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Title: **Analysis and Modeling of Joint Operational Command and Control in the Canadian Forces**

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Authors: Anet Greenley and Gord Youngson
CAE Professional Services
Ottawa, Ontario, Canada

Larry Cochran
Lansdowne Technologies
Ottawa, Ontario, Canada

Kendall Wheaton and Walter Dyck
Defence Research and Development Canada
Department of National Defence
Ottawa, Ontario, Canada

Micheline Belanger
Defence Research and Development Canada
Department of National Defence
Val Belair, Quebec, Canada

Point of Contact:

Kendall Wheaton
Centre for Operational Research and Analysis
National Defence Headquarters
101 Colonel By Drive
K1A 0K2
Office: (613) 996-6511
Fax: (613) 992-3342
Kendall.Wheaton@drdc-rddc.gc.ca

Analysis and Modeling of Joint Operational Command and Control in the Canadian Forces

by
Anet Greenley, Gord Youngson[1],
Larry Cochran[2],
Kendall Wheaton, Walter Dyck, Micheline Belanger[3]

ABSTRACT

Concepts such as network enabled, coalition and effects based operations are transforming militaries worldwide as they become increasingly distributed, modular, and interoperable. Command and control needs to evolve to manage new dimensions of complexity. This paper describes the initial requirements analysis and architecture modeling for the Joint Command Decision Support for the 21st Century (JCDS 21) Technology Demonstration Project sponsored by Defence Research and Development Canada. A key JCDS 21 objective is to understand the implications of net-centric operations within a joint, interagency, multinational and public framework and then design and demonstrate a net-enabled collaborative environment that supports military decision-making processes within this framework. To achieve this, JCDS 21 required a complete understanding of the relevant business and cognitive processes.

The development of a high level view of the military Enterprise Architecture was completed for the initial requirements analysis using the United States Department of Defense Architectural Framework. The paper will demonstrate how the architecture work captured functional activities within a scenario set, facilitating the analysis of a dynamic, multi-stakeholder environment and enabling its extension into a simulation environment. It also introduces methodologies that can be used for providing complementary and in-depth requirements gathering and analysis of the cognitive processes involved.

1. INTRODUCTION

The aim of the JCDS 21 project is to demonstrate a joint net-enabled collaborative environment to achieve decision superiority. The results of studies and experimentation in this project will validate assumptions with respect to decision superiority and what are believed will be its key enablers. The JCDS 21 project is working in collaboration with the Canadian Forces (CF) to develop operational and system requirements for a net-enabled collaborative environment to support decision making, within a joint, interagency, multi-national and public (JIMP) framework. This paper will present the requirements analysis that was performed to capture the enterprise architecture (EA) of the command and control (C2) functions in the CF at the joint operational level. It will then discuss the plans to develop a simulation based upon the information from this analysis. This requirements analysis forms the basis for the JCDS 21 experimentation campaign which is to predict the impact of JCDS 21 technologies and processes on the CF's C2 environments. The simulation of the processes for joint operational C2 in the CF will support the design and evaluation of these experiments.

The focus of JCDS 21 was originally the Canadian Department of National Defence (DND) Joint Staff at National Defence Headquarters. During the conduct of the study, the Canadian Forces

[1] CAE Professional Services
[2] Lansdowne Technologies Inc.
[3] Defence Research and Development Canada

introduced a transformation of the command and control structure, which led to the creation of four new joint commands. On 6 February 2006, the new C2 structure for the Canadian Forces was formally established. The transformed structure consists of:

- Strategic Joint Staff to support the Chief of Defence Staff;
- Canada Command (Canada COM), supported by a regional joint command structure;
- Canadian Expeditionary Forces Command (CEFCOM) supported by a Standing Contingency Task Force (SCTF);
- Canadian Special Operations Forces Command (CANSOFCOM); and
- Canadian Operational Support Command (CANOSCOM).

The JCDS 21 project was re-aligned as a result of this transformation. The data presented in this paper is done so in reference to the joint operational command capabilities in the new CF structure.

A logical, well-defined approach to identify and validate the military requirements for command decision support for staff at the joint operational level in the CF should be the first step for a technology demonstration project such as JCDS 21. In conjunction with a study of the military staff involved in operational decision making, formal systems engineering processes should be employed for analysis and requirements capture and human engineering processes should be employed to identify the impact of human limitations and capabilities and provide specifications for the human interface requirements. There are several recognised models in use that may assist with this endeavour and the JCDS 21 requirements analysis included a review of these models. The goal of this review was to provide a more in-depth understanding of existing methods in order to assist in selecting the best methodology for analyzing the requirements for the JCDS 21 project (and other future projects). Therefore, a sub-set of published cognitive analysis methods was identified and an overview of the comparison methods, with a few results and conclusions, is presented in section 2.

The resulting strategy for the requirements analysis was a two phase approach: (1) collect the EA information based upon a systems engineering methodology; and (2) collect the human interface information based upon human engineering process methodologies. The EA information would be used to determine the overall objectives of the JCDS 21 project and support the development of a C2 simulation to model collaboration, information and intelligence analysis, and decision making as workflow processes. The requirements analysis, based on the EA information collected for joint operational C2, is presented in section 3 and the considerations for the development of a C2 simulation is presented in section 4. The more detailed requirements analysis of the human interface information (cognitive analysis) for the JCDS 21 project is future work that is outside the scope of this paper, but that will eventually broaden the understanding of the C2 processes identified herein.

2. COGNITIVE ANALYSIS METHODS FOR REQUIREMENTS ANALYSIS IN JOINT COMMAND & CONTROL SITUATIONS

In general, complex situations involving the Canadian Forces in joint operations may involve a number of factors including, for example, the time sensitivity of responses, the possibility of multiple concurrent incidents, the interaction and collaboration required by many stakeholders, the need for resource sharing, and the collection, fusion, distribution and sharing of information. In addition, within a joint operational headquarters, a mix of formal and informal procedures may be used, policies and/or legal constraints may change, moral and ethical issues may differ between individuals and groups, and public opinion and roles may change as situations change.

To achieve its goals, the JCDS 21 project required a validated requirements gathering and analysis strategy to provide a comprehensive understanding of the cognitive processes involved in

the complex joint operational environment. A sub-set of published cognitive analysis methods was identified as possible methodologies for requirements analyses. These methods included existing systems engineering processes, task and function analysis methods, and requirements analysis methods. This review[4] assisted JCDS 21 in the development of a more in-depth understanding of existing methods and in the selection of the best methodology for analyzing the requirements for the JCDS 21 project. The review process consisted of the four phases:

Phase 1: Identification of requirements analyses methods to be characterized. A preliminary list of potential methodologies was proposed. A review of literature was conducted to justify changes to this list by the addition or deletion of methodologies. A final list of seven methodologies was selected for further investigation.

Phase 2: Identification of a format for the characterization of the methodologies. A template was developed that was used to characterize the different methodologies. For consistency with previous research, the selected format of the template included elements from a NATO Defence Research Group report on analysis methods for man-machine systems design[5], as follows:

Description – briefly describes the method.
Inputs to the method – describes the information that is input to the method or its sub-procedures.
Outputs from the method – describes the outputs of the method or its sub-procedures.
When to use the method – describes when in the project lifecycle the method or its sub-procedures can be used.
Related tools and methods – briefly describes tools available for use with the method and other closely related methods.
Resources required to use the method – describes the level of effort required by practitioners and stakeholders who use the method.
Advantages of the method – briefly states proposed advantages of the method in comparison to other related methods (where possible).
Issues related to the method – describes reported problems, including disadvantages, of the method or its sub-procedures.
Applications of the method – describes example projects where the method has been deployed.
Quality assurance considerations – describes methods available to ensure reliability and validity of the method.
Relationship to system performance requirements – describes the relationship of preliminary requirements gathering methodology to more in-depth systems requirements gathering.
Contacts – lists some known developers and users of the method.
References – provides references.
Bibliography and Websites – provides other relevant resources.

