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A Framework for Resource and Execution Management

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Abstract: *This paper presents the approach, architecture and implementation guidelines for a resource visibility framework suitable for the aggregation of up to date information related to organizational resources based on the requirements of the decision makers within the organization. The contribution of this paper is threefold. First it presents the State-of-the-Art with respect to several resource visibility initiatives followed by a classification procedure of organizational resources. Second, it illustrates a new approach for a resource and execution management framework that is supported by an elaborated case-study. Finally, the paper is demonstrating the underlying achievements in implementing such a framework.*

Keywords: *Assets classification, Total Assets visibility, Execution management, Plan adaptation, Decision support system, Defence enterprise resource visualization, Data integration.*

I. INTRODUCTION

Resource visibility plays an instrumental role in achieving key decision support objectives inside large institutions. Resource visibility may be defined as the capability of the system to provide accurate information of the organizational resources to the decision makers. It also encompasses the idea of tracking various aspects such as location, movement, status and identification of the resources in storage or in transit. Furthermore, it represents a strategic level operating concept that allows the decision makers to achieve a balanced resource management in the context of their respective capabilities and in accordance with the organizational policies and visions.

In organizational management, decision makers are ranging from group leaders to senior executives. Also, the scopes of their decision areas are generally different. Therefore, the provision of having a relevant body of logistics information in a timely manner is not enough to assure effective decision making at each level. Consequently, a supportive framework for resource visibility can be put forward as a dedicated infrastructure in terms of software and hardware. In this setting, a framework is necessary to identify the needs of a particular level of decision making and to classify organizational assets with specific categories in a relevant hierarchy where the essential resources form should be positioned with higher visibility from the top of the hierarchy. Such a framework is also required to provide support for achieving decision superiority by sharing and gathering resource information from other network centric collaborative and competitive environments.

Several avenues and approaches for achieving full-scale resource visibility can be found across academic institutions, business industries and military organizations. Commercial organizations are highly focused on achieving a decision support system that readily identifies the pitfalls inside the institutions. Military organizations are also placing a strong emphasis on profound research to achieve accurate assets information visualization for the mission commanders in order to be globally relevant, responsive and effective. The knowledge about the utility of an asset is the key for success either to commerce or combat management.

The extraction and visualization of asset information is challenging due to the enormous amount of inter-related data that resides inside organizations in structured and unstructured manners. Also, existing classification approaches are often inadequate and not always customizable to the industrial needs. Monitoring of particular asset properties are demanding in terms of technologies and infrastructure. Finally, offering high situational awareness by resolving the utility of an asset with respect to a particular operational environment is research intensive.

In this paper, a framework for resource and execution management is proposed in order to address the aforementioned issues. After a careful analysis of the critical requirements, the objectives of this research initiative have been set as follows:

- A study on similar contemporary research initiatives.
- Classification of assets information based on relevant and well-established criteria.
- Modelling of a visualization framework for the organizational assets.
- Modelling the execution management and plan adaptation.
- A case study of specified visualization techniques over a specific application.
- Implementation of a proof of concept.
- Guidelines for integrating the proposed resource and execution management framework into a network centric operational environment.

The framework can be used in a coalition setting since interoperability to share assets information within Canadian Department of National Defence (DND) or externally with other government agencies, NATO and allied partners is central in the framework.

We will discuss in this paper the Total Resource Visibility (TRV) prototype, developed for JCDS 21 TDP (Joint Command Decision Support for 21st Century Technology Demonstration Program) and its interoperability with other JCDS 21 modules such as Execution Management and Plan Adaptation (EMPA) tool.

TRV is a decision support system for near real-time resource visibility providing asset information to the Joint Command Decision Support components (JCDS). It is a system offering the ability to know the identity, location, status, and condition of assets in the logistics chain at the operational level. It enhances information capability to support logistics decision-making and support to planning. It can be used to analyze/visualize contingency plans and their assigned resources. TRV can also be used to analyze and perform measurement of resources employment and usage.

EMPA is a distributed, multi-layered prototype providing execution management services to JCDS 21. EMPA supports time-sensitive as well as deliberative operations execution through continual monitoring of situation inputs and execution reports.

The rest of the paper is organized as follows. Section II illustrates the state-of-the-Art on the resource visualization initiatives. It clearly identifies different criteria of the assets classification. Section III describes the proposed approach of asset visualization followed by a case study in section IV. The case study is based on an R&D activity carried by the Defence Research and Development Canada (DRDC) at Valcartier. The implementation of the proof of concept is demonstrated in section V with specific guidelines to integrate the framework for information sharing at inter-organizational boundaries. Finally in section VI, the conclusions are drawn along with the idea of future work in this direction.

II. Related Work

From the perspective of assets or resources in the context of large organizations, there are a number of salient aspects such as the information integration, asset visibility and planning activities. In this respect, certain military related initiatives have been considering the forenamed aspects. The integration of data sources, web-services and legacy systems, is outlined in the direction of a Network Centric Operations (NCO) framework and its related Network Centric Continual Distributed Planning (NCDCP) concept presented in [7] and [12]. Relevant recommendations have been found in the Concept of Operations (CONOPS) report [8] with respect to mission planning and assets information visualization. Moreover, some aspects covered by CONOPS are also implemented in the Collaborative Operations Planning System (COPlanS) [5]. COPlanS has been developed in an R&D project, initiated by DRDC-Valcartier that has investigated some of the potential logistic analysis on military assets. It represents an integrated suite of distributed planning and workflow management. The CONOPS report also mentions plans for a Defence Enterprise Resource Planning (ERP) solution "that will include legacy application rationalization and aggressive migration to exploit ERP Investment". However, DND agrees that such a solution is multi-generational and strenuous in terms of "people, time, money, preparation and focus".

Another important aspect is represented by the assets information monitoring which is responsible for retrieving near real-time information on the visualized assets. A Java Messaging System (JMS) based middleware-centric messaging service is implemented in the NCDCP project for information monitoring [7].

In all major planning and resource allocation activities, visualization of military assets is of paramount importance. Additionally, a comprehensive appraisal of the operational readiness, availability and suitability of the assets for particular operations or military activities is also essential. There are several systems, projects and R&D initiatives in these areas. Among the relevant ones are: Defence Total Assets Visibility (DTAV), National Movement Distribution System (NMDS), Materiel Acquisition and Support Information System (MASIS) and Canadian Forces Supply System (CFSS). The DTAV tool is an established DND tool that deals with assets visualization. However, it does not offer possibilities related to mission planning using the visualized information. Moreover, in DTAV the materials are tracked as individual pieces, containers or boxes of a numbers of pieces of the same materiel and containers/boxes (e.g. shipping containers, tri-walls, sea containers) of different types of materiel, etc. However, while such a granularity may provide a certain level of detail it also exhibits less impact on the overall goals of assets visualization. DTAV may provide only a limited support for the necessary asset information required for operational decision making. Similarly, other systems such as NMDS may provide transit visibility of the assets but it is not integrated to all similar assets visibility systems. Hence, there is an apparent lack of thorough coordination in asset visibility and corresponding working relationships among systems. In addition, the aforementioned assets visibility tools depend on data entry in DND/CF's major and essential information systems. An estimate for MASIS shows a figure of 40% increase in the data entry workload without inclusion of automated data capture modules. Similar situations are being experienced with CFSS and NMDS.

