Pour être d'une complexité suffisante, la nature des interactions, la dynamique de la situation et de l'incertitude présente dans les scénarios doivent montrer les caractéristiques d'une situation complexe. Pour être pertinents pour les Forces armées Canadiennes (FAC), les scénarios doivent être liés à des questions militaires, être réalistes en ce qui concerne les opérations des FAC et impliquer les utilisateurs. La faisabilité d'un scénario est définie par la qualité et la maturité du matériel, et la capacité à le mettre en œuvre dans IMAGE. Le démonstrateur d'innovation est la capacité des scénarios à démontrer la plus-value des outils techniques proposés dans IMAGE, caractérisés par des concepts de simulation, d'exploration et de représentation des connaissances. Une grille d'évaluation est proposée pour chacun des critères de sélection.

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Executive summary

Selection Criteria for the Complex Scenarios used in the IMAGE Project

Bernier, F.; Boivin, É.; Ducharme, M.; Lizotte, M.; Mokhtari, M.; Pestov, I.; Poussart, D.; DRDC Valcartier TM 2007-561; Defence R&D Canada – Valcartier; October 2007.

IMAGE is a 3-year TIF (Technical Investment Funds) project whose objective is to develop a tool to create a shared, dynamic, global and interactive environment for enhancing the understanding of complex situations relevant to the Canadian Armed Forces (CAF). The development of the IMAGE tool requires the use of scenarios for the exploration of concepts and ideas. The objective of the present document is to describe the criteria to be considered in selecting scenarios deemed to be appropriate for IMAGE. Five selection criteria were identified to be critical to the project: completeness, complexity, relevance, feasibility, and innovation demonstrator. To be considered complete, an IMAGE scenario must include a suitable description, the presence of relevant metrics, an explicit intent, and sufficient background material. To be of adequate complexity, the nature of the interactions, the situation dynamics and the uncertainty present in the scenarios should show characteristics of a complex situation. To be relevant to the CAF, the scenarios should be related to CAF issues, be realistic with regard to CAF operations and involves cooperative users. The feasibility of the scenarios is defined by the quality and maturity of the material, and the ability to implement it in IMAGE. The innovation demonstrator is the capacity of the scenarios to demonstrate the plus-value of the proposed technical tools in IMAGE, namely the simulation, exploration and knowledge representation concepts. An evaluation grid is proposed for each of the selection criteria.

Sommaire

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IMAGE est un projet FIT (fonds d'investissement technologique) de trois ans dont l'objectif est de développer un outil pour créer un environnement dynamique, global, interactif et partagé pour améliorer la compréhension de situations complexes relatives aux Forces armées Canadiennes (FAC). Le développement de l'outil IMAGE nécessite l'utilisation de scénarios dans le but d'explorer concepts et idées. L'objectif de ce document est de décrire les critères à prendre en considération dans le choix des scénarios jugés appropriés pour le projet IMAGE. Cinq critères de sélection ont été identifiés comme étant critiques : exhaustivité, complexité, pertinence, faisabilité et démonstrateur d'innovation. Pour être considéré comme complet, un scénario IMAGE doit inclure une description appropriée, des paramètres pertinents, une intention explicite, et des documents de support suffisant. Pour être d'une complexité suffisante, la nature des interactions, la dynamique de la situation et l'incertitude présente dans les scénarios doivent montrer les caractéristiques d'une situation complexe. Pour être pertinents pour les FAC, les scénarios doivent être liés à des questions militaires, être réalistes en ce qui concerne les opérations des FAC et impliquer les utilisateurs. La faisabilité d'un scénario est définie par la qualité et la maturité du matériel, et la capacité à le mettre en œuvre dans IMAGE. Le démonstrateur d'innovation est la capacité des scénarios de démontrer la plus-value des outils techniques proposés dans IMAGE, caractérisés par des concepts de simulation, d'exploration et de représentation des connaissances. Une grille d'évaluation est proposée pour chacun des critères de sélection.