Phase 3: Characterization of the methodology. Literature surveys and, where possible, telephone interviews with users and/or developers of the methodologies were conducted to gather information to complete the templates for each methodology.

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[4] Darvill, D., Kumagai, J.K., and Youngson, G., Greenley & Associates Inc., "Requirements Analysis Methods for Complex Systems", Defence Research and Development Canada Contract Report CR 2005-076, Jan 2006.
[5] Beevis, D., Bost, R., Doring, B., Norde, E., Oberman, F., Papin, J-P., Schuffel, H. and Streets, D., "Analysis methods for man-machine system design (Vol 2)", NATO Technical Report AC/243 (Panel 8) TR/7, 1994.

Phase 4: Final report of results. A meeting was held to discuss the results of the review and finalize the report.

The following methods were considered in the context of supporting the requirement for a requirements analysis methodology for joint, distributed and complex command situations. Each method considered is associated with a vast amount of research and written documentation that could not be explored completely given the time available for the review.

1. Mission Function Task Analysis (MFTA)
2. Cognitive Work Analysis (CWA)
3. Applied Cognitive Work Analysis (ACWA)
4. Hierarchical Goal Analysis (HGA)
5. Team Cognitive Task Analysis (Team CTA)
6. US Dept of Defense Architectural Framework (DoDAF)
7. Joint Application Design/Development (JAD)

Gathering and analysing requirements for large complex systems is itself a complex endeavour. The methods evaluated appear to have characteristics and components that would support their use in a coordinated process to gather and analyze data to support requirements identification and analysis. Selection of an appropriate methodology to support the JCDS 21 requirements analysis would depend on the nature of the complex system and the specific objectives of the analysis. The methodology must be selected to correspond to the appropriate level of analysis. For example, if project objectives focus on the definition of a specific system interface for a team, JAD may be an appropriate match. Alternatively, DoDAF may be appropriate if project objectives focus on the definition of the numerous entities and communications in a complex system of systems environment.

Because certain methods appear better suited for specific levels of requirements analyses within a complex system, some methods can be viewed as complementary. For example, DoDAF could be used to identify and understand the overall framework of the multiple organisation, application, and personnel entities and communication links that exist in a complex system of systems. Analysis of the linkages, information flows and relationships of all of the entities within the complex system allows the analyst to identify actual or potential problem areas based on reported issues or on similar situations.

Gathering information about entities, whether they are application, organisation or human, needs to be done in a systematic manner. Basic observational, interview or questionnaire techniques are typically used for this purpose. Currently, DoDAF may be less equipped to assess the 'user-centered' aspects of the systems; consequently, an analyst could employ techniques from the MFTA or JAD methodologies or from Team CTA as a means of eliciting knowledge from subject matter experts to support the development of the architectural framework. In particular, JAD is a method that can be used for gathering and disseminating information in a structured way. The information gathered can be used to support both descriptive and analytical tasks within DoDAF in order to get the big picture of the system under investigation or development. Conversely, JAD can be used to address a specific problem that will be investigated using one of the other analysis methods.

Although JAD and Team CTA were identified to be effective in eliciting knowledge about a system, they are less definite about how to analyze and represent that system information. Once a problem has been identified within a large complex system, other analysis methods might be better suited to understand and visualise or model specific issues in order to discover solutions to specific problems. These analysis and visualisation methods could include the full methodology or specific components of MFTA, Team CTA, CWA, ACWA or HGA. These could be utilized

to provide a contextual and graphical representation of the tasks and/or goals elicited from stakeholders.

The selection of MFTA, CWA, ACWA, HGA or Team CTA arguably must depend on the type of analysis that will best support the objectives of JCDS 21. Work analyses are techniques for analyzing workers' responsibilities and actions. MFTA, CWA and ACWA define the functional structure of the work domain or system being controlled. Task analysis is an example of a work analysis technique that specifies tasks to be achieved and how they should be achieved. Goal analyses focus less on the functions and tasks and more on the end states to be achieved by a system.

Since the aim of JCDS 21 is to demonstrate a joint net-enabled collaborative environment to achieve decision superiority within the CF joint operational command structure, and since this organisation is quite large and in transition to a new structure, it was necessary to focus the aim on a smaller more manageable part of the organisation where decision superiority could be best demonstrated. A model of the pre-transition joint operational command structure had already been started in another project using DoDAF, and since this was deemed to be an excellent method to describe a complex system, it was decided to build on the existing model to gain a better understanding of the client. It was further assumed that although the CF command structure was being transformed, many functions of the old command system would remain and could be mapped onto the new system. The resulting DoDAF "views" showed an expected complexity of information flows within the joint operational command structure and with partners outside the CF and did allow scientists studying the decision-making process in complex situations to decide on nodes of interest within the model. In order to model the decision-making process further to define gaps, more information of the human cognitive processes in the system was required, a shortcoming of the DoDAF. The focus areas were the intelligence (J2), command (J3), logistics (J4) and public relations throughout the command structure, which corresponded to existing functions (i.e., intelligence gathering in J2 and operational planning processes in J3) and new capabilities (i.e., a joint information and intelligence fusion capability- JIIFC). Since all the methods used to define the cognitive processes employ some form of MFTA analysis, and since the ability to start at a random part of the process and work up or down was deemed advantageous, and since an executable model has already been use in conjunction with it, HGA was chosen to assist in the cognitive modelling of the existing functions. Since this method is not deemed to work well on a project in early development (i.e., JIIFC), it was decided to use JAD to gather data in that case.

3. METHODOLOGY

The Application of Architecture Frameworks

Architecture products are simply perspectives of a system of systems[6] construct when viewed through the lens of operations (what needs to be done and the various organizations involved in performing actions), systems (what systems will support operations and their functional characteristics) and technical standards (which govern system implementation). As discussed in the preceding section, the preparation of DoDAF architectural views was chosen as the analysis approach for requirements gathering for the JCDS 21 project problem space; the complex net-enabled collaborative environment to support decision making within a joint, interagency, multi-national and public framework. The complexity of the command structure for a military

[6] Although 'system' is used as DoDAF was developed from the C4ISR Framework and tends to focus on system interoperability issues, the extension to 'system of systems' is suitable when used to develop an architecture of a capability (i.e., sense, command, ISR, etc.).

headquarters engaged in several national/international missions involving other government departments and other nations, both in terms of its inherent characteristics and dynamic relationships, can be captured through these architectural views, depicted in Figure 1. DoDAF contains operational views (OVs), system views (SVs), and technical standards views (TVs) and is used to support overall system design, evolutionary acquisition and interoperability within the U.S. Department of Defence Joint Capabilities Integration and Development System (JCIDS).

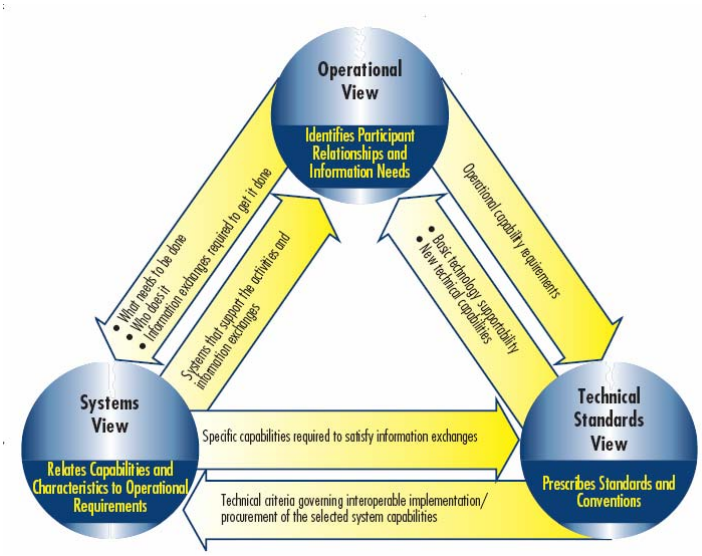

Figure 1: DoDAF illustrating relationships between OVs, SVs, and TVs[7].