Furthermore, a critical requirement is to define the concepts of asset and asset visibility in a standardized manner. NATO Assets Visibility Group has clearly defined the aspects of the military assets along with their DND partners. According to the CONOPS [8], the scope of asset visibility is encompassing the following:

- A unique identifier for each asset created by using standard technology.
- Particular location (latitude, longitude) of the assets and the status information.
- Scope to integrate any information source to retrieve information on the asset.
- Standards (ISO and NATO), technology, and network security information required to visualize assets in a business process.

- Interoperability to share assets information within DND or externally with other government agencies, NATO and allied partners.

An integrated enterprise system always requires a front-end system that provides a clear insight over fresh data. In this respect, asset visibility represents the key ingredient of decision support systems (DSS) involving planning and resource allocation. Thus, it is noteworthy to mention the relevant research in this area.

In order to have an effective interface for a decision support system, there is a need for well-presented high level collections of information in a hierarchical manner through a common interface while allowing navigation to detailed information by drilling down on the desired components. Furthermore, a near real-time information aggregation is empowered in this setting by monitoring mechanisms that listen to the changes in remote information sources.

In the context of DSS, a Service Oriented Architecture (SOA) is seen as the candidate able to address the challenging integration issues by focusing on independence of platform, implementation language, data, and communication protocols.

The SOA based solutions are offering service description, publication, and binding. In this context, businesses can describe their services and publish them in accessible repositories where from service clients can find and utilize them. All of this is achieved in a transparent way while hiding all the complexity from the end user. Most of the concepts of SOA are pointing to the use of Web Services as the most effective enacting of this paradigm. As for the implementation of SOA using Web Services, e-Speak [13], a software product developed by HP in 1999, was the first Web Service implementation of SOA. After that, companies started developing frameworks for web services integration and the results are J2EE from Java, WebSphere from IBM, and .Net from Microsoft. This lead to the evolution of web services, which are self described, self-contained, and modular units that are build using standard based protocols and allow service integration over multiple platforms. Consequently, web services are gaining huge momentum by providing the above stated characteristics which distinguishes them from previous technologies. The architecture of web services is straight forward: service providers describe their services using Web Service Definition Language (WSDL) and place the corresponding description in a repository. A service requestor uses Universal Discovery, Description and Integration (UDDI) to find the appropriate Web service which fits the profile of the requestor. Further interaction is achieved via Simple Object Access Protocol (SOAP). Standardized protocols made web services very appealing but in many cases a business workflow is too complex to be provided by single service. Therefore recent initiatives automate the sharing of information by multiple services by realizing a choreographic language on top of multiple services. BPEL4WS [10] is one of the business process and choreography APIs designed by IBM and Microsoft. It provides a language for the formal specification of business processes and business interaction protocols. Another such collaborative business applications API is Web Service Choreography Language (WSCI). It was an initiative of World Wide Web Consortium (W3C) represented by many of the industry leaders such as BEA Systems, IONA, Oracle Corporation, SAP AG, Sun Microsystems, etc. Actually, these languages define an interoperable integration model that should facilitate the integration of intra-organizational processes from the perspective of automated business support.

Decision makers, entrepreneurs and executives need to rely on automated systems that can present a “big picture” from the tremendous amount of information that is well beyond the human capability to fully manage, evaluate and understand their content. Decision support systems represent such software solutions that are mainly underpinned by databases, user interfaces, communication networks and information processing tools. From the architectural point of view, a DSS is usually built on top of data warehouses or federated architecture. While a federated architecture allows real time retrieval of information from all participating databases, the warehouse architecture is capable of providing historical or previous data in general. The DSS introduces information processing capabilities over data retrieved from remote sources.

In [3] Miksa and Carlson discuss the recent attention directed towards the improvement of logistical efforts in pursuit of swift, uninterrupted support to the operation theatres. In this respect, the forenamed work discuss the constraints that led to a change in the Canadian Forces (CF) policy of maintaining excess supplies as provision for contingency resolution and moving towards a paradigm revolving around the operations support service on the need basis. This approach is seen as better suited in the context of increasingly uncertain operational environments wherein asset visibility represents a critical aspect in the process of effectively and thoroughly tracking the materiel required for the operations. Consequently, this approach leads to improved levels of readiness in the field of operations.

In “Command and Control Doctrine for Combat Support" (US Doctrine) [4], the authors explain the need for an unabated operations tempo promoting a minimal idleness of organizations. Thus, the emphasis is put on the transfer of focus. In this setting, the resources are continually utilized or consumed and replenished or reconstituted in a single resource pool. Consequently, there is a requirement to have the temporal perspectives time slices available in order to support a streamlined ability to arbitrate, allocate and relocate resources amongst competing demands. In this respect, given that the operations might be supported by dispersed headquarters staffs working in different time zones, a decision-support system must provide for shared work spaces and asynchronous collaboration.

III. Approach

After a careful analysis of the state-of-the-art, this section demonstrates the proposed approach to obtain an assets visibility framework. The approach is based on three phases, namely:

- Classification of the assets,
- Modelling the visibility of asset properties, and
- Integration of the visibility model to a network centric framework.

However, in reality, a framework of resource visibility may require further implementation from this generalized approach due to specific requirements of the stakeholders.

A. *Assets Classification*

Assets classification is treated as a five-step methodology as shown in Figure 1 and include: Assets identification, assets accountability, assets valuation, assets classification schema and schema implementation [13].

1) *Assets Identification*: Identification of assets determines the scope of the classification. However, for a wide variety of organizational resources, a precise identification of all assets is difficult and time-consuming; moreover the value of an asset is dependent on several dynamic economic factors. An improvement in this respect might be achieved by identifying the assets based on some pre-identified categories within the scope of business. In practice, an asset may also be seen as a collection of many unique assets. Therefore, a class of asset may be divided in sub-classes with a finite depth for a given space and time and required precision. Three basic categories are proposed as follows:

- Unique Asset: A unique asset is an economic entity that may solely identify its market value. It may depend but does not contain other unique assets inside it, as defined by the standard.
- Aggregated Asset: An aggregated asset is defined as a collection of several independent assets. Example: A fleet of ships.
- Complex Asset: A complex asset is a collection of dependent assets that constitute the complex asset. Example: A collection of rifles and bullets.

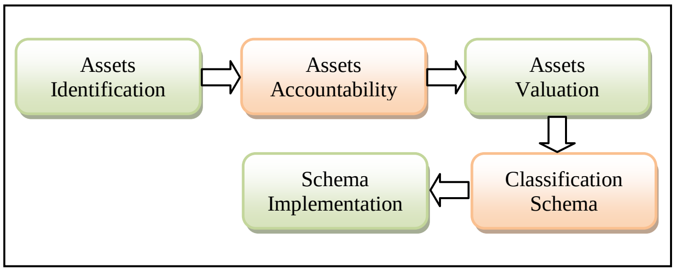

Figure 1: Five-step methodology of assets classification

Emerging technologies such as semantic technology can be used for asset identification in the case where coalition systems or databases are used.

