NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

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RTO TECHNICAL REPORT **TR-HFM-155**

Human Systems Integration for Network Centric Warfare

(Intégration des systèmes humains dans les opérations réseaux centrées)

This Report documents the findings of Task Group HFM-155: Human Systems Integration for Network Centric Warfare. HFM-155 focused on networked enabled capability and operations, and identified, defined, and documented a solution approach for challenges faced by key decision-makers in the Defence enterprise.

Published February 2010

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Foreword

The Human Factors and Medicine (HFM) Research Technology Organization (RTO) Task Group (RTG) 155 began in 2005 as Exploratory Team (ET) 062. The Human Factors and Medicine Panel (HFMP) approved the Technical Activity Proposal (TAP) and the Terms of Reference (TOR) at the Executive Session of the Research Technology Board on 31 March 2006. HFM-155 held nine (9) meetings. Programme committee, programme committee changes, and meetings held are given in the Programme Committee section. The TAP and the TOR are given in Annexes A and B, respectively. Annex C lists all the publications and presentations that were a result of work done in HFM-155. In addition there are two (2) enclosures:

Enclosure 1: ***The NATO Human View Handbook***

This handbook reviews the three prevalent architectural frameworks (Canada, GBR, and USA), as differences in perceptions of the current state of the human in the architecture framework lead to differences in the concept of the human view. It then describes the initial work that was done by different organizations to propel the idea of a human view. Finally the handbook describes the eight products that compose the human view. This initial list of products is described only at a high-level, leaving flexibility for interpretation by individual users. The handbook concludes with a way ahead for continued development. The appendices add supplementary development work. In this way the handbook represents a compendium of the development and research that supports the evolution of the Human View.

Enclosure 2: ***NATO Human View Quick Start Guide***

The purpose of the NATO Human View is to capture human requirements and to inform on how humans interact within systems. The Quick Start Guide provides a practitioner's approach for completing the Human View. It provides instructions and templates to create an initial Human View for further development and analysis.

Programme Committee

PARTICIPANTS

HFM-155 had participation from the following countries:

- Canada
- France
- Germany
- Italy
- Netherlands
- Sweden
- Ukraine
- United Kingdom
- United States

Changes in Team Composition including Leadership:

Chair: Roche, Patrick – US Navy (SPAWAR)
[Dee Quashnock retired]

Member: Punte, Patrick – TNO, Netherlands
[Replaced Peter Essens]

Peter Berggren – FOI, Sweden
[Erland Svensson retired]

Justin Hollands – DRDC Toronto, Canada
[Replaced Keith Hendy]

Dates and Places of Meetings Held:

8-9 November 2005, Soesterberg, Netherlands

31 May – 2 June 2006, Toronto, Canada

8-9 November 2006, Wachtberg, Germany

6-8 March 2007, Venice, Italy

23-25 July 2007, Toronto, Canada

18-19 September 2007, Arlington, VA, United States

4-6 March 2008, Birmingham, United Kingdom

16-18 September 2008, San Diego, California

9-12 March 2009, Kiev, Ukraine

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Human Systems Integration for Network Centric Warfare

(RTO-TR-HFM-155)

Executive Summary

Network Enabled Capabilities (NEC) allows platforms and Command and Control (C2) capabilities to exploit shared awareness and collaborative planning, to communicate and understand command intent and to enable seamless battlespace management. The NEC environment consists of a highly uncertain and unpredictable situation, with coalition forces, multiple distributed units, limited resources, but operating network based. The challenge is to effectively use information, take initiative, and exploit ad-hoc collaboration to achieve timely coordinated massed effects. Problems arising from the role of humans in NEC systems, such as the inability to use the information in an accurate and timely manner, is the concern of Human System Integration (HSI). HSI integrates human capabilities and limitations into system definition, design, development, and evaluation to optimize total system performance in operational environments. It is part of the total systems engineering approach to analysis, design, development, and testing.

The goal of HFM-155 was to focus on those aspects of networked enabled capability and operations that are human centric and to use the processes and methods afforded by HSI as the means to identify, define, and document a solution approach for challenges faced by key decision-makers in the Defense enterprise (e.g., warfighters, policy-makers, capability specifiers, acquisition managers, system engineers). This solution approach includes appropriate focusing on the human-network issues in design, as well as, acquisition.

This report describes and documents the Human View (HV) as a viable method for HSI to identify and assess the human specific aspects of a total systems engineering approach (architecture framework) for system design and development. Modeling and simulation extends the HV to illustrate and capture the dynamic nature of human performance in a variable environment. Experimentation provides the data to populate HVs and the resultant models and, to validate the modeled simulation.

HVs provide a means by which HSI activity can be related to Systems Engineering so that Human Factors can be represented in systems design and development. This provides an opportunity for the Human Factors engineer to 'talk the language' of the Systems Engineer. It also means that some of the considerations that relate to humans in systems operation, which may have been previously difficult to consider because they were deemed 'non-functional requirements' can now have an expression in Systems Engineering. The implications of this proposal can be considered in terms of three primary recommendations:

- HSI should be described in terms which are amenable to HVs. This should allow conventional representation practices, e.g., in the form of diagrams, tables or other formats, to make up the appropriate HVs. This provides a means of communicating the recommendations and information from different HSI domains to System Engineering.
- System engineering should incorporate HVs into current practices surrounding Architecture Frameworks. This would provide an opportunity for the 'non-functional requirements' that often describe human factors to be given greater focus and attention.

- In addition to proposing changes to the communication between HSI and systems engineering, the report suggests integrated roles for modelling and simulation and experimentation as vehicles for testing, exploring and developing operational concepts that have strong human factors foundations. This would not only require traditional approaches, but would ultimately see novel developments by which HVs would become central to experimental design or model specification.

Intégration des systèmes humains dans les opérations réseaux centrées

(RTO-TR-HFM-155)

Synthèse

La Network Enabled Capabilities (NEC) permet aux plate-formes de Commandement et de Contrôle (C2) d'exploiter des connaissances partagées et une planification collaborative afin de communiquer, de comprendre les intentions de commandement et permettre une gestion continue du champ de bataille. L'environnement NEC se compose d'une situation extrêmement incertaine et imprévisible, avec des forces de coalition, des unités réparties multiples, des ressources limitées, mais basée sur des opérations en réseau. Le défi est d'utiliser l'information de manière efficace, de prendre des initiatives, et d'exploiter une collaboration ad-hoc afin de réaliser des effets de masse coordonnés dans le temps. Les problèmes générés par l'intervention des humains dans les systèmes NEC, tels que l'incapacité à utiliser des renseignements d'une manière exacte et opportune, constituent l'objet de l'intégration des systèmes humain (HSI). Le HSI intègre les capacités humaines et leurs limites dans la définition, la conception, le développement et l'évaluation d'un système, afin d'optimiser la performance globale de ce système dans des environnements opérationnels. Cela fait partie de l'approche globale de l'ingénierie des systèmes pour l'analyse, le concept, le développement et les essais.

Le but du HFM-155 était de se concentrer sur les capacités et opérations réseau-centrées et sur les opérations qui sont centrées sur l'homme et d'utiliser les processus et les méthodes permises par le HSI comme moyen d'identifier, de définir et de documenter l'approche d'une solution face aux défis qui sont posés aux preneurs de décisions dans le domaine de la Défense (par exemple, combattants, décideurs politiques, responsables des spécifications de capacité, gestionnaires d'achat, ingénieurs système). Cette approche de solution met l'accent de manière appropriée sur les problèmes homme-réseau dans la conception comme dans l'acquisition.

Ce rapport décrit et documente la Vision Humaine (HV) comme une méthode fiable permettant au HSI d'identifier et d'évaluer les aspects spécifiquement humains d'une approche globale de l'ingénierie des systèmes (architecture cadre) pour le concept et le développement d'un système. La modélisation et la simulation élargissent la Vision Humaine (HV) pour illustrer et appréhender la nature dynamique de la performance humaine dans un environnement variable. L'expérience fournit des données pour alimenter la Vision Humaine (HV) et les modèles résultants et pour valider la simulation modélisée.

La Vision Humaine (HV) permet de relier l'activité HSI à l'ingénierie des systèmes de manière telle que les facteurs humains puissent être représentés dans le concept et le développement de ces systèmes. Cela fournit l'opportunité à l'ingénieur chargé des facteurs humains de « parler le langage » de l'ingénieur système. Cela signifie également que certaines des considérations relatives aux humains dans le fonctionnement des systèmes, qui peuvent avoir précédemment été difficiles à prendre en compte (car elles étaient jugées comme des « exigences non fonctionnelles »), peuvent maintenant avoir un sens dans l'ingénierie des systèmes. Les implications de cette proposition peuvent se traduire par trois recommandations principales :

- Le HSI devrait être décrit en termes qui relèvent de la Vision Humaine (HV). Cela devrait permettre aux techniques de représentation conventionnelle, comme les graphiques, tableaux ou autres formats, de s'adapter à la Vision Humaine appropriée. Cela fournit le moyen de communiquer les recommandations et les informations de différents domaines HSI à l'ingénierie du système.

- L’ingénierie du système doit incorporer la Vision Humaine (HV) dans les pratiques actuelles qui entourent le cadre de l’architecture système. Cela fournirait aux « exigences non fonctionnelles » tels que sont souvent décrits les facteurs humains l’occasion de bénéficier d’une attention et d’une importance accrues.

- En plus de proposer des changements dans la communication entre le HSI et l’ingénierie des systèmes, le rapport suggère que des modèles intégrés de modélisation, de simulation et d’expérimentation servent de vecteurs pour tester, explorer et développer des concepts opérationnels qui sont fortement fondés sur les facteurs humains. Cela ne nécessiterait pas seulement des approches traditionnelles, mais appellerait finalement des développements nouveaux par lesquels la Vision Humaine (HV) deviendrait centrale dans les concepts expérimentaux ou la spécification des modèles.