Data Collection to Support the Development of an Integrated Architecture

Data collection activities for the JCDS 21 requirements analysis have led to the creation of a set of DoDAF-compliant architecture products that describe the current "as-is" capabilities and provide a visual representation of the data products. The data collection consisted of a structured approach to conducting observations of the meetings of the joint operational staff and interviews with selected members of the staff. The analysis of the data collection activity allowed for functional decomposition and process model development.

Information to support the data collection objectives was gathered in the following ways:

- Operational Documentation. Review of existing operational documentation such as doctrine, standard operating procedures (SOPs), tactics techniques and procedures (TTPs), concepts of operations (CONOPS), etc. provided an understanding of how work is "supposed" to be conducted.
- Observations. Observation of the conduct of relevant meetings that convene the joint operational staff. This included observing daily situation briefs (SB), daily staff action team (SAT) meetings, and mission specific SATs. Daily SBs and SATs were observed in order to develop an understanding of the battle rhythm, urgency of issues, how issues percolate up and when decisions become critical, who is involved and how they become involved. Mission specific SATs were observed to provide an understanding of the CF operational planning process (OPP) and strategic issues as a mission unfolds.

[7] Pagotto, J. and Walker, R.S., DRDC Ottawa, "Capability Engineering – Transforming Defence Acquisition in Canada", presented at SPIE Conference, Orlando, FL, April 2004.

- Interviews. Observations of meetings only supported the collection of overt factors, interviews with staff provided additional means to gather information. Targeted interviews were conducted in order to gain an understanding of areas that were not easily observed and to clarify certain aspects of decision-making and collaboration activities.

Although a major portion of the data collection was done through the observation of meetings, the intent was to capture data that would provide insight to decision-making and collaboration processes, technologies and infrastructure. A complexity matrix for decision making, problem solving and finding information and a complexity characterisation for collaboration was completed to complement the raw data collection. This information contributes to the understanding of trends and the dynamics involved in decision making, collaboration and information and intelligence (I2) analysis. These insights will contribute to the cognitive process analysis and the definition of entities, relationships and attributes for the simulation model. This methodology has been termed the Activity Based Methodology, "a tool-independent approach to developing fully integrated, unambiguous, and consistent DoDAF Operational, System and Technical views"[8].

The Joint Capabilities Integration and Development System, depicted in Figure 2, applies the Activity Based Methodology to supply the means to implement capability-based planning in the U.S. DoD. JCIDS was designed by DoD as a methodology and governance structure to ensure interoperability of systems in accordance with DoD's Joint Vision 2010. The intent is to institute concept-based, top-down direction and for concepts to underpin investment/divestment decisions. Integrated architectures, in turn, are viewed as a key enabling component. JCDS 21 applied the JCIDS methodology to structure the requirements analysis of the joint operational staff for use by the project scientists. The DoDAF products helped to frame data collection and supporting analysis and offered a mechanism for the presentation of related findings. The results of the data analysis activities have been structured into three integrating components: Functional Area Analysis, Functional Needs Analysis and Functional Solution Analysis.

Functional Area Analysis (FAA) - At a macro level, the objective of the FAA is to establish capability objectives. It identifies scenarios and through mission analysis determines the operational tasks, conditions and standards needed to implement national strategy and sanctioned concepts. An FAA should produce a comprehensive, prioritized listing of capability requirements and tasks.

Functional Needs Analysis (FNA) – The subsequent FNA assesses the ability of existing and programmed systems to satisfy these capability requirements, under the full range of conditions and to the standards (measures of effectiveness) the FAA has established. The primary output of a FNA is a prioritized list of capability gaps. The FNA further defines and refines the initial architecture products.

Functional Solution Analysis (FSA) - The FSA identifies candidate solutions for filling (or at least mitigating) the capability gaps defined in FNA. This includes non-materiel changes, changes in quantity of existing materiel, product improvements to existing materiel or facilities, adoption of other service or interagency solutions, acquisition of foreign materiel and new materiel acquisition. The FSA compares alternatives to determine the most effective solutions (in order of preference):

- Use existing capabilities through non-material enhancements (adjustments in procedures and organization);

[8]Pagotto, J. and Walker, R.S., DRDC Ottawa, "Capability Engineering – Transforming Defence Acquisition in Canada", presented at SPIE Conference, Orlando, FL, April 2004.

- Acquisition of off-the-shelf solutions; and
- Insertion of emerging technologies.

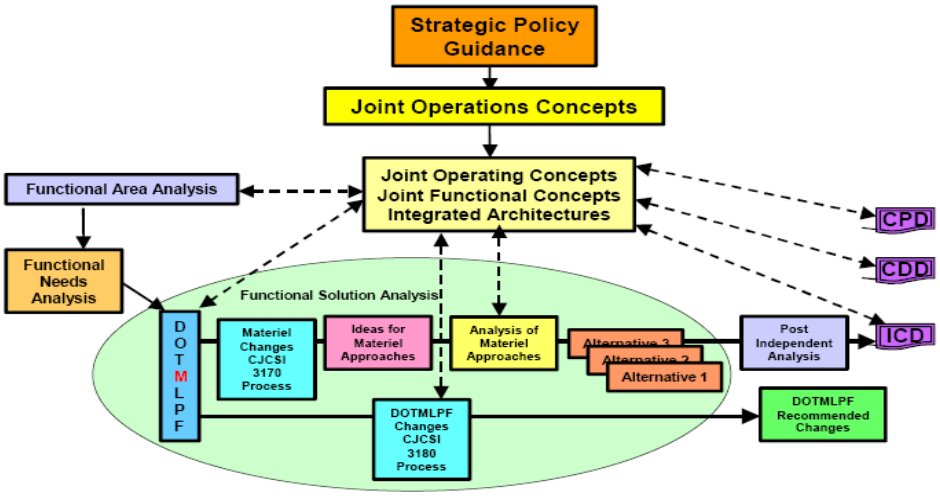

Figure 2: JCIDS Capability Definition & Assessment Process[9]

It may be appropriate to commission more than one FSA to address the capability gaps a FNA identifies. Architecture serves to relate candidate solutions to existing systems and ensures that dependency relationships are understood.

This paper contains the first two components, the FAA and the FNA. These components present information in a structured way so that the scientific team can use the material to conduct an FSA for each of the group in the JCDS 21 project. The DoDAF products and data analysis will contribute to the future development of a simulation model of decision making, collaboration and I2 analysis in a joint operational headquarters. The purpose of this model will be for use with the FNA by the JCDS 21 scientists to enhance the studies and experimentation required throughout the project. These activities will assist each group to develop a robust FSA.

Integrated Architecture Products

The application of an architecture based approach enabled the team to develop scenarios and conduct analysis for a dynamic, multi-stakeholder environment. This allowed the team to compare and contrast the roles and responsibilities of stakeholders, and identify linkages within the CF and to some external agencies.

The application of architectural frameworks helps the analyst to obtain relevent information by employing a structure to orientate raw data. The architectural approach can be extended to take the work into the realm of simulation for validation exercises and option evaluation. In this sense we are referring to taking the "architecture" of the resulting capability (organizations, their roles,

[9] Analysis Handbook, Office of Aerospace Studies, July 2004, pg. 15

relationships, information flows, and systems) and putting it into the battle field through simulation and exercising that architecture in contextually relevant scenarios, extending the applicability of architectural approaches beyond verification.