2) *Assets Accountability:* In an industry each asset has a hierarchy of owners. It is necessary to define ownership of the assets to define its availability, scope of use, strategic decision and other business rules associated to the asset. Accountability is also important to judge and evaluate the asset and the responsibility of the owner. Theoretically, a military hierarchy may be treated as an evidential network. Each node in the network represents an asset-owner (personnel or a department) and a line between two nodes reflects a relation between them. An evidential network is potentially able to represent super-ordinate, subordinate and peer-to-peer relationships. A genetic algorithm is also available to decide possible owner/s of a military asset [1].

3) *Assets Valuation:* Evaluation of assets is a critical process that depends on numerous factors. A subset of these evaluation criteria is static while the remaining subset is dependent on market value and specific business environment. Some of the basic criteria may be seen as follows:

- Financial: From an economic standpoint, the value of an asset lies in its manufacturing-cost, liabilities, reusability, mobilization, current condition and the possible business from it. Assets may range from a very low cost to a very high cost (from bullets to fighter jets). Reusability affects the valuation as a plane can be used many times whereas a bullet is for one-time use. However with every reuse an asset-value decreases and it requires to be replaced after a certain age.
- Risk: Risk calculation allows the estimation and pre-computing the importance and the threat on a defended asset for a specific situation. It may incur higher maintenance cost for an important asset. The risk calculation also depends on business plan. A highly exposed asset is clearly possessing a higher likelihood to be attacked while assets such as a ships, operating from sea, are exposed to a lower threat level.
- Dependency: Assets valuation requires to analyse the dependency between its sub-components. There exist three types of dependencies, namely: Integral dependency, relational dependency and support dependency. Integral dependency presents the relation between the assets and a step/phase to accomplish an executing plan. Relational dependency may be defined as the relationship between two sub-components in a complex asset. Support dependency offers replenishment possibilities for an asset during a plan or operation execution.

4) *Classification Schema:* The design of the assets classification is requirement-specific. An example of classification schema is presented in paper [13]. Some of the selected properties may be seen as follows:

- Confidentiality: It defines the exposure of the asset. Asset information may be unclassified, shared, restricted, secret and top-secret.
- Asset value: It denotes the evaluation score of the asset. It helps to understand importance, risk and dependency of assets.
- Authorization: This property denotes the access rights of a personnel or a group of personnel on an asset. The set of rights may include read-only, write-only, read-write, etc. Asset-owners are responsible for presenting such rights to others.
- Time: This property of an asset is common for commercial use of an asset. It provides the production

date of an asset that may be used when judging the availability, validity, relevance of an asset with respect to present time.
- Destruction: An invalid asset is required to be destroyed or disposed. Destruction of assets is also subjected to several issues.

5) *Schema Implementation:* Asset classification procedure should be tested by implementing the classification schema and using organizational assets. Test results should be documented after uniquely identifying through the schema.

B. Visualization Modelling

The main objective of the resource visibility framework is to view assets from three perspectives:

- Assets Properties: The prime objective of assets visibility is to locate an asset through a software application and to retrieve status information about the asset. The status of an asset presents asset specific information that uniquely identifies an asset within the institution. Furthermore, movable assets are often changing location during a mission according to the strategic plans and such information is always updated to the data sources. Since the data sources contain dynamic information, a monitoring component is required in order to provide users with real-time notifications and updates of the presently information. The ultimate goal of this monitoring is to translate data into a useful and up-to-date knowledge in relation to an asset.
- Assets Accountability: As mentioned earlier, assets accountability refers to the sub-units that control the asset. It implies that although an asset is a property of the whole organization, the accountability of an asset may change over time to a particular group in order to execute business plan(s). Once the asset is accounted to a particular group; it determines the use of the asset to its respective plans or for other plans.
- Business Plan: Business plan is one of the most important aspects of assets visualization. Extensive requirements analysis reveals that the military Decision makers are interested in customized assets visualization that may offer the best understanding to their responsibilities in the organization. Instead of observing a plethora of asset statuses, one user is most interested to receive hierarchically customized sets of information according to his/her requirements. The plan aspect of assets visualization presents hierarchical information in terms of existing business plans in the organization.

C. Assets Visualization Framework

The visualization framework is initially developed as a proof-of-concept application and later integrated to the ‘enterprise service bus (ESB), developed for JCDS 21 TDP, of the network centric framework. Figure 2 describes the general architecture of the assets visualization system.

Information of assets is distributed among many information systems at the bottom level. In the second level upwards of the architecture, there exist two sub modules that are responsible for asset metadata (schema) extraction and assets monitoring. Assets metadata extraction unit is equipped with XML parser APIs to retrieve the structure of the data that are normally kept in xml file structure. Assets monitoring unit is responsible for retrieving real-time information on a visualized asset so that the user is always notified about the present status of the object. During a mission critical situation, while several movable assets are involved, it keeps the decision maker aware of the situation.

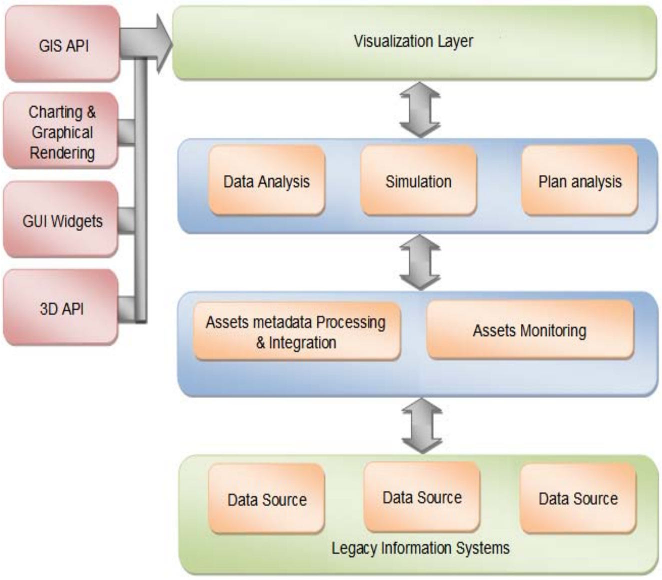

Figure 2: Multi-level architecture of visualization framework.

On the third level up, the architecture comprises three application modules, namely data analysis, plan analysis and simulation. The necessity of data analysis is to extract desired knowledge from the visualized information. Mission Plan analysis unit is proposed to present the classification of assets with respect to different plans. A business plan may be seen as a graph of nodes and relationships among the nodes. These nodes represent several states in a plan. Each state contains a set of assets and maintains specified relationships with other assets of the same or different state. Simulation capability of the assets visibility system allows replicating predefined courses of action for given set information of the assets. For example, the system of assets transportation should be able to perform a simulation that shows the changing locations of assets over the maps. This simulation capability may lead users to better situational awareness in a collaborative or competitive environment where more than one business processes might be executed in the same geographic location.

Finally, the topmost level is presenting the visualization layer of the architecture which uses several APIs for elaborated information display. Elaboration of this layer is requirement specific and may be different from one project to another.

