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Title: **Knowledge elicitation and formalization through argumentation models**

Topics: Track 3: Modeling and Simulation
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Knowledge elicitation and formalization through argumentation models

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Abstract

Building knowledge based systems (KBS) in support to command and control (C2) applications requires the elicitation and gathering the knowledge from a subject matter expert (SME) and some formalization of that knowledge for its computer-based exploitation in C2 systems. The traditional approach to the tasks of elicitation and gathering of such knowledge is to have an unlimited access to SMEs, observe their day-to-day work as well as go through formal/informal interviews. In the actual military context, such approach has almost become unworkable since operational urgency makes it difficult for a SME to plan and respect meetings with knowledge engineers. To satisfy the current need of knowledge elicitation and gathering, we propose a new approach based on the exploitation of models that have been used in the field of argumentation. This paper presents the proposed knowledge elicitation methodology, including its implementation and an initial assessment.

1.0 Introduction

The Canadian Forces Operational Planning Process (CFOPP) is a methodical approach to analyzing a situation, bringing staff expertise to bear on the relevant factors, narrowing courses of action, obtaining the commander's approval, and developing the detailed annexes necessary to produce an executable plan [1]. The CFOPP can be used at the strategic as well at the operational and tactical levels. It is the process used to prepare plans and orders for Canadian Forces (CF) operations, and accordingly, it concentrates on establishing the areas of focus, the kinds of issues to be resolved, and the outputs that must be produced [2].

Most of the time, military operations are evolving into a dynamic, complex and uncertain environment. Accordingly, the CFOPP is often performed under high time pressure and stressful conditions. Under the influence of these factors, the human capacity of reasoning and judgment can be significantly reduced. Different types of decision-support systems can be proposed to support the commander and his team in carrying out the CFOPP [3]. One of them is the development of a COA critiquing system.

The design of a COA critiquing system involves the development of a knowledge based supporting the production of critiques. To do so, a knowledge elicitation and gathering tasks, which usually require an unlimited access to SMEs, needs to be conducted. Traditional approaches for such tasks are usually executed through the observation of the SME's day-to-day work as well as formal/informal interviews. In the actual military context, such approach has almost become unworkable since operational urgency makes it difficult for a SME to plan and respect meetings with knowledge engineers.

In order to facilitate the knowledge elicitation and gathering in a military environments, we propose a new approach based on the exploitation of models that have been used in the field of argumentation. This paper starts by introducing the Canadian Forces Operational Planning Process (CFOPP) and a critiquing system that could be developed to support it. Traditional knowledge elicitation approaches and argumentation models are then presented as means for knowledge elicitation. A new Toulmin based model is proposed and the results of initial assessment are presented and discussed.

2.0 Canadian Forces Operational Planning Process

The Canadian Forces Operational Planning Process (CFOPP) is a methodical approach to analyzing a situation, bringing staff expertise to bear on the relevant factors, narrowing courses of action, obtaining the commander's approval, and developing the detailed annexes necessary to produce an executable plan [1]. The CFOPP can be used at the strategic as well at the operational and tactical levels. It is the process used to prepare plans and orders for Canadian Forces (CF) operations, and accordingly, it concentrates on establishing the areas of focus, the kinds of issues to be resolved, and the outputs that must be produced [2].

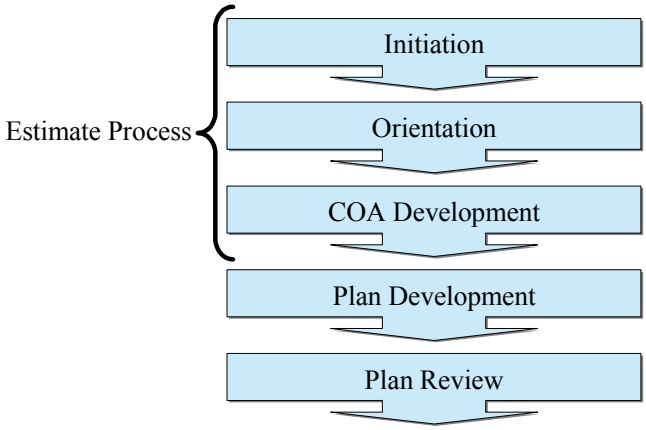

Figure 1. CFOPP

CFOPP is comprised of five main stages (Figure 1) with specific outputs [1]:

- the *Initiation* stage results in the activation of the planning staff, and the commander's guidelines about the kind of planning process to achieve;
- the *Orientation* stage results in the development of the commander's planning guidance. In this stage, the commander orients his/her staff in the determination of the nature of the problem and the confirmation of the results to be achieved;
- the *Course of Action (COA) Development* stage results in the production of the concept of operations (CONOPS) that identifies the commander's line of action in order to accomplish his/her mission. It presents the COA that will be implemented. In previous version of the CFOPP there was a decision stage that has been integrated into this *COA development* one;

- the *Plan Development* stage results in a set of orders based on the commander's decision to provide subordinate and supporting units with all of the necessary information to initiate planning or execution of operations;
- the *Plan Review* stage results in a regular review of the plan to evaluate its viability. The period used to review the plan depends on the evolution of the situation, the type of operation and the environment.

