16TH INTERNATIONAL COMMAND AND CONTROL RESEARCH AND TECHNOLOGY SYMPOSIUM

Collective C2 in Multinational Civil-Military Operations

Joint Command Decision Support System

Topic 5: Collaboration, Shared Awareness, and Decision Making

POC: Adel Guitouni
Decision Support Systems Section
Defence Research and Development Canada – Valcartier
2459 Pie-XI Blvd North
Val-Bélair, Québec
G3J 1X5, Canada
Tel. (418)844-4000 ext. 4302
Email: adel.guitouni@drdc-rddc.gc.ca

Micheline Bélanger
Decision Support Systems Section
Defence Research and Development Canada – Valcartier
2459 Pie-XI Blvd North
Val-Bélair, Québec
G3J 1X5, Canada
Tel. (418)844-4000 ext. 4734
Email: micheline.belanger@drdc-rddc.gc.ca

Donna Wood
Project Manager
Defence Research and Development Canada – Centre for Security Science
222 Nepean St.,
Ottawa, ON, Canada
K1A 0K2
Tel: 613-943-2472
Email: donna.wood@drdc-rddc.gc.ca

Joint Command Decision Support System

Abstract: *The Canadian Forces has articulated the requirement for Decision Support to be "command centric". "During CMX 05 achieving Decision Superiority was found to be critically dependent on building a shared, common awareness of crisis situations"(White 2006). This involves improved integration between systems, timely fusion and tailored depiction. A time sensitive decision support system should effectively support time-critical as well as deliberate collaborative joint and integrated planning, distributed team problem solving and options analysis. In this paper, we illustrate the concepts of joint command decision support system (JCDS). We describe the JCDS technology demonstration project. We propose the decision support architecture and components. We discuss the complexity of time-sensitive decision-making, the decision support requirements and the different components of a decision support system are including knowledge and information management concepts to support individual and collective situation awareness, decision and planning aids for emergency and crisis management situations, and execution support enablers to permit oversight and facilitate plan repairs and timely corrective adjustments. We present the results from two experiments and a set of lessons learned and overarching principles for JCDS requirements in a Joint, Inter-agency, Multi-national and Public framework.*

1. Introduction

The 2004 draft of the Canadian Forces (CF) Strategic Operating Concept (SOC) reinforced that decentralization enhances response by allowing subordinates to seek innovative and timely solutions. It introduced networking as an enabler to mission command allowing for shared Situational Awareness (SA), rapid feedback and dissemination of knowledge. Therefore, the capabilities and tools delivered to support joint command capability must enhance Commanders' ability to function efficiently and effectively in order to make timely decisions aimed at synchronizing and coordinating the delivery of effects against the right target at the right time. In other words, "mission command is the empowerment of soldiers and leaders to use their initiative, will and professionalism to carry out tasks and to operate independently within the commander's intent" (Army Force Employment Concept (FEC), 2004). It is soldier-focused with soldiers knowing that as long as they stay within the commander's intent (and applicable Rules of Engagements (ROE)) they have the freedom to make decisions of import without having to second-guess the consequences. The ability to communicate, move information and data quickly across the chain of command in support of decision making is at the center of a Commanders ability to practice mission command. In addition, all components of command and command support must be focused on supporting the commander; Command Centric. While not defined in doctrine, it places the commander at the centric point with staff structures, processes and systems facilitating the centric activity required to ensure mission success therefore providing support to Commanders. Command-centric also includes the notion that human will and creativity (whether the commander's or not) is at the centre. The intent is to enhance a Commander's ability to command not automate.

The CF have articulated the requirement for Decision Support to be "command centric". "During CMX 05 achieving Decision Superiority[1] was found to be critically dependent on building a shared, common awareness of crisis situations" (White 2006). This will involve improved integration between systems, timely fusion and tailored depiction. Most of the Canadian Forces employment scenarios involve multiple stakeholders to be engaged in planning, executing and sustaining operations in complex settings. For example, 346 organizations converged to the one area during a massive fire near Nanticoke, Ontario, Canada; this included 27 Federal Government, 25 Provincial Government, and 10 Regional agencies, 7 Local Government Departments, 31 Fire Departments, 8 Voluntary Groups, 41 Religious/Hospital/Schools groups, 4 Utilities, and 52 Private Sector players (Quarantelli). During Vancouver 2010 Olympics and Paralympics games, about a hundred agencies and organizations were involved with the safety and security of the games. Accordingly, the

[1] Decision Superiority: the ability of the Commander, based upon information superiority and situational understanding, to make effective decisions more rapidly than the adversary, thereby allowing one to dramatically increase the pace, coherence, and effectiveness of operations. (US Joint Forces Command Glossary)

complexity of the challenges facing the CF demands innovative means and technologies to support critical thinking, team building, and courses of action development, shared situation awareness and execution management.

A time sensitive decision support system should effectively support time-critical as well as deliberative collaborative joint and integrated planning, distributed team problem solving and options analysis. "A decision without analysis is akin to a trip without roadmaps" (US Government 2002). The provision of situational awareness is the prelude to informed analysis, adaptive planning, and effectual management of operations. The sheer complexity of the operations in the 21st Century requires investigation, trial and adoption of more sophisticated decision support aids for crisis and emergency management (e.g., planning, options analysis, resource visibility, logistics, readiness, and sustainability tools). Another very important requirement is to monitor execution and to provide clear, comprehensible feedback linked to the plan and allows progress to be tracked, and adjustments to be made in near if not real time. The performance parameters established during the planning phase that are linked to the desired effects should provide measurement standards and advance warning of failure.

The Joint Command Decision Support for the 21st Century (JCDS 21) was a Technology Demonstration Project. JCDS 21 demonstrated Joint and Net-Enabled Collaborative Environment concepts and technologies to support Joint Command Decision Making process: situation analysis and intelligence, visualization, planning support and operations management. Process, Organization and Technology are elements of a 'net-enabled collaborative environment'. The effective networking of people, organization and technologies to conduct collaborative work is considered key to achieving decision superiority. JCDS 21 assumed that Collaboration and teamwork were factors for success in the decision-making environment. Accordingly, enablers for a Joint Command Decision Support are:

- Trained staff and Command on the CF business processes;
- A comprehensive C4ISR architecture and standards. Therefore, JCDS 21 software and hardware products with the potential for transition needed to be capable of working within the existing or planned C4ISR infrastructure;
- A Command Network providing the backbone for information exchange and connectivity; and,
- Availability of information sources across the command network.

The methodology used by JCDS 21 to develop decision support in such complex environment started with the understanding of the different business processes involved in a Joint Interagency Multinational and Public (JIMP) decision making context. Considering some mission objectives, function analyses was conducted to identify gaps and areas for possible improvements in current CF decision making processes. These findings were used to identify a set of decision support requirements corresponding objectives and desired effects to be achieved (i.e., increased speed of command and operational tempo; adaptability resulting from the use rapid feedback loops). The design of Joint Command Decision Support required a sound appreciation of Human and Organizational sciences. Support cognitive capacity, shared situation awareness, common intent, trust in distributed teams and in automation, as well as communication and information strategies are key foundations for joint decision effectiveness. Considering the scope covered by the context addressed in the JCDS 21 project, many decision support solutions needed to be identified. The integration of these different solutions was realized using a System of System (SOS) architecture. This SOS architecture was implemented using a service oriented architecture which allowed the integration of these solutions into the existing technical baseline of the Canadian Forces which involves multiple information systems. Finally, the JCDS21 solution was assessed positively during an experiment using the metrics identified while developing the decision support requirements.

In this paper, we illustrate these concepts with a focus on domestic operations in a joint, inter-agency and public framework. We use the case of the development of the JCDS 21 systems to illustrate these concepts.

We describe the decision support architecture and components. This paper is structured as follows. In section 2, we discuss briefly the Joint staff decision making processes and activities. In section 3, we present the decision support concepts and requirements. In section 4, we discuss the different components of a decision support system including knowledge and information management to supporting individual and collective situation awareness, decision and planning aids and execution support enablers to oversight and facilitate plan repairs and timely corrective adjustments. In section 5, we discuss empirical results. This paper is concluded in section 6.

2. Joint Staff Decision Making Processes

JCDS 21 project started by undertaking the development of an understanding of existing staff planning and decision support activities through the conduct of CF functional area and needs analyses. Data collection and analysis activities were conducted between January and October 2005. A structured approach which included a review of the literature, observations and interviews was adopted and daily and mission specific activities were observed. Data collection focused on decision making, problem solving, finding information, collaboration, and Information and Intelligence analysis. This section presents an overview of the joint staff decision making processes.