The integration of the assets visualization framework may be accomplished to web-services and web-portal. Once the assets visibility system is built, it is required to be integrated into a portal around the enterprise service bus. Furthermore, the framework also requires retrieving and offering information that can be achieved through web-services. Web services will retrieve information from the same location of the portal but is required to be integrated to the ESB separately to be benefited from other systems in the framework.

D. Interoperability

TRV module interacts with EMPA and COPlanS. However, EMPA module interacts with three of the JCDS core test-bed (JCDS CTB) external systems: COPlanS, TRV and CHESS (Commander HandhEld Support System). The following sections give a brief description of each system.

EMPA (Execution Management and Plan Adaptation): The EMPA system was designed to be integrated as a service within the JCDS core test-bed. This test-bed includes several external systems. The EMPA system has also a portlet component integrated to the C2CE (Command and Control Collaborative Environment). This portlet displays synthetic information coming from EMPA in order to keep the operator updated with the latest plan execution status. In order to obtain more detailed information about the execution, the user needs to open the EMPA application in order to be able to interact with the plan execution. The portlet mainly displays all the events related to the current operation. This information corresponds to the status view of the EMPA client but with one major difference. It displays only relevant information that may change the status of the operation.

COPlanS : COPlanS is an integrated flexible suite of planning, decision aid and workflow management tools designed to support a distributed team involved in the Military Operations Planning Process (CFOPP). COPlanS provides the ability to plan an operation in a net-centric environment with integrated collaborative tools. The system offers functions to design and manage multiple concurrent distributed battle rhythms at different planning levels. It helps synchronize workflows, document processes and replay the decision-making path. The planning tools allow sketching courses of actions (COAs) on maps, performing time and space synchronization, managing resources and ORBAT, and performing limited logistics analyses. The decision aid tools rationalize the process, improve COA evaluation and comparison, and rapidly produce documents to support the commander's decisions.

CHESS (Commander HandhEld Support System) : CHESS was designed to provide commanders with access to different communication mechanisms and networks to maintain contact between their staff, subordinate commanders and key joint, coalition and public sector partners with devices such as cellular phones, email, Voice over IP (VoIP), web. It also allows the commanders to transmit and receive information in environments with limited bandwidth or/and connectivity. CHESS is able to provide notifications, alarms to draw the commander's attention to time sensitive information.

Interactions within JCDS CTB systems: EMPA uses a special notification service offered by the JCDS CTB in order to interact with other systems. This notification service complies with a publish-subscribe architecture, where different systems can subscribe in order to be notified when a specific event happens. The notification service is offered by the ESB (Enterprise Service Bus) to which all JCDS CTB systems are connected (Figure 3). The following sections describe the main services used by EMPA to interact with the JCDS CTB systems. These services are grouped under five modules:

- Manage plans – interaction with COPlanS;
- Assign specific resources – interaction with TRV and CHESS;
- Execute plan instance – takes care of all monitoring functions by EMPA;
- Terminate plan instance execution – interactions with JCDS CTB;
- Internal Simulator – necessary for the emulation of a plan execution.

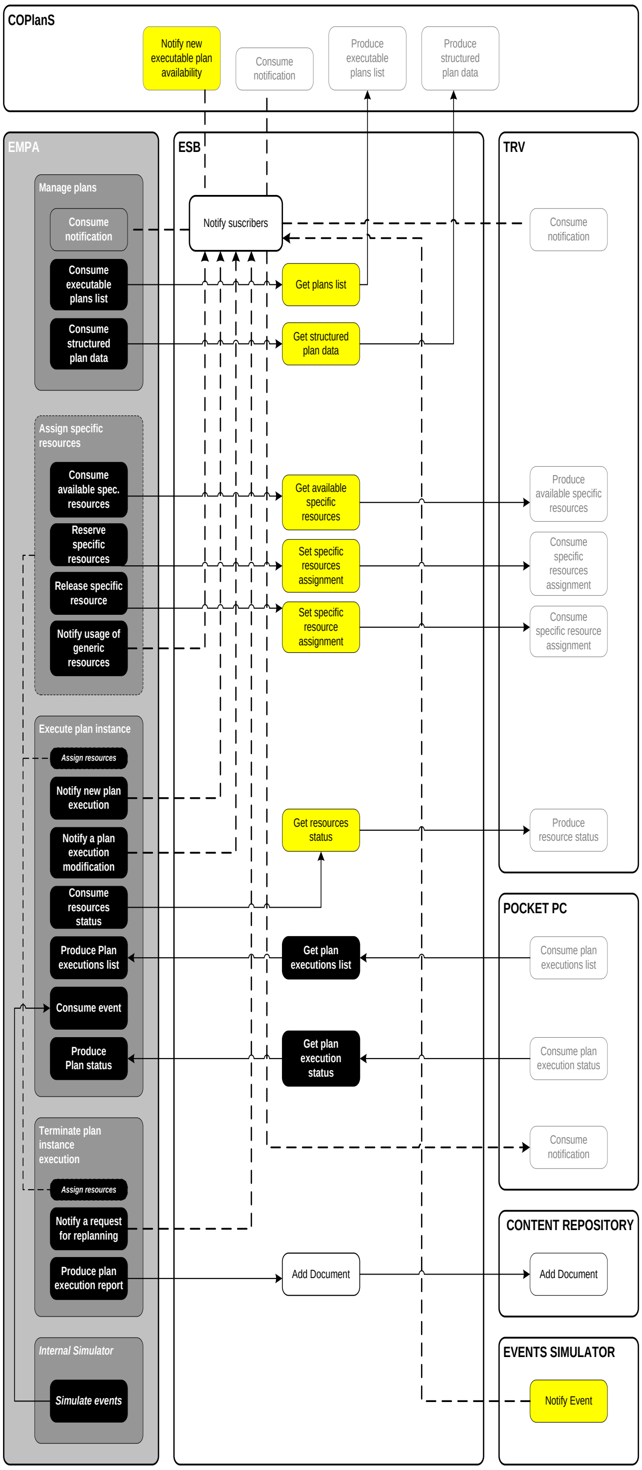

Figure 3: Interactions of TRV & EMPA with JCDS CTB systems

Technically, EMPA has a module called *Manage Plans*. This module consumes any notification coming from an external system for which EMPA is subscribed. It also consumes the plan list from COPlanS by invoking a method *Get plans list*. Finally, it consumes the structured plan data from COPlanS by invoking a method called *Get structured plan data*. During execution, if there is no possible adaptation to the plan that prevents an execution failure, the user may initiate a request for re-planning, which sends a notification to the JCDS CTB for which COPlans has a subscription.

Interaction of EMPA with TRV: The interactions between EMPA and TRV are presented in Figure 4: Interaction of EMPA with TRV.