The three first stages of the CFOPP constitute what is called the Estimate Process. It involves the elaboration of different COAs following situation analysis and the selection of the most appropriate one for its subsequent planning. The intent of the Estimate Process is to optimize logical, analytical steps of decision making in conditions of uncertainty and ambiguity while maximizing the commander's and staff's creative thinking and associated thought processes [1]. Besides, it needs to be tailored to units' and formations' specific needs as well as to standing operations procedures. It is assumed that the execution of the Estimate Process will maintain a minimum of quality in the planning results.

The Estimate Process is accomplished by a team with different expertise areas. Even if the different functions to be executed at the different stages are well identified, no formal procedures to execute them are defined [2]. Therefore, the planning staff employs intuitive strategies to execute these functions [2]. Based on their experience, background and capacity to retrieve relevant knowledge stored in their memory, they use the Estimate Process to guide them in order to provide their commander with a recommendation on the best COA to execute [2,3].

Different types of decision-support systems can be proposed to support the commander and his team in carrying out the Estimate Process [3]. One of them, which is further described in the following section, is a COA critiquing system.

3.0 Critiquing Systems

The core task of critics in critiquing systems is to recognize and communicate debatable issues concerning a product [4]. Critics point out problematic situations that might otherwise remain unnoticed. Accordingly, a COA critiquing system would be able to provide the planning team with the strengths and weaknesses of each COA according to the situation. A COA can be criticized based on different aspects. For example, a critique can be related to [5]:

- the structure of the COA;
    - detection of any ambiguity (clarity);
    - conflict (temporal or logical);
    - incoherence (temporal or logical incompleteness and inconsistency); or
    - reality mismatch in the structure of tasks within each phase of a COA as well as in the amalgamation of the different phases when considering them as a whole COA);
- the way COA handles operation issues identified during the staff analysis. Such issues could be related to Area of Operations (AOO), opposing forces capabilities, political considerations, own forces capabilities, time and space, command and control, logistics and movement, rules of engagement, conflict termination, risk, assigned/implied tasks, lessons learned, etc.;
- the viability of the COA [1];
    - does it achieve the mission, satisfy the commander's intent and accomplish the tasks?
    - does it counter enemy COAs? (suitability);

    - do force structure and resources exist to mount and sustain? (feasibility);
    - does it account for limitations placed on the operation, is it worth the risk? (acceptability);
    - does it conform to approved CF doctrine and applicable policy, regulations, legislation and/or guidelines? (compliance);
- the way COA counters the different known Enemy COAs;
- any criteria identified by the commander or the planning staff that is considered important for the comparison of the COAs. For example, in a situation of counter-drug, the factors/criteria presented in Table 1 have been identified;
- any effects, direct or indirect (physical or psychological), caused by the execution of this COA.

The critique of a COA is often performed by the commander and his senior staff, who must rely on their experience and on their capacity to retrieve relevant knowledge stored in their memory. Accordingly, to be able to develop a COA critiquing tool, relevant knowledge and expertise need to be identified, documented and translated in a way that a computer can work with it. Most of the tacit knowledge and expertise has been acquired through the years by different subject matter experts (SMEs), and is not actually documented anywhere. In fact, it is the usual knowledge elicitation problem that is encountered in the development of any knowledge base systems.

Table 1. Evaluation criteria

Factor	Criterion	Concerned with
Flexibility		
	C1: Covering Operational Tasks	the ability of a COA to adapt to possible changes in operational task which may occur during its implementation
	C2: Covering Mission's Possible Locations	the ability of a COA to adapt to possible changes in the predicted mission's locations which may occur during the implementation of a COA
	C3: Covering Enemy's COA	the ability of a COA to adapt in time to possible changes in the enemy's COA that may occur during the implementation
Complexity		
	C4: Operations Complexity	the COA implementation difficulties caused by its operational requirements
	C5: Logistics Complexity	the COA implementation difficulties caused by its logistics requirements
	C6: Command and Control Complexity	the COA implementation difficulties caused by command and control relationships and co-ordination requirements in operation
Sustainability		
	C7: Sustainability	the ability to continue (stay in) the operation as a function of the on-station time associated with the COA
Optimum use of resources		
	C8: Cost of Resources	the cost of the resources being used
Risk		
	C9: Impact of the Sensors Coverage Gap	the possibility of mission failure caused by the existence of radar and/or radio gaps
	C10: Military Personnel Loss	the likelihood of military personnel loss during the mission
	C11: Collateral Damage	the possibility of collateral damage (anything but the target) during the mission
	C12: Confrontation Risk	the possibility of mission failure due to confrontation
	C13: COA Equipment Reliability	the equipment reliability and the robustness of the COA
	C14: COA Personnel Effectiveness	the effectiveness of the personnel which may be jeopardized by fatigue, stress, etc. at any moment during the mission

4.0 Knowledge Elicitation

Knowledge elicitation is the process of getting the data needed for knowledge modeling [6]. Knowledge elicitation techniques attempt to elicit knowledge of a domain specialist through some form of direct interaction with that expert. The domain specialist, usually called the expert, is a person that possesses knowledge about solving the application task we are interested in [6].

Amongst the different techniques that are traditionally used for knowledge acquisition/elicitation, there are [7]:

- interviews (structured and unstructured);
- observations;
- think-aloud verbal protocol;
- task performance with questioning;
- surveys and questionnaires.

