A Decision Support System for CoA Selection

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Abstract

A Decision Support System (DSS) prototype was implemented to assist the staff of an Air Operations Centre (AOC) in dealing with events of counter-drug operations. This prototype, called *Commander's Advisory System for Airspace Protection* (CASAP), aims to help the AOC staff to describe and share information about events, to develop pertinent courses of action (CoAs), to evaluate these CoAs and to determine which one is the most appropriate. CASAP is based on an investigation of the AOC Command and Control related activities, particularly CoAs evaluation and selection processes. Within CASAP, the CoAs evaluations and ranking are performed according to a Multiple Criteria Decision Analysis framework. CASAP provides a series of structured tools to analyse the proposed CoAs prioritisation. Based on CASAP experience, this paper identifies a set of facilities that would be needed by a generic DSS for CoA selection.

1. Introduction

The 1 Canadian Air Division/Canadian NORAD Region (1 CAD/CANR) Air Operations Centre (AOC) is responsible for planning, conducting and monitoring air operations. For routine operations, Command and Control (C2) decisions are effected through established doctrine, orders, and procedures that clearly delineate what is expected from whom. Routine operations usually have a default course of action (CoA) defined, which is executed without going into any CoA sub-processes.

Most violation of Canadian airspace falls into routine operation [1CAD/CANR OC, 1999]. However, when an event of airspace violation does not fit into the routine operation, it is considered as an immediate operational contingency operation. During contingency operations (crisis, contingency deployment or conflict), the AOC staff's responsibilities include initial assessment, contingency planning, CoAs development, as well as dissemination of warning and execution orders [1CAD/CANR OC, 1999]. The military planning process achieved by the AOC staff is composed of the following six steps [1 CAD, 1997]:

- *Step 1- Initiation*: corresponds to mission trigger and task reception
- *Step 2- Orientation*: includes mission analysis (assessment), mission statement (who, what, when, where, why) and Commander's planning guidance
- *Step 3- Concept development*: includes staff's analysis, friendly and enemy courses of action development, courses of action analysis, and Commander's estimate
- *Step 4- Decision*: includes courses of action comparison and selection, course of action approval, Commander's direction, review of critical assumptions

- *Step 5 - Plan development*: mainly concerned by synchronisation and finalisation
- *Step 6 - Plan review*: includes analysis and revision of plans.

Elaboration, mitigation and evaluation of different CoAs are thus significant steps of the planning process. CoA development and analysis are cognitive exercises in which officers simulate how they forecast a CoA would unfold. Nowadays, AOC staff uses reports, briefings and war gaming to share information, to synchronise CoAs development, and to analyse these CoAs. In fact, time usually constrains the process to generate a wide-range of CoAs, and intensively evaluate them according to significant point-of-views, before selecting and executing the *"best"* one.

Defence Research Establishment Valcartier (DREV) is conducting a research study aiming at defining decision support system (DSS) functionalities to support the Command Post staff to effectively generate, properly evaluate, and rigorously compare potential CoAs. A DSS prototype, called *Commander's Advisory System for Airspace Protection (CASAP),* was developed to demonstrate the potentiality of a DSS to support the AOC with advanced tools. The application domain retained is counter-drug operations. CASAP aims to help the AOC staff to describe and share information about such events, to develop pertinent CoAs, to evaluate these CoAs and to determine which one is the most appropriate. The evaluation and ranking of the CoAs is accomplished within a Multiple Criteria Decision Analysis framework [Roy and Bouyssou, 1993] [Hung and Yong, 1981].

Based on lessons learned from the development of this prototype, this paper reviews a set of facilities for a generic DSS dedicated to the analysis and selection of CoAs within a military decision-making context. In section 2, we portray the operational context within the AOC during contingency situations. Then, in section 3, we introduce CASAP, and its possible integration within a global Command and Control Information System (C2IS). Finally, in section 4, we identify a set of DSS beneficial facilities for the AOC staff related to CoA selection.