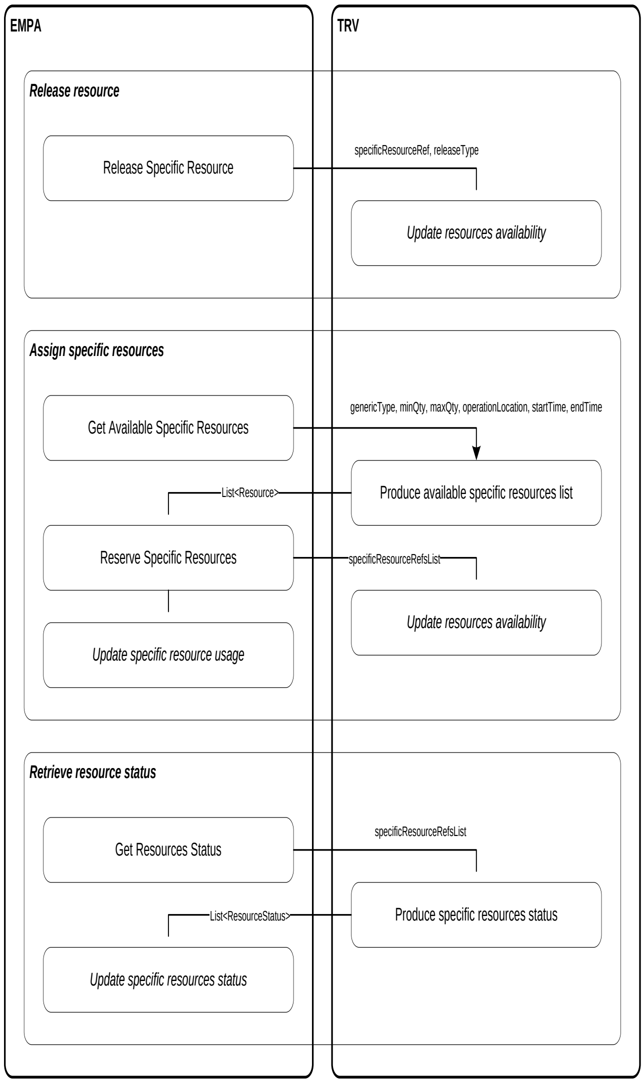

Figure 4: Interaction of EMPA with TRV

First EMPA will ask TRV for the list of needed resources that are available (*Get Available specific Resources*). EMPA needs to send along with this request the generic type of the needed resources (F/C 18 for instance), the minimum and maximum required quantities, the operation location, the expected start and end times of the operation. TRV will use this information in order to produce the list of available resources corresponding to these parameters (*Produce available specific resources list*). EMPA will then assign these resources to the plan (*Reserve Specific Resources* and *Update specific* *resource usage*), notify TRV in order to update their status (*Update resources availability*) so that they will become unavailable for other plans. In fact, the notification is sent to the JCDS CTB so that all systems that subscribed to this information will be notified including TRV.

During execution EMPA will need to constantly retrieve the status of the assigned resources (*Get Resources Status*). TRV will produce the status of the list of resources indicated by EMPA (*Produce specific resources status*). Based on this status EMPA is able to update the resource status (*Update specific resources status*).

Once the execution is complete, EMPA releases the reserved resources (*Release Specific Resources*) and notify TRV to update their status (*Update Resources Availability*).

Interaction of EMPA with COPlanS : Each time a new executable plan is available in the COPlanS database, EMPA is notified of the existence of this new plan (see Figure 3). EMPA will then query COPlanS in order to obtain the list of new plans in the database and their data structures. After receiving the data structure of a plan, EMPA can create a plan instance necessary for starting the execution of the plan. Once the plan execution is started, the JCDS CTB is notified. This notification will be available for any other external system that might be interested to know that the plan execution has started.

Interaction of EMPA with CHESS : As shown in Figure 3, during plan execution, EMPA needs to communicate the currently executing plan list (*Produce Plan Executions List*) and their execution status (*Produce Plan Status*). To this end, CHESS will invoke the *Get plan execution list* and *Get plan execution status* functions, and then displays this information in a synthetic way (*Consume plan executions list* and *Consume plan execution status*).

Other interactions with the JCDS CTB : In order to emulate the plan execution, EMPA uses two event simulators. These simulators generate events that need to be taken into account by EMPA. The internal simulator is located within EMPA and generates events (*Simulate events*) related to the execution of the current plan, such as goal related and task end events. A generated event is taken into account by EMPA (*Consume event*) to update the different views of the plan execution, allowing the user to adapt the plan when necessary. The external simulator generates events (*Notify Event*) by using the notification service of the ESB. EMPA among other systems may be interested to subscribe to those events. For example, a sudden traffic blockage of a route can be an event generated by the external event simulator.

Once the execution of a plan is terminated, EMPA generates an execution report (*Produce execution report*) and sends it to the ESB (*Add Document*), which will store the report (*Add Document*) as a document in the CONTENT REPOSITORY. The content repository can be used by any external system to store results and relevant information that might interest other systems. It also allows any system to have a log of the past activities. For example, in the EMPA case, the execution report will contain all occurred events during the plan execution and all the decisions made by the user to adapt the plan during the execution. Such a report is very useful to perform a post-analysis of a plan execution.

IV. Case Study

This section elaborates a case-study using aforementioned approach. The research and development work is a part of Total Resource Visibility (TRV) developed for JCDS 21 TDP. The aim of the software solution is to create high resource visibility for several military resources.

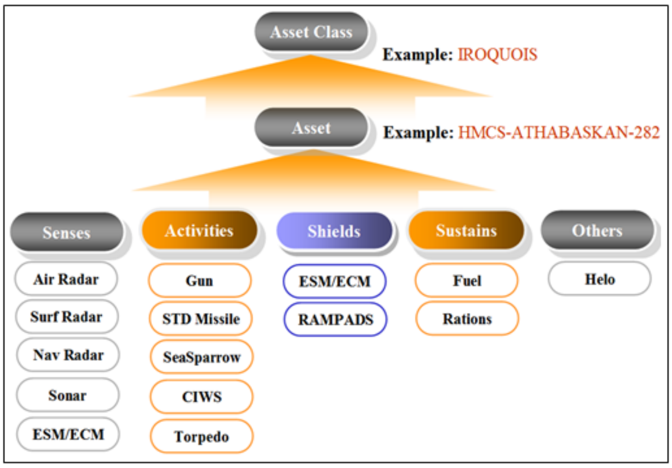

Figure 5: Example of assets features and hierarchy.

Following a discussion with DND professionals in relation to military assets, it became apparent that most of the military assets may be broadly identified as two categories of economic identities:

- Strategic Asset: These are considered as typical military assets with high importance and low availability. Examples: Polaris aircrafts, C17 aircrafts, etc. Other assets may also be raised to this category depending on its importance in a mission critical situation. Mission commanders require knowledge of such asset information at any time and not knowing the status (in serviceable, in maintenance, etc) of such an asset incurs immense loss to the Defence department.
- Generic Assets: Generic Assets may be well described as a class of assets rather than a single asset. Example: Hornet aircrafts, military trucks, etc. DND has a set of such assets. Generic assets are mainly important for mission planning instead of constant monitoring. There are two types of generic assets:

i. Renewable Asset: An asset is renewable if it can be repeatedly used for certain duration of time. Example: Aircraft, guns, etc.
ii. Consumable Assets: Military organizations use several consumable assets that can be used one-time during a mission. Example: Missiles, bullets, money, fuel, etc.