The requirements anlaysis work analyzed civilian emergency response plans and CF doctrine and SOPs in the area of terrorist activities and asymmetric threats in order to document decision-making and collaboration activities during emergency response. The nature of the various 'system of systems' relationships that exist in complex situations such as the Canadian Incident Response Environment exceed the mandate of any single system in terms of definition, development and operational implementation. The independence of systems (i.e., operational, managerial) coupled with their dynamic and multi-faceted interface relationships, demands an overarching, integrating architectural framework that captures operational and system characteristics, supported by analytical rigour sufficient to make mission level capability decisions.

An architecture based approach supports the analysis and decomposition of functional requirements, encompassing all aspects of a capability (people, processes and materiel) with suitable rigour to support decision making in an agile and efficient structure. Architecture captures the structure of components and interrelationships as they evolve over time, allowing the analyst to manage complexity and incremental change, while serving as a common "language" for all stakeholders and supporting multiple uses of data.

JIMP Environment Scenario

The primary role of the Department of National Defence is to defend Canada and, in cooperation with Canada's allies, protect and advance Canadian interests in a global community. As such, DND is in a constant state of engagement with numerous allied nations, international organisations, and domestic departments and agencies.

In domestic emergency operations, interfaces are critical for the management of the complexities which arise from the uniqueness of every emergency incident. These interfaces are portrayed through the response team, adversary, environment, and incident characteristics. Most emergencies start at the individual or family and evolve in a bottom up nature, engaging community, provinicial and federal stakeholders as the incident unfolds. Command and control structures and legislation help to address complexity. Command is formalized in structures through emergency operation centres (EOCs) that exist at each level of response (municipal, regional, provincial, and federal). Organisational relationships are defined for each incident, with the lead agency for command and control and support agencies/departments determined by resource capabilities and incident requirements. C2 structures realise that these relationships are dynamic and can change as the incident unfolds.

Both the international and domestic incident response environments are framed by a hierarchy of relationships that are defined by legislation, policy and emergency response plans. These facilitate the ability for multiple governments, departments and agencies across Canada to share resources and provide a mechanism for interagency collaboration. The two conflicting orientations of a top-down structure for a bottom-up response, can lead to confusion and misrepresentation as information flows from the top-down and bottom-up can cross paths and may work in detriment to each other.

As mentioned in our methodology, the DoDAF was chosen for this project. It was used to provide a structure for the presentation of the analysis of the Canadian Incident Response Environment and the development of a scenario to illustrate multi-level collaborations and dynamic decision making. DoDAF provides a wide selection of "views" that are developed and used to fully document the current state, or the proposed future state, of a system or capability. In

the Framework, there are three major perspectives (i.e., views) that logically combine to describe an architecture. These are the operational views, systems views, and technical standards views. Each of the three views depicts certain architecture attributes. Some attributes bridge two views and provide integrity, coherence, and consistency to architecture descriptions. The development of systems to support the activities, and the analysis of the impact of new operational requirements on the systems may include new updates to the system. Analysis must consider the requirements of each system as well as the impact of each new system on the 'system of systems'.

In the case of the Canadian Incident Response Enviroment, the CF is one of the systems in the system of systems. When conducting an analysis of the CF and its role in this environment, consideration of other departmental roles and responsibilities are key to understanding interoperability within the system of systems. A subset of the DoDAF OVs were developed, capturing a description of the tasks and activities, operational elements, and information exchanges required to accomplish missions. The OVs contain graphical and textual products that comprise an identification of the operational nodes and elements, assigned tasks and activities, and information flows required between nodes. They define the types of information exchanged, the frequency of exchange, which tasks and activities are supported by the information exchanges, and the nature of information exchanges.

Operational View 1 – High Level Graphic

The focus of the architecture modeling effort was on the roles and activities of the members of the joint operational command structure in the Canadian Forces. An OV-1 high level operational concept graphic is a conceptual visualisation of the mission space – it depicts where the command staff, in Figure 3, see themselves within the Canadian Incident Response Environment. As a result of the evolving security environment, the Department of National Defence and the Canadian Forces are realigning strategic operating concepts in order to create conditions for future success in new environments. The JIMP construct, postulated by the office of the Vice Chief of the Defence Staff, provides the structure for the key drivers for these capabilities

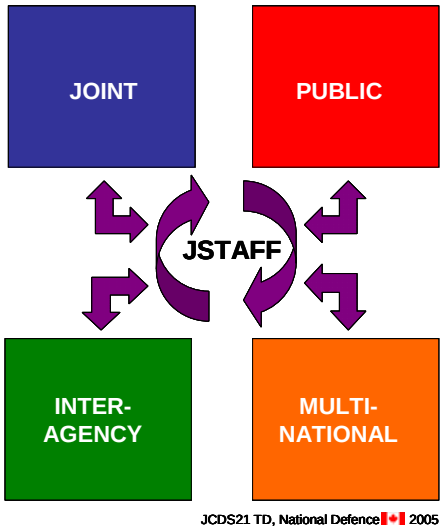

Figure 3: JCDS 21 OV-1

Communication and collaboration for decision making and information and intelligence analysis in the OV-1 graphic is represented by arrows that are intrinsic to the "jointness" of the environment. In addition, the arrows illustrate the engagement that exists between the CF and the other entities. The interaction that occurs within the joint operational command structure and between the JIMP elements is multidimensional. The arrows in the OV-1 graphic illustrate that

as the staff of the comamnd structure are communicating and collaborating internally, they are also engaged with external agencies to do the same. The exchange with external entities occurs both from the joint operational staff to the JIMP elements and from the JIMP elements to the joint operational staff.

Operational View 4 – Organisational Relationships

The objective of the OV-4 graphic and supporting documentation is to capture the command relationships between the key players. When a project is focused on a system, or a given scenario set, there is often only one OV-4 that can be easily drawn, interpreted, and understood. However, when a project must address an overall capability, comprised of systems of systems responding to a wide range of scenarios, a hierarchy of OV-4's is required to systematically document the organisational structures.

The presentation of the OV-4 was developed in five different levels of granularity. The top level relationship view has been developed, as shown in Figure 4, to depict a generic overview of the relationships within the Canadian Incident Response Environment during a domestic or international incident. Three core components have been identified that formulate the structure of the relationships:

Legitimizing Authority - where the top level decision makers provide the authority for the lead agency/department to execute command and control for the Canadian response;

Execution of Command and Control - where the execution of command and control for incident response is be spearheaded by a lead agency that will coordinate and dictate the overall response efforts; and

Support Agencies - who report to the incident commander as appointed by the lead agency.