An important step was to map out the Command Levels within which they will operate. This assisted in defining the interaction between nodes, the information exchange requirements between them and the degree of connectivity required to support the exchange between Commanders. JCDS 21 was focused on Commander Canada Command and his subordinate Regional Joint Task Force Commanders. This view can easily expand to include other Joint Command Commanders deployed on operations outside the Canadian Theatre of Operations. They may include Air, Maritime and Land Component Commanders depending on the operation being conducted. However, these Commanders do not operate in isolation and therefore must retain some connectivity with partners and superiors. In addition, because of the Continental focus of Canada Command, it must interact with Bi-lateral entities such as North American Air Defence (NORAD) and with his counterpart in the US, Commander United States Northern Command (USNORTHCOM) and elements of the Home Land Defence & Security Department.

The joint staff members are involved in many processes in support of the Commander. This section focuses on five main staff processes: Command process, situation awareness process, planning process, decision-making process and current operations management process. The role of the staff is to assist the commander in making timely decisions in order to accomplish assigned missions on time and to assist subordinate commanders in the accomplishment of their tasks. A military staff, in support of their Commander -whether at the strategic, operational or tactical levels-, will fill seven basic functions:

- Control and coordinate allocated resources on behalf of the Commander;
- Gather and analyze information and data to generate and maintain SA;
- Conduct Planning in accordance with the CF Operational Planning Process (OPP) both as a deliberate activity and in support of current operations;
- Conduct and coordinate training to generate forces required for the conduct of upcoming operations;
- Manage current operations by maintaining situational awareness, synchronizing and coordinating the execution of operations and, when required, adjusting the plan in accordance with the changing situation;
- Manage resources on behalf of the Commander whether personnel, money, equipment, vehicles, weapons or ammunition; and,
- Manage and disseminate information by communicating orders and directives, share and exchange information in a collaborative environment.

The staff activities within a Headquarters (HQ) are organized functionally in order to streamline and focus planning, decision-making and delivery of effects. They normally group together specialist staff from different branches to create the necessary critical mass of expertise to effectively produce staff work. Accordingly, HQ staff can be sorted in relation to the following functional groupings:

- The Command Information Management (IM) group. This group is headed by the Chief of Staff (COS) who coordinates staff workflow, manages information and the overall running of the HQ. It includes a number of specialist advisors who provide input to all HQ functions (e.g. Legal, Political Advisor);
- The Current Operations group. This group coordinates and synchronises all current operations and activities for the commander. It contains the staff to manage the battle, react to changing operational situations and monitor the status of all other HQ functions;
- The Sense, Fuse and Target Functional Group. In accordance with the Commander's Critical Information Requirements (CCIRs), this Group tasks and coordinates all collection assets. The information gathered is analyzed and fused in order to produce SA products in support of the planning, targeting and decision making processes;
- Effects Synchronization Group. This group coordinates and synchronizes the delivery of lethal and non-lethal effects in order to achieve the Commander's desired end-state;
- Plans Group. The Plans Group conducts deliberate planning and includes a core team from all HQ Branches with advice being sought collaboratively from other specialist staff, HQ and agencies, often through a reach-back process;
- For the deployment of a HQ there is also a need for Communications and Information Systems (CIS) Support, Protection and Sustainment, which can be tailored to the mission and HQ configuration. The CIS function integrates the presentation and networking of Command Control and Information Stystems (C2IS) tools. HQ protection and sustainment will be tailored to the size and configuration of the staff functions;
- JIMP operations and the Common Operating Environment (COE) now demand greater emphasis on several staff competencies and specialist knowledge at lower levels; in particular those related to Information Operations (IO), Civil-Military Co-operation (CIMIC), Psychological Operaitons (PSYOPS), Electronic Warfare (EW), Public Affais (PA), etc. Equally, competent and well-informed Liaison Officers (Los), with strong interpersonal skills, will be essential for ongoing SA and cultural awareness during deployments. These competencies will need to be built into the core capabilities of HQ staff.

The Command Process

Command is the operational process that gives cohesion to the other staff processes. The CF is moving towards employment concepts and command structures that are increasingly joint, within a national strategy of Diplomacy, Development and Defence (3D), and with most operations now having joint, interagency, multinational and public dimensions to them (JIMP). Given the realities of Command today, the aim of the CF is to achieve decision superiority by enabling Commanders to make informed and timely decisions and to synchronize the effects relevant to the success of a mission. This requires a Command Support Capability that is founded on the principles of Network Centric and Network enabled operations. In the end, we want to provide Commanders the information required to support a timely decision cycle optimized for the new CF operating environment.

The Command Process provides the environment within which all other Staff Processes are integrated in order to support Commanders. The IM function is driven by the CCIRs and to be effective, must exist within a shared information space in order to generate and maintain SA. The ability to perform these functions is enhanced and enabled by Command and Control infrastructures and tools coming together to generate

Command Support Capabilities. These conditions are aimed at enhancing the Commanders' ability to be warned and oriented to a situation, conduct timely planning, communicate orders and direction, lead and manage the execution of the mission, monitor progress and adjust the plan as required to achieve the stated end-state.

It is necessary to ensure that command-centric and mission commands are not in conflict. The aim is not to feed information to the Staff for command decisions, but rather to feed information to the Commander through the Staff so that tasks and resources are assigned to enable subordinates to execute their missions. Commanders must personally communicate intent in order to start the planning process. The Staff then enables the Commander and sets the conditions for the success of subordinates. Ideally, applications and processes must be tailored to the Commander's needs, rather than the Commander adjusting his needs to match the applications and processes available. JCDS 21 Command Support Capabilities development must respect these fundamental principles. The tools should enable the Staff to support the Commanders' ability to articulate and communicate intent to subordinates along with the critical information required. Timely and pertinent information is the basis of an efficient Information Management System. In order to better understand which information is required and when, we must look at the purpose it will be used for. The sub paragraphs below provide the definition of the four sub processes of the Command process:

- **Battle Command** is the art and science of battlefield decision making and leading soldiers and units to successfully accomplish the mission. The battle command basic elements are decision making, leading, and controlling. The battle command system enables commanders to lead, prioritize, and allocate assets required to employ and sustain combat power;
- **Deliberate Planning** currently used by the Canadian Forces is the CF OPP. The deliberate planning process normally occurs in parallel to the conduct of current operations and is aimed at preparing follow up plans or contingencies. The planning horizon of the deliberate planning cycle will vary based on the level of Command of the Headquarters but it can be measured in days, weeks or months;
- **Battle Planning** allows Commanders to adjust the current plan to exploit or react to situations as they unfold in order to be able to achieve mission success. Typically, time is of the essence and a more deliberate planning cycle is not feasible. Battle planning allows the Commander to rapidly consult with higher and subordinate Commanders, key advisors and staff, to quickly develop a solution to the situation, coordinate the assets required and issue direction quickly. The aim is to get the right assets to the right place at the right time to have the desired effect; and,
- **Battle Management** provides the ability for a commander to concentrate the right forces, at the right place, at the right time, at the right target to achieve the desired effect.

The Situational Awareness Process

Situational Awareness (SA) is often defined as the mental representation and understanding of objects, events, people, system states, interactions, environmental conditions, and other situation-specific factors affecting human performance in a complex and dynamic tasks. The SA required by Commanders is generally a combination of both Intelligence and Operational Reports analyzed and placed in their respective Geographic Information System (GIS) context in order to help answer the following simple questions: What is happening? Why is it happening? What will happen next? What can I do about it? SA is not about volume of information but about quality information getting to the right audience at the right time.

Based on the task to be executed, different types of SA can be distinguished:

- **Baseline or Routine SA**: The aim is to provide monitoring and warning services about the status of the Commander's area of responsibility. This SA fuses information from Superior levels of Command, Subordinate Levels of Command, Public and or Private Sector partners, open sources and Allies. It

basically provides the Commander with his state of the union while monitoring threats and risks with a view of delivering sufficient early warning to trigger a sequence of events or a specific response.

- **Targeted SA**: This type of SA is focused on a specific operation or event. The aim is to generate actionable information/intelligence to assist the Commander in making timely decisions to maintain mission success while coordinating and synchronizing the actions of all players. This situation specific SA fuels the Commanders decision and battle planning processes during the execution of an operation until its completion.
- **Decision Support SA**: This information type includes all pertinent information from the Baseline SA and Targeted SA that will necessitate the Commander's intervention and ultimately a decision from him. To be successful he must make timely decisions to keep a plan on track including making changes to elements of the plan and rapidly communicate his intent to both his superiors and subordinates.

