DEFENCE **R&D** DÉFENSE

**Knowledge Elicitation and Formalization
through Argumentation Models**

Micheline Bélanger and Alain Auger

DRDC Valcartier

Information Systems Sector

12th ICCRTS, Rhode Island, June 2007

Defence Research and
Development Canada

Recherche et développement
pour la défense Canada

Canadä

The problem

- The design of a COA critiquing system involves the development of a knowledge based supporting the production of critiques.

- Building knowledge based systems (KBS) in support to command and control (C2) applications requires the elicitation and gathering the knowledge from subject matter experts (SME) and some formalization of that knowledge for its computer-based exploitation in C2 systems.

- In the actual military context, traditional knowledge elicitation approaches are unworkable due to operational urgency.

- Need for new approaches to support knowledge elicitation in the military context.
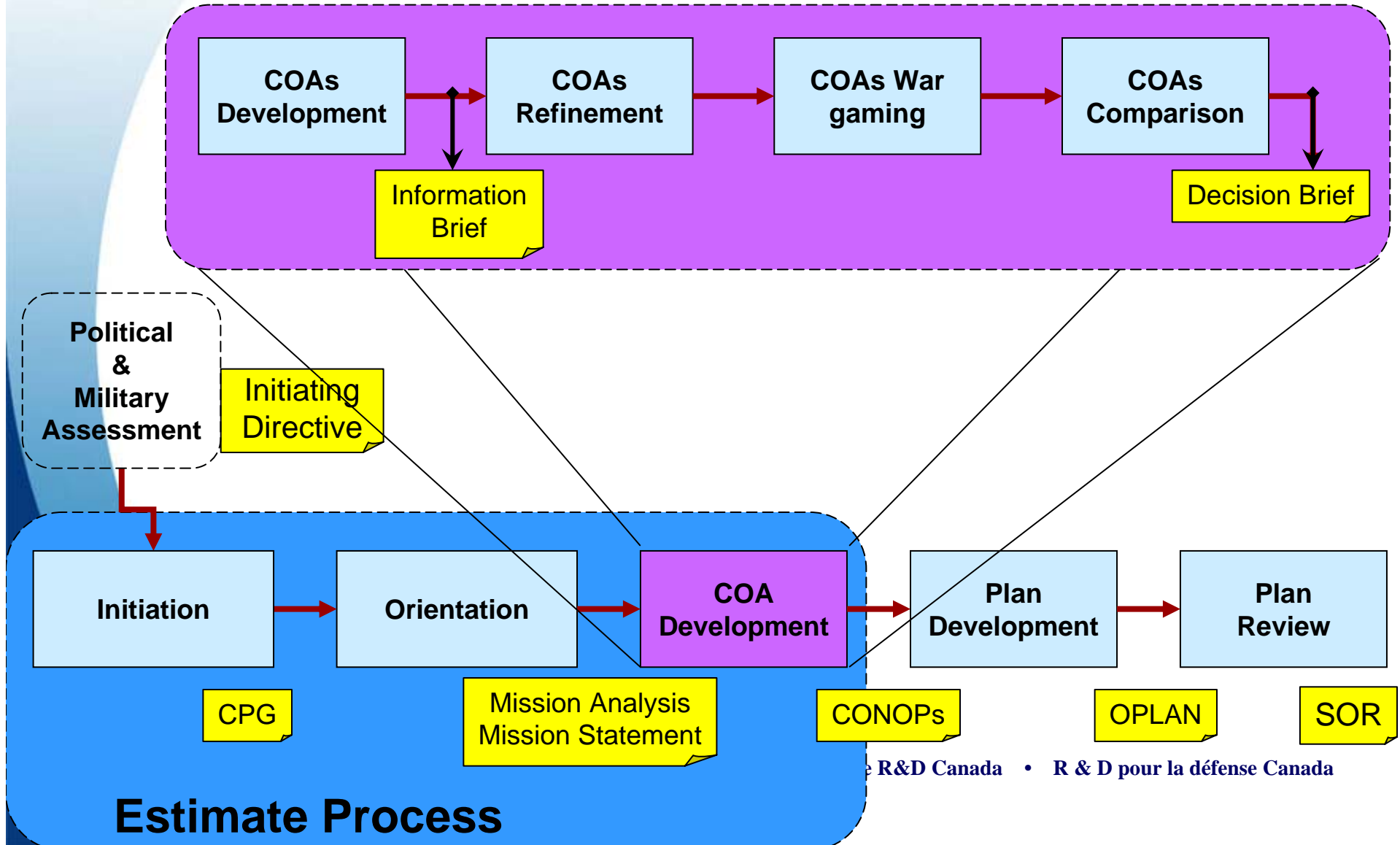
Overview