All these techniques involve the interaction of a knowledge engineer with a SME. In a military context, such approach has almost become unworkable since operational urgency makes it difficult for a SME to plan and respect meetings with knowledge engineers. To overcome this problem, some R&D activities are being conducted to develop automated knowledge-elicitation tools. For example, the goal of the DARPA's Rapid Knowledge Formation (RKF) program is to develop technologies that will allow SMEs to develop knowledge bases directly, without the intervention of professional knowledge engineers. Until such tools are ready and largely available to be used, we have to find other ways to gather the SME knowledge. The one we have decided to experiment with is to provide the SME with a means that will facilitate the description of the knowledge related to the critique of a COA. Considering all the work that has been done in the field of argumentation, we thought that the use of argumentation models could be useful to gather and formalized the knowledge needed to be able to produce such critiques.

5.0 Argumentation Models as Means of Knowledge Elicitation

In recent years, argumentation has been found to be particularly powerful in the areas of knowledge representation, commonsense reasoning, logic programming, legal reasoning, decision making, and negotiation. Argumentation theory has been applied in the design of intelligent systems in several ways over the last decade.

By nature, the critique of a COA relies on argumentation. One cannot produce any critique without using some form of arguments. Since critiques use arguments, could argumentation models be used to support the elicitation and the formalization of the knowledge used by SMEs in the building of their critiques?

Argumentation has been used to specify patterns of reasoning in several domains: artificial intelligence, law, political science, etc. The well-known example of an argument from artificial intelligence is:

Tweety flies because Tweety is a bird,

which can be counter argued by the argument:

But Tweety is different, so perhaps Tweety does not fly.

The understanding of an argument as a tentative proof and a chain of rules attends to its internal structure, as analogous to a chain of inference steps connecting a set of premises to a claim. A second strand of research in artificial intelligence has emphasized the relationship between arguments when considered as abstract entities, ignoring their internal structures. This approach has enabled argumentation systems to be defined as semantics of *defeasible* reasoning systems.

Arguments are thus defeasible, meaning that the argument by itself is not a conclusive reason for the conclusions it brings about. When a rule supporting a conclusion may be defeated by new information, it is said that such reasoning is defeasible. When we chain defeasible reasons to reach a conclusion, we have arguments, instead of proofs. It makes sense to require defeasible

reasons for argumentation. In defeasible logic (also called *nonmonotonic* logic), inferences are defeasible, that is, the inferences can be defeated when additional information is available. Several nonmonotonic reasoning formalisms have been proposed. In these formalisms, conclusions which have been drawn may be later withdrawn when additional information is obtained.

In a logical proof, we have a set of premises and a conclusion which is said to follow from them. The premises are considered to be entirely homogenous. Many argumentation systems make no distinctions among their premises. In contrast, in arguments expressed in natural language we can typically observe premises playing different roles. By identifying these roles, we can present the arguments in a more readily understandable fashion, and also identify the various ways in which the argument may be attacked. Structuring the argument in this way produces an *argument scheme*. Analyzing practical reasoning in terms of argument schemes produces a taxonomy of arguments, which may provide useful guidance for building implemented argumentation systems, analogous to the guidance provided by domain ontologies for building knowledge-based systems [8]. One argument scheme that has been widely used in artificial intelligence and law was proposed a long time ago by Toulmin.

5.1 Toulmin's Argumentation Model

In the domain of philosophy of law, Toulmin [9] introduced a conceptual model of argumentation. He considered a diagrammatic representation for legal arguments, in which six parts are distinguished:

1. ***Claim*** (*C*). An assertion or a conclusion presented to the audience and which has potentially a controvertial nature (it might not meet the audience's initial beliefs);
2. ***Datum*** (*D*). Statements specifying facts or previously established beliefs related to a situation about which the claim is made;
3. ***Warrant*** (*W*). Statement which justifies the inference of the claim from the datum;
4. ***Backing*** (*B*). Set of information which assures the trustworthiness of a warrant. A backing is invoked when the warrant is challenged. The backing is the ground underlying the reason.
5. ***Qualifier*** (*Q*). A statement that expresses the degree of certainty associated to the claim;
6. ***Rebuttal*** (*R*). A statement presenting a situation in which the claim might be defeated.

Counterarguments are also arguments that may attack any of the first four elements (*Claim*, *Datum*, *Warrant* and *Backing*). A disputation can be visualized by chaining diagrams of arguments.

Toulmin's model of argumentation represents a structure that can be represented using typical natural language markers:

Given *D* (and Since *W*), Therefore *C*, unless *R*.
W Because *B*.

Figure 2 illustrates an example of Toulmin's model. This argument claims that Harry is a British citizen (*Claim*) because he was born in Bermuda (*Datum*). This claim is presumably true since people born in Bermuda are generally British citizens (*Warrant*) because there are statutes and other legislation substantiating this rule (*Backing*). However, there are exceptions to this rule, such as when a person born in Bermuda has parents of another nationality or if this person becomes a naturalized American citizen (*Rebuttal*). A complete presentation and discussion of Toulmin's model can be found in chapter 5 of Eemeren *et al.* [10].

Ye [11] indicated that Toulmin's model is significant in that it highlights the discrete response steps that an expert system explanation facility should follow in order to answer a user's queries in a convincing way. For example, let us consider the typical format of a rule used in an expert system:

IF $Premise_x$ ($certainty\ factor_y$), THEN $Conclusion_z$.