The process of valuation of an asset takes into account those features that are contributing to the functionality of the asset in order to appropriately perform its intended function. Moreover, each of the contributing features or factors may be having a different importance or weight for the overall functionality. Thus, each of the contributing features must be factored in the process of assessing the readiness according to its corresponding weight. The factors are partitioned in our case in senses, acts, shields, sustain, and other categories as depicted in Figure 5.

Depending on the asset type, one or more of the aforementioned categories may be required. Furthermore, the considered weighting procedure is based on scores assigned by Subject Matter Experts (SMEs) in the form of numerical values on a given scale wherein higher values generally correspond to higher importance. Since the weights assigned for various categories may not necessarily be on the same scale, weight adjusting, weight normalization and combined readiness assessing procedures are required.

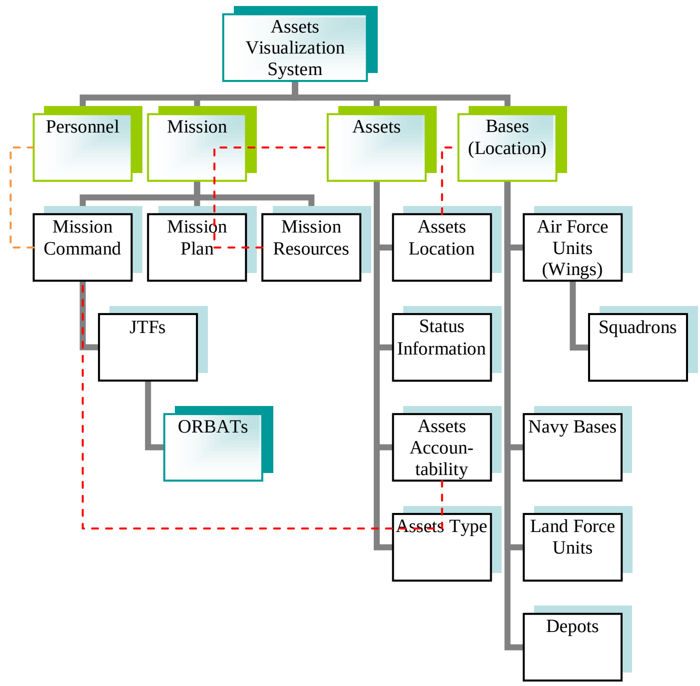

Figure 6: Visualization hierarchy model of "Total Assets Visibility" solution.

The hierarchical assets visualization model presented in Figure 6 may be considered as the presentation of the underlying information system data sources of the DND. Initially the visualization system allows for four different aspect of inter-related DND information, namely: Personnel, Mission, Assets and Bases.

- Personnel: Actually personnel information is necessary to an assets visualization system to understand the responsibility and accountability of an asset. It may range from mission crew, aircraft pilot to command and control generals. They share different accountabilities over the visualized plans and assets. The Department of Command and Control owns different ranks under the Joint Task Forces (JTFs).
- Mission: Mission information allows command and control decision makers to decide on executing the current mission after being assured of the mission support. Such support includes air force support, land force support, navy support, etc. The relationships between the military assets and plans are often established using color-codes. When air force support is shown adequate (green in color-code) for a plan, it means that all the allotted aircrafts and other related military assets (missiles, guns, etc.) are available for plan. If not, the highest level of mission support presents yellow symbol with possible explanation. A mission status, shown in red color, means that the mission is critically lacking asset support.
- Assets: The implementation of the TRV project intends to present the capability of full-fledged resource visualization applications however considers only a certain properties of the assets such as: Geographical location, class of the assets, some status information, and accountability of assets as in Figure 6.
- Bases: Military bases are in fixed locations of military forces that include: Air force, Land force, Marine, Coast guard, Depots, etc. Most of the fixed military assets are concentrated in these places. In the proposed visualization system, the military bases are mainly shown as the location of some fixed assets, or sub-organizations. Example: The location of "425 squadron" is in WING 3 which has a specific location and contains some aircrafts.

In the following, the implementation (elaborates the solution to realize the framework) of the Total Resource Visibility (TRV) project is discussed.

V. Implementation

Among the high-level functionalities of the TRV system, the most prominent ones are the visualization of the military assets and the related information thereof and the editor for the assets information. In the requirements phase, a fishbone diagram can better represent the possible visual capabilities to be implemented in the TRV visualization tool. Figure 7 presents the fishbone diagram of the total assets visibility framework.

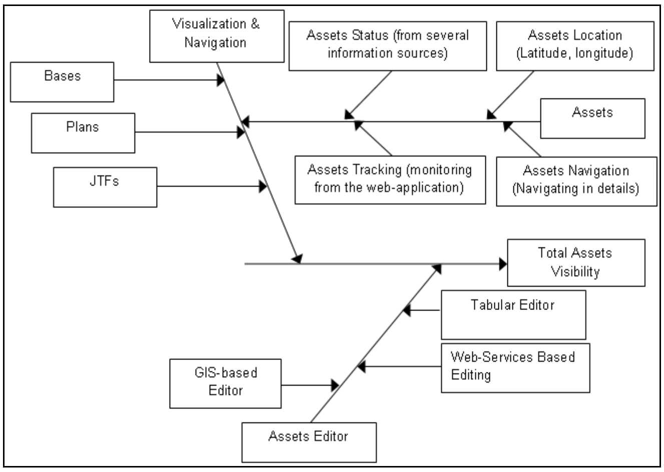

Figure 7: Total assets visibility fishbone diagram.

There are two main components of the total assets visibility:

- Visualization: The system allows for the visualization of information in different ways such as: Tables with drill down navigational capabilities, Tree structured data and a Geographic Information System (GIS). As of the information visibility, TRV is focusing on the visualization as follows: areas of accountability in the form of Joint Task Forces (JTFs), Bases, Plan-related asset data and Military assets. The JTFs' information can be visualized in tabular form along with the corresponding area of operation which is represented in the GIS. Defence bases (including air-bases, navy bases, depots, army units, etc.) can also be shown in the GIS with proper location information while their detailed information can be browsed and drilled down in a tabular form. TRV is also categorizing the assets related to the military plans. In this respect, the plans can by created by another software system such as COPlanS. The visualization of assets is concerned with three objectives: Location of the assets, status of assets and monitoring of assets. One key objective of the TRV is to locate military assets within a GIS through a software application and to retrieve information about them. Location of an asset includes its current latitude and longitude coordinates. The status of an asset presents asset specific information that uniquely identifies an asset within the huge information set of the DND. The monitoring of assets presents the capabilities of the software application to track the assets on a time-frame. The system can of show the movement of the assets and project the corresponding expected path.
- Asset Editor: The editing of military assets information is very important, since the interest has been expressed by military officials. As the fishbone diagram suggests, asset editing can be performed in three different ways as follows: using the exposed TRV web-services, from the TRV web application through Java Script and Servlet generated dynamic web content and to some extent from the GIS (such as changing routes for asset movement). Despite having different methods for assets editing the TRV system is using a functionality that is part of a common layer in order to insert/update/delete asset information and to reflect the changes of the information consistently and correctly. The rationale of having different types of editing capabilities is to facilitate the interaction of different system users according to their area of interest, expertise or responsibility. While web-services allow the interaction with other software components, the other two means of asset editing allow the user to provide textual/graphical input directly from the TRV user interface.