2. Immediate Operational Contingency Operations Activities

The analysis of the tasks performed by the AOC staff during contingency situations led to the functional decomposition of the Command Post presented in figure 1. This functional decomposition highlights the different steps the AOC staff is trained to go through in order to overcome a contingency situation. The process is initiated when a certain external tasking/request is received. After being initiated, the process is executed in an ongoing, recursive and non-linear mode. The first step, start of battle management, consists in recalling the personnel, terminating or suspending current operations, and changing the status of the AOC. The second step is the assessment of the situation, which includes monitoring, analysing, compiling resources status, etc. Then, the staff begins to generate options, which are in fact the potential CoAs to overcome the situation. In step 3, the selection process includes evaluation, analysis and comparison of these potential CoAs. Once a CoA is selected, depending on the time available, the AOC staff develops Air Tasking Orders (ATOs) or Immediate Tasking Orders (ITOs). Then a process of dissemination of these ATOs/ITOs begins. Then different functions are performed simultaneously. For instance, the monitoring of the situation is an ongoing operation throughout the entire process. Even if the event ends, the AOC staff might be busy

terminating the battle management, post-analysing actions, and changing the AOC status to routine operations.

The elaboration of the CoAs is based on a full problem appreciation through situation assessment, mission analysis, and resources status assessment. Depending on the time available, the AOC staff should develop three to five different CoAs. These CoAs "should answer fundamental questions of when, who, what, where, why and how" [1CAD, 1997]. Each CoA should be suitable, feasible, acceptable, exclusive and complete. The actual process to analyse these CoAs is based on war gaming. The central framework used by the staff in the war gaming is a discussion of the actions, reactions and counter-reactions [Army, 1997], [U.S. ACGSC, 1995]. Experience shows that war gaming is a frustrating tool for the military community since the selected CoA is never wargamed sufficiently to achieve synchronisation [Naval 1999], [U.S. ACLL, 2000].

Based on the fact that the AOC staff has to deal with a large volume of information within a very short time period during contingency situation, it appeared that a DSS would be helpful in any step of the operation planning process. In this work, we limit the study to a DSS concerned with the generation, the evaluation and the comparison of the CoAs as well as the selection of the most appropriate one. In fact, we uphold that it would be very useful to use a CoA advisory tool assisting the AOC staff to ensure that all the necessary CoA related activities are completed and verified, and the selection of a suitable CoA is accomplished in a timely manner. Moreover, this system could be useful to structure and share the information among different parties.