The building of SA occurs at all levels of Command where it is consolidated, packaged to meet the needs of the various Commanders (Superiors, Peers, Subordinates) and Staff (Planners, Current Operations & Specialists) to be finally distributed and\or displayed. The flow of information that may contribute directly or indirectly to a Commander's understanding of the situation is constant and therefore the SA at all levels of Command is dynamic and constantly evolving. In order to avoid overwhelming Commanders and Staff, it is essential to provide focus around the CCIRs or around decision points or warning indicators closely tied to a Commander's Decision Support Template. Once pre-established criteria have been confirmed, Commanders will be in a position to make choices based on the SA developed around each decision point.

The Planning Process

The CF OPP is a coordinated and coherent process for determining the best method of accomplishing objectives or for planning for possible future tasks. This process facilitates the logical, analytical and thorough consideration of the many factors that impact on a particular situation without stifling the Commander's and his Staff's freedom to apply their creativity and innovative spirit to develop ideas and concepts to achieve success. The process can be used to develop Campaign Plans, Operations Orders, Contingency Plans and the detailed planning of each campaign Phase, Branch and Sequel. Essentially, the Planning Process is carried out by the Staff in support of the Commander's Decision Making Process. The CF OPP is composed of five steps: Initiation, Orientation, COA development, Plan Development and Plan Review.

The CF OPP is fuelled by information that serves very specific purposes within the CF OPP. The information required to allow the Commander to remain engaged in this Command Support function falls in two basic areas. First, the Commander must have unrestricted access to documents received from his superior Headquarters to initiate and orient his own planning process. From this point on, the Commander will be required to review and comment on key deliverables from the CF OPP and provide guidance and decisions to his Staff. The final step would require the Commander to review a plan, approve it and authorize its distribution.

Typically, the CF OPP at the Operational Level occurs over longer periods of time leading to the production of contingency Plans or operational Plans. Contrary to the planning and decision making process associated with an incident or on-going operation, these activities are less time sensitive. The Commander would most likely have time to return to his Headquarters to be directly involved in the planning.

The Decision Making Process

Decision making is the process of sufficiently reducing uncertainty and doubt about alternatives to allow a reasonable choice to be made from among them. In military terms, it is the process by which Commanders make decisions. The Commander's Decision Process is intimately linked to the Staff Planning Process

discussed earlier. The output of the Planning Process feeds information to the Commander and enables him to make decisions. The decision making process is all about the dynamic which exists between a Commander and his subordinates, the Commander and his Staff and the Commander and his superior(s). The information requirements needed in support of the decision making process represent a combination of all the other Command Support Processes. The following information is required to make timely and relevant decisions:

- SA information to include both baseline and targeted SA input and products;
- Planning Information and Data Input & products;
- Intelligence input and products;
- Orders, instructions and guidance; and,
- Decision Support Templates.

The Current Operations Process

This is the process by which Commanders and Staff exercise command and control over the elements involved in the execution of a specific plan or routine operation. It is the process by which resources are coordinated and synchronized to accomplish given tasks to generate the desired effect(s) on the right target and the right time with a view of meeting the Commander's intent and objectives. The critical information product in support of this process is the generation and maintenance of relevant, accurate and timely SA to support the Command Support Functions of Battle Command, Battle Management and Battle Planning.

The information flow during the conduct of operations is principally aimed at generating and maintaining the Situational Awareness required making sure the execution of a plan and its integral and supporting tasks are progressing as planned. The intent is to be able to detect problems before they arise and quickly adjust the plan in order to maintain the aim.

During the conduct of operations the CCIRs are most often tied to measuring the success of the operation against pre-identified triggers and or decision points. CCIRs are crafted in order to provide as much advance warning that conditions tied to a decision have been met in order to generate the response intended by the Commander. Furthermore, such information requirements may also be tied to conditions or threats that may require the Commander to modify the current plan in order to counter the impact on the conduct of operations. Therefore, the Current Operation Process is aimed at gathering information on a series of specific pre-identified trigger points associated with critical decision points for the Commander (ie: The Commander's Decision template).

3. Joint Command Decision Support Concepts

The requirements identified during the gap analysis conducted part of the Canadian Force business process analysis (Greenley *et al.* 2006) resulted in the identification of a set of overarching principles for the implementation of Joint Command Decision Support (Hales and Scipione 2008).

Cohesive Visioning

> *Joint Command Decision Support should be developed around agreed concepts, a shared vision and ongoing unity of effort.*

The first overarching principle relates to unity of effort. The CF has articulated the requirement for Decision Support to be "command centric". A US study into lessons learned following Hurricane Katrina distinguished between Unity of Command and Unified Command (Townsend 2006). The former describes a hierarchical

organization construct and well defined reporting lines. The latter is an extension of the Incident Command System in which designated representatives work together to establish common objectives, agree on a plan and coordinate actions. Cohesion and inclusion are important enablers and unified direction is a key to success. JCDS 21 worked with the broader community to appreciate emergent needs, determine opportunities and assess potential "solutions". JCDS21 maintained close liaison with key stakeholders to ensure unity of effort. The JCDS 21 was inclusive and attempted to incorporate multiple perspectives and focus efforts.

Integration

> *Joint Command Decision Support should be developed around a system-of-system vision integrating process, organization and technology enhancements and leveraging investments to achieve decision superiority.*

Collaboration is one piece of the puzzle; program integration is another. As decision-making includes four different domains (cognitive, knowledge, organizational & observable), successful command decision support must create an integrated view of the different dimensions influencing the Commander's ability to make decisions. All three Process, Organization and Technology (POT) axes must be addressed. Human-Human, Human-Organization and Human-Technology thrusts should be integrated, and the integration based on fully net-enabled and connected forces with a command-centric philosophy. JCDS 21 System Integration & Interoperability involved the design and construction of a test bed to support integration, and to provide the means to carry out rapid prototyping and as well as to trial procedural, tool and system improvements.

Incremental Progress

> *Joint Command Decision Support should be developed around continuous, successive enhancement and capability augmentation.*

Conventional systems engineering is requirements-driven while complex adaptive systems design must cater for "rampant uncertainty, persistent surprise and disruptive innovation" (Boardman and Sauser 2006). Complex adaptive systems are, of necessity, built incrementally. JCDS 21 might equally be characterized as a complex adaptive system; provision must be provided for changes in the environment.Given urgent requirements and the pace of innovation, the majority of the work program focused on incremental/evolutionary change, providing the immediate/next generation support to operators. Concurrently, the JCDS 21 team was asked to identify where revolutionary change may be warranted. "*Thinking about command and control must be conceptually based, rather than focused on technology and material*" (US DoD, Joint Vision 2020, 2000). The JCDS 21 concepts provided for cyclical conceptualization, assessment, integration and capability.

Understanding Human and Organizational Factors

> *Joint Command Decision Support should be conceived based on a sound appreciation of Human and Organizational sciences. Supported cognitive capacity, shared situation awareness, common intent, trust in distributed teams and in automation, and communication and information strategies are key foundations joint decision effectiveness*

JCDS 21 focused on the human and organizational factors with a view to characterizing interactions between stakeholders, facilitating collaboration and improving decision performance in the complex and dispersed environment. JCDS 21 investigated the implications of theories such as net enabled operations on individual and team decision making (roles and rules). Underlying assumptions (e.g., more information is helpful, information polling will lead to shared interpretation) have been partially validated and issues (e.g., cognitive capacity and readiness, trust in distributed teams and in automation) were explored to determine whether implementation will complicate command competency, authority and responsibility.

A broad range of interests are represented and organizations will be required to integrate disparate Command and Control systems, processes, and philosophies to ensure activities are coordinated and desired effects achieved. An understanding of information interoperability and the impediments to communications and trust will inform Preparedness and Response planning and performance. JCDS 21 introduced a preliminary concept of operations and explored the value of generating partnerships (e.g., to identify requirements to enable collaborative work in a JIMP environment). JCDS examined decision effectiveness with a view to identifying factors and proposing performance measures. Sub thrusts included investigation into how information is integrated/advice exploited in making decisions and the importance of a Commander's decision making style.

Personnel stability and residual experience is a major Department of National Defence (DND)/CF concern. As much as 25% of the CF's time is devoted to training, and approximately 1/3 of headquarters staff at each level rotate (change appointments) each year. Collaboration is fundamentally a human and social activity. Consequently, such turnover poses challenges in maintaining a knowledge base and in sustaining trust.