- Course of Action Analysis

- Critiquing systems

- Knowledge elicitation

- Argumentation models

- Knowledge elicitation using an argumentation model

- Conclusion

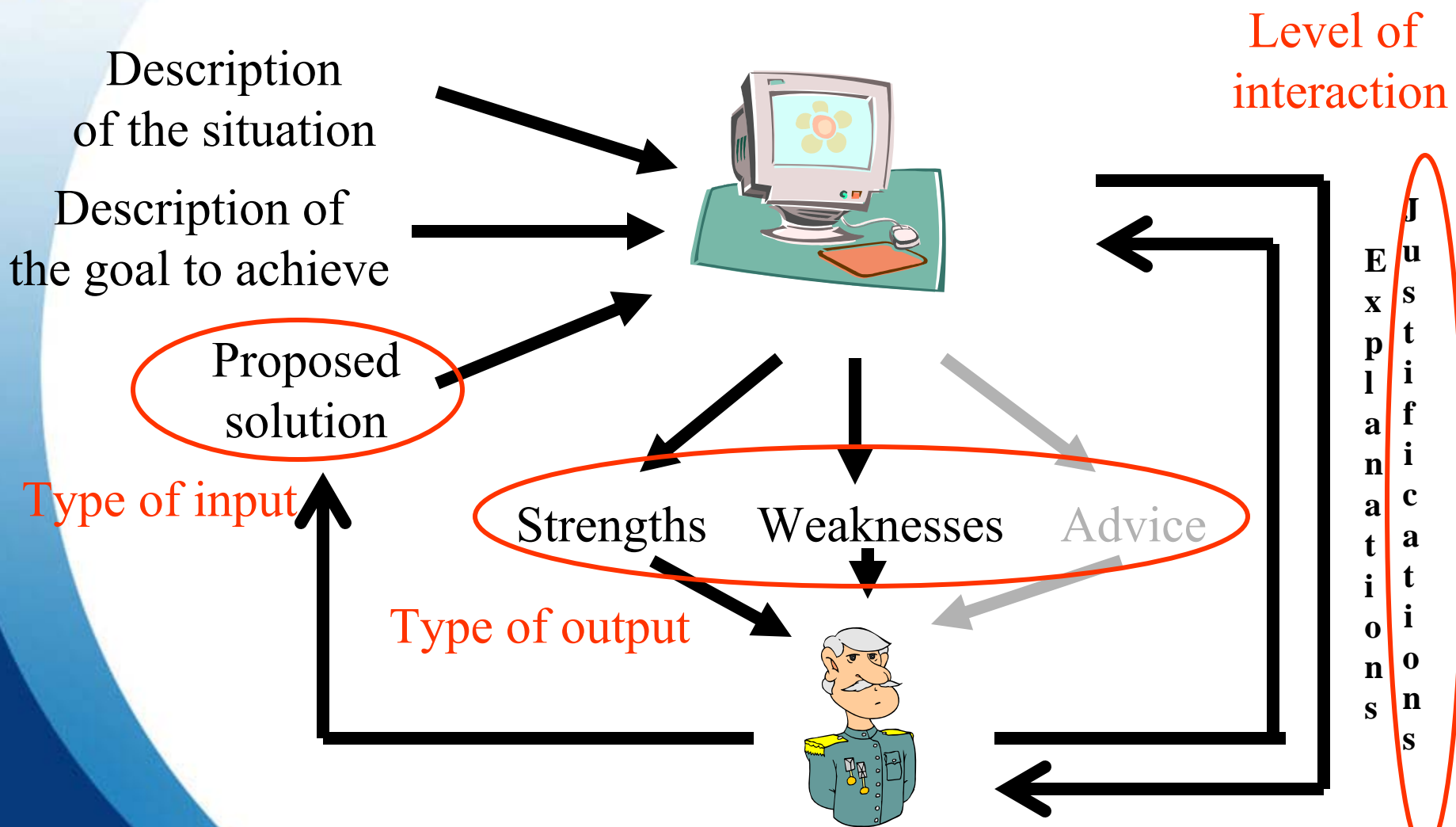# Canadian Forces Operational Planning Process (CFOPP)

- COAs Development
- COAs Refinement
- COAs War gaming
- COAs Comparison

Information Brief

Decision Brief

Political & Military Assessment

Initiating Directive

Estimate Process

- Initiation
- Orientation
- COA Development
- Plan Development
- Plan Review

CPG

Mission Analysis Mission Statement

CONOPs

OPLAN

SOR

e R&D Canada • R & D pour la défense Canada

Course of Action 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

Computer-based Critiquing Systems

Description of the situation

Description of the goal to achieve

Proposed solution

Type of input

Type of output

Strengths   Weaknesses   Advice

Level of interaction

Explanations

Justifications

Defence R&D Canada • R & D pour la défense Canada

Critiquing a COA

- Considering:

    - Conception problems;

    - Viability;

    - Enemy COAs;

    - COA evaluation criteria;

    - Direct as well as indirect effects.