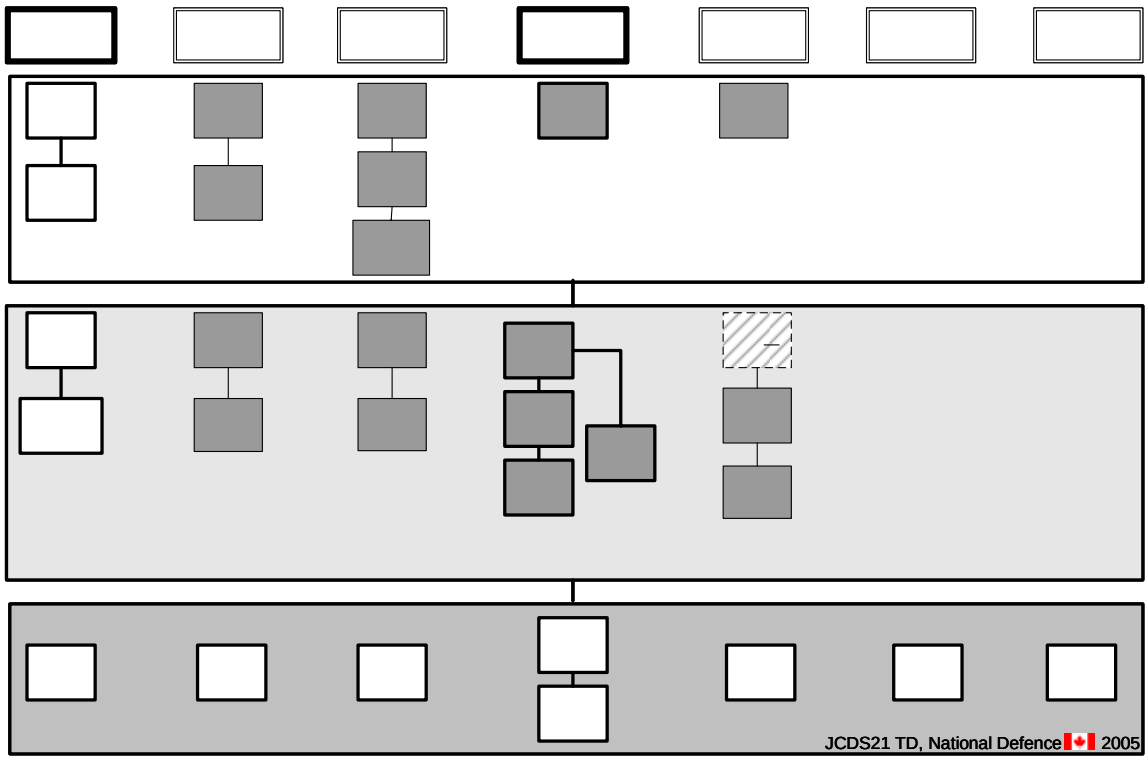

Figure 4: JCDS 21 OV-4

Operational View 2 – Operational Node Connectivity

The OV-2 operational node connectivity product graphically depicts the operational nodes (or organisations) and the needlines between those nodes that indicate a need to exchange information. The conventions employed for representing the essential information are in accordance with DoDAF guidelines whereby each oval represents an operational element (OE) and the needlines are depicted as arrows joining the respective OEs. In addition, the arrows on the needlines denote the direction of traffic flow between the two elements of interest.

Similar to the OV-4 diagrams, the OV-2 diagrams are presented in different layers of granularity in order to present the complexity of the information captured in a more reasonable format. Figure 5 illustrates the top level view of the relationships in the Canadian Incident Response Environment. Further decompositions highlight the joint operational staff and its operational elements and the needlines between DND and other stakeholders such as other government departments (OGDs) at the federal, provincial/territorial and municipal level as well as international governments, NGOs and industry.

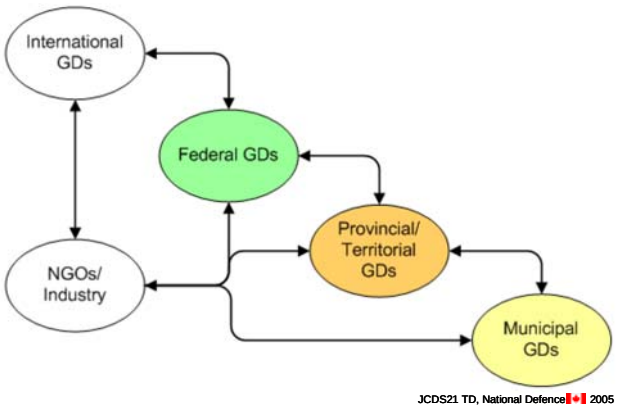

Figure 5: JCDS 21 OV-2 Level 1

With respect to the civilian OGDs, the primary operational elements are represented in a generic manner for simplicity as well as to depict commonality across the federal, provincial/territorial, and municipal domains. This second level of decomposition diagram, Figure 6, highlights the three common components: legitimizing authorities, execution of command and control, and supporting agencies (also articulated by the OV-4 within the structure of organisational relationships).

Each agency's role with respect to individual incidents will depend on the nature of the event and may change as the incident unfolds. For example, DND typically provides support for domestic operations. In some instances, DND may play a support role to a municipal government body at the beginning of a local incident, which then may change to one of supporting the Royal Canadian Mounted Police (RCMP) if the incident becomes one of national terrorism.

Operational View 5 – Activity Model

The OV-5 operational activity model defines how events unfold and articulates interoperability linkages within the Canadian Incident Response Environment. Three scenario events have been mapped out in a composite scenario to create the OV-5 activity models. These scenarios involved natural disasters and acts of terrorism. The swim lane diagram format was used to create the components of the scenario that illustrate roles and responsibilities and show linkages between each of the stakeholders involved in the incident. The models are structured to show various levels of government and agency participation, including municipal, provincial/territiorial,

federal, international and defence agencies. Within each model, the Department of National Defence was separated from the federal group to help to define how DND links in with civilian agencies in support of a large scale domestic event. Figure 7 is an overview of a scenario that was developed using the DoDAF.