Enabling Individual and Collective Situation Awareness

> *Joint Command Decision Support should enable seamless individual and collective situation awareness.*

JCDS 21 focused on the representation and management of information and knowledge at the Operational Level. The preliminary Gap Analysis suggested that this is an area ripe for research and development (R&D). The requirement for integration and analytical tools to realize Effects Based Planning, enable Net Enabled Operations and to exploit a Collaborative Information Environment is obvious. Both the interviews and observations affirmed that information discovery and retrieval in addition to knowledge exploitation are problematic. The goal is "seamless situational awareness". This will involve improved integration between systems, timely fusion and tailored depiction.

Development of a search tool to address the difficulty identified in terms of locating existing information is crucial to taking full advantage of a virtual knowledge base. This is significant as knowledge needs to be both accessible and situated contextually; the gap analysis noted in particular the need for staff to be able to readily evaluate the knowledge source. Addressing the requirement for an adaptive, user-centric Portal to facilitate efficient information manipulation and visualization was raised in an earlier discussion. Portals provide access to shared information and applications. JCDS 21 contributed to the development of an advanced portal through progressive, incremental changes of the existing Command View. However, the requirement to support strategic, operational and tactical commanders and staffs requires Views (within Command View) to be customized, particularly in time critical situations. This includes accommodating traditional geographic filters and providing for synthesis (production of a high level amalgam) and /or detailed analysis (drill down). Stakeholders also require a functionally oriented View (e.g., a Recognized Logistics Picture). Moreover, videoconferencing and a shared suite of web-based tools facilitate information sharing and enhance collaborative *analysis and planning by distributed staffs.*

Facilitating Joint Reactive and Deliberative Planning and Decision Analysis

> *Joint Command Decision Support should effectively support time-critical as well as deliberative collaborative joint planning, distributed team problem solving and options analysis.*

The provision of situational awareness is the prelude to informed analysis, adaptive planning, and effectual management of operations. The sheer complexity of the operations in the 21st Century requires investigation, trial and adoption of more sophisticated decision support aids. There is a requirement for Total Resource Visibility for the Strategic Joint Staff (SJS), Canada Command and all other regional Commands. Logistics, Readiness and Sustainability are critical planning factors. A big part of the Command and Control challenge revolves around administering and managing resources in the face of uncertainty. The intent of Total

Resource Visibility is, where possible, to eliminate unknowns relating to Own/Blue Forces. Current, reliable, synthesised resource-related information will highlight shortfalls early on, ensure impact analyses are accurate and support enlightened decisions. Importing and exporting information to and from Peers and Partners will be needed to provide a complete picture. Total Resource Visibility must support both incident planning and continuous planning. There is a requirement to present contingency operations as both a discrete event and part of a continuum. There are often several engagements running at one time and resources continue to be consumed and reconstituted between contingencies. Total Resource Visibility is needed to support arbitration, allocation, and adjustment of resources, and longer term feasibility planning. As highlighted in the Joint Staff Front End Analysis report (Greenley *et al.* 2006), most issues the Joint Staff dealt with required resolution/decision within a week, but had longer term implications. Total Resource Visibility should also provide for a "dashboard" highlighting asset status. Beyond visibility tools such as predictive modelling and concepts such as Sense & Respond, Logistics need to be considered and advantage taken of emergent technology such expert/intelligent software agents.

Information and Intelligence must be readily comprehensible and sources must be recognizable to a Commander and staff, since they are often working while tired, as well as under considerable time constraints. The Joint Staff Front End Analysis emphasized the requirement for fusion and meaningful representation. The requirement for improved Risk Management tools and processes appears self evident. Greater objectivity, better defined metrics, and a more traceable and responsive process for investigating mitigation strategies would enhance decision support. A Handheld Decision Support Tool is required to support the concept of commander on the move. Finally, it is often difficult to assess options when faced with complexity (e.g., multiple stakeholders, diverse issues, and a dynamic situation). A Management Tool would assist in framing the problem/identifying factors and supporting multi-criteria decision making.

Supporting Execution and Plan Management

> *Joint Command Decision Support should support execution oversight and facilitate plan repairs and timely corrective adjustments.*

Another very important requirement is to Monitor Execution and to provide clear, comprehensible feedback linked to the plan and allow progress to be tracked, and adjustments to be made in near if not real time. The performance parameters established during the planning phase that are linked to the desired effects should provide measurement standards and advance warning of failure. No plan survives contact with the enemy (Barnett, 1963). Perhaps now more than ever given the complexity and tempo of operations, there is an imperative to monitor implementation and adjust plans accordingly. Systemic recognition should be done of when and where intervention is required to provide timely analysis of corrective options. This will involve addressing human & organizational capacities, presentation of unfolding operations (e.g., timely alerts) and provision of time-sensitive decision support tools.

4. Joint Command Decision Support System (JCDS 21)

To support Commander's decision cycle, JCDS 21 developed a set of tools for the Joint Command Staff. These tools aim at improving information and knowledge management for situation awareness support as well as planning, options analysis, execution and operations management. These tools were then integrated using a service oriented architecture.

Information and knowledge management for situation awareness support

The Advanced Command Portal (ACP) provides the foundations for a Command and Control Collaborative Environment (on top of Command View and other C2 applications) supporting shared situation awareness, information management, systems integration and collaborative working (Figure 1). The ACP illustrates how

a command portal environment can be tailored to user's roles and needs, with new information/knowledge management services to provide enhanced situation awareness, and access to C2 applications. The Knowledge Management services, including notification, document management with metadata, search, collaboration in communities, ontology, GIS, and the underlying core services lay the foundation for the JCDS 21 command and control collaborative environment. Timely locating and exploiting knowledge assets and artefacts during crisis management are very important enablers for good decision support. The knowledge assets are considered along four different dimensions:

- Social including knowledgeable/experienced individuals, groups and organizations;
- Knowledge artefacts including explicit knowledge such as documents, databases and websites;
- Procedural including the knowledge assets associated to specific organizational processes; and,
- Conceptual including knowledge assets related to key subjects, and linked to specific domain through domain ontology.

A Knowledge Mapper (KMapper) concept (**Error! Reference source not found.**) has been developed to enhance situation understanding, sense-making and knowledge awareness through the visualization of related knowledge assets (KAs), as well as their relationships. KMapper provides knowledge assets discovery and visualization. The KMapper is a dynamic system supporting the identification, localization, visualization, and exploitation of information/knowledge assets (knowledge sources). It seeks the enhancement of situation understanding, sense-making, and knowledge awareness through the visualization of knowledge assets as well as their relationships. This ontology-based system provides mechanisms supporting the identification, localization, visualization, and exploitation of knowledge assets. For example, when an incident has been reported into the Incident Management System, it will automatically show up on the ACP and a Knowledge Map will be generated to help the Watch officer finding key knowledge assets like the subject matter experts, concept of operations, crisis management check-lists, etc.

JCDS 21 has also developed a Total Resources Visibility (TRV) tool for near real-time resource visibility providing asset information (Figure 3). It can be used to analyse/visualize contingency plans and their assigned resources. TRV can also be used to analyze and perform measurement of resources employment and usage. The aim of TRV is to offer the ability to ascertain the identity, location, status and condition of assets in the logistics chain at the operational level. The scope of TRV is to enhance information capability to support logistics decision making and planning. TRV provides integrated functions for assets visualization with drill-down capabilities and readiness estimation based on the operational plans (Op Plan or Contingency Plans). In case of crisis or emergency, the TRV is a vital capability to quickly locate and assess the readiness of different response units or movement assets to deploy and assist with the crisis unfolding. TRV is also handy for planning and re-planning in dynamic way. TRV allows also monitoring the status of different pre-planned plans or contingency plans for execution under short notice.