This structure obviously corresponds to the schema:

GIVEN $Datum_x$,THEREFORE ($Qualifier_y$) $Claim_z$.

where subscript variables represent the correspondence between the elements of these structures. Certain rules might include the equivalent of a rebuttal as for example:

IF $Premise_x$ AND NOT $Premise_y$ ($certainty\ factor_z$), THEN $Conclusion_w$

This structure corresponds to the schema:

GIVEN $Datum_x$, THEREFORE $Qualifier_z$ $Claim_w$, UNLESS $Rebuttal_y$.

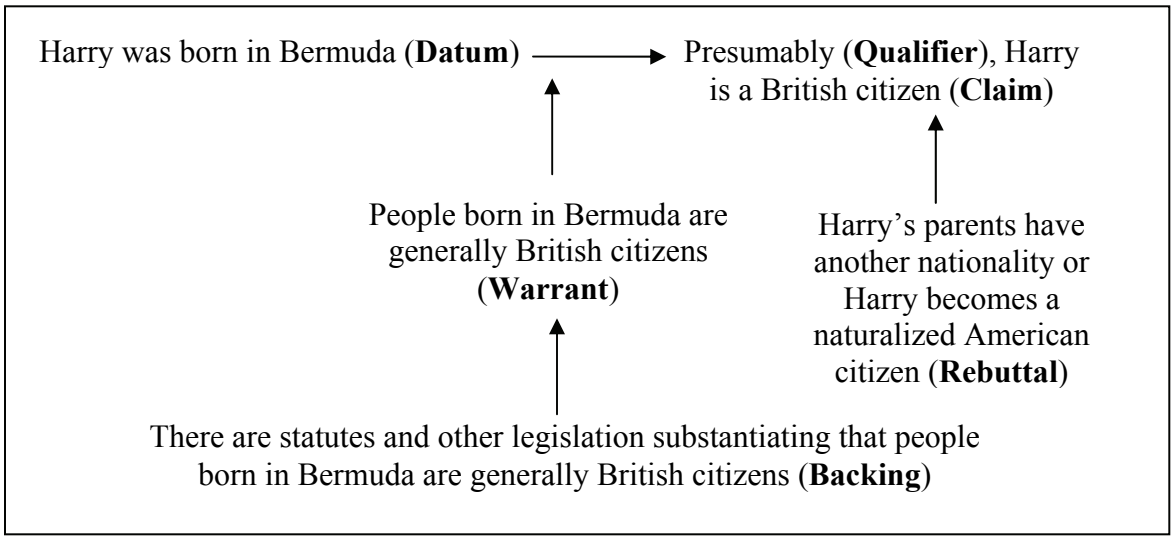

Figure 2: Example of Toulmin's model

Toulmin's model is one of the argumentation models that have been documented in the literature [12]. In order to identify which of these models had the most interesting characteristics to support the representation of critiquing knowledge, a review of several argumentation models was conducted in a previous study [12] including the models proposed by Dung, Simari and Loui, Rescher, Lin and Shoham, Hamblin and MacKenzie, Amgoud et al., Bentahar et al, Toulmin's, Reed and Walton, Anscombre and Ducrot, Breton, Cabrol-Hatimi.

From this study, we identified that:

- some of the models focus on structural relationships between arguments, highlighting the process of argumentation in a dialogue structure;
- others put the emphasis on dialogical structures to model the connectedness of utterances with the capacity to identify fallacious arguments, i.e., invalid arguments that appear to be valid. They are rule-governed structures of organized conversations in which two parties (in the simplest case) speak in turn in an orderly way. These rules are the principles that govern the participants' acts, and consequently the use of dialectical moves in argumentation;
- others emphasize the structure of the argument itself. What is important in these models is not the relationship that can exist between arguments, but the relationships between the different components of a given argument.

The comparison done at that time identified *Toulmin's Model* as having the most interesting characteristics to support the representation of knowledge involved in critiquing systems. Toulmin's model has the advantage of taking into account the different components of an argument structure and the link between these components. In addition, it allows to model the inference rules that are used to infer a conclusion from a set of premises, and it facilitates the construction of textual arguments. However, this model does not illustrate how a warrant supports the inference of a claim from a datum. In addition, this model does not include a justification of the rebuttals. Toulmin's model has another limit because rebuttals are considered as counterarguments that cannot be defeated. Consequently, the only way to represent these counterarguments is to consider them as rebuttals of certain claim in a new model. Nevertheless, this solution has the same disadvantages of the previous one.

For the reasons discussed above, we proposed the following modifications and improvements to the Toulmin's model in order to better support the requirements of knowledge elicitation:

1- add the names of the argumentation relations on arrows. These names allow us to represent the semantics of the relations between different components;
2- replace the original restrictive backing by a new component explaining the warrant. Instead of only backing it, this component explains why the warrant supports the inference of claim from the datum;
3- add a new component justifying the rebuttal, and a new component that can be used to attack this justification.