Traditional Knowledge Elicitation Means

- Traditional techniques:
    - interviews (structured and unstructured);
    - observations;
    - think-aloud verbal protocol;
    - task performance with questioning;
    - surveys and questionnaires.
- New approach:
    - Automated knowledge acquisition system:
        - Ex. DARPA's Rapid Knowledge Formation.

Argumentation models as Knowledge Elicitation Means

- Critique of a COA relies on argumentation.

- 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?
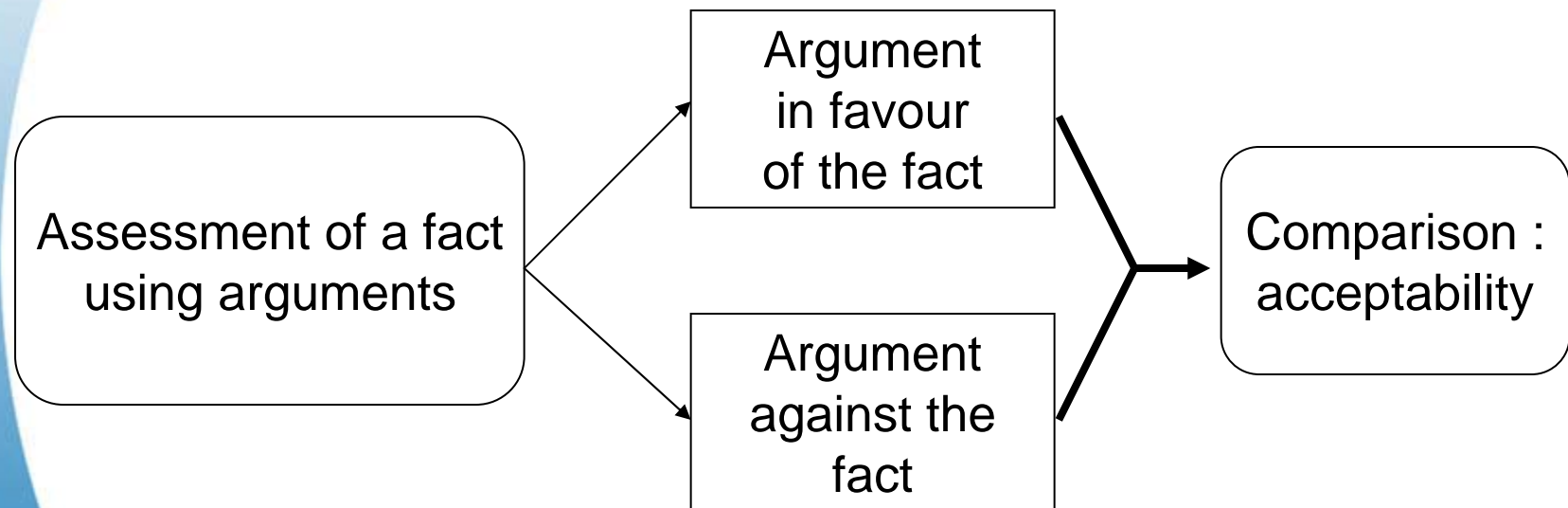
Argumentation Theory

- The notion of argument: (Dung, 1995)

  a pair <Premises, Conclusion>

- An argument is a pair (H, h) where H is a set of beliefs and h is a formula, such that:

  i) H is consistent,

  ii) $H \vdash h,$

  iii) H is minimal.

Argumentation Process

- An argument is a structured chain of rules

```
                          ┌─────────────┐
                          │  Argument   │
                    ┌────▶│  in favour  │───┐
                    │     │ of the fact │   │
┌──────────────────┐     └─────────────┘   │    ┌──────────────┐
│ Assessment of a  │                        ├───▶│ Comparison : │
│      fact        │                        │    │ acceptability│
│ using arguments  │     ┌─────────────┐   │    └──────────────┘
└──────────────────┘     │  Argument   │   │
                    └────▶│ against the │───┘
                          │    fact     │
                          └─────────────┘
```

- Example

  – Argument: *Tweety flies because Tweety is a bird*

  – Counterargument: *Tweety is different, so perhaps Tweety does not fly*

Defeasible Reasoning

- Argumentation systems are defined as semantics of *defeasible* reasoning systems (Pollock, 1974):

    - 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.