Figure 1 – Collaborative Portal

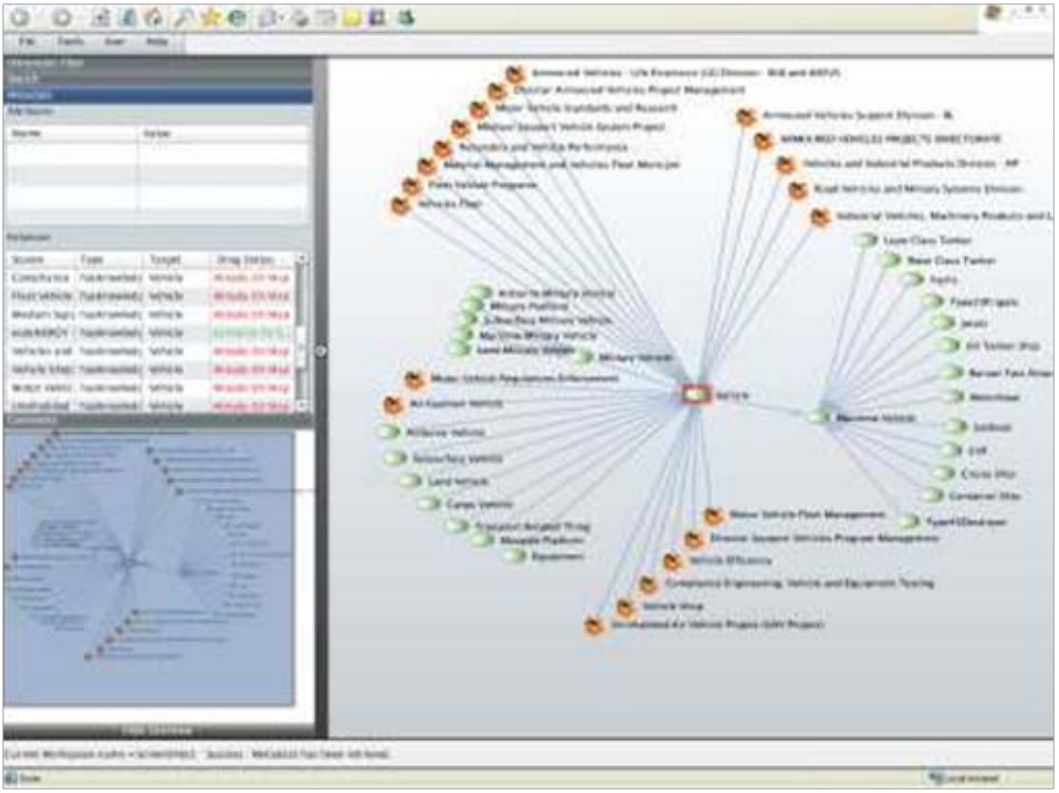

Figure 2 – View of KMapper

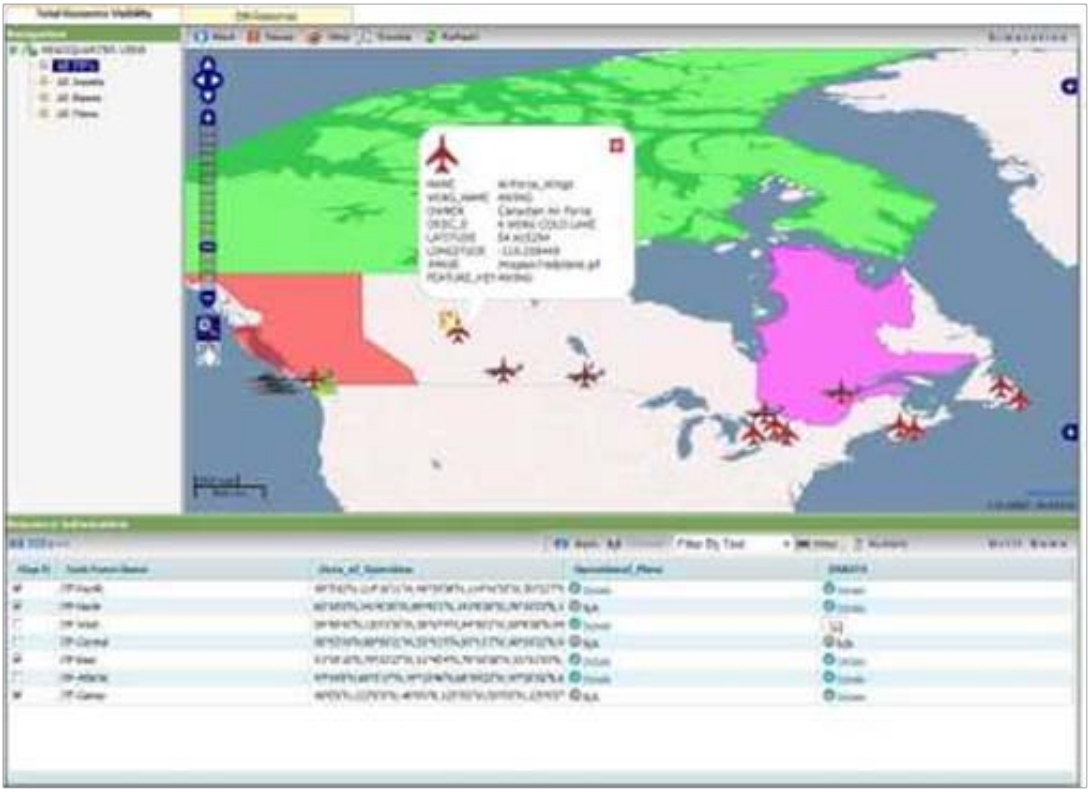

Figure 3 – View of TRV

Planning, options analysis, execution and operations management

One facet of crisis and emergency management decision support is to shorten the time required to make good decisions. The Operations Planning Process Advanced Decision Support (OPP-ADS) consists of an integrated suite of tools able to create/store/retrieve and rapidly adapt operational plans and contingency plans to produce executable plans for specific situations (Figure 4). Additional reasoning support include link management allowing for better integration of tools supporting the design of a campaign plan (ex. Center of Gravity analysis and Decisive Point analysis), the management of risk elements, the management of criteria with their associated after action report and the management of decision-matrixes. This concept of linking key analysis elements provides the capability to rapidly identify pieces of analysis that requires to be revised according to modifications of the situation. This works has lead to the identification of functional requirements related to decision-support tools for the planning of operations.

Crisis and emergency management will require the ability to exploit wireless technologies and exercise command regardless of time and space distribution. Many communities and emergency management organizations count on the cellular phones for emergency and crisis management. In collaboration with Secure Mobile Environment Portable Electronic Device (SME PED) capital project, JCDS 21 has produced a Commander's HandHeld Support System (CHESS) to support Commanders and senior staff officers on the move or with limited connectivity to access real-time (or near real-time) information from Command View and COPlanS and provide guidance and decision to the staff in a secure manner (Figure 5). To support Commanders on the move, enabling technologies will have to encompass communications capabilities, handheld mobile hardware handling secure as well as unclassified information and mobile device applications providing access in real-time to current operational military C2 applications. CHESS has demonstrated that mobile device applications such as the SME PED can be used to exchange information with Command View, Incident Management System (IMS), COPlanS and Execution Management and Plan Adaptation (EMPA).

The lessons identified related to the design/development process of user interfaces for a portable device are part of the key achievements of CHESS.