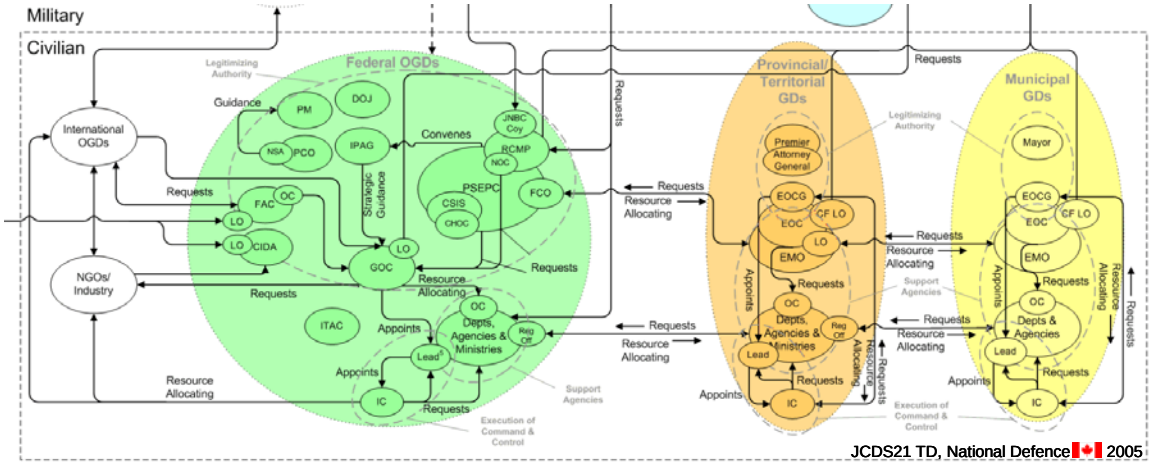

Figure 6: JCDS 21 OV-2 Level 2 for Civilian Nodes

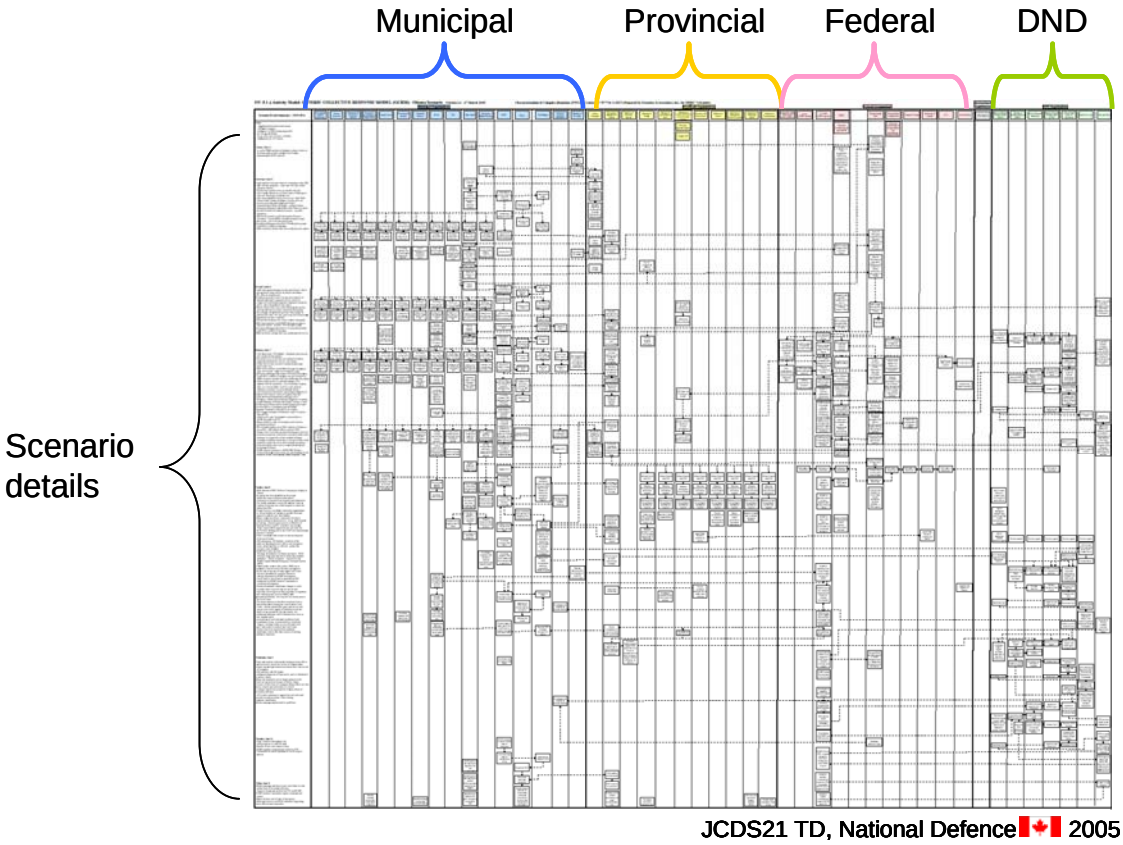

Figure 7: JCDS 21 OV-5 Scenario

Functional Area Analysis

The analysis of the observations and interviews and of the associated DoDAF products enabled the development of the Functional Area Analysis and the Functional Needs Analysis. The purpose of the FAA is to characterize the capabilities required to achieve CF military objectives. The data collection activity has led to the high level definition of capability packages for the joint operational staff. These capability packages alone do not provide a thorough characterisation of the decision-making, collaboration and I2 analysis activities in this command structure. To capture requirements for the domains of decision making, collaboration and I2 analysis; the characterisation was extended to identifying influences on the joint operational staff's ability to perform functions within the capability packages, issues that shape the environment that the staff engages in while executing within the capability packages, and the areas that are impacted by these influences and issues that affect the staff's ability to perform functions within the capability packages.

The following high-level capability packages have been identified through the research and observation activities as essential to the joint operational command structure achieving a net-enabled collaborative environment to support decision making within a JIMP framework:

1. Monitor and collect data;
2. Develop shared situational understanding;
3. Develop continuous integrated operations plans (the OPP);
4. Execute plan with leadership and direction; and
5. Monitor execution and adapt as necessary.

A total of 151 observations were recorded. Their applicability to each of the five capability packages has been determined, with many applying to more than one. For example, an observation could affect (3) Develop continuous integrated operations plans (the OPP), and (5) Monitor execution and adapt as necessary. Thus, the 151 initial observations have been recorded as a total of 320 observations on the capability packages. Figure 8 presents the number of observations pertaining to each of the capability packages, (3) Develop continuous integrated operations plan (the OPP) had the greatest number recorded while (1) Monitor and collect data had the least. This number is influenced by observation forums that were focused mainly on OPP deliverables.

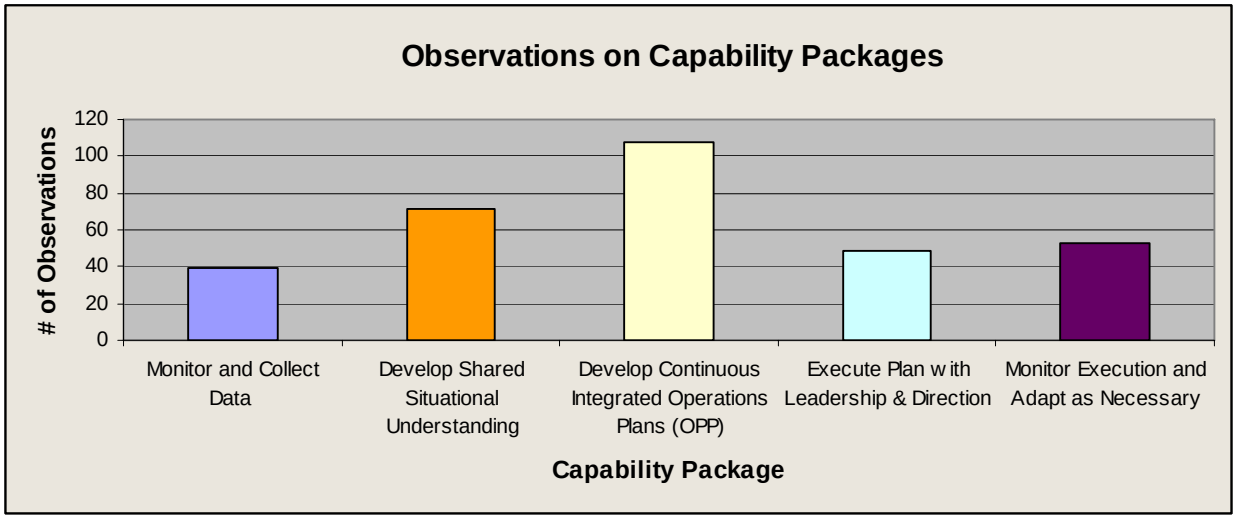

Figure 8: Observations on Capability Packages

These packages characterise the main capabilities that are necessary for the joint operational command structure to act effectively within the three domains of decision-making, collaboration and I2 analysis functions. The capability packages cannot be viewed as one-dimensional. Rigid structures restrict agility; therefore it is important that a multidimensional approach is taken for examining the future capabilities of joint operational headquarters.

The breadth of information collected and the dynamic nature of joint operational staff's activities resulted in the extension of the characterisation of the data that was collected into three classes:

1. Influences on the staff's ability to perform functions;
2. Issues that shape the staff's environment; and
3. Areas that are impacted by the influences and issues listed above.

It was intended that these three classes of data would be used by each of the JCDS 21 teams to achieve a better understanding of the requirements for the capability packages in each of their specific areas of concentration. This approach would also assist in developing mitigation strategies for the influences and issues and setting priorities for areas of future work around the capability packages during the conduct of the Functional Solutions Analysis.

The observed influences on the joint operational staff's ability to perform functions within the capability packages have been categorized as follows:

1. Doctrine, tactics and procedures;
2. Coalition partners/OGDs/NGOs;
3. Government of Canada;
4. Strategic guidance;
5. Operational level activities;
6. Individual experience and knowledge;
7. Tactical level activities;
8. Mission location/host country;
9. Public opinion;
10. Media; and
11. Knowledge management.

The observed issues that shape the environment that the joint operational staff engages in while executing within the capability packages have been categorized as follows:

1. Sharing Information;
2. Processes;
3. Policy/Legislation;
4. Environment (influenced by: individuals (i.e., leadership style), mission location, public opinion, media); and
5. Finance.