6.0 Knowledge Elicitation Using Modified Toulmin's Model

To exploit the modified Toulmin's model for the task of knowledge elicitation from a subject matter expert, it was necessary to transform its presentation to facilite its understanding and its documentation. Since the terminology used in the model might not be obvious for everyone and that the drawing of arrows and boxes makes it not easy to use, it was decided to propose a grid as presented in Table 2 below. The explanation of the grid to a SME can be stated this way:

Table 2: Adapted Toulmin's model for knowledge elicitation

1	Claim:	
2	Claim description (if needed):	
3	The degree of confidence associated to this claim (Certain, Presumably, Uncertain, Always, Frequent, Unlikely…)	
4	What are the facts that lead you to this claim:	
5	What is(are) the rule(s) that you used to go from the facts to this claim	
6	Why is(are) this(these) rule(s) valid:	
7	What additional facts/assumptions could lead to the invalidation of this claim:	
8	What is(are) the rule(s) that could be used to go from these additional facts/assumptions to the negation of the claim	
9	What additional facts/assumptions could lead to the invalidation of the previous rule	

- given facts in (4) and the rule (5), therefore we can infer/claim (1) according to the level of confidence expressed in (3);
- the inference described in rule (5) is supported by (6). On the other hand, the claim (1) can be invalidated by additional facts and/or assumptions (7);
- these additional rebuttal facts (7) can be used to infer the negation of the claim (1) using rule (8);
- finally, rule (8) can eventually be invalidated by facts in (9).

For instance, Table 3 presents the example presented in Figure 2 translated using the proposed grid format.

Table 3: Knowledge elicitation grid for the example of Figure 2

1	Claim:	Harry is a British citizen.
2	Claim description (if needed):	
3	The degree of confidence associated to this claim (Certain, Presumably, Uncertain, Always, Frequent, Unlikely…)	Presumably.
4	What are the facts that lead you to this claim:	Harry was born in Bermuda.
5	What is(are) the rule(s) that you used to go from the facts to this claim	People born in Bermuda are generally British citizens.
6	Why is(are) this(these) rule(s) valid:	There are statutes and other legislation substantiating that people born in Bermuda are generally British citizens.
7	What additional facts/assumptions could lead to the invalidation of this claim:	Harry's parents have another nationality or Harry becomes a naturalized American citizen.
8	What is(are) the rule(s) that could be used to go from these additional facts/assumptions to the negation of the claim	Parents can ask that their kids have the same nationality that they have.
9	What additional facts/assumptions could lead to the invalidation of the previous rule	Delay to ask citizenship is expired.

The next section describes how this improved version of Toulmin's model was assessed to gather, elicit, and formalize the knowledge involved in COA critiques.

6.1 Illustrative Case

This new knowledge elicitation approach was tested with a former air force military officer. He has extensive experience in the Canadian Air Force as a pilot, a Wing Operation Officer as well as a Wing Commander. As a A-3, he directed A-staff planning as well as operations. He also assumed the duties of Task Force Commander. He was familiar with office automation tools, particularly Microsoft Office Suite. With such background, he was considered a SME for this evaluation task.

First, all material related to the description of a scenario was provided to the SME who was requested to execute the CFOPP in order to propose different COAs and identify their strenghts

and weaknesses. Then it was requested that the SME use the knowledge elicitation template to document the rationale (considerations and thinking process) in the COA selection for one of the COA. These correspond to the differents critiques that could be provided for a COA.

It was decided to use a NATO-like scenario involving an escalation from a deterrence posture to a fully deployed combat operation. Called FINAL LANCE, this scenario is about a crisis resulting of years of growing tensions amongst different countries on the continent of Atlantis (fictitious) that has erupted into armed conflict [13]. As a result of the critical situation between the different counterparts (ORANGELAND/REDLAND and BLUELAND), the UN requested an Alliance Council to consider a military response to help resolve the crisis. A generic international military alliance called the ALLIANCE in this fictitious world receives the mandate to restore international peace and security in the area.

The scope of this demonstration is limited to a combat search and rescue (CSAR) mission occuring in the ongoing air campaign and joint planning cycle related to the ALLIANCE mandate execution. From the CSAR vignette [14] that we worked with, the key guidance for mission planning is:

a. The Joint Force Commander's (JFC's) Intent –
   - to recover the personnel by the fastest and most effective means possible. End state is the successful recovery and evacuation of personnel to a medical facility within the next 24h;

b. The Air Component Commander's (ACC's) Objectives –
   - to strike (if necessary);
   - to contain enemy local ground forces;
   - to establish air superiority;
   - to establish local force protection;
   - to maintain communication superiority;
   - to recover and extract downed aircrew by the fastest and most effective means possible;
   - to suppress local air defence;

c. Success Criteria –
   - casualties are evacuated to medical facilities as quickly as possible;
   - crew recovered and extracted as quickly and effectively as possible;
   - deployment of forces is performed within the planning timelines;
   - no laps of communication, RAP or coordination with Alliance allies that could jeopardize the success of the mission;
   - operational planning in accordance with established doctrine and procedures.

A mission analysis was done and COAs were developed (Figure 3). A COA, coded T1 and named "Op Hasty", was analysed to identify its strengths and weaknesses. The time-based aspects of this COA were predicated on extracting the downed crews as soon as possible. The operation is to take place at the earliest time according to daylight conditions and to ensure at least one air-to-air refuel (AAR) and one uninhabited aerial vehicule (UAV) was available. No joint surveillance and target attack radar system (JSTARS) are available. The routing aspect of this COA is coded S3 and named "Beach". This routing is to attempt to achieve maximum deception with an initial track away from the Straits and, once over water north of Wahhabe, the helicopters and escort ingress at low level using Celtic coastline to mask their approach.