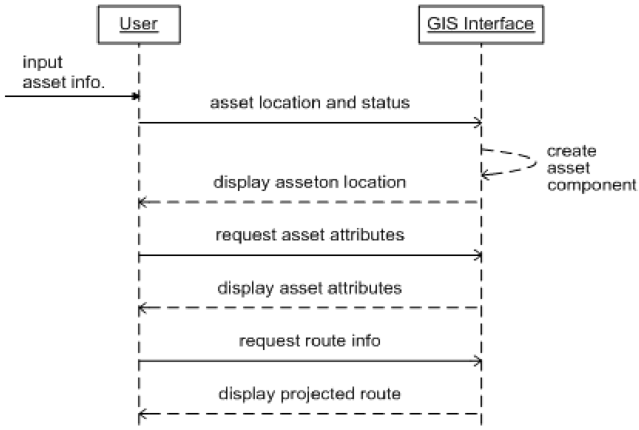

Figure 8: Sequence diagram between user and geographic information system.

Operational scenarios involving the use of the TRV can be represented through sequence diagrams as the one in Figure 8.

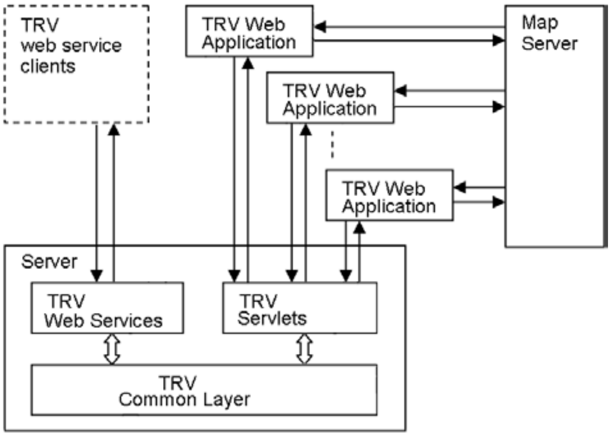

Figure 9: TRV perspective software architecture

The proof-of-concept software application has been designed considering high-level interactions between the user and the system. Figure 9 presents the TRV Architecture. The participating entities are: the TRV Web Client Application(s), The Map Server, the TRV web service clients and the server baseline that host the TRV Web Services, TRV Servlets, the TRV Common Layer and other (non TRV) Services belonging to other interacting applications. Hereafter we detail the TRV components.

The GIS component of TRV is responsible for the display of maps and the visualization of assets on top of maps. It is depicted below in Figure 10.

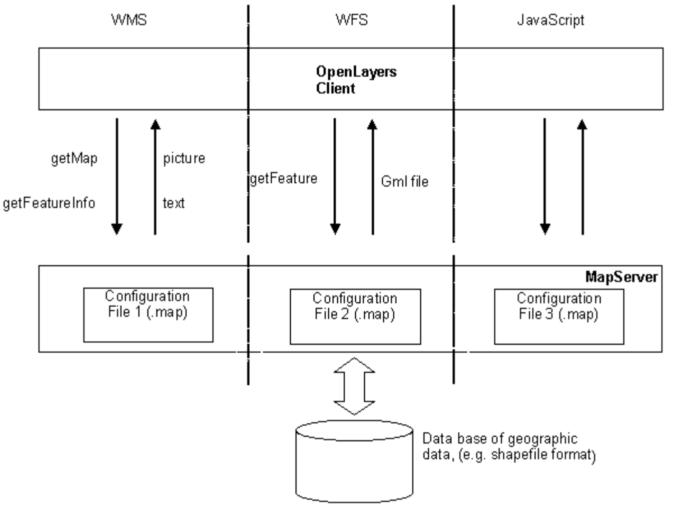

Figure 10: GIS component.

MapSever is an "open source" server application that can generate maps and text from geographic data. Moreover, it can handle several formats of geographic data (e.g. shapefiles) and can produce vector graphics, (e.g., SVG format), raster graphics, (e.g., PNG format), XML-based geographic data, (e.g., GML format), and plain text or HTML. MapServer accepts requests through an HTTP server such as Apache. MapServer implements the OpenGIS WMS and WFS client-side and server-side specifications. It can therefore provide services to clients directly or contact other servers to get data.

On the other hand, to display the map at client side, a Javascript API has been selected that enables developers to embed map objects into web applications. The envisioned interaction consists of using OpenLayers as a client for map servers. Moreover, OpenLayers will provide various capabilities such as:

- Retrieval of digital maps from several map severs.
- Managing the rendering of various layers on the same map.
- Choosing what layers to be displayed.
- Providing user control (e.g. zooming and panning).

In order for MapServer to handle requests correctly, it has to be properly configured for the type of requests that it is expected to handle. Using OpenLayes, MapServer and an SQL database, three interaction approaches have been identified for the implementation of TRV requirements, namely, Web Map Server, Web Feature Server and JavaScript. Each of them is detailed in the following:

- Web Map Server: The set-up for this implementation is based on the WMS specification, which defines an interface between client and server applications. The two basic requests in this interface are getMap and getFeatureInfo. In the getMap request, the client asks for a map of a certain geographic area and receives a graphics file, mostly in png format. In the getFetaureInfo request, the client asks for information about features in the map using certain criteria such as the feature location. The client then receives text information, such as the names of all features that satisfy the request criteria. The exact information that the client receives, depends on the configuration of the server.
- Web Feature Server: This implementation is based on the openGIS WFS specification. The main request in this case is the getFeature request, where the client asks the server about geographic features and the server sends a file, in the gml format (an xml-based format), describing these features.
- JavaScript: The set-up for this implementation based on the idea of extending the OpenLayers API with another JavaScript API that can provide the required and additional functionality that might not be provided by the MapServer. In this case, the MapServer is needed just to get the base layers of the maps, i.e., layers that describe geographic areas. This relies less on the server side logic for displaying map artefacts thus being more lightweight from the server side perspective and also more responsive from the client side perspective.

We opted for the use of “Web Feature Service” architecture for its flexibility and standard specifications. Moreover, most of the web client application programming was done using Java script as follows:

- TRV Main Display: Presented through an elaborated tabbed component using a Javascript package that comes under GNU license DHTMLX Software Development Company. The TRV web-client consists of two main pages, one for the TRV visualization while the other is on TRV resource editing. The display tab component holds both of these pages and offers switching views between them.
- Tabular Drill Down: Tabular Drill-Down capability is an essential part of the TRV web-application client that offers navigation into the inter-related military assets and other information. DHTMLX Grid API has been extended and modified to meet all the requirements of the display as mentioned before. Some of the core features of this component are:
  - i. Color code representation for asset’s status,
  - ii. Versatile searching and sorting abilities,
  - iii. Image and data grouping of common assets information presented in the same table,
  - iv. Dynamically loading of server side data.
- Tree-based Navigation: The presented information is including the assets in a tree structure. The structure was designed according to the indications of the DND professionals. The presentation and drill down navigation structure is based on a Java Script component that uses DHTMLX tree API component in order to reflect DND high-level information structure. Each node in this tree structure presents a particular military hierarchy or information while the

details of the corresponding node allows for similar hierarchical navigation. This component allows for Java-script based interaction with other TRV web-application component.