Chapter 1 – OVERVIEW

1.1 INTRODUCTION

Network Enabled Capability (NEC) is a concept that envisions the coherent integration of sensors, decision-makers, effectors, and support capabilities to achieve a more flexible and responsive military. NEC allows platforms and C2 capabilities to exploit shared awareness and collaborative planning, to communicate and understand command intent and to enable seamless battlespace management. The NEC environment consists of a highly uncertain and unpredictable situation, with coalition forces, multiple distributed units, limited resources, but operating network based. The challenge is to utilize information effectively, take initiative, and exploit ad-hoc collaboration to achieve timely coordinated massed effects.

While many believe that NEC should provide wider and deeper information availability that will dramatically improve military operations information availability, it does not necessarily mean human operators can or will use it effectively. NEC benefit chains Figure 1-1, make assumptions about the relationship between information transfer and decision making, such that a highly-connected network should lead to the right information being seen by the right people at the right time. Problems arising from the role of humans in such systems, such as the inability to use the information in an accurate and timely manner, are the concern of Human System Integration (HSI). HSI is a systematic process for identifying, tracking and resolving human related issues, ensuring a balanced development of both technological and human aspects of capability. It ensures that the human component is adequately considered in capability development.

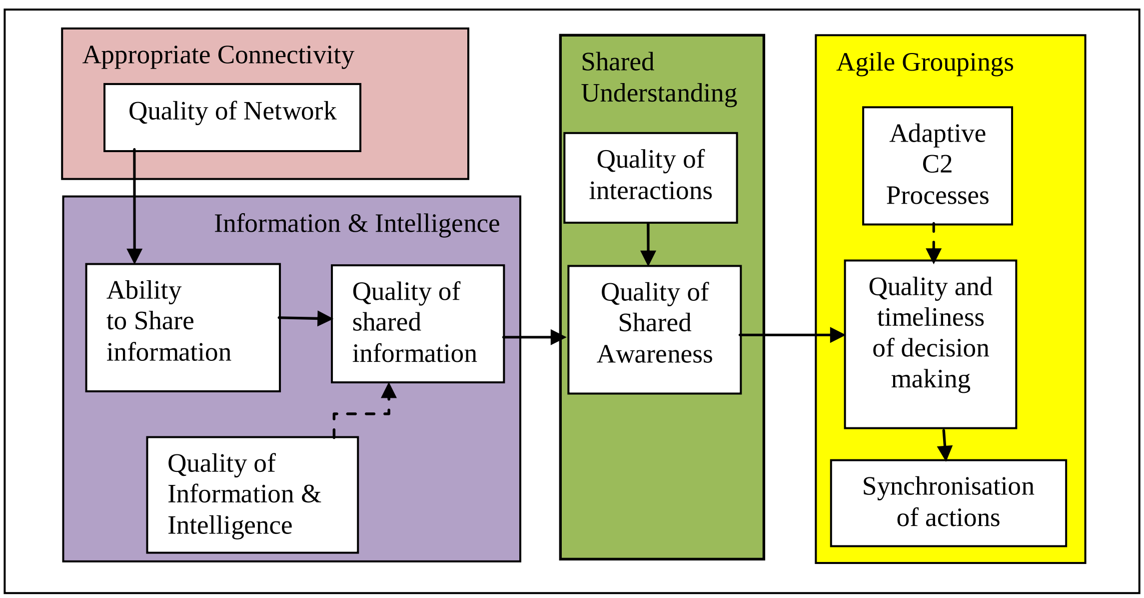

Figure 1-1: Modified NEC Benefits Chain [after Court, 2007].

1.2 BACKGROUND (FROM TOR)

As the Militaries of NATO transform to a more integrated capability of sensors, networks, command and control, platforms, and weapon systems, it is important to understand and effectively support the warfighter's role in these emerging distributed, scalable defence concepts. Throughout NATO, the transformations have different labels and some slight differences in definition, but there are commonalities that all NATO countries support. Prior to the establishment of HFM-155, its predecessor, the Exploratory Team (ET) 065, strongly supported the need for such a focused Research Task Group (RTG) effort. The ET went on to describe each of the national interests that supported a need for wide-spread coordination and cooperation.

For example, documents in the United Kingdom define a Networked Enabled Capability (NEC) as the coherent integration of sensors, decision-makers, weapon systems, and support capabilities; it has implications for both the operational and non-operational environments enabling shared situation awareness and distributed collaborative working [Ministry of Defence, 2004]. In Canada, the Network Enabled Operations (NEOps) is considered a concept that has the potential to generate increased combat power by networking sensors, decision makers and combatants to achieve shared battlespace awareness, increased speed of command, higher operational tempo, greater lethality, increased survivability, and greater adaptability through rapid feedback loops [Defence Research and Development Canada, 2004]. Canada states that NEOps will offer the means to improve the ways that people throughout the system (i.e., the soldier, the diplomat, and the developer) work together, promoting information sharing and greater cooperation in a variety of defence, diplomatic and developmental contexts [Thompson and Adams, 2005]. The US, on the other hand, approaches network-centric operations as an operational construct and architectural framework for warfare in the information age which integrates warriors, sensors, networks, command and control, platforms, and weapons into a networked, distributed combat force, scalable across the spectrum of conflict from seabed to space, from sea to land. Regardless of the overall emphasis, the common set of tenets about network centric operations are [Alberts and Hayes, 2003]:

- Development of a robustly networked force improves information sharing.
- Information sharing and collaboration enhance the quality of information and shared situation awareness.
- Shared situation awareness enables self-synchronization.

These, in turn, dramatically increase mission effectiveness. The expectation is that network-centric operations will greatly expand the sovereign options available to Joint and Coalition force commanders – with the goal of building a networked, jointly integrated, power projection force.

The challenges then are the proper mix of innovative technologies, organizational changes, and new behaviors or competencies that will combine to achieve the desired end state. Technologies are oriented towards easy and quick access to more information with the assumptions that the information will be better and that there will be shared understanding and shared situation awareness, improved and faster decision-making, and better command, control and coordination of forces to achieve the commander’s intent. What is unclear, of course, is whether or not the organizational changes and the human behavior adaptations needed to take full advantage of these new capabilities enabled by the transformation technologies are achievable.

Human Systems Integration (HSI) integrates human capabilities and limitations into system definition, design, development, and evaluation to optimize total system performance in operational environments. It is part of the total systems engineering approach to analysis, design, development, and testing. HSI has been defined as the integration of domains of personnel (skills), manpower (workload), training, human factors engineering, safety, survivability, and habitability to inform trade-offs during the systems engineering process. Increasingly, issues of organisation are being seen as integral to HSI, although there is still some debate about practical boundaries here.

The goal of HFM-155 was to focus on those aspects of networked enabled capability and operations that are human centric and to use the processes and methods afforded by HSI as the means to identify, define, and document a solution approach for challenges faced by key decision-makers in the Defence enterprise (e.g., warfighters, policy-makers, capability specifiers, acquisition managers, system engineers). This solution approach includes appropriate focusing on the human-network issues in design as well as acquisition.

1.3 OBJECTIVES (FROM TOR)

HFM-155 adopted the endorsed term NATO Network Enabled Capability (NNEC) to align with the Studies, Analysis, and Simulation (SAS) panel proposal for a follow-on group to SAS-050 (which became SAS-065). Thus NNEC embodies the concepts described in the Introduction. In this broader definition it included not only warfighting but also public security and peacekeeping operations that require significant interaction with non-military organizations. In addition, the work of HFM-156, which explored, defined and developed human performance concepts and metrics was leveraged by HFM-155.

The knowledge and perspective that is provided by the integration of a broad range of human disciplines will be critical to ensure that NNEC realizes its potential as a force multiplier. These disciplines include not only traditional HSI domains but also broader socio- and organizational elements (e.g., exploration of the characteristics of agile organizations or consideration of culture as a key component of implementing NNEC).

The objectives of HFM-155 were to:

- Establish a common framework to define the challenges and opportunities presented by NNEC as it is incrementally implemented throughout NATO, from the perspective of human systems integration.
- Align the work of the NATO nations across the spectrum of experimentation (laboratory to Concept Development and Experimentation – CDE) to coordinate, collaborate, and share HSI results.
- Conduct a cooperative technology demonstration on HSI and NNEC concepts.
- Explore interoperability and reuse of metrics and measures that support effective NNEC implementation and instantiation.

Promote incorporation and adoption in the nations of the defined HSI NNEC-focused processes, tools, and activities through educational and learning activities.

1.4 APPROACH

The panel decided on three subdivisions of effort – human view, modeling, and experimentation.

In the human view (HV), the group agreed to launch an initiative to develop draft characteristics and parameters for a “human view” component to augment the systems architecture products used by systems engineers responsible for design of defence acquisition programs. The HV was scoped as follows:

- Since each country has an “Architecture” requirement similar enough in nature and intent, develop a basis for review and analysis, and show gaps in how human roles are currently represented.
- Identify at least one defence architecture subject matter expert from each country’s defence establishment, and obtain samples of NNEC system architectures for comparative analysis.
- Develop proposals to specify the characteristics and parameters of a human view product.

- Represent human view parameters in a structured way.
- Derive strategies for incorporation of the human view within the total architecture to show the value added.
- Formalize the business case for the introduction of a human view in the systems architecture was formalized by addressing human performance in a NEC environment.
- Select a number of NNEC system cases to test the viability of the human view component.
- Describe the results of test case analyses to show how architectural frameworks should incorporate the human view.