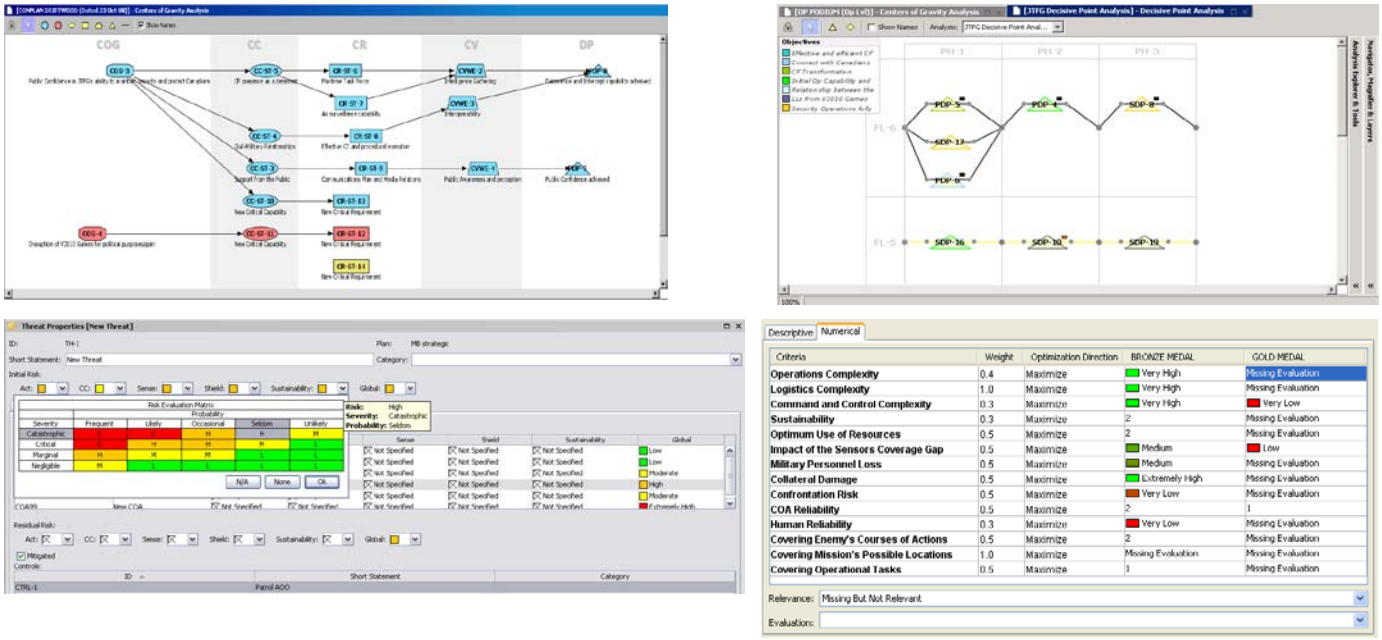

Figure 4 – Views of OPP-ADS Tools

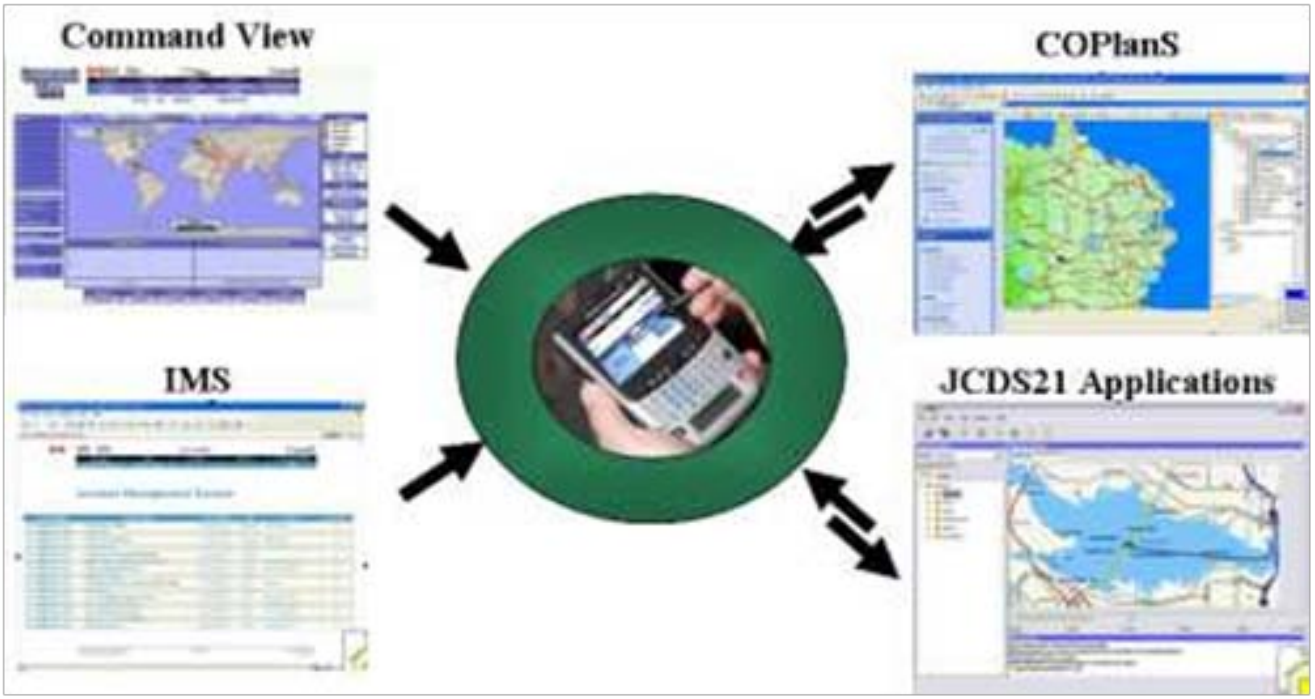

Figure 5 – CHESS Concept

The EMPA supports time-sensitive as well deliberative operations execution through continual automated monitoring of the situation inputs and execution reports (Figure 6). In an uncertain operational environment, good plan development must be followed by good plan execution, which involves real-time monitoring of external events and actions by friendly, enemy and neutral forces, continuous comparison of observed effects to expected effects, and rapid adaptation of goals, assumptions, risk assessments, subsequent activities and expected effects in light of current goals and constraints. JCDS 21 has developed an EMPA prototype in order

to provide essential decision aid to current operations staff officers as well as to commanders and other potential end-users. EMPA is a distributed, multi-layered system providing execution management services to JCDS 21. It communicates with several situation-awareness and asset-visibility services. EMPA supports time-sensitive as well as deliberative operations execution through continual monitoring of situation inputs and execution reports and plan repairs advices. EMPA allows managing assets; they can be tracked on the map and can be assigned to tasks. EMPA also presents different visual indicators of the plan progress and status. The execution of this work also led to the identification of areas of research that has been the subject of a new applied research project on Collaborative Multi-Level Plan Monitoring.

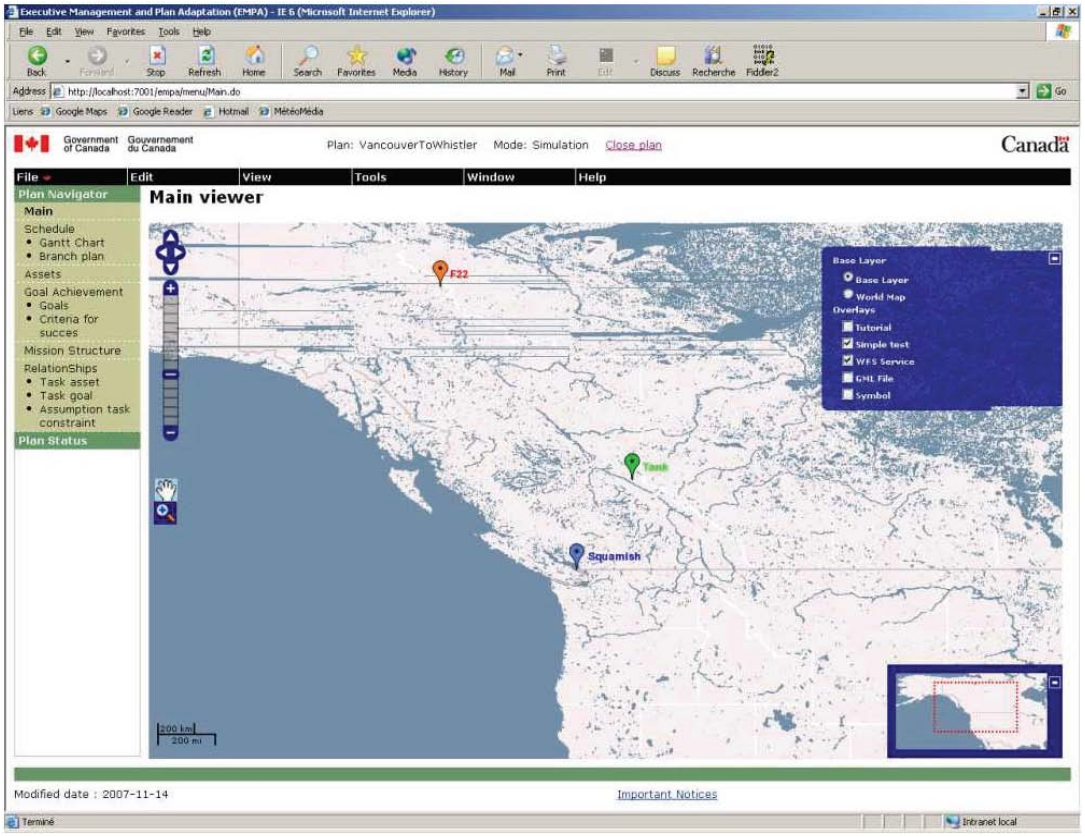

Figure 6 – EMPA Concept

System of Systems Integration

Crisis and emergency management decision support requires human-system integration (HSI). One solution that was explored in JCDS 21 is the creation of a Human Computer Interaction (HCI) style guide. Such guidelines enable developers to create software tools that share similar 'look and feel'. Since existing industrial guidelines do not focus on military applications, it was the plan of this study to create tailored guidelines for supporting the CF C2 applications. The scope of the style guide consisted of both the common interface components and the typical user interaction styles. The topic areas that were covered in this study ranged from general design concerns (e.g., user input devices, data display) to more specialised type of interfaces (e.g., hand-held devices, web portal and portlet interfaces). It is useful to point out that symbology was considered a sub-category in the style guide. An effort was made in this study to review existing symbol sets for C2 applications, particularly the framework that was used to create these symbol sets. Like the rest of the style guide, the use of common symbols across the JCDS 21 tools likely will reduce users' training effort. In addition, a properly designed symbol set potentially could improve commanders' SA by reducing their mental recognition effort. Such benefit becomes more pronounced in situations where time-critical decision needs to be made.