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1 Introduction

IMAGE (An interactive computer-aided cognition capability for C4ISR complexity discovery) is a TIF project whose objective is to develop a tool to create a shared, dynamic, global and interactive environment for enhancing the understanding of complex situations.

From its original inception, the development of IMAGE has planned to use a limited number of scenarios that would provide a suitable backdrop for the exploration of concepts and ideas. The purpose of this document is to summarize key aspects to be considered in selecting scenarios deemed to be appropriate. It also provides a rating form for assessing potential scenarios.

The work plan of IMAGE mentions the need to define (at least) two scenarios. Scenario A is to support the start-up phase of IMAGE and has a fairly low, but significant complexity. It is used for early prototyping of the modeling, simulation and visualization tools. Scenario B is more comprehensive, realistic and relevant to future users. It supports the main phase of the project and is used to validate concepts and methods.

Scenarios play a critical role in IMAGE.

Scenarios ground the development of relevant concepts – which are quite abstract – in the realm of concrete events / issues. They support the inductive, experimental component of research that is needed to complement its deductive dimension. In particular they provide

- ♦ a context for suggesting approaches and assessing the strengths, weaknesses, applicability and performance of IMAGE;
- ♦ a common focus and shared objectives within the IMAGE team; and
- ♦ for future users, an indication of the relevance and applicability of IMAGE in their own area.

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2 Scenario Evaluation

The evaluation of potential scenarios is performed on the basis of five critical aspects: *completeness, complexity, relevance, feasibility, and innovation demonstrator*.

2.1 Scenario completeness

In the context of IMAGE, a given scenario consists of a compound object made up of four main components. This section outlines their respective *nature*. Subsequent sections address their *attributes* as needed to fulfill the research plan of IMAGE.

To be considered as complete, an IMAGE scenario must include:

- ♦ the *description* of a situation where complexity is present at a *suitable level*. The source may range from an actual, documented event to that of a hypothetical, albeit plausible one. The situation and its vignettes may be expressed by annotated text (such as storybook), data records (with metadata), capture of historical or simulated events, etc.;
- ♦ the *types* and *sources* of relevant information that is (supposedly) available from the theater of the situation, together with their appropriate *metrics*. The available information is typically limited and constrained. When information relates to well defined entities (e.g. the speed of a vehicle, the level of radioactivity in a building), the metric is reasonably obvious. When dealing with non-tangible entities, however (e.g. the operational fitness or the readiness level of an adversary faction), qualitative “soft” metrics need to be applied, and these should be described accordingly;
- ♦ the explicit *intent* / objective pursued by user(s) of IMAGE as the scenario is being explored. It is a common characteristic of a complex situation that its understanding cannot be fully dissociated from the point of view of its observer. This fact is at the root of much of the confusion – and conflicts – that surrounds us. For instance radically different courses of actions (even conflicting assessments) may arise depending on the temporal horizon of the desired effects. In order to limit such potential confusion, IMAGE explorations must have an objective that is as explicitly documented as possible. This is especially critical when multiple experts are involved, to insure that they do share a common intent and work in synergy. This intent may be expressed by annotated text, qualitative / quantitative statements on measurable by-products of the dynamic evolution of the situation, etc. It may be associated with exploring a course of action, training, or a post mortem especially during this initial development phase, it may consist of evaluating / validating particular concepts / methods of IMAGE;
- ♦ *background material* such as auxiliary narratives, models of particular aspects, lessons learned from similar situations, insights from a community of practice, i.e. the set of supplementary material that may help in addressing the problem and facilitating its exploration / implementation.

Judgment needs to be fully exercised in assessing whether this completeness is present to a satisfactory degree in view of the IMAGE work plan.

2.2 Scenario complexity

The selected scenario(s) must exhibit a level and type of complexity that matches the research objectives of IMAGE. IMAGE will consider the scenarios which have the following four characteristics.