For modelling, the overall goal was to consider generic metrics for performance, structure, resilience, and complexity. The approach was to:

- Evaluate SAS-065 “cube”.
- Develop multi-level views, e.g., social, task, knowledge for specific scenario.
- Link to Human-View.

In experimentation, the question addressed was ‘what is the status of human in the loop experimentation in NNEC’. The approach was to:

- Provide an example provided that illustrates which human dimensions are critical for NNEC operations.
- Describe levels of realism and control in experimentation and define a four-level categorization.
- Survey the literature with respect to the categorization, summarize the results, and discuss the implications.

It is important to distinguish between the process of Human Systems Integration (HSI) as a component of systems engineering, from the research and development efforts in HSI science and technology (HSI S&T). The latter would include the range of modeling approaches used, from descriptive modeling techniques like task, function, or mission analysis (collectively called front end analysis) to computational modeling and simulation, to statistical modeling approaches, and experimentation. Modeling and experiments can also vary in granularity from micro to macro, as summarized in Table 1-1.

Table 1-1: Granularity of Focus on HVs x Data Collection Approach

	M&S	Experiments	Front-End
Micro	Discrete	Lab	Single role / function
Mid-level	Combined	Lab+ Field+	Multi-person collaboration interaction/ communication team
Macro	Socio-technical	Field	Organisation

HSI S&T is often conducted without a complete representation of how the human operator works within a large socio-technical system. That is, specific display technologies might be evaluated without a clear specification of the operator’s role, or a proper understanding of the range of activities or tasks in which an operator might engage, or how a user might be trained prior to operations. While there is nonetheless considerable value in the output of such S&T activity for the process of HSI in systems engineering and acquisition, the process of applying the outputs to real system acquisition processes is often difficult, complex, and multi-faceted. This problem becomes especially salient when HSI is considered within a NNEC context, given its additional complexity.

Architecture frameworks provide system engineers a structured language and evolved to support the acquisition process of complex, military systems. The Human View is a means of supporting dialogue between System Engineering and HSI through the use of a common modelling language. This language will link to the architecture frameworks being developed to support System Engineering, e.g., NATO Architecture Framework (NAF), Department of Defence Architecture Framework (DoDAF), Ministry of Defence Architecture Framework (MoDAF), Department of National Defence Architecture Framework (DNDAF). The Human View not only offers a method for representing human components of a complex socio-technical system for systems engineering purposes, but provides more pervasive benefits. Specifically, the value of HSI S&T can be thought of in terms of its ability to contribute to and refine the information contained in Human Views. Moreover, the set of particular Human Views can be used to shape the way HSI S&T is conducted.

The Human Views provide a taxonomic framework to situate particular HSI S&T activities. Data gathering and front-end analysis techniques should address the HV set, and their sub-elements, so that their outputs are similarly organized. The selection of variables and metrics, the identification of relevant constraints, or the specification of performance shaping functions for subsequent modeling and simulation or experimentation would be shaped by the Human View framework.

Modeling and Simulation is used to take the formalized Human View descriptions and allows the system engineer to analyze and evaluate alternative system configurations in order to assess design options in a dynamically modeled environment. These predictive models enable analysts to address ‘what-if’ questions about the system. Modeling and Simulation can also be used to identify data discrepancies across views; enhanced simulations make it possible to cross-validate the data and examine their concordance and integrity. In experimentation, the choice of variables, constraints, roles, human dynamics, or training expectations can be specified through a Human View analysis and then implemented through the experimental design.

The roles of modelling and simulation and experimentation, from this perspective, then become defined in terms of their ability to refine the information contained in Human Views. This broad approach is illustrated in Figure 1-2. Notice that a ‘Data Repository’ provides a link between the Human Views and work in the modelling and simulation and experimentation areas; this ‘data repository’ can be considered as a collection of ‘patterns’ of previous designs, and human performance data (from a range of Human System Integration Domains, training, personnel, safety, etc.), which can be used to both inform the Human Views and also help develop models or guide the design of experiments. The modelling and simulation and experimentation work thus becomes a means of populating the ‘data repository’ through the collection of new human performance data or the testing of particular assumptions that are presented in the Concept of Operations on the system being designed or the refinement of current human performance data through testing or simulating under new operational constraints and conditions. The objective of the Modeling and Simulation work for this group has been to take the formalized Human View descriptions and allow the system engineer to analyze and evaluate system dynamics under various configurations to consider design options in a dynamically modeled environment. These predictive models enable analysts to address ‘what-if’ type of questions about the system. Modeling and Simulation can also be used to identify data discrepancies across views; enhanced simulations make it possible to cross-validate the data and examine their concordance and integrity.

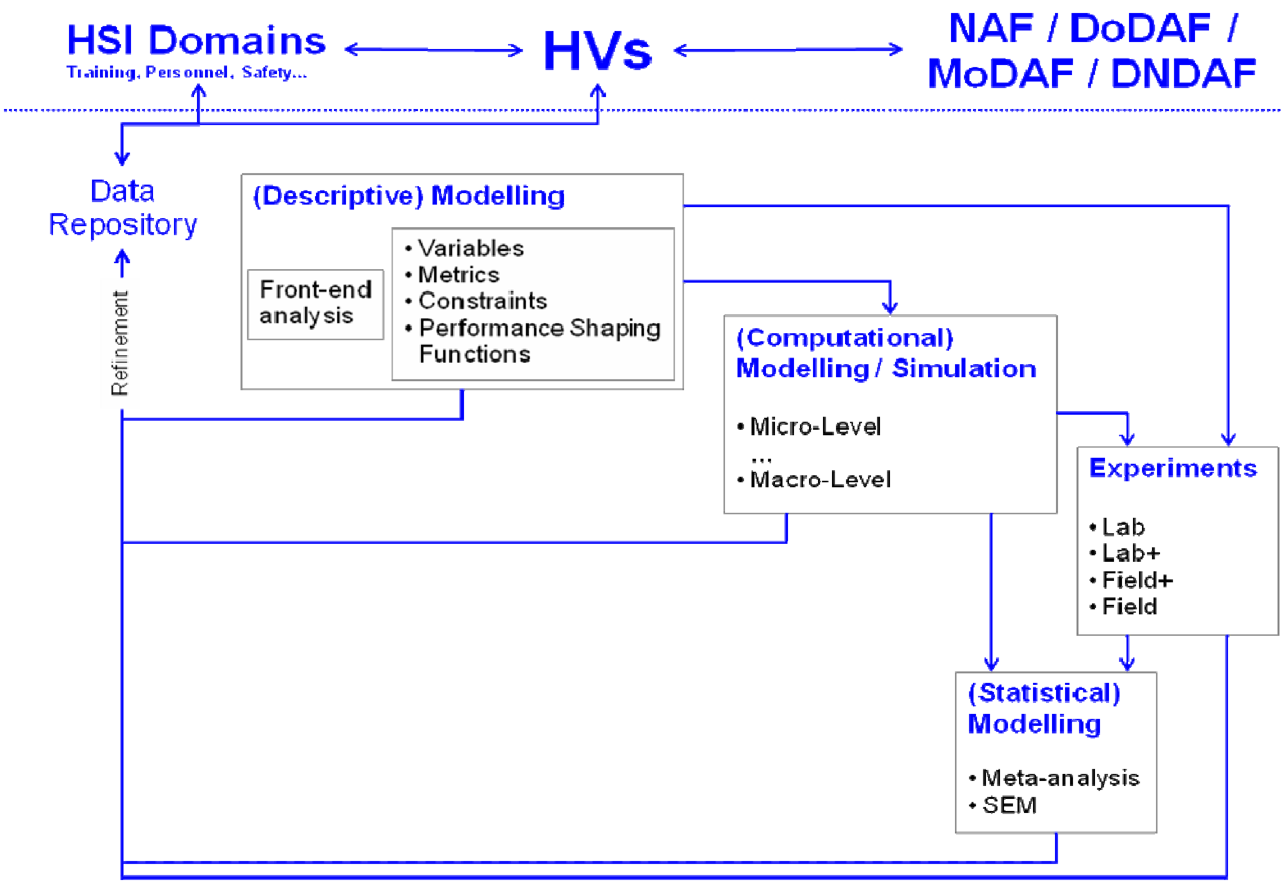

Figure 1-2: Relating Human Views to System Engineering.

1.5 PURPOSE

This report describes and documents the NATO HV as a viable method to identify and assess the human specific aspects of an architecture framework) for systems engineering. Modeling and simulation (M&S) extends the HV to illustrate and capture the dynamic nature of human performance in a variable environment. Experimentation provides the data to populate HVs and the resultant models, and validate the modeled simulation.

The Human View products collect information about human-relevant parameters in a system. For instance, the Human Dynamics (HV-H) product is a simulation model that provides the systems engineer with a preliminary evaluation of data captured in the static views. The M&S effort of HFM-155 is a further extension of HV-H and presents a wider array of models and evaluations using the Human View data. It allows further investigation of trade-offs between data captured in the Human View and identified in HV-H.

Three different types of integration of the Human View with M&S were investigated and are described further in Chapter 3:

- Discrete Human Views. These models take data relating to a single Human View, such as unit-task times, and apply them in terms of logical combinations as simulations (e.g., a task model or sequence diagram).

- Combined Human Views. These models take data from one Human View, e.g., a definition of operator capability, and use them to manipulate the data in another view. A Combined HV model can predict the effects of varying an independent variable defined by one HV upon a dependent variable defined by data from another HV.
- Socio-technical system performance. These models apply to varying domains. For example, a Human View could be used to define the theatre of operations (with targets at specific locations, time-based events occurring, movement of Agents in the theatre, etc.), such that Agents will respond to events in the world as they traverse it. This differs from the event-based modelling in Discrete or Combined HVs in that the discovery of the events arises from Agent movement and is not scripted.