This study reflects an initial step toward the creation of a standardized HCI style guide for C2 applications. Major efforts in this study involve the collation and reconciliation of existing style guidelines which cover mature interface technology. As a result, a functional integration of the different C2 applications has been implemented.

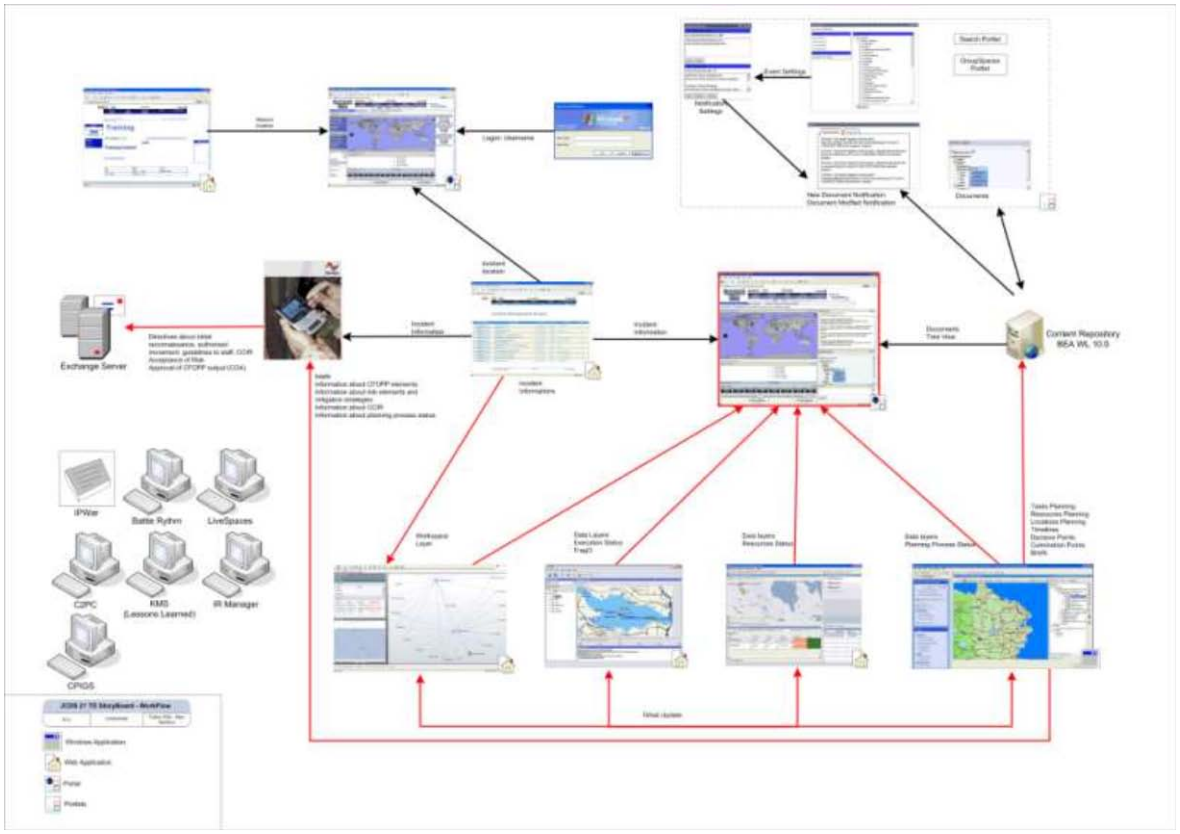

Figure 7 – Functional Integration of C2 Applications

The different tools implemented to support Joint Command Decision Support have been integrated using a system of system approach (Figure 8) . A set of system of systems interoperability mechanisms have been implemented based on web services standards, Service Oriented Architecture (SOA) paradigm, Enterprise Service Bus (ESB), discovery of services using the Universal Description, Discovery and Integration (UDDI) service and the implementation of publish/subscribe mechanism based on the JCDS 21 notification service (Figure 8).

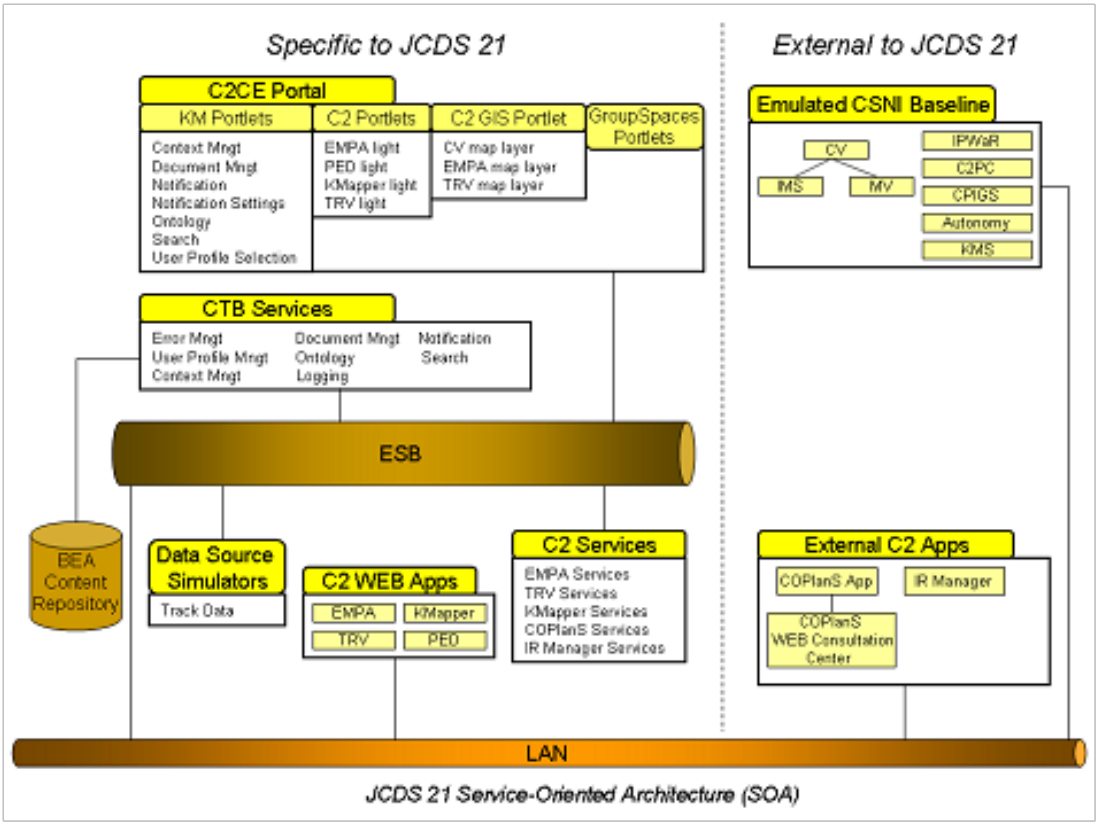

Figure 8 – JCDS 21 SOA

5. Empirical Results

An experiment was conducted at the end of the project to demonstrate JCDS 21 concepts and tools in a pertinent operational context. The JCDS21 experimentation objectives were to:

1. Determine whether the Integrated Command and Control Collaborative Environment (IC2CE) supports and influences CF time-sensitive decision-making processes;

2. Determine if the IC2CE improves shared situation awareness within the Command Post; and,

3. Determine if the IC2CE improves collaboration within the Command Post and with external agents.

Several Joint Task Force Games (JTFG) staff members were augmented with other Command Staff from Canada Command and Canadian Operational Support Command (CANOSCOM) to create an operational HQ. The scenario used for demonstration was based on fictitious Olympic Games (Breton and Guitouni 2008). The scenario time space was from the 17th of October to the 22nd of October 2008. During this time, different events occured ranging from protesters, an earthquake, destruction of buses by home-made fire bombs, bomb threats to British Columbia (BC) ferries, an oil spill, vessels of interest to monitor, computer worm attacks, etc. JTF team was composed of the following player roles: Commander, COS, J2,J2 Ops, J3, J3 Ops, J3 Ops 2, J3 Plans, J3 IM, Battle Watch, Ops Non-Commissioned Officer (NCO), J4, J5, J6, Maritime Component Command (MCC). Each experimentation day was distinct, with a focus on a different aspect of C2. The first day focused on situation awareness, information sharing and planning within a JTFG OPP cycle; whereas Day 2 focused more on collaboration, decision-making and execution management (Rehak 2008).