2.2.1 Topology and nature of interaction

There is a large number of interrelated elements (entities, factors, effects, etc.) which interact with each other and with their environments, and the interactions are at least partially:

- a- non-linear

Non-linear interactions mean that the combined effect is not equal to and could, in fact, be much greater and different than the sum of constituent effects.

- b- dynamic; and

- c- non-hierarchical

Examples of non-hierarchical interactions include interactions between military, civilian, and aid organizations. Non-hierarchical also means the presence of some feedback mechanism or, in other words, the two-way traffic of information between entities.

2.2.2 Situation dynamics

The time dynamics of the scenario is non-linear and showing some of the following characteristics:

- a- exponential growth / decay;

- b- oscillatory processes; and

- c- phase transition.

“Phase transitions” (3d) develop when some threshold (critical) values of parameters are reached.

- d- Multi-scale processes

A multi-scale process (3e) is a process that occurs at the micro scale, whereas its effects are felt / observed at the macro scale. Self-organization and adaptiveness may result from a multi-scale process.

- e- multi-temporal scale

2.2.3 Uncertainty

There is a high degree of uncertainty in the scenario that could be aggravated by factors such as:

- a- incomplete, false or noisy data; and

- b- multiplicity.

Multiplicity may mean multiple entry points, access/escape routes, etc.

- c- variability.

Variability may include changing environmental conditions (wind direction, weather, visibility, etc.) or market conditions, or similar

d- human factor influences.

Examples of human factor influences may include panic, low morale, fatigue, and information overload as the potential causes for error.

2.2.4 Level of complexity

The level of complexity in the scenario can be adjusted for the purpose of evaluating the development of understanding by the user.

2.3 Scenario relevance

This criterion ensures significance of the scenario for the Canadian defence context. It estimates the military interest in the complex situation involved in the scenario which will be used to demonstrate the potential impact of IMAGE for DND/CAF. The level of truth of the following statements allows to establish this criterion value.

- ♦ The scenario subject matter is related to DND/CAF issues (e.g. Capability Engineering, Terrorism, Emergency response, North West Passage, Natural disaster, Effects Based Operations ...);
- ♦ The scenario involves cooperative users of multiple disciplines and backgrounds;
- ♦ The scenario is realistic with regard of past, present or future CAF operations (peace keeping, military operation, national security, natural disaster relief, SAR);
- ♦ The scenario uses a context of interest to DND/CAF potential partners of the DRDC Valcartier's System of Systems section and CORA's Central Operational Research Team;
- ♦ Selected scenarios should appeal to future customers but should not lie on their immediate critical paths. At this early stage, scenarios are here to help the development of IMAGE. While the ultimate objective of IMAGE is in providing assistance in actual complex situations, this cannot be expected to be fulfilled early into the project.

2.4 Scenario feasibility

This criterion reflects the pragmatic aspect of the scenario selection. The feasibility involves the availability and the quality of the material and the authoring on the scenario, its maturity level and the ability to implement it.

- ♦ The scenario is sufficiently plausible, mature and complete. It is supported by sufficient documentation and data. A community of interest and some analyses on this scenario may exist;
- ♦ Scenarios are often described as implemented on a specific simulator infrastructure. This later recreates the systems and the environment that the scenario depicts. The selected scenario should be playable autonomously by at least one existing constructive simulator. The simulator should behave deterministically to ensure repeatability and also support run-time serialization;

- ♦ From a software engineering perspective, IMAGE will rest upon the successful integration of a number of computational resources. Its development will be greatly facilitated if its components adhere to recognized standards. Specifically, scenarios should be readily editable (e.g. as XML statements), simulator I/O should be accessible through well-documented APIs, the source code of the simulator should be available, etc.;
- ♦ The scenario allows short duration experiments. Therefore a sufficient number of subjects should be tested to ensure statistical significance in order to demonstrate the tool efficiency;
- ♦ The scenario is playable by one subject to assess his complex system understanding that follows every experiment.