The areas that are impacted by the influences that affect the joint operational staff's ability to perform functions within the capability packages and the issues that shape the staff's environment include:

1. Constraint management;
2. Functional activities of each of the specific joint staff (i.e., personnel, operations, intelligence, logistics, finance, public affairs, policy, legal, etc.)
3. Multi-departmental linkages; and
4. Resource management.

The number of times a capability, influence, issue or area of impact was observed has been captured. Areas relevant to each of the three domains of decision making (DM), collaboration (C) and information and intelligence analysis (I2) are highlighted in the analysis below. Due to the fact that the data is a direct result of the observation environment, the results could be misleading. A higher rating indicates a capability package was observed more frequently. The rating does not necessarily mean an element is broken or needs to be fixed; the rating result is rather a product of the observation and interview forums that were provided by the case studies.

In order of frequency observed, the capability packages appear as:

1. Develop continuous integrated operations plans (the OPP);
2. Develop shared situational understanding;
3. Monitor execution and adapt as necessary;
4. Execute plan with leadership and direction; and
5. Monitor and collect data.

Figure 9 presents the capability packages and their observed relevance to decision making, collaboration and I2 analysis:

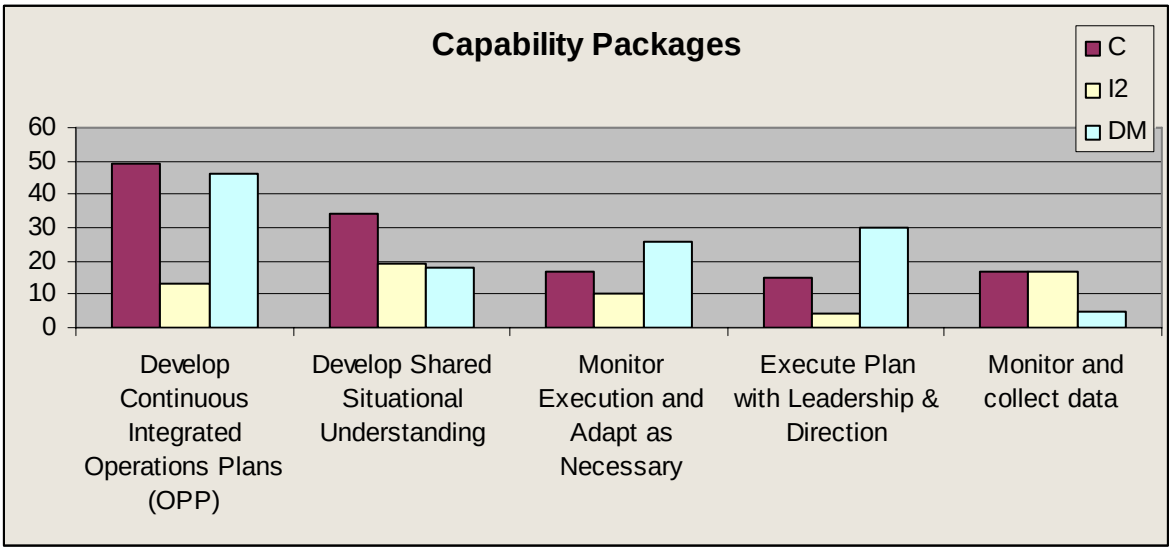

Figure 9: Capability Packages and their Relationship to Decision Making, Collaboration and Information and Intelligence Analysis

Functional Needs Analysis

The Functional Needs Analysis (FNA) leads to the identification and definition of new capabilities that are aligned with strategic priorities. These are capabilities for which solutions must be found or developed. Within the CF's current state of transformation, the future "to be" state has not yet been documented in such a way that we could make a direct comparison with the "as is" state. Therefore, the FNA uses the capability packages to represent the future "to be" state as determined by strategic priorities.

The FNA for the requirements analysis team of the JCDS 21 project was developed in a collaborative manner involving all of the JCDS 21 project teams in a series of activities that involved: the presentation of the data collection results, including the FAA; presentations from DND stakeholders on transformation and information and intelligence fusion to give the scientists specific examples of military requirements; and teleconference working sessions. Requirements for each of the project teams were discussed in the context of the data collection findings and the results of the FNA activities were combined in tabular format identifying gaps pertinent to the focus of each of the JCDS 21 project teams. The relevance of these gaps to the FAA capability packages was mapped in order to provide a guideline to each of the groups as to which are relevant and to what degree for their focus areas.

This information presents a baseline for future functional solution analysis work for the JCDS 21 project and illustrates that those solutions that will progress the definition and development of a capability are a combination of people, process and material; there is no one single solution or magic technological bullet. Extending the analysis during the FSA activities and incorporating analysis on cognitive processes and simulation models will facilitate the development of concrete recommendations for the JCDS 21 project.

4. DEVELOPMENT OF A SIMULATION ENVIRONMENT

A simulation based upon the DoDAF architecture of the joint operational command structure would be useful to assist JCDS 21 scientists to design experiments for new headquarters such as Canada Command, which is still defining its' organizational and operation procedures. Such a simulation would also assist scientists in the assessment of potential gaps and deficiencies and the validation of metrics. The goal is to enable concept development and experimentation through modelling and simulation capabilities that allow operational concepts to be demonstrated and evaluated. This will provide the means to better understand the potential impact of conceptual C2 or I2 techniques in the form of capabilities (people, process and technologies). The initial requirements for the simulation environment are related to the challenges of integrating concepts and capabilities from a large number of stakeholders operating in a JIMP operational environment employing net-centric capabilities. The initial scope was to simulate C2 process models to validate the joint operational staff processes as well as the simulation framework.

Developing a modelling and simulation capability that supports the broad range of operating concepts and stakeholders requires an integrated approach that incorporates the following features:

1. A method for describing operating concepts and capabilities that is common for all stakeholders:
2. A common architectural information base that enables future conceptual capabilities to be described in the context of the existing architecture.
3. A method for expressing capabilities in a dynamic simulation that provides traceability to operators' concepts.

4. A consistent metrics framework for C2 capabilities for indicating the degree to which performance objectives may be achieved in the simulation and the scenario.
5. Models net-centric services in a service-oriented architecture.

Common Capability Definition Method

The DoDAF specifies a suitable standardized method for describing large systems of systems architectures as described previously. The DoDAF information model can be the basis for achieving interoperability across a variety of tools by providing a common information environment with which data from different tools can be mapped[10]. The DoDAF is supported by a Core Architecture Data Model[11] (CADM) which can be expressed as an XML schema[12].

In this project the architecture information has been acquired and stored in an XML data store derived from the CADM. UML use case information has been mapped to DoDAF architecture elements as operational nodes (actors), activities (use cases) and information entities using XML[13]. Employing UML standard tools to express DoDAF architectures has proved to be a useful and straightforward process using XSLT transformation[14] to map XML products from tools to the architecture data and to convert architecture data to XML data to be ingested and processed by other tools. The process is illustrated in Figure 10 below.

The UML use cases have been developed using an inexpensive text-editing application such as Serlio's Case Complete[15]. It is an XML-based tool that exports use case data in Word, XML and XMI formats. It is an appropriate tool for operators to capture concepts and requirements and to integrate the information in the DoDAF XML architecture data repository. XSLT transforms are XML documents used to map or transform data in one XML document to the structure of the second document. The concept established in Figure 10 has been extended to provide a common architectural environment for multiple projects. The use case tool is the primary means for developing an operational architecture as an integrated set of use cases.

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[10] The documentation for the DoDAF can be downloaded from the following site: http://www.aitcnet.org/dodfw/.

[11] CADM Provides a common approach for organizing and portraying the structure of architecture information, and is designed to capture common data requirements. The CADM facilitates the exchange, integration, and comparison of architecture information throughout the Department of Defense, improving joint Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance interoperability. http://akss.dau.mil/dag/Guidebook/IG_c7.2.4.3.asp.