Toulmin's Model Components

1. **_Claim:_** An assertion or a conclusion.

2. **_Data:_** Statements specifying facts about which the claim is made.

3. **_Warrant:_** Statement which justifies the inference of the claim from the data.

4. **_Backing:_** Set of information which assures the trustworthiness of a warrant.

5. **_Qualifier:_** A statement that expresses the degree of certainty associated to the claim.

6. **_Rebuttal:_** A statement presenting a situation in which the claim might be defeated.

Example of Toulmin's Model

Harry was born in Bermuda (**Data**)

Presumably (**Qualifier**), Harry is a British citizen (**Claim**)

People born in Bermuda are generally British citizens (**Warrant**)

Harry's parents have another nationality or Harry becomes a naturalized American citizen (**Rebuttal**)

there are statutes and other legislation substantiating that people born in Bermuda are generally British citizens (**Backing**)

Advantages

- Toulmin's model takes into account the different components of an argument structure and the link between these components.

- It is based on philosophical and empirical foundations.

- It models the inference rules that are used to infer a conclusion from a set of premises.

- It facilitates the construction of textual arguments.

Limitations

- They are based on an informal description.

- They only emphasize the structure of the arguments without taking into account the participants and their knowledge bases.

Application of Toulmin's Model for Knowledge Elicitation

Limitations

- Does not illustrate how a warrant supports the inference of a claim from a data.

- Does not include justification of the rebuttals.

- Rebuttals are considered as counterarguments that cannot be defeated:

  – Possible solution: to represent the counterarguments as rebuttals of certain claims in a model.

Propositions

- Replace the original restrictive backing by a new component explaining the warrant.

- Add a component justifying the rebuttal.

- Add a component to attack the justification.

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 aircraft would be limited,
• …
(Data. 4)

Support

The COA T1-S3 has a high tactical risk. (Qualifier certain)
(Claim: D1a. 1, 2)

Warrant

• JSTARS is needed for RGP compilation
• JSTARS is airborne and has better communication with other resources for C2 of RGP
• …
(Warrant. 5)

Justification   **Rebuttal**

• Implicit AF 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.
• …
(Backing 6)

Backing

• 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
• …
(Rebuttal. 7)

•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
• …
 (8)

•If enemy air-to-air threat greater, more combat fuel required independent of extraction time
•Despite being far away, enemy SAM systems may still reach
• …
(9)

Rebuttal

Adapted Toulmin's Model for Knowledge Elicitation

1	Claim:	
2	Claim description (if needed):	
3	What is 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?	

Example

1	Claim:	Harry is a British citizen.
2	Claim description (if needed):	
3	What is 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.

Example produced by a SME

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	What is 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.

Knowledge Acquisition Requirement

COA	Advantages	Disadvantages
COA T1 **Op Hasty** **COA S3** **Beach**	A1 - Earlier extraction to get crews back (medical) A2 - Enemy further from target area A3 - …	D1 - High tactical risk D2 - High technical risk D3 - Some RAP degradation due to terrain D4 - …

		A1-2... / D1-2-…
1	Claim:	
2	Claim description (if needed):	
3	What is the degree of confidence associated to this claim?	
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	What makes 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?	

		Advan./ Disadvan.
1	Claim:	
2	Claim description (if needed):	
3	What is the degree of confidence associated to this claim?	
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	What makes 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?	

Example of Knowledge Acquisition

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	What is 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.

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	What is 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.

SME Feedback

#	Question	Result	Scale
1	What was the level of difficulty required to document the COA critique using the grids?	2	•0: representing a **low level of difficulty** •5: representing a **high level of difficulty**
2	To which extent would you say the grids had facilitated the elicitation of information?	4	•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
3	To which extent would you say the grids had stimulated the production of complete information?	4	•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
4	To which extent would you say the grids had prevented the production of complete information?	2	•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

Conclusion

- The SME was able to document and to organize the COA critiques without the help of a knowledge engineer.

- Observations limited to only one SME: no generic conclusion.

- The proposed Toulmin-based knowledge elicitation template is a valuable tool to support self-elicitation of the knowledge involved in the critique of a course of action.

DEFENCE R&D DÉFENSE