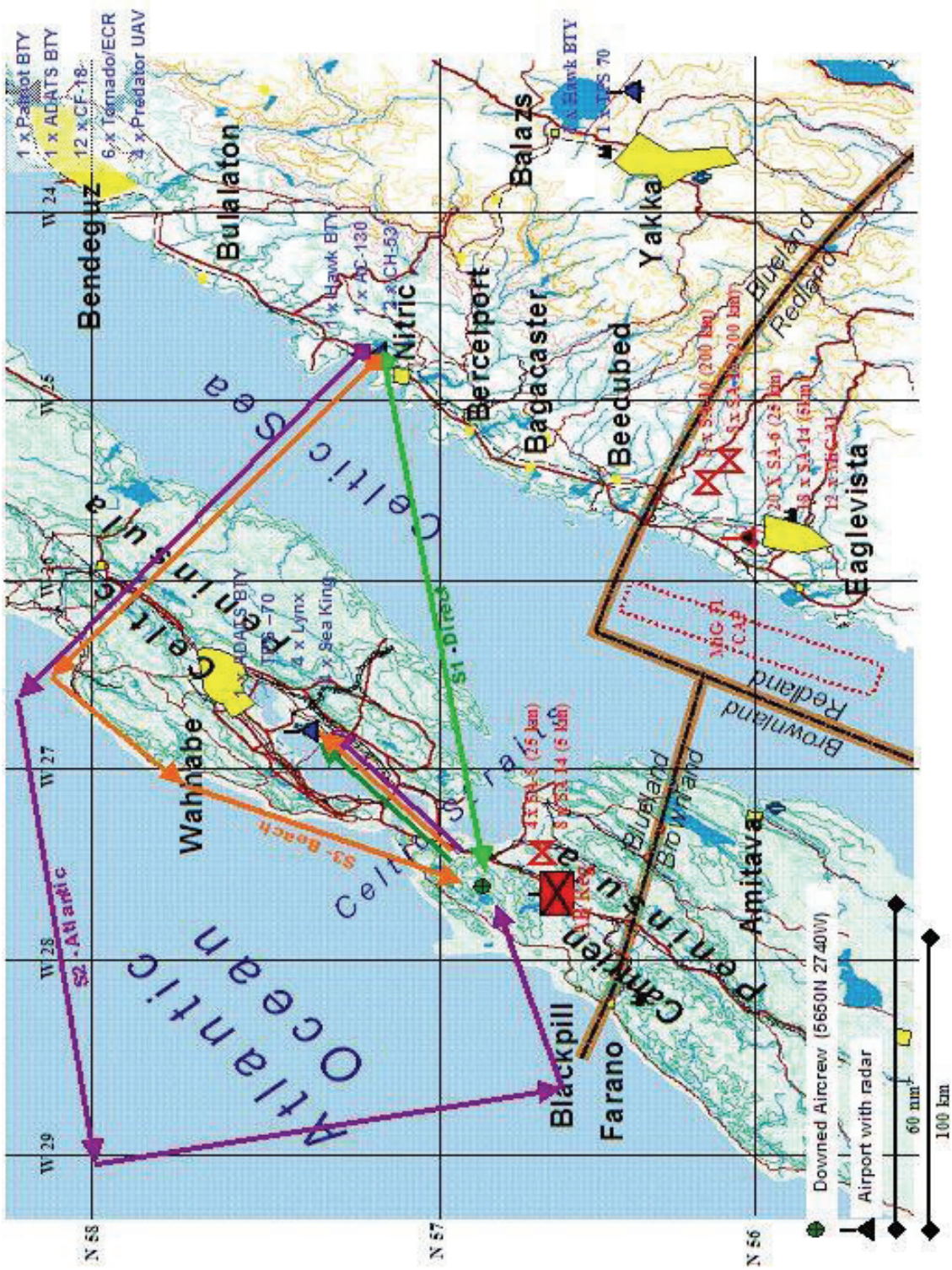

Figure 3 – COAs developed

To limit the scope of the work, it was decided to evaluate the COA against the tactical principles that yielded advantages and disadvantages. Table 4 below lists the COA advantages/ disadvantages that were identified for COA T1/S3, Op Hasty/Beach.

Then, the SME was asked to complete two grids for each aspect considered as an advantage or a disadvantage,

- one (1) argumentation grid to focus on why the aspect could be deduced for this COA;
- one (1) argumentation grid to focus on why this aspect is considered an advantage or disadvantage.

The documentation of the second aspect was required because the classification of each aspect as an advantage or a disadvantage is not always trivial.

Table 4: Op Hasty/Beach Analysis

COA	Advantages	Disadvantages
COA Op Hasty/ Beach (T1/S3)	A1 - Earlier extraction to get crews back (medical) A2 - Enemy further from target area A3 - Air Defensive less established A4 - Maximum flexibility in the event of delays A5 - Routing for deception A6 - Terrain mask for stealth A7 - Supports a Hi/Lo/Lo profile A8 - Can accommodate Lo/Lo/Lo profile A9 - Ingress direction suits anytime of day for sun angle	D1 - High tactical risk D2 - High technical risk D3 - Some RAP (Recognized Air Picture) degradation due to terrain D4 - Longer than direct routing D5 - No mission rehearsal time D6 - Gaps in CAP (Combat Air Patrol) on-station time D7 - Only 1 Tanker D8 - Decreased capability to locate and track enemy D9 - No JSTARS (Joint Surveillance and Target Attack Radar System) D10 - Limited UAV (Unmanned Aerial Vehicle) support (only 1 available)

In total, 38 grids were filled up by the SME. The content of these populated grids is sometimes very detailed, sometimes very concise, depending on the quantity of information the SME was able to identify for each element of the grid. The following tables show how the Toulmin-based argumentative grid has been used by the SME to decompose the advantages and disadvantages of this COA. Tables 5 and 6 substantiate argumentation supporting the disadvantage D1 of Table 4: Highly tactical risk. Table 7 and 8 substantiate argumentation supporting the advantage A1 of Table 4: Earlier extraction to get crews back (medical).