[12] Extensible Markup Language, XML Schemas express shared vocabularies and allow machines to carry out rules made by people. They provide a means for defining the structure, content and semantics of XML documents. http://www.w3.org/XML/Schema .

[13] The Unified Modeling Language, UML™ managed by the OMG (Object Management Group, http://www.uml.org/) is perhaps the most widely used standardized method for describing software applications, business processes, operational behaviour and architecture. UML is well suited to modeling operating concepts in the form of use cases. Concepts are described in terms of the actors, their roles and the activities they perform in carrying out the conceptual capability. Another benefit of UML is that it is XML-based, using XMI (XML Metadata Interchange[13]), another OMG standard, (http://www.omg.org/technology/documents/modeling_spec_catalog.htm#XMI) which enables the transfer of a UML model from a standardized tool into an architecture repository or to another tool.

[14] XSLT, is a language for transforming XML documents into other XML documents, http://www.w3.org/TR/xslt.

[15] Case Complete is a Use Case authoring tool. http://www.serlio.com/casecomplete/ .

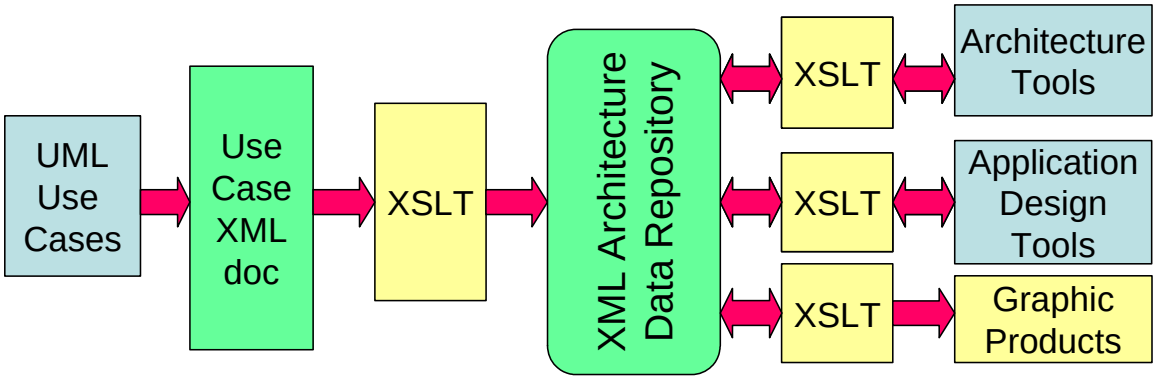

Figure 10: XML Transformation Process

A common operational architecture defines the pattern employed in each operational node, as shown in Figure 11. This diagram illustrates the interactive behaviour that is to be used to simulate C2 behaviour in the CF. The concept of net-centric operations is embodied in the ability for each node or user to be able to interact with superiors, subordinates, peers, partners and the external information environment. Furthermore, each node or user will perform activites that can be classified as Observe, Orient, Decide, Act and/or Share. This operational architecture is suitable for characterizing the behaviour of the organization and for defining net-centric services in a manner consistent with the Global Information Grid or Net-Centric Operations Warfare (NCOW) Reference Model.

Equipped with a common operational architecture pattern, a suitable reference model for net-centric services and a standards-based XML architecture development environment, the CF will have a model-driven architecture to enable capability definition and assessment through Functional Area Analysis, Functional Needs Analysis and Functional Solutions Analysis. However, to evaluate the peformance of conceptual architectures, an executable architecture is required.

Dynamic Executable Architectures

Having a common operational architecture information base creates the opportunity to translate architectures into dynamic simulations that model the behaviour of capabilities employed in mission-specific scenarios. The architecture information expresses a general case, or collection of capabilities that may be employed or applied in response to the events and conditions of a particular scenario. Measuring the performace of the architecture in the mission-specific case is a basis for comparative evaluation of competing operating concepts and technologies. There is a clear need to minimize the round trip time and expense from concept development through capability assessment using simulations to estimate the performance and cost-benefit of conceptual capabilities. By using the standards-based model-driven architecture environment, it is possible to streamline the process to include simulation development using the UML/XML output to drive the simulation environment.

The secondary objectives of the simulation framework relate to modelling and evaluating technologies that might enhance cognitive and decision-making processes in the JIMP environment. Business process models tend to be linear sequential views of operating concepts. The models may function well in cases of deliberate contingency planning, but the models may

not adequately portray the behaviour of organizations and technologies in time-critical planning and execution at higher tempos where decisions may be based more on the information that becomes available and the timing of that information rather than the state of the process at the time the information is received. Therefore, once the process model simulation is established and validated, the next step will be to employ the capabilities of UML to model highly interactive processes and to model the technologies that might be employed to enhance cognitive and decision-making activities for command and control.

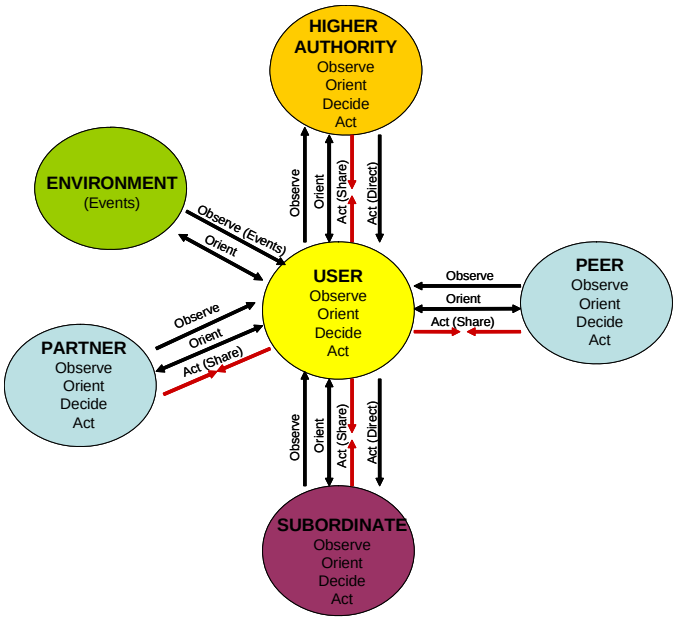

Figure 11: Common Operational Architecture

5. CONCLUSION

On 6 February 2006, the new C2 structure for the Canadian Forces was established, creating a strategic joint staff and four joint commands. The CF is embracing transformation not only physically, but also conceptually as core net-centric services upon which collaborative planning and decision-making services are reliant are being developed to enable horizontal and vertical collaboration throughout the organization. Transformation reinforces the necessity for senior leaders and decision makers in the Canadian Forces to act effectively within the three JCDS 21 domains of decision making, collaboration and information and intelligence analysis as they move forward in the 21st century.

The new joint operational headquarters of the CF will reflect elements of the complex C2 environment analysed in this study. The requirements analysis and architecture products that have been developed can be applied to this new structure. As the CF transforms and works increasingly within a JIMP structure, the physical and conceptual aspects of transformation are captured in the capability packages defined in the Function Area Analysis as:

1. Monitor and collect data;
2. Develop shared situational understanding;
3. Develop continuous integrated operations plans (the OPP);
4. Execute plan with leadership and direction; and
5. Monitor execution and adapt as necessary.

The influences, issues and areas of impact on the capability packages defined in the requirements analysis helped to focus the JCDS 21 scientists in the conduct of the functional needs analysis. The development of a high level view of the military enterprise architecture has identified relevant business processes enabling the application of methodologies that can be used for providing in-depth requirements gathering and the analysis of the cognitive processes involved in command and control. This work has also provided the information required for the development of a simulation that will support the JCDS 21 project's experimentation campaign.