In summary, the static HV products can populate different models in the M&S domain. HV-H bridges the two domains by providing preliminary simulations that identify areas for further study with more complex models. In this way the Human Views become a basis for simulation, rather than just architectural descriptions. The M&S domain brings information from the rest of the system design, (i.e., the operational and system functionality), into the simulation environment to provide a more realistic evaluation of the role of the human in the system. Both the HV and M&S areas rely on Experimentation to provide appropriate NNEC human performance data and to validate the modeling concepts.

Final products of HFM-155 are:

- Completed HV construct and guidance – HSI issues for systems that interface with other systems (systems of systems) are described and emergent behaviors are addressed (Enclosure 1 contains the NATO HV Handbook and Enclosure 2 contains the NATO HV Quick Start Guide);
- Guidance on use of models to address uncertainty and/or discover emergent behaviors;
- Guidance on how to do experimentation using NNEC variables, and conducting experiments or gathering existing data to address uncertainty; and
- Recommendations for follow-on actions.

Chapter 2 – HUMAN VIEW

2.1 INTRODUCTION

As a result of information technology and acquisition reform in 1996, the United States Department of Defence Architecture Framework (DoDAF) emerged as the structure for development of a systems architecture or enterprise architecture. DoDAF approaches are applicable to large systems with complex integration and interoperability challenges and are used by the engineering and acquisition communities to describe the overall system. Using DoDAF as the basis, similar approaches outside the US evolved, including the Canadian Department of National Defence Architecture Framework (DNDAF), and the United Kingdom Ministry of Defence Architecture Framework (MODAF). Importantly, the NATO Architecture Framework (NAF) has now also been defined.

While these frameworks have evolved to include new Systems Engineering concepts, the portrayal of the human as a unique part of the system has not been broached. NATO RTO HFM-155 examined how the human can be better represented within the total system, through the specification of a Human View (HV). The HV explicitly represents the human and documents the unique characteristics humans bring to a system design.

The HV enables an understanding of the human role in system or enterprise architectures. It provides a basis for stakeholder's decisions by linking the engineering community to manpower, personnel, training, and human factors communities. It integrates HSI into the mainstream acquisition and system engineering process by ensuring that human roles are considered early and often. It provides early coordination of task analysis efforts by both systems engineering and human factors teams. A universally accepted HV enables consistency and commonality across service elements and NATO coalition forces. By capturing the necessary decision data and integrating this view with the rest of the architecture framework, the HV provides a more complete set of system data attributes.

2.2 ARCHITECTURE FRAMEWORKS

An architecture framework defines a common approach for development, presentation, and integration of architecture descriptions. It should ensure that architecture descriptions can be compared and related across organizational boundaries (including Joint, inter-agency, and multi-national). The application of the framework should contribute more effectively to building interoperable systems, and provide a mechanism for understanding and managing complexity. Newer architecture framework versions address net-centric, system of systems, and system service concepts. Frameworks capture much more than abstract or functional decomposition of large systems. The products capture multiple views of a complex system, which can be integrated to recreate the system. Executable models used to evaluate performance measures can be created from the information captured in the products.

DoDAF defines different perspectives or views that logically combine to describe system architectures (Department of Defence, 2007). DoDAF views are organized into four basic sets: the overarching All View (AV), the Operational View (OV), the Systems View (SV), and the Technical Standards View (TV). AV products provide an overarching description of the entire architecture and define its scope and context. OV products provide descriptions of tasks and activities, operational elements, and information exchanges. SV products provide graphical and textual descriptions of systems and system interconnections that provide or support functions. TV products define technical standards, implementation conventions, business rules and criteria that govern the architecture. Each of the four views depicts certain architecture attributes. Some attributes bridge two views and provide integrity, coherence, and consistency to architecture descriptions.

MODAF was adapted by the United Kingdom Ministry of Defence (MoD) from the DoDAF (Ministry of Defence, 2005, 2008). The original four DoDAF Views were extended into six MODAF Viewpoints. Along with the All View, Operational View, Systems View, and Technical Standards View, MoDAF added the Strategic View (StV), and the Acquisition View (AcV). The StV consists of views that articulate high level requirements for enterprise change over time, whereas the AcV consists of views that describe programmatic details to guide the acquisition and fielding processes.

The Canadian DNDAF (Department of National Defence, 2007) is also closely based on DoDAF. DNDAF provides a Common View (CV), Operational View (OV), System View (SV), and Technical View (TV), all similar to the four DoDAF views, but also includes an Information View (IV) and Security View (SecV).

Architecture products are developed in the course of building a given architecture description and describe characteristics pertinent to the purpose of the architecture. They can take graphical, textual, or tabular form. It is important to distinguish between an architecture view and an architecture product. A view represents a perspective on a given architecture, while a product is a specific representation of a particular aspect of that perspective. Thus, a view will consist of one or more architecture data products. At the lowest level of the framework, the architecture data elements are basic building blocks for inclusion in each architecture data product. An integrated architecture insures that data elements defined in one product are the same as the elements in another product. This creates common points of reference, linking together architecture data elements, ensuring that relationships between the architecture data products and linkages between the views are represented.

2.3 THE NATO HUMAN VIEW

The NATO HFM-155 Panel proposed that it was essential to examine how the human could be better represented as a part of the total system, in a NATO coalition context. Thus, a primary focus of the panel was to develop the specification for a NATO HV. Using a workshop approach, draft characteristics and parameters for a HV component were developed which would be used to augment the systems architecture products required of systems engineers designing or acquiring defence capabilities within NATO nations. Each country had an architecture requirement similar enough in nature and intent to provide the basis for review and analysis, and show gaps in how human roles and requirements were represented.

The purpose of the NATO HV is to define the role of the human in the system and to capture the human operator activities, tasks, communications and collaborations required to accomplish NATO mission operations and support operational requirements. Therefore, HFM-155 used the workshop approach and invited representatives not only from Systems Engineering but also different Human Systems Integration domains (specifically Personnel and Selection, Training, and Human Factors Engineering). Those representatives devoted three days developing and specifying core HV architecture for NATO HVs. Within the HV, the role of the human within the system is defined and task activities are described at a level useful for analysis. Those human characteristics, limitations, and constraints that affect performance can then be considered. The need for human activities in the system can be weighed against manpower and training costs associated with human presence. The HV should be the driver for the systems and technical views in a human-centered design. Without this view, there is no basis in the architecture for analysis of human issues.

The workshop grouped HV elements into related themes; the HV elements were derived from a list created from individual nations (Canada, Netherlands, UK, and US). There was considerable duplication in the HV elements across the national systems, and a consensus on NATO HV groupings was easily reached. The number of themes was reduced to create a manageable set of products for the NATO HV; the groupings were reduced by noting overlap between themes in the national HVs and reassigning the HV elements until each group was unique. Each theme then became a potential HV product. These products were then evaluated to determine if each product should be a discrete product in the HV, should be included in another HV product, or should be suggested as a supporting element to another existing view. Suitable terminology was then agreed upon to identify the HV products. The final set of products that compose the NATO HV are listed below, and their interrelationships shown in Figure 2-1.

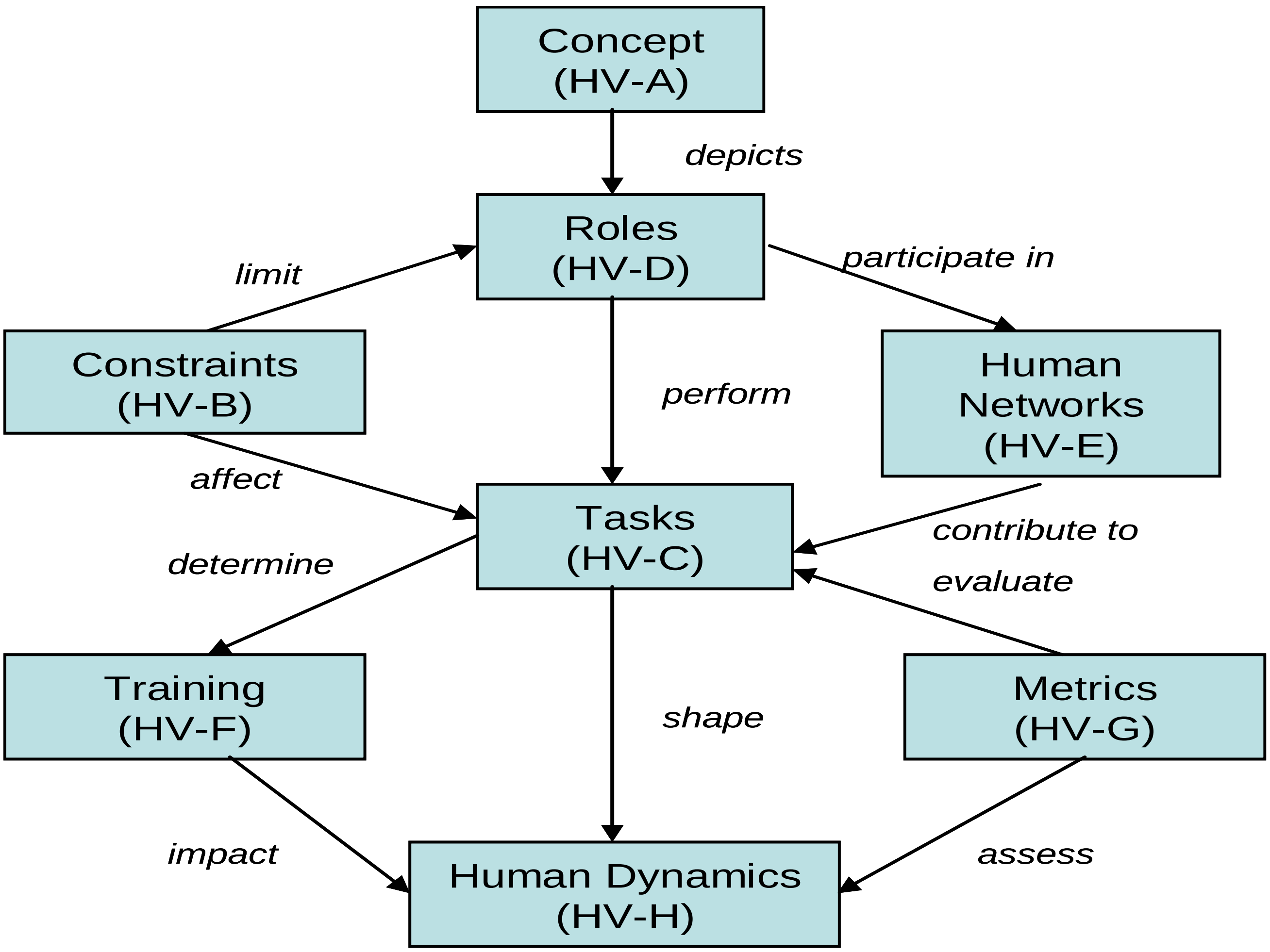

Figure 2-1: Relationships between HV Products.