- TRV Utilities: TRV web-application graphical user interface contains two Java-scripts based utility toolbars that provide several functionalities and allow the user to execute various actions on the interface. The 'Simulation toolbar' allows to start, pause, stop and adjust the speed of the simulation along with displaying of routes on the GIS. The navigation toolbar can be used for sorting, colour code evaluation, moving back and forward in table data for higher accessibility, etc.
- TRV Timers: The TRV Timer component is an in-house built background Javascript component that offers to create repetitive request from the client side to the server to get particular information. The TRV web-application uses such features while monitoring a set of assets information on the GIS.
- TRV Simulation: The simulation feature of the TRV web-application clients acts on the GIS. It simulates the movement of the assets on the planned route and presents a big picture over the plan to the user which is able to start, pause and stop the simulation in order to view a particular state of a situation. Users may also control the speed of the simulation at the desired level. A situation during simulation may consist in the "big picture" from one or multiple plan resources that are supposed to be engaged during a mission.

In the following, we present a number of relevant screen shots of the TRV web application in order to provide a visual appraisal of the aforementioned components.

Figure 11 illustrates a graphical user interface screenshot from the plan editor, presenting asset classes engaged in a particular plan. Particular assets belonging to this class can be obtained by drilling down through the mission. The overall readiness of the asset is presented. Also the readiness of each asset from Sense, Act, Shield, Sustain perspective is presented. Figure12 is presenting on top of geographical information system (GIS) the assets assigned to a mission plan. Elaboration of a pre-designed plan on GIS allows mission commanders to visualize the plan in terms of assets location and is presenting a customized "big picture" of desired assets as required. Visual inspection of such integrated view will definitely help decision makers to take fast and accurate mission related decisions. Simulations related to the projected routes of assets (aircrafts) are presented in Figure 13.

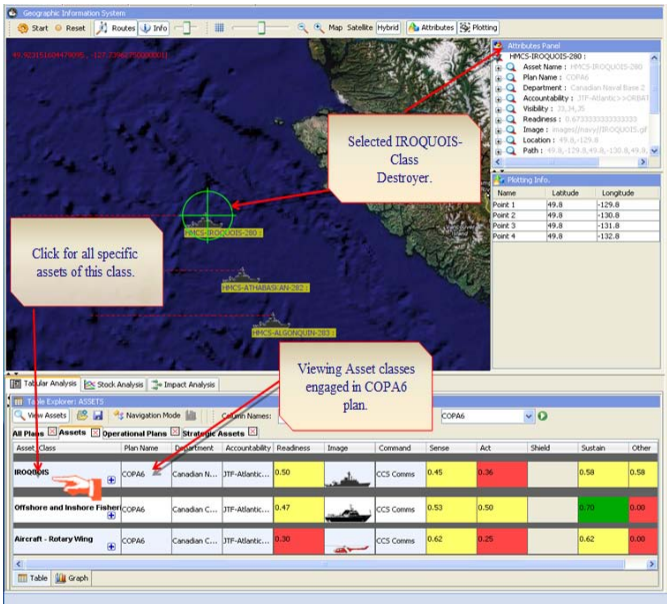

Figure 11: Assets class information associated to a particular mission.

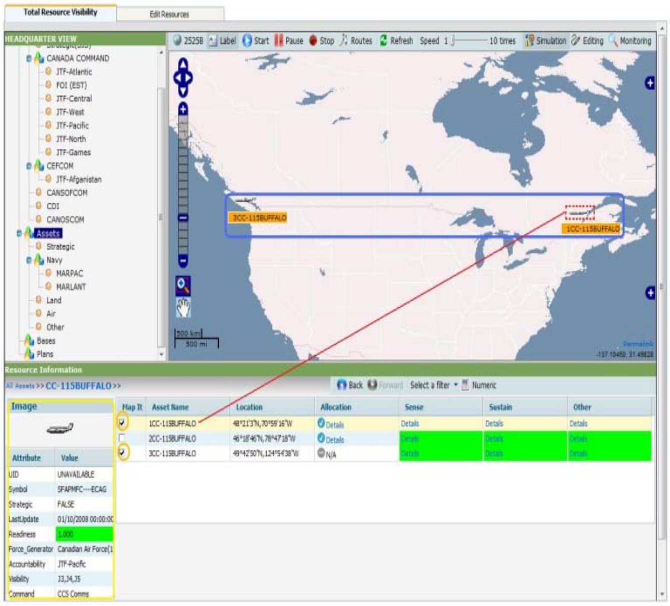
Figure12: TRV Asset drill down features and asset display on GIS

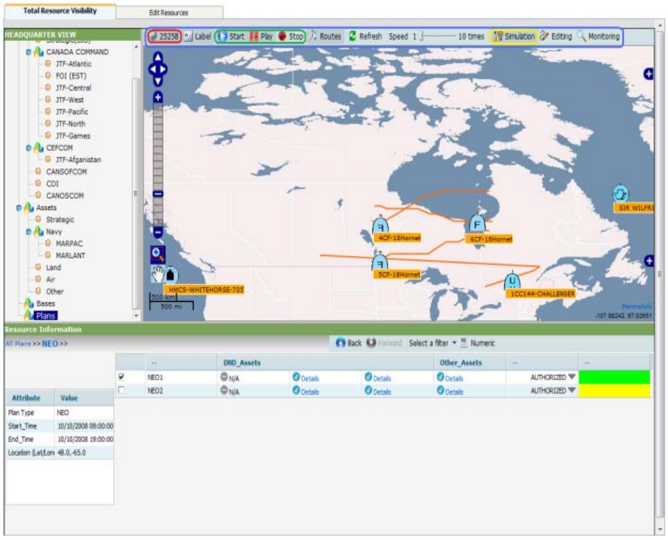

Figure 13: TRV Animation of the asset movements along the projected routes

VI. CONCLUSIONS

The initiative of the resource visibility framework aims to provide a quick and effective visualization solution for the assets of large organizations in order to present a vantage point to the organizational decision makers. This is achieved by aggregating large amounts of asset information in an up to date manner and with an easy to interact interface. The resource visibility framework exhibits two distinguished directions in its development. First, it intends to quickly visualize desired assets from a huge infrastructure. Second, it allows for a "big picture" analysis from the available assets information that may help decision makers to take fast and accurate decisions in pursuit of different plans and operations. The displayed information and the mission plans also provide functional knowledge for decision support to the business executives. Asset information is also essential in the process of conducting information analysis and creating and testing new operational plans. We presented in this paper a framework for resource visibility that has been implemented for a proof of concept prototype. Issues related to the computational complexity of the simulation, plan and data analysis are beyond the scope of this paper.

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