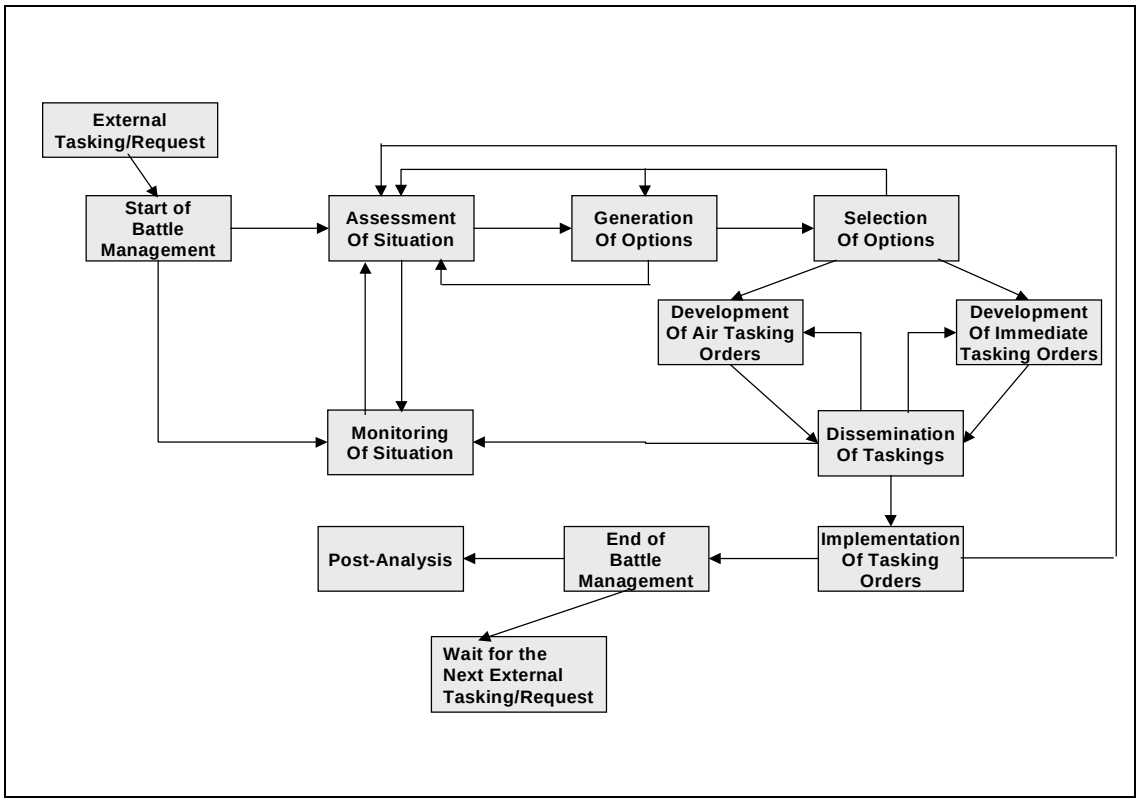

Figure 1. Functional model for the command post activities

3. Overview of the Commander's Advisory System for Airspace Protection (CASAP)

DREV defence scientists have designed CASAP to assist the AOC staff in the management of events and their related CoAs, as well as in the prioritisation of these CoAs according to evaluation criteria. Let's recall that CASAP was foremost developed to deal with events of counter-drug operations. CASAP is a tool that can take descriptions of a counter drug event and its possible CoAs. CASAP offers semi-automated evaluation of the CoAs with respect to a set of selected criteria. Then a multi-criteria aggregation procedure is used to rank (prioritise) the CoAs, and to make suggestions to the Commander. The results are presented to the Commander (or its representative) in form of charts, performance tables, and comparison graphs.

CASAP is based on a detailed investigation of how the AOC officers perform C2 related activities, particularly CoAs evaluation, analysis and selection. This analysis led to the identification of five factors to be considered while analysing CoAs for counter-drug scenarios in a peacetime context. These factors were decomposed into 14 evaluation criteria as shown in table 1. Heuristics were then proposed to evaluate the CoAs according to each criterion. The measurement scales associated to these evaluation criteria were conceived to preserve the natural AOC staff inputs (e.g. linguistic evaluation). These criteria are then associated with scales ranging from quantitative deterministic to qualitative, fuzzy, and probabilistic [Abi-Zeid *et al.*, 1998]. The comparison and prioritisation of the CoAs is performed using a Multiple Criteria Aggregation procedure called PAMSSEM [Guitouni *et al.*, 1999].

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 jeopardised by fatigue, stress, etc. at any moment during the mission

Table 1. Criteria Description

Since the evaluations of the CoAs according to the different criteria might include uncertainty, ambiguity, fuzziness, and subjectivity, several analysis tools were defined to help to minimise the risk component introduced during the evaluation process. A graphical and intuitive tool was designed to balance the relative importance of the criteria. A stability interval analysis tool was proposed to increase the awareness of the decision-maker about the role of relative importance coefficients. Further, two different heuristics were designed to help to perform "what-if" analyses on the values of the thresholds and the evaluations.