Table 5: Knowledge acquisition Grid #1 for D1

1	Claim: D1a	The COA T1-S3 has a high tactical risk
2	Claim description (if needed):	Tactical risk means that the COA would endanger the success of the mission based on using the optimum tactics and optimum numbers of available resources to complete the mission. In this claim, although the routing is optimal the timing of the mission, TOT (Time on Target) of 0800, would result in the mission being conducted without key mission resources.
3	The degree of confidence associated to this claim	Certain
4	What are the facts that lead you to this claim:	The mission conducted at 0800 would have to be completed: • without JSTARS, which is a critical resource in locating enemy positions using ground movement detection radar; • with only one (1) refueller, the combat radius and/or time on station of fighter/bomber and SEAD (suppression of enemy air defences) aircraft would be limited; and • with only one (1) UAV, seriously diminishing the ability to detect the enemy and/or the downed crews in the target area. These resource availability factors cumulatively add to the tactical risk.
5	What is(are) the rule(s) that you used to go from the facts to this claim	• JSTARS is needed for RGP (Recognized Ground Picture) compilation; • JSTARS is airborne and has better communication with other resources for C2 of RGP; • Mission flow does not allow one (1) refueller to fuel all mission resources requiring AAR (Air-to-air Refuel); • Mission calls for two (2) UAV to best provide RGP information on enemy and downed crew locations.
6	What makes this(these) rule(s) valid:	• Implicit AF (Air Force) tactical experience that recognizes the linear relationship between having detailed information of enemy locations and strength in order to properly attack their weaknesses and avoid their strengths; • Experience and lessons learned that support the premise that extended on-station time is valuable such that air-to-air refuellers are considered a force multiplier doctrinally; • Two (2) UAVs are required to ensure RGP due to terrain in CSAR area.
7	What additional facts/assumptions could lead to the invalidation of this claim:	• The enemy force may not be looking for the downed crews and would not oppose the CSAR mission; • The enemy force has not left their garrison start point and thus cannot oppose the mission; • The enemy force positions and ECOA (Enemy COA) are exactly as briefed by the J2 (Intelligence) staff; • Extraction could be done quickly reducing on-station time of assets.
8	What is(are) the rule(s) that could be used to go from these additional facts/assumptions to the negation of the claim	• With no enemy threat then tactical risk is low; • With enemy far away they pose little threat and risk is low/medium; • With enemy in exact location then real-time RGP not necessary negating the requirement for JSTARS and UAVs; therefore they would not contribute one way or another to the risk; • With on-station time requirements reduced due to reduced extraction window, the mission could be accomplished with only one AAR.
9	What additional facts/assumptions could lead to the invalidation of the previous rule	• If enemy air-to-air threat greater, more combat fuel required independent of extraction time; • Despite being far away, enemy SAM (Surface-to-air Missile) systems may still reach; • Enemy distances could be closed rapidly if they possess helicopters.

Table 6: Knowledge acquisition Grid #2 for D1

1	Claim: D1b	High tactical risk is a disadvantage.
2	Claim description (if needed):	It is a disadvantage because resources could be lost due to enemy action and/or, if the helicopters are amongst the losses then the mission would be unsuccessful.
3	The degree of confidence associated to this claim	Certain
4	What are the facts that lead you to this claim:	• Risk is detrimental to a mission; • High tactical risk is to be avoided; • Increased risk to will likely lead to higher losses; • Higher losses could jeopardize the mission.
5	What is(are) the rule(s) that you used to go from the facts to this claim	• Doctrine; • Logic.
6	What makes this(these) rule(s) valid:	• Experience and lessons learned.
7	What additional facts/assumptions could lead to the invalidation of this claim:	None.
8	What is(are) the rule(s) that could be used to go from these additional facts/assumptions to the negation of the claim	None.
9	What additional facts/assumptions could lead to the invalidation of the previous rule	None.

Table 7: Knowledge acquisition Grid #1 for A1

1	Claim: A1a	The COA permits earlier extraction.
2	Claim description (if needed):	This COA takes place at the beginning of the TOT window. It is the earliest possible time to extract the downed crews.
3	The degree of confidence associated to this claim	Certain.
4	What are the facts that lead you to this claim:	• This TOT is the first opportunity to extract the downed crews based on availability of resources; • Sunrise; • Lack of night vision capability.
5	What is(are) the rule(s) that you used to go from the facts to this claim	• Resource availability; • Command guidance; • Environmental factors.
6	What makes this(these) rule(s) valid:	• Logic.
7	What additional facts/assumptions could lead to the invalidation of this claim:	• NVG (Night Vision Goggles) capability for CSAR assets; • Other support resources, like AAR and UAV, available at 0600.
8	What is(are) the rule(s) that could be used to go from these additional facts/assumptions to the negation of the claim	• NVG capability allows pre-dawn extraction; • Command allocation inflexible.
9	What additional facts/assumptions could lead to the invalidation of the previous rule	• Commanders reallocate resources.