2.3.1 HV-A Concept

The Concept view (HV-A) is a high-level representation of the human component of the enterprise architecture framework. Its purpose is to facilitate understanding of the human dimension in relation to operational demands and system components. It serves as a single point of reference and departure to depict how the human impacts performance (mission success, survivability, supportability, and cost) and how the human is impacted by system design and operational context (e.g., personnel availability, skill demands, training requirements, workload. well-being).

HV-A elements could include:

- Pictorial depictions of the system and its human component;
- High-level indicators of where human system interactions may occur; and
- A textual description of the overall human component of the system.

2.3.2 HV-B Constraints

Not only is the human the most important and unique system within the system-of-systems, but it also represents the weakest link or highest risk. Expressing human capabilities and limitations in the system is required. The Constraints view (HV-B) contains the data elements used to adjust human roles and functions. It acts as a repository for sets of constraints affecting parameters from different views that impact the human system. If a system requires a human interface, then the system must accommodate the human. For example, it should account for human limitations, and support the human to at least a minimum acceptable level.

HV-B sub-views include:

- Manpower Projections (HV-B1) – illustrates predicted manpower requirements for present and future projects that contribute to larger capabilities.
- Career Progression (HV-B2) – illustrates career progression and essential tasks, skills, and knowledge (including proficiency level) required for a given job.
- Establishment Inventory (HV-B3) – Defines number of personnel within each establishment by rank and job.
- Personnel Policy (HV-B4) – Defines department policies dealing with (governing) HR issues.
- Health Hazards (HV-B5) – Considers design features and operating characteristics of a system that could create a significant risk of illness, injury or death.
- Human Characteristics (HV-B6) – Considers the physical characteristics and movement capabilities and limitations of an operator under various conditions.

2.3.3 HV-C Tasks

The Tasks view (HV-C) describes human-specific activities (i.e., functions assigned to humans over a system's entire life cycle). It also captures how functions are decomposed into tasks. (The term *task* in this product refers to a piece of work that can be assigned).

The HV-C will:

- Clarify human-related functions in a system;
- Provide justification for task allocation (allocating functions to humans or machines);
- Decompose functions into a set of tasks that can be mapped to roles identified in HV-D;
- Describe tasks in terms of various criteria and KSA (knowledge, skill, ability) requirements;
- Produce a task-role assignment matrix; and
- Create interface design guidelines on the basis of task requirements.

2.3.4 HV-D Roles

The Roles view (HV-D) describes the job functions that have been defined for humans interacting with the system. A role therefore represents a job function defining specific behavior within the context of an organization, including the authority and responsibility conferred to the role, and *competencies* required to do the job. The role structure can be mapped to the HV-C task decomposition to define organizational responsibilities, and relationships between roles can be defined to provide the basis of the organizational structure.

The HV-D defines additional attributes of a role including:

- Responsibility – A form of accountability and commitment (roles are generally defined by their responsibilities);
- Authority – The access level an individual user needs to perform a specific task;
- Competency – The quality of being able to perform; a combination of knowledge, skills and attributes; these should be trainable and measurable; and
- Multiplicity – A role may be performed by a single user or by many users; role performance may occur sequentially over time or all at once.

2.3.5 HV-E Human Network

The Human Network view (HV-E) captures human-to-human communication patterns resulting from ad hoc or deliberate team formation, including teams distributed across space and time.

Elements of the HV-E include:

- Role groupings or teams formed, including physical proximity and roles (real and virtual) included for specific team functions.
- Interaction Type – Collaboration, coordination, supervision, etc.
- Team cohesiveness indicators – Trust, sharing, etc.
- Team performance indicators – Synchronization (battle rhythm), level of engagement (command directed).
- Team dependencies – Frequency or degree of interaction between roles.
- Technology impact – Effects of information technology on the team network – distributed cognition, shared awareness, common operational picture, etc.

2.3.6 HV-F Training

The Training view (HV-F) is a detailed accounting of how training requirements, strategy, and implementation impact the human. It illustrates the educational level or training required to provide personnel with those tasks, skills, and knowledge necessary to meet job requirements.

HV-F Data elements include:

- **As-is** training resources, availability, and suitability;
- Risk imposed by **to-be** operational and system demands;
- Cost and maturity of training options for trade-off analysis;
- Impact of system and capability design on training requirements and curricula;

- Training required to obtain necessary knowledge, skills, and ability to support career progression; and
- Differentiation of basic, intermediate, or advance job training; operational vs. system specific training; and individual vs. team training.

2.3.7 HV-G Metrics

The Metrics view (HV-G) is an optional product since it can be incorporated into other architecture products. HV-G provides a repository for human-related values, priorities and performance criteria, and maps measures to other HV elements. It maps high-level (qualitative) values to quantifiable performance metrics and assessment targets and maps measurable metrics to human functions. It provides the basis for human factors assessment that underpins enterprise performance assessments, or for requirements tracking and certification.

Elements of HV-G include:

- Definitions of all levels 1…n;
- Human Performance Metrics (what is to be measured);
- Acceptable Target Values;
- Function to Metrics mapping;
- Value definition links;
- Value to design element mapping; and
- Methods of compliance.

2.3.8 HV-H Human Dynamics

The Human Dynamics view (HV-H) captures dynamic aspects of human system components defined in the other views. HV-H provides a repository for states, conditions, or performance parameters which may vary over time, or as a result of changes in conditions or triggering events. It pulls together definitions from across the HVs to communicate enterprise behavior. It can inform other design aspects (when capturing ‘as-is’ behavior aspects) and to assess design decisions (by modeling ‘to-be’ behavior). It provides the basis for developing executable models of dynamic human behavior or related simulation tools.

Elements of the HV-H include:

- States (e.g., snapshots) and State Changes (e.g., varying organizational or team structure).
- Function or Role assignments to people.
- Team interaction modes.
- Demands on collaboration load (e.g., effort to build shared awareness, to achieve consensus, to communicate).
- Task switches or interruptions.
- Conditions [e.g., triggering events or situations; different scenario types (critical, frequent, representative, typical)].
- Operational constraints (e.g., extensive heat stress).
- Time conditions: sequence, duration, concurrency.

- Measurement Units:
  1) Timeline; Defined mission phases; sequence of consecutive tasks;
  2) Performance measures (observed or predicted) – e.g., Workload;
  3) Decision speed;
  4) Team interaction/collaboration style;
  5) Trust in commander's intent; and
  6) Quality of shared awareness/coordination/implicit communication. (Different methods of assessment, such as observer rubrics, may be necessary for the more subjective attributes).

HV-H could also be represented as a computer simulation based on the static information captured in the other Views. This could range from simple process diagrams to sophisticated executable computer simulations of human system interactions in dynamic environments. The model or simulation can answer questions on whether a given system architecture meets performance expectations given the type of human resources allocated, or how system parameters impact human performance metrics. A comprehensive model that maps to defined HV products is desired, to evaluate the spectrum of HV parameters. This relationship is shown in Figure 2-2.