The data collection plan (Breton and Guitouni, 2008) was developed to assess the completeness, correctness, timeliness and quality of each one of the tools. Figure 9 presents the average results obtained from the experiment for each day (the scale is ordinal increasing where 0 represents no worse and 4 is best). IC2CE includes the collaborative portal as well as the TRV and EMPA tools. The results show that most JCDS 21 tools have been positively assessed by the military officers. KMapper was not used on the first day therefore was not assessed on Day 1. IMS, MV and CV are existing and deployed C2 systems. As can be seen from Figure 9, the assessment of all JCDS 21 tools (total) is very comparable to these mature and deployed C2 systems.

Assessment

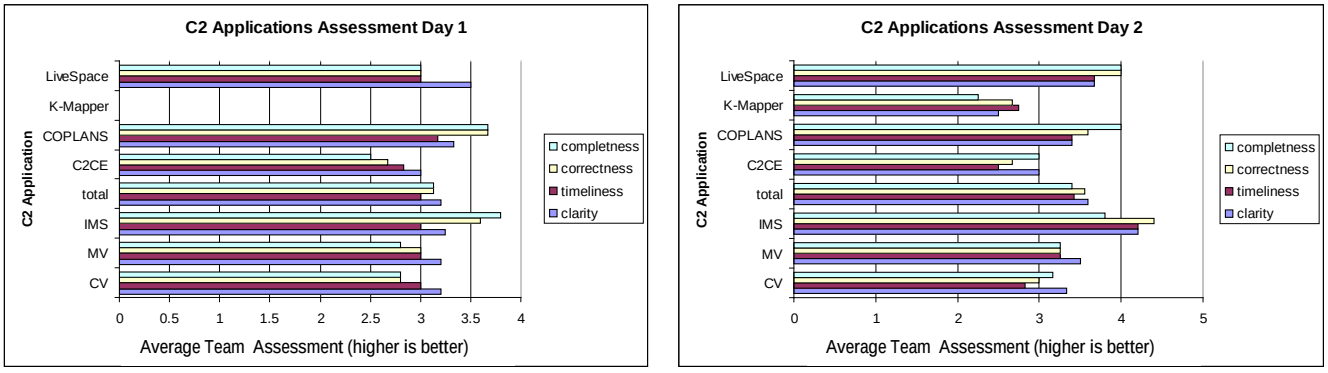

Figure 9 – Assessment of JCDS 21 C2 Applications

Figure 10 shows the average assessment of the impact of JCDS 21 tools on the performance of the joint staff. The impact is measured with regard to the information sharing: clarity of the information, timeliness of the information, correctness of the information and completeness of the information. It is important to mention that day 2 has seen a significant increase in the complexity of the situation at hand. Despite a more difficult situation, the staff members' answers show that JCDS 21 applications provided contributed to supporting the staff members sharing critical information.

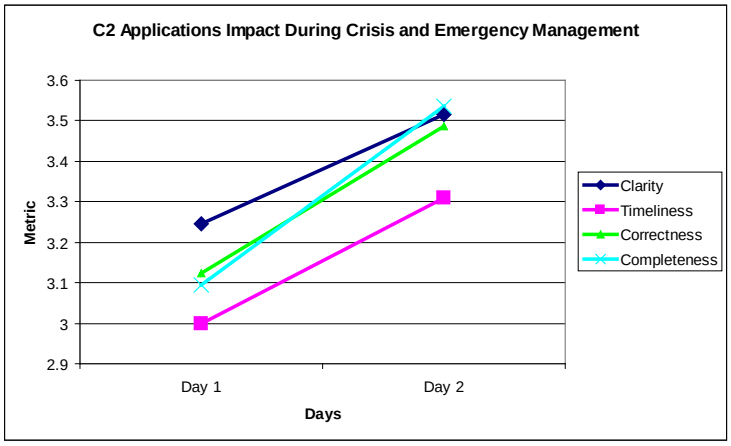

Figure 10 – Impact of JCDS 21 Application

6. Conclusion

JCDS 21 demonstrated an integrated environment to support Joint Command Staff to upport the Commander's decision cycle. JCDS 21 ACP provides the foundations for a IC2CE (on top of Command View and other C2 applications) supporting shared situation awareness, information management, systems integration and collaborative working. This environment and all JCDS 21 solutions are guided by Human and

Organizational Factors in Distributed Operational Teams. JCDS 21 has developed a formal method for selecting collaboration enablers based on team characteristics, and applied Social Network Analysis to inter-agencies communication in a JIMP environment. The JCDS 21 KMapper supports organizational management of knowledge assets and provides advanced link displays and reporting tools. The OPP-ADS is an integrated suite of tools including the latest decision support enhancements; time-sensitive planning, planning dependencies and implications management, analysis, risk management and reporting tools (including operational plans contingency plans branch plans and sequel plans management tool). JCDS 21 has produced a CHESS that supports Commanders and senior staff officers on the move or with limited connectivity to access real-time (or near real-time) information from Command View and COPlanS and provides guidance and decision to the staff in a secure manner. The TRV tool is a decision support system for near real-time resource visibility providing asset information: identity, location, status, and condition of assets in the logistics chain. The EMPA tool supports time-sensitive as well deliberative operations execution through continual automated monitoring of the situation inputs and execution reports. JCDS 21 Architecture is a system of systems integration based on service oriented architecture (an enterprise service bus, standards and data exchange services).

Considering that key to Decision Superiority lies in knowledge management and exploitation, JCDS21 demonstrated a Joint, Net-Enabled Collaborative Environment able to achieve Decision Superiority. Decision supports have been proposed including knowledge and information management to supporting individual and collective situation awareness, decision and planning aids and execution support enablers to oversight and facilitate plan repairs and timely corrective adjustments. A decision support architecture considering a context of domestic operations in a joint, inter-agency and public framework, has been developed.

7. References

Canadian Forces Army, The Force Employment Concept: One Army, One Team, One Vision, Department of National Defence, March 2004.

Barnett, C. (1963). The Swordbearers: Studies in Supreme Command in the First World War, London, 1963

Boardman, J. and B. Sauser. (Apr 24-26, 2006). "System of Systems - the meaning of", IEEE International Conference on System of Systems, Los Angles, CA. Paper accessed via web: http://personal.stevens.edu/~bsauser/index_files/pdf/Boardman%20IEEE%20SoS%20Conf.pdf (Accessed August 16, 2007)

Breton, R., and Guitouni, A. (2008). Joint Command Decision Support Experiment 1 – Data Collection Plan, DRDC Valcartier TM-2008-168.

Frances Fragos Townsend (2006). The Federal Response to Hurricane Katrina Lessons Learned, Washington, D.C. February 2006.

Greenley, A., Baker, K. & Cochran, L. (2006). JSTAFF Front End Analysis (FSSE Task 147). Technical Report. Ottawa, Canada.

Greenley, A., Baker, K., Greenley, M., Kelleher, D., Unrau, D. and Nadeau, J. (2005). Characterisation of Complex Situations: JSTAFF Business Processes and the Canadian Incident Response Environment – Summary Report. PWGSC Contract # W7701-3-4327. DRDC Valcartier.

Hales, D. and Scipione, A. (2008) Joint Command Decision Support for the 21st Century (JCDS 21) Technology Demonstration (TD) Project Concept of Operations (CONOPs), DRDC-CR-2008-002.

Paquet, R. (2009). JOINT COMMAND DECISION SUPPORT FOR THE 21ST TECHNOLOGY DEVELOPMENT ENVIRONMENT (JCDS 21 TDE) CONCEPT OF USE DOCUMENT. DRDC Valcartier. Contract Number: W7701-5-3182.

Quarantelli, E.L. Disaster Related Social Behaviour: Summary of 50 Years of Research Findings, Disaster Research Centre University of Delaware, pg 2.

Rehak, L. (2008). Demonstration and Experimentation Plan for JCDS. Contractor report.

Department Of The Army, US Field Manual 7-30 Headquarters, Washington, Dc, 2000.

US Department of Defence, Joint Vision 2020, http://www.fs.fed.us/fire/doctrine/genesis_and_evolution/source_materials/joint_vision_2020.pdf.

US Government. (2002). *Decision Processes*, Executive Summary, http://www.usbr.gov/decision-process/analysis.htm, as cited in: Disbrow, Lisa. Decision Superiority: Transforming National Security Decision-Making.

United States Joint Forces Command. Joint Forces Command Glossary. http://www.jfcom.mil/about/glossary.htm; Accessed August 16, 2007.

White, Orrick. (2006). *The State of the Art and State of the Practice: Achieving Decision Superiority at NATO Headquarters*, DRDC, Command and Control Research Program (CCRP) Submission #c-110. pg. 5.