The design, development and implementation of CASAP are based on formal models of a CoA and a Canadian airspace violation event. These models have been designed through a series of knowledge acquisition sessions. The event model encompasses operational information required by the evaluation and analysis tools (e.g. type of enemy aircraft, enemy intention, etc.), as well as contextual information (e.g. political and social considerations, etc.). Even if the event model would have been a lot simpler without this contextual information, it appeared that this information is crucial for the AOC staff in the CoAs generation process.

In order to facilitate the integration of CASAP to the AOC organisation, a distributed architecture was implemented as shown in figure 2. Users interact with CASAP through Intranet browser (e.g. Netscape, Explorer). This choice has been motivated by the fact that every person in the command post has access to a browser from his desk station. CASAP uses Java applets and servlets technology, which permit the transportability of the different modules on different platforms. The client side (event description, CoA description, and CoA selection) is implemented through applets, while the servlets are used on the server side to provide access to different databases and to evaluate the different CoAs. The transportation of JAVA objects is performed through an Http transportation layer.

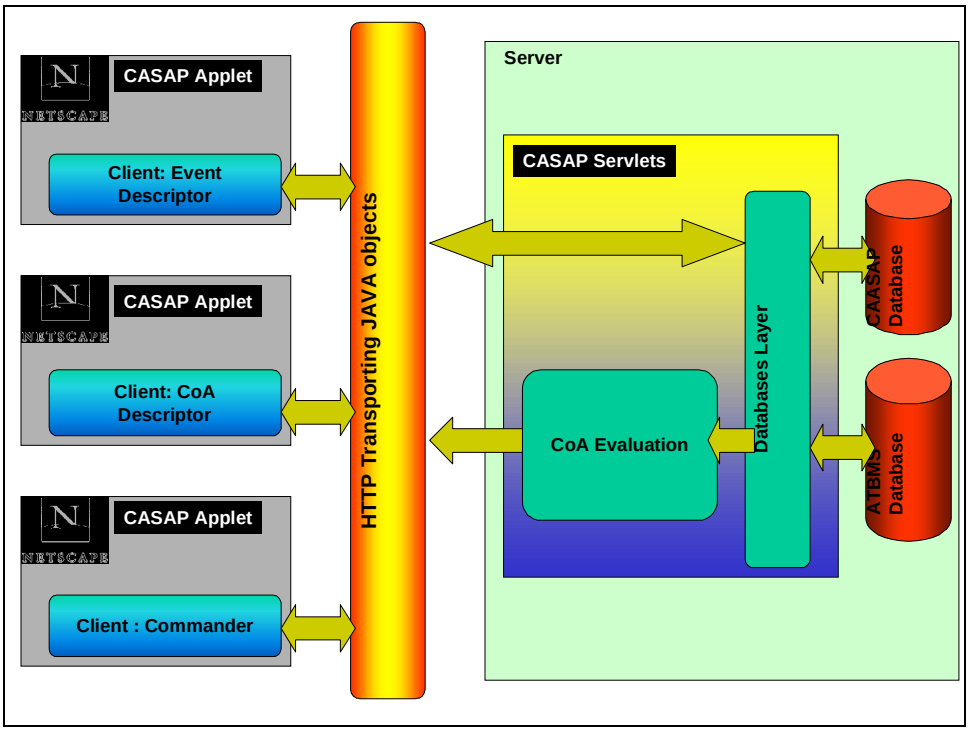

Figure 2. Physical Architecture

Furthermore, CASAP has been designed to eventually interact with many other information and planning systems within a global C2IS. It would need to access information about the event (commonly referred to as situational awareness or SITREP), resources status, conditions of operations, etc. It would also need to provide the selected CoA to a tactical planning and scheduling system in order to develop tactical plans, and to task the mission for execution. This planning and scheduling system could provide an ATOs/ITOs system with the information to generate and disseminate the orders. The mission execution will be monitored by the AOC during its execution, and feedback could be gathered for post-execution analyses. CASAP would need to have access to a database containing information on resources status, airfield, etc. This database is called AEDM in figure 3; AEDM stands for Air Environment Data Model.