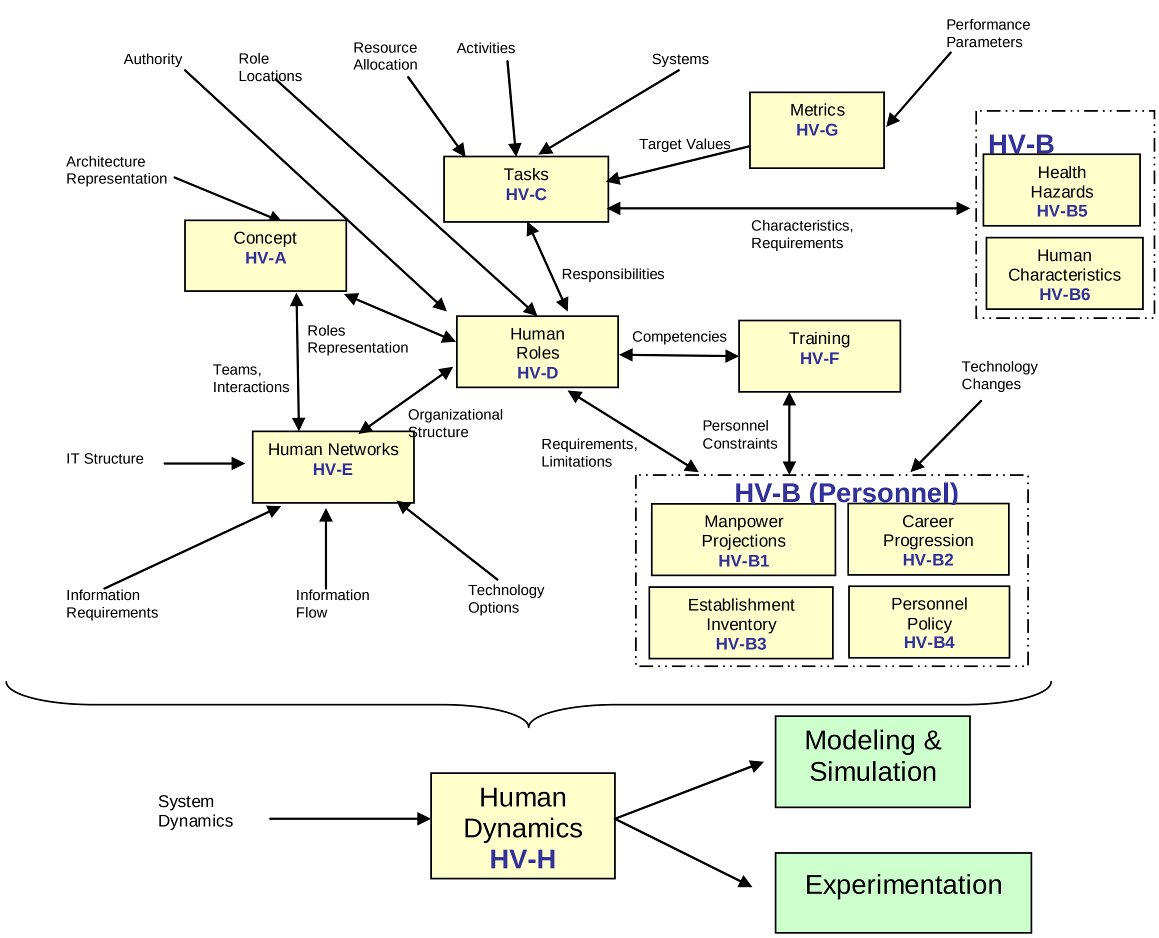

Figure 2-2: Relationship of Human Dynamics to HV Static Products.

2.4 INTEGRATION WITH NATO ARCHITECTURE FRAMEWORK

There is a strong coupling between the Human View products defined in the previous section and the existing Operational View (OV) and System View (SV) products in existing architectures. Many data elements are shared between views and contribute to the integrity of the integrated architecture. The complete set of Human View products and their relationship with the NATO Architecture Framework products is shown in Figure 2-3.

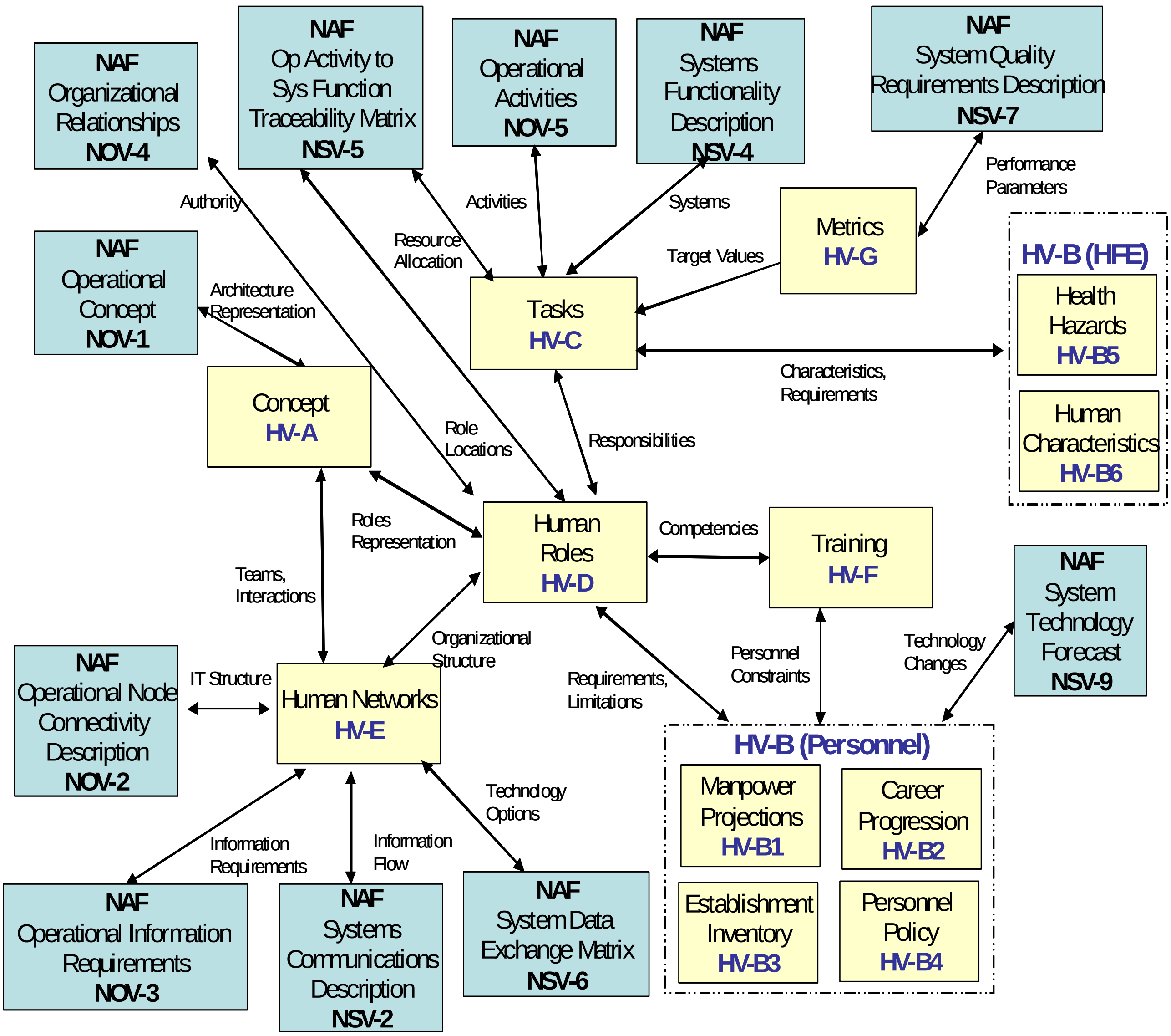

Figure 2-3: NATO Human View Products Integrated with NATO Architecture Framework.

Additionally, an approach to develop the DoDAF architecture products based on the traditional Structured Analysis approach has been defined (Wagenhals, et al., 2000). This approach can be extended to the NATO Architecture Framework, and the appropriate stage to produce the Human View products can be identified and included in the process. This mapping is shown in Table 2-1.

Table 2-1: Human View Development Products

Process Stage	NAF Products	Human View Products	Purpose
Stage 1: Develop the operational concept that guides the remaining stages.	NOV-1 Operational Graphic	HV-A Concept	Includes human roles into high-level representations
Stage 2: Determine which organizations to include in the architecture and the command relationship that will exist between them.	NOV-4 Command Relationship Chart	HV-B Constraints	Constraints adjust expected roles and functions of the humans
		HV-D (Part 1) Role Definition	Roles that are required with selected attributes
		HV-F (Part 1) Existing Skill Inventory	Attributes of personnel currently in roles
Stage 3: Determine the functions that need to be performed and organize them into a functional decomposition, as well as capturing the desired behavior of the architecture.	NOV-5 Activity Model NOV-6 b&c Operational State and Rules Models NOV-7 Logical Data Model	HV-C (Part 1) Task Decomposition	The operational activities are decomposed into human tasks
		HV-D (Part 2) Task Responsibility Matrix	The tasks from the activity decomposition are assigned to available roles.
Stage 4: Create the initial physical architecture composed of system nodes and allocate system functions to perform operational activities. Additionally the activities are allocated to the operational elements and nodes.	NOV-2 Operational Node Connectivity Description NOV-3 Operational Information Exchange Matrix NSV-5 Operational Activity to System Function Traceability Matrix NSV-11 Physical Data Model SV-4 Systems Functionality Description	HV-E (Part 1) Role Groupings	Roles are grouped into functional teams
		HV-E (Part 2) Team Interactions	Interactions of the teams across physical locations
		HV-E (Part 3) Information Requirements	Information Exchanges across the teams
		HV-C (Part 2) System Interface Matrix	Systems that are utilized to complete tasks
Stage 5: Complete the design of system architecture by defining the system nodes and the system information elements that flow between and the required system interfaces.	NSV-1 System Interface Description NSV-2 System Communication Description NSV-3 Systems2 Matrix NSV-6 System Information Exchange Matrix NSV-8 System Evolution Description NSV-9 System Technology Forecast NSV-7 System Performance Parameter Matrix	HV-F (Part 2) Training Requirements	Training required provide personnel essential tasks, skills, and knowledge
		HV-F (Part 3) Training Resources	Instruction, education, on-the-job or unit training available
		HV-G Metrics	Human performance metrics defined

Chapter 3 – MODELING AND SIMULATION

3.1 INTRODUCTION

We propose that M&S is a logical extension of HV-H (Human Dynamics) and can inform HV-G (Metrics). The manner in which this occurs arises from the nature of the simulation used. Following Pew and Mavor (1998), a *model* is a computational representation of system activity, and a *simulation* is a method for implementing the model, usually in software, to run over a period of time and under different conditions. This extends the premise of HV-H by focussing on the performance of humans within a system in response to changing environmental conditions. From this perspective, M&S form part of the dynamic view by providing 'animation' of state-transitions through which system components interact in pursuit of a mission. Thus, input to the HV-H should be read in the context of the activities of the M&S group. The simulations could lead to computer-generated forces and similar efforts. However, an important caveat is that the focus of the NATO HFM-155 panel has been on HSI rather than M&S per se. Thus, the models presented in this section offer a proof-of-concept rather than full-scale simulations. Overall, the objectives of the M&S effort have been to propose formalized HV descriptions that should allow the systems engineer to analyze and evaluate system dynamics under alternative system configurations. Thus, the engineer can consider design options in a dynamically modelled environment, affording prediction of processing bottlenecks.