Table 8: Knowledge acquisition Grid #2 for A1

1	Claim: A1b	Earlier extraction is an advantage.
2	Claim description (if needed):	Command guidance dictates to quickly and efficiently perform the extraction. Due to the medical condition of the downed crews, an early extraction would be beneficial. In addition, the enemy is further away from the downed crews early in the TOT window. Therefore, the earlier the extraction the better for the downed crews.
3	The degree of confidence associated to this claim	Presumably.
4	What are the facts that lead you to this claim:	• ACC (Air Component Commander) guidance; • Enemy is further away earlier in the TOT; • Logic.
5	What is(are) the rule(s) that you used to go from the facts to this claim	• Experience; • Daily movement rates of enemy troops.
6	What makes this(these) rule(s) valid:	• Experience and lessons learned.
7	What additional facts/assumptions could lead to the invalidation of this claim:	• The crews are uninjured; • The threat of the enemy is minimal throughout the period.
8	What is(are) the rule(s) that could be used to go from these additional facts/assumptions to the negation of the claim	• Enemy location is known and static.
9	What additional facts/assumptions could lead to the invalidation of the previous rule	• Enemy moving faster than projected.

6.2 SME Feedback

In order to obtain an initial assessment of the Toulmin-based knowledge elicitation grids, the SME was requested to answer to a short feedback questionnaire to provide an appreciation on the utility of such a template for knowledge elicitation.

The first question was related to the level of difficulty to document the COA critique using the grid. On a scale of 0 to 5 with:

- 0: representing a **low level of difficulty;**
- 5: representing a **high level of difficulty.**

the SME selected 2 representing a slighlty low, almost medium, level of difficulty to document the critique of a COA using the grid. The elicitation of COA critiques being not an easy task, the documentation of the knowledge used to produce these critiques is also a challenge. Accordingly, this rating can be considered rather good.

The second question was trying to capture an indication about the extent to which the use of the grids facilitated the process of elicitation of the information. On a scale of 0 to 5 with :

- 0: representing that the structure of the grid **DID NOT** facilitate the elicitation of my knowledge;
- 5: representing that the structure of the grid **DID** facilitate a lot the elicitation of my knowledge.

The SME selected 4, representing that the structure of the grid did facilitate the process of elicitation of the information. He also identified some aspects that were still a challenge with the grid. He mentioned that "the model called for constraints to constraints (two negatives yielding a positive) which is sometimes difficult to comprehend and answer. This is a difficult task in isolation, and I would have much preferred to have been led through the process by a "elicitation" expert who can effectively reword the sense of the constraint or argument to draw out the knowledge."

The third question tried to measure to which level the use of the grids stimulated the production of complete information. On a scale of 0 to 5 with :

- 0: representing that the structure of the grid **DID NOT** stimulate the production of complete information;
- 5: representing that the structure of the grid **DID** stimulate a lot the production of complete information.

The SME selected 4, representing that the structure did stimulate the production of complete information. He also mentioned that the grid "allowed a free flow of information once the question was put into context in the scenario and COA." This seems to suggest that the use of the proposed structure was contributing to stimulate the elicitation of an exhaustive set of knowledge while used in conjunction with a scenario.

The fourth question tried to measure to which extent the grid has prevented the production of complete information. On a scale of 0 to 5 with:

- 0: representing that the structure of the grid **DID NOT** prevent the production of complete information;
- 5: representing that the structure of the grid **DID** prevent a lot the production of complete information.

The SME selected 2, representing that the structure of the grid did not really prevent the production of complete information. This result, even if almost neutral, may indicate a slight tendancy.

Further evaluation tasks shall be conducted in order to clearly establish the usefulness of the Toulmin-based knowledge elicitation grid in the building of KBS.

7.0 Discussion/Conclusion

Since only one SME was involved during the evaluation task, it is not possible to draw generic conclusions on the proposed approach. Nevertheless, the results obtained indicate that the SME was able to document and to organize the COA critiques without the help of a knowledge engineer. Even if the use of the grid for documenting the COA critique was not considered as representing a low or a high level of difficulty, the SME considered that it facilitated the elicitation of the information. This reflects the fact that providing critiques about a COA is not an easy task in itself. And since the aim of this work was not to facilitate the COA critique but to better support elicitation, gathering, and formalisation of relevant information/knowledge, the approach we propose did address our goal: to find a way to faciliate the elicitation of the knowledge involved in a COA critique while minimizing the need for face-to-face meetings with knowledge engineers.

In fact, when looking at the content of a completed grid, we can notice that it provides a lot of information about the reasoning process that leads to a specific deduction as well as a lot of complementary information that links the core information to other related information. A lot of this complementary information would not have been collected without the use of this grid. It is confirmed by the SME when he ranked to 4 the question about how the structure of the grid **DID** stimulate the production of complete information.

According to our observations, the Toulmin-based knowledge elicitation grid is a valuable tool that minimizes the need of face-to-face meetings with knowledge engineers during the elicitation phase of knowledge required to support the critique of a COA.

As well as SMEs, knowledge engineers could also use the Toulmin-based grid to collect the information during structured interviews. Providing tools to SMEs such as our Toulmin-based knowledge elicitation grid ensure both comprehensive elicitation and formalization of knowledge involved in a COA critique.

Further investigations are to be made in order to evaluate to which extent the knowledge asset grids resulting from the application of the Toulmin-based knowledge elicitation method could be integrated in a COA critiquing system.

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