2.5 Scenario innovation demonstrator

This criterion is related to the capacity of the scenario to demonstrate the plus-value of the proposed tool, which comprises innovative concepts in simulation, exploration and representation of complex systems. It should also facilitate the tool assessment.

- ♦ The scenario supports the simulation concepts. It allows the exploration and comparison of various Courses of Actions (CoA), which result from model and parameter changes in the executed simulated world. CoA have to differ moderately to generate significant comparisons;
- ♦ The scenario supports the exploration concepts. First, it should present a geographical context with, preferably, more than one scale of visualization. It contains many types of data to generate various analyses, such as three-dimensional rendering and plots. Also, these data must facilitate, by their combination, conversion and manipulation, the creation of higher level metrics;
- ♦ The scenario supports the concepts in knowledge representation. It reveals abstractions and high level concepts.

3 Evaluation Form

The evaluation of the potential scenarios for IMAGE was performed using an evaluation form that was developed based on the five evaluation criteria described above. A sample of the evaluation form is presented here.

Evaluation Form

The following form is designed to facilitate scenario evaluation. Please indicate your level of agreement with the following statements (5 – in full agreement, 0 – in full disagreement) and justify / comment your estimated assessment in the space provided.

Evaluation by: _____

Scenario ID: _____

1- Completeness

The situation is clearly expressed	5 – 4 – 3 – 2 – 1 – 0
There is presence of multiple measurable metrics	5 – 4 – 3 – 2 – 1 – 0
The intent is clearly expressed	5 – 4 – 3 – 2 – 1 – 0
The background information is adequate	5 – 4 – 3 – 2 – 1 – 0
Overall, the description of the scenario is complete	5 – 4 – 3 – 2 – 1 – 0

Comments

Justify. Describe what improvements could be introduced

--

2- Complexity

The complexity of the interactions is adequate	5 – 4 – 3 – 2 – 1 – 0
The complexity of the situation dynamics is adequate	5 – 4 – 3 – 2 – 1 – 0
The level of uncertainty is adequate	5 – 4 – 3 – 2 – 1 – 0
The level of complexity can be adjusted	5 – 4 – 3 – 2 – 1 – 0

The complexity level is adequate	5 – 4 – 3 – 2 – 1 – 0
---	------------------------------

Comments

Justify. Describe characteristics that should be added / removed and simplifications / constraints that should be introduced.

Among the various characteristics of this scenario, what are those that you expect to constitute the greatest *conceptual* challenges

3- Relevance

The scenario is relevant to DND and CAF	5 – 4 – 3 – 2 – 1 – 0
--	------------------------------

Comments

Justify. Describe how it could be improved.

4- Feasibility

There is a high probability of successful implementation of this scenario within the available resources and time frame	5 – 4 – 3 – 2 – 1 – 0
--	------------------------------

Comments

Justify. What are the critical *technical* challenges and the corresponding risk?

5- Innovation demonstrator

The scenario supports the simulation concepts of IMAGE	5 – 4 – 3 – 2 – 1 - 0
The scenario supports the exploration concepts of IMAGE	5 – 4 – 3 – 2 – 1 - 0
The scenario supports the concepts of knowledge representation of IMAGE	5 – 4 – 3 – 2 – 1 - 0
The scenario has the capacity to demonstrate the plus-value of IMAGE	5 – 4 – 3 – 2 – 1 - 0

Comments

Justify. How it could be improved?

--

6- Overall rating of the scenario

1- Completeness	/ 5
2- Complexity	/ 5
3- Relevance	/ 5
4- Feasibility	/ 5
5- Innovation demonstrator	/ 5
6- Overall rating	/ 25

Overall comments on the scenario

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IMAGE; selection criteria; complex scenario

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