The use of HVs to provide different perspectives on Network-Enabled Capability (NEC) raises a challenge for M&S analogous to the challenges facing the System of Systems concept. As De Laurentis (2009) noted, "A system-of-systems (SoS) consists of multiple, heterogeneous, distributed systems that can and do operate independently but also assemble in networks to achieve a unique function" (p. 22-2). This notion is fundamental to the shift in procurement practice from 'requirements' to 'capability', in which stakeholders integrate a mix of systems to support a capability. "[S]takeholders are being asked to provide capabilities that must integrate existing, new and future systems that interface well with the individual end users and satisfy a global need." (*ibid.*, p.22-2). Hence, there is a need for appropriate systems engineering methodologies to represent the SoS. Beyond this, there is also the need to make predictions (or at least provide informed descriptions) about the performance of different capabilities. From this viewpoint, M&S play a role in exploring the manner in which these capabilities might respond to different situations. We propose that the capability should relate to the skilful integration of human and technology. We begin with a statement of assumptions that informed and influenced the panel's work.

HVs are snapshots of different aspects of a socio-technical system. Thus, particular stakeholders can choose a specific view to consider their issues of interest. For example, an interface designer might want to check HV-C (Tasks) before deciding on an interface scheme, while a human resource manager may be more interested in HV-B (Personnel) for manpower planning. Since the views can be used independently, data discrepancies across views are sometimes not easily detectable. Other than HV-H, most existing HVs are static; as a result, the dynamic aspects of system behaviour are not readily captured.

A solution is to extend the HVs into a simulation model. This makes it possible to cross-validate the data and examine their integrity. A predictive model enables the analyst to address 'what-if' questions about the system. Specifically, the panel posits two solutions for extending the HVs into simulation models:

1) A performance model based on specialized human performance modeling tools; and

2) A process model that uses generic front-end analysis techniques [such as the hierarchical goal analysis (HGA) developed by DRDC].

We are especially interested in simulation models that can use data from a number of different HVs, such that the inter-connection between the different views can be studied and the data can be cross-validated. The report discusses some approaches to modelling and simulation from this perspective.

The second issue involves the consolidation of HV data into a process model. An HGA solution focuses on goal-oriented human behaviour to piece together the different HVs. HGA assumes that human behaviour is goal-driven and goals are represented in a hierarchical form (Hendy et al., 2002; Chow et al., 2006). The technique is fairly straightforward, starting with an identification of the highest level goals that an operator, or a team of operators, should achieve. These goals are decomposed into sub-goals, and the decomposition is performed iteratively, stopping at a level sufficient to address the analytical questions. Individuals are assigned to each goal and an internal variable is identified that measures the completeness of each goal. By the end of the decomposition, a goal hierarchy is created. The HGA output can be used to create a system process model using software tools like task architect® and G2/Rethink®.

With respect to the HVs, HGA output can verify the completeness of HV-C (Tasks) and HV-D (Roles). For example, the lower-level goals identified in HGA can be directly mapped to system tasks. For each operator, assigned goals can be linked to roles and responsibilities. Farrell et al. (2006) analyzed UAV operators' knowledge and skill requirements using an HGA, and computed the level of correspondence (in terms of skills and knowledge) between existing Canadian Forces occupations and UAV operations, using a job similarity index (JSI). The Farrell et al. study shows the potential for extending HGA to incorporate relevant HV products (HV-B and HV-D) An HGA-based process model implemented in G2/Rethink could simulate the dynamic aspect of the system as well, albeit emphasizing the process flow rather than operator performance. Although views like HV-H (Metrics) and HV-E (Networks) are not captured, less stringent input data are required to populate the model (compared to performance models), reducing model construction cost.

3.1.1 Assumptions

Simulation of HVs Should Describe the Problem, not Specify the Solution

M&S provides the analyst with alternative perspectives on a problem. By making a system architecture dynamic and testing it under different constraints, modeling can test an analyst's assumptions and determine whether the system architecture will respond appropriately to different operational demands. The aim, therefore, is not simply to demonstrate a solution's validity, but refine the solution through exposure to different conditions.

The Dynamic Interplay between Analyst and Simulation Gives Insight

As the simulation is run under different constraints, an analyst can see how it fares and what changes could modify or improve performance. Not only should analysts have access to usable tools to support the construction of HVs, but they need easy-to-use techniques for building models from these HVs. To date, tools are lacking in both areas.

M&S Should Identify Potential System Design Bottlenecks

By running the simulation under different constraints, the analyst can identify potential issues or bottlenecks affecting performance. The analyst should be able to explore the bottlenecks from the multiple perspectives offered by HVs and then explore strategies to modify the system. For example, the analyst might modify the task model (HV-C) in order to allow parallel performance of some tasks in order to improve performance time, or might alter the allocation of actors to specific tasks (HV-D) in order to have more highly skilled operators performing specific tasks.

M&S Should Focus on Links between HVs (not Single HVs)

In order to run the simulation, it is necessary for combinations of HVs to produce the model under test. For example, to perform a given mission the analyst would need a Task Model (HV-C), in which actors with particular capabilities are assigned tasks (HV-C), and perform to certain criteria (HV-B).

Simulation Should Reveal Emergent Properties of the System

The assumption that the simulation can provide the analysts with new insights, implies that the simulation will produce outcomes which are not easily predictable. Given the combinations of HVs which would inform the models to be simulated, it is plausible that some factors might interact in previously unpredictable ways.

Simulation of HVs Will Involve More than One Modeling Approach

While there are many techniques for developing models for simulation, each technique works with particular sets of data and is more appropriate for exploring particular HVs. Thus, there are numerous techniques to explore HV-C Tasks, but fewer techniques to explore HV-D Roles or HV-F Training. It is proposed that there should be a continuum from HV to descriptive model to prescriptive model to predictive model to simulation, with each type of model having different abilities to work with each HV and produce output for HV-G Metrics.

The Analyst Needs to Appreciate the Limits of M&S

A model is an abstraction of reality and, as such, is only a partial reflection of the ‘real’ environment and people performing tasks within it. Each HV provides a perspective on the system being designed, with different emphasis on human characteristics and system performance. Thus, models based on HV should capture the data in terms of the HV products, and indicate the ways in which these data are used within the system.

There Should be a Close Relationship between Modeling and Empirical Data

Models should be populated with human performance data from different operating conditions, and should allow prediction of the impact of those conditions on human performance, (e.g., in terms of workload). Human performance data should be combined with technical performance data to produce integrated socio-technical data.

The M&S Analyst Should Consider the Required Degree of Validation for Proposed Systems and Define Measures of Effectiveness

There is a need to demonstrate goodness of fit between predicted and actual human performance. In addition to validating human performance predictions, the models should be able to apply measures of effectiveness that are operationally relevant.

NEC is About Communication between Elements in the System

A key aspect of NEC is the manner in which information is passed through various systems with a view to achieving defined effects. In addition, models should show how an effect is achieved through different SoS configurations. NEC will achieve some of its effects through the emergent interaction of different systems; effective M&S must capture this interaction.

3.1.2 Conclusions

These assumptions are not fully realized in contemporary M&S. For example, assumption (h) – that the models will be populated with reliable empirical data – is not valid. A concerted, international effort to collect and catalogue a repository of human performance data would be valuable. NEC requires the ability to adapt to operational demands in order to manage resources in pursuance of the effect. Thus, Assumption (j) – that the models describe NEC – requires a degree of adaptation not always apparent in models, particularly some event-driven approaches where effects are 'scripted'.

3.2 MODELING AND SIMULATION OF HUMAN VIEWS

Figure 3-1 traces the approximate HV development path in relation to currently used architecture views. In this figure two levels of abstraction are shown for simplicity. The higher layer includes Operational Views (OV), Strategic Views (StV), Acquisition Views (AcV), and Technical Views (TV), as well as higher-level HVs (HV-B, C, G). The lower layer focuses on resource specifications with OVs and System Views (SV), including all the HVs (HV-A, B, C, D, E, F, G). The two layers reflect each other in terms of the technical areas. The HVs drawn in plain white around the outside are 'as-is' views (i.e., a model of what currently exists), showing how they relate to the 'to-be' models (i.e., new design options or decisions). The blue lines between numbered star symbols show the order of progression, and do not imply technical dependencies. The figure does not include iteration loops.