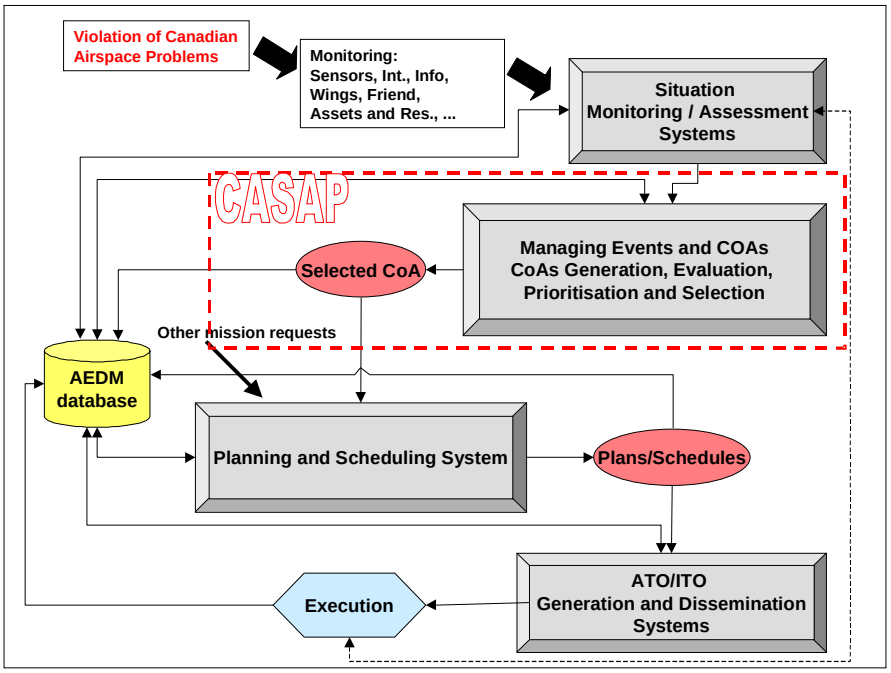

Figure 3. Context of operation for a CoA Advisory tool

4. Generic functionalities for a CoA Selection Decision Support

From the CASAP experience, we learned that any decision support technology provided to the Command Post should be integrated to the organisation workflow, and should be designed in a way to facilitate the acceptance and the transition within the AOC staff's work-domain. In our opinion, a DSS should interact with other information, planning and decision systems used within the AOC. A DSS should be user-friendly, and integrated within the *habitual* tools used by the AOC staff.

It became obvious that any DSS devoted to CoAs selection must have facilities to support six different functions (Figure 4). These functions are:

- description of the event,
- development/description of possible CoAs,
- identification of criteria to be used in the evaluation process,

- evaluation of the CoAs according to the selected criteria,
- analysis and comparison of these CoAs,
- and post-execution analysis.

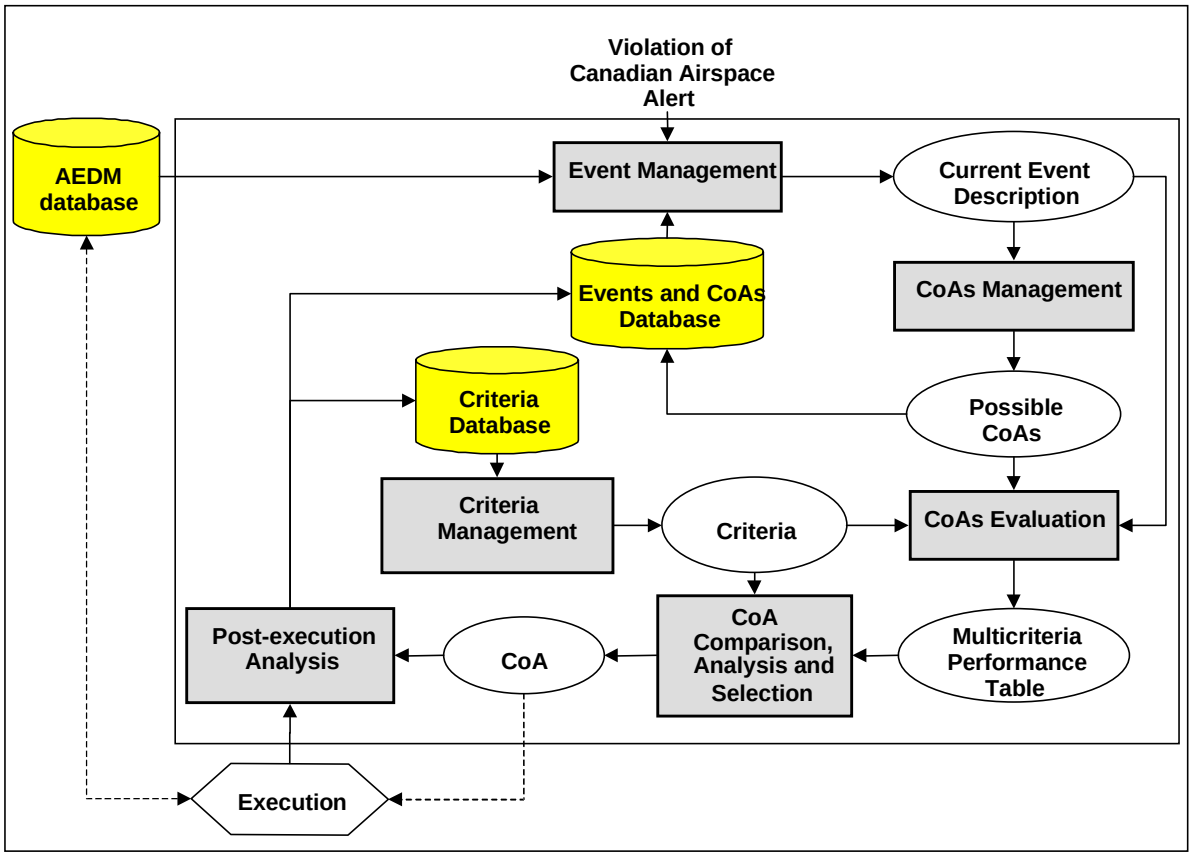

Figure 4. Functions to be supported by a CoA Selection DSS

Many of these functions are executed sequentially, while others could be performed simultaneously. An officer or a team within the AOC is in charge of describing the events. A facility to support this function must allow the creation of new events, the update of the description of an existing event, the retrieval of past or current events and the communication with other AOC members to trigger the CoAs development or the selection processes. The event description should be based on a formal model that must include information related to situation review, assumptions about the enemy, enemy forces and CoAs, planning guidance, other consideration aspects, theatre of operation features, and own forces' capabilities. These informations will contribute to gain a full problem appreciation, and better assessment of the situation.

Another facility should be available for the planning team to develop and describe potential CoAs. The CoAs facility must include the creation of a new CoA, the update of existing ones, and the verification of CoA feasibility, quality, etc. This facility should also allow the duplication of CoAs. Here again a formal model should be used to represent a CoA. This model must include information related to action items describing the actions to be performed by the

resources (what, who, how, when). As soon as the CoAs description is completed, the planning officer needs a communication channel to trigger the evaluation and selection processes.

A facility should provide automated (when possible) or semi-automated assistance in the evaluation of each CoA according to each criterion. Heuristics may be used or subjective assessment may be directly provided by the users. A verification of a minimum level of quality can be easily provided using different "filtering thresholds" according to selected criteria to filter the CoAs. If a CoA does not respect these thresholds, then the Commander can be notified and this CoA should not be considered in the comparison process.

A selection facility must allow automated CoAs comparison and semi-automated analyses. According to different types of situation, the decision-maker may want to consider different criteria when comparing CoAs. This facility should then, according to different types of situations, propose different criteria to be considered in the evaluation process, and predefined weights and thresholds accordingly. Even if the proposed criteria should be considered, the decision-maker should have the possibility to select those he considers most appropriate for the actual situation. This should be performed in an interactive way. When the criteria are selected, the CoA comparison should be done automatically, using Multiple Criteria Decision Analysis (MCDA) procedure, and different types of results must be presented to the decision-maker. A graph may represent the prioritisation (ranking) of the CoAs. Furthermore, it is essential that some information about the quality of each CoA should be presented since this graph only indicates that a CoA is better than another one. Among the analyses that can be provided to help a decision-maker, there is a dominance check which verifies if a CoA is better than all other CoAs on all the criteria, no matter the value that can be assigned to the different thresholds. A weight stability analysis that lets the decision-maker knows how the result is sensitive to the criteria weights changes. A what-if analysis on the model parameters or on the CoAs evaluations allows the decision-maker to foresee the effects of the actual settings on the prioritisation of the CoAs. Finally, this facility should enables the user to either select any CoA while providing justifications, or ask for more satisfactory CoAs and information.

A post-analysis facility should allow the reconsideration of the relevance of the choice made while the event is completed. Once a CoA has been selected and executed, the commander could then re-evaluate if its decision was the best one or not, and why. This precious knowledge should be archived for reference to future operations. This knowledge will be used to learn from experience.

Finally, the functional facilities must allow the management of the criteria, and the default parameters used within the different decision analysis procedures. This facility must support an analyst in creating new criteria, updating existing ones and associating criteria with generic instances of events. Also, this facility should enable him to set default values for different parameters.

Since the processes of defining events and CoAs, evaluating and comparing CoAs, and selecting the most appropriate one are realised through a team effort, it is important to be able to assign different facilities to different people. This can be done by defining different profiles of users and

assigning people of the command post to these profiles. From our experience with CASAP, it appeared that five different user profiles are needed:

- Event Editor: user responsible to describe an event;
- CoA Editor: user responsible to define and describe appropriate CoAs for a specific event;
- Commander: user responsible to select the most appropriate CoAs for a event;
- Analyst: user responsible to manage the criteria and to set the parameters according to the preferences of the decision-maker;
- System Administrator: user responsible to define who can have access to the system to do what.

Finally, as in any information system, a CoA selection DSS must have a facility to manage the user's profile, and maintain the Event, CoA and Criteria databases. This facility would be used by a system administrator to create new users, assign privileges, and update user's profile.

5. Conclusion

During contingency situations, the AOC staff must implement the planning process in a focused way even if the level of stress is high. AOC staff must ensure all factors affecting the mission are carefully considered when developing possible CoAs. The development of these CoAs, their analysis and comparison have to be carried out within a short time frame. To help them with their workload, DREV has developed CASAP. CASAP is a DSS that assists the AOC staff in the management of events and their related CoAs, as well as in the prioritisation of these CoAs according to evaluation criteria. The CASAP prototype employed innovative technologies that enable AOC staff to manage airspace violation events and related CoAs, and provide evaluation, analyses and comparison tools to support the decision making process.

The work done to develop CASAP led to the definition of a set of seven facilities that would be appropriate for any decision support system developed for the evaluation and selection of CoAs. These facilities are:

- Event management facility;
- CoA management facility;
- CoA evaluation facility;
- CoA comparison, analysis and selection facility;
- Post-analysis facility;
- Criteria management facility;
- System administration facility.

It is important that the people working with such type of tools be aware about their limitations. They have to be able to estimate the level of trust they can have in such tools in order to avoid mistrust as well as overtrust. We think that an explanation facility providing result explanations adapted to the user (his background, his experience, his knowledge, his preference, etc.) and the context (time available, etc.) could be used for this purpose.

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