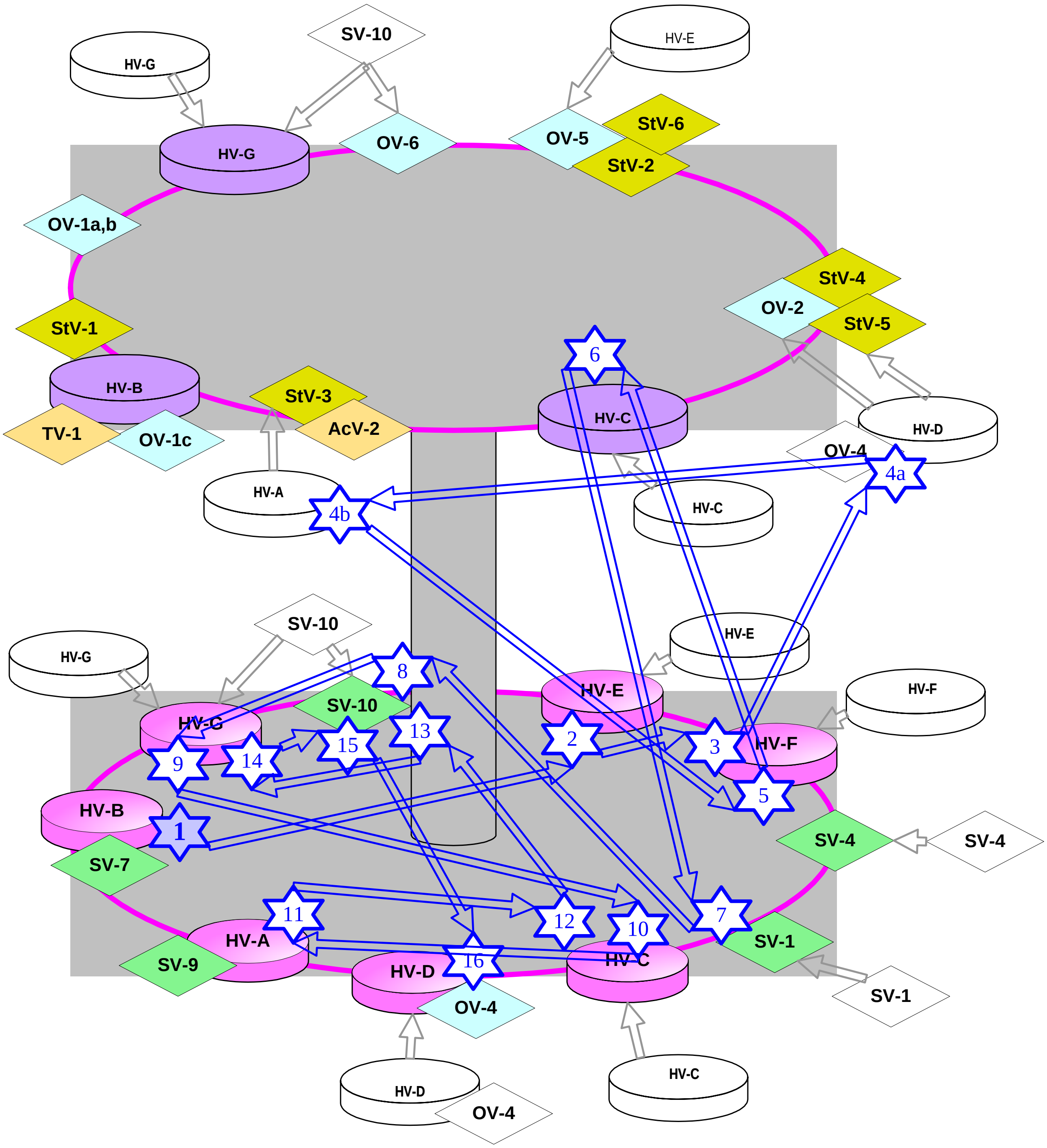

Figure 3-1: Sample Progression of HVs Development Showing Two Different Levels of Enterprise Definitions, with the Order Progressing from One Blue Star to Another.

Table 3-1 provides a code key. The ‘Section’ column indicates which section of this report is primarily concerned with models and simulations for a specific HV.

Table 3-1: An Ordered Sequence of HVs and Their Relation to Report Sections

	NATO HV	Description	M&S Parameters	Section
1	HV-G	Define performance parameters and assessment objectives		
2	NOV-5 HV-C	The tasks required to perform a mission	Task model	3.3.1 Simulations of discrete HVs
3	HV-D	Define roles (to be taken by people) to perform tasks Tasks allocated to roles	Agent – task mapping	3.3.1 Simulations of discrete HVs
4	NOV-4 HV-D	List defined job types with certain (standardised) characteristics (e.g. skill, rank), depending on currently envisaged personnel	Agent Capabilities	3.3.1 Simulations of discrete HVs
5	HV-D	Personnel characteristics (for person in intended roles) ***Assess: the right skills/characteristics for the right demands***	Agent Capabilities	3.3.2 Simulations of combinations of HVs
6	HV-E	Team and network configurations communication/interaction structure variables, including network parameters; organisational conditions; command structure; redundancy options	Social / Command Network, or information chain	3.3.4 HV-C Tasks, HV-D Roles and HV-E Human Networks: modelling collaboration and communication processes
7	NSV-1	Technology use options and available channels of communication		–
8	HV-C NSV-10	Resulting tasks and task flow	Sequence diagram	3.3.3 Case Study using IMPRINT to model combined HVs
9	HV-H	Conditions, time, task dependencies, operating conditions, operational phases; settings ***Assess: compare resulting tasks for human performance***	Operational demands (e.g. success rates, overall mission time, reaction times, error rates, workload)	3.3.3 Case Study using IMPRINT to model combined HVs
10	HV-E	Environmental conditions and associated physical variables ***Assess: performance or health degradation***	Effect of environmental stressors	3.3.2 Simulations of combinations of HVs
11	HV-F HV-B	Actual personnel (actors) with skills/characteristics assigned to roles; ***Assess: crew size***	Agent-task mapping	3.4.1 A Probabilistic Approach using Agent-based Simulation
12	HV-E	Location constraints requiring movement of people or material	Constraints	3.4.1 A Probabilistic Approach using Agent-based Simulation

	NATO HV	Description	M&S Parameters	Section
13	NSV-10	Model of system behaviour (e.g. UAV is managed by both flight path and location of target) ***Assess: represent the movement of agents relative to the terrain and each other***	Probabilistic models of system state transitions	3.4.1 A Probabilistic Approach using Agent-based Simulation 3.4.2 Combining Agent-based Simulations with Network Topologies
14	HV-H	Conditional variations (e.g. events causing loss of nodes; variable efficiency of individual nodes; loss of communication links) ***Assess: performance of network exchanges* (affected by human constraints)**		
15	NSV-10	Human agent activities ***Assess: behaviour of human nodes:***	Agent performance	3.3.7 Network Metrics: packet loss and delay
16	NOV-4	Define organisation based on preferred network, roles and task sequences		3.4.1 A Probabilistic Approach using Agent-based Simulation1

3.3 TYPES OF SIMULATION

In this section, three simulation types undertaken by the NATO HFM-155 panel will be described. Following assumption (f), examples are provided to show how M&S could be undertaken, rather than how it should be undertaken. We acknowledge that the reader might prefer to use alternative modeling and simulation approaches to those presented. The main point is that the HVs provide a useful and coherent framework within which to develop models that can be simulated.

While M&S combines several HVs in terms of second or third order interactions, there is still a potential shortcoming to the approach. In terms of simulation, the behaviours of the Agents are likely to be 'scripted' into the task model. This means that the model provides an account of system performance under one set of conditions (those which informed the design of the model) but not for other sets, or under changing conditions. This is important because NEC concepts tend to emphasize agility, or the ability of the network to adapt appropriately to changing conditions. This means that M&S should consider relationships between the network and the conditions in which it operates (and that perhaps the simulation should include some means of varying such conditions). We suggest that M&S of HVs uses three levels of simulation:

- *Level 1. Simulation of discrete HVs*. The model takes data relating to the HV (e.g., unit-task times in HV-C Tasks), and logically combines these as simulations (e.g., a task model or sequence diagram). This produces predictions of operations and activity within that view (e.g., performance time in HV-C Tasks);
- *Level 2. Simulation of combinations of HVs*. The model will take data for one HV (e.g., a definition of operator capability in HV-D Human Roles), and use these to manipulate data in another view (e.g., HV-C Tasks). This can predict operations and activity resulting from varying an independent variable defined by data in one HV (e.g., operator capability), to measure an effect on the dependent variable defined by data in another HV (e.g., performance time).

- *Level 3. Simulation of system performance*. At this level, the model could take a level 2 model and apply to a varying domain. Thus, for example, HV-A Concept could define the theatre of operations (with targets at specific locations, time-based events occurring, movement of Agents in the theatre, etc.), such that Agents respond to events as they traverse the theatre. This differs from the event-based modeling in Levels 1 and 2 in that the discovery of the events in not scripted so much as arising from Agent movement.

The simulation levels concept is not meant to imply a neat continuum. The levels focus on different aspects of system performance and are populated by different data, so it is not simply that the levels increase in complexity; rather, the models should be sufficiently complex to explore the human factors at issue when considering different HV sets. In broad terms, the intention of the first two levels is to operationalise HVs to produce a 'Dynamic View' that allows testing of the underlying models to pursue defined missions and support comparison of different system concepts to perform the mission. Model output in terms of 'Metrics' will reflect the relationship between different human performance views (e.g., by showing workload or error variation). Such simulation should address the following question: are resources (personnel numbers, capabilities, communications, etc.) sufficient to complete the mission? In contrast, simulation of system performance is intended to capture emergent performance (e.g., in terms of Agents responding to events and behaviours in an environment). For such simulation, models need not specify a mission task sequence but rather provide agents with a task repertoire from which tasks can be selected in response to situational demands. Such simulation could ask how resources (personnel numbers, capabilities, communications etc.) might operate in pursuit of the mission. Ideally, the simulation would show how Agents re-evaluate Intent and re-plan operations. We suspect that this objective has not yet been realized (although it is possible to model the processes through which Intent is evaluated and missions re-planned).

3.3.1 Simulations of Discrete Human Views

Simulations of discrete HVs take specific HVs and make them dynamic. We illustrate this using HV-C Task. It is straightforward to quantify Tasks (e.g., by assigning time or probability of completion to a task). Although there is no complete and agreed-upon set of such data, the definition of time to complete a task can be reached through experimentation, observation or discussion with subject matter experts. The first step is to decompose the overall mission into a sequence of tasks shown in Figure 3-2. A time could be assigned to each task and system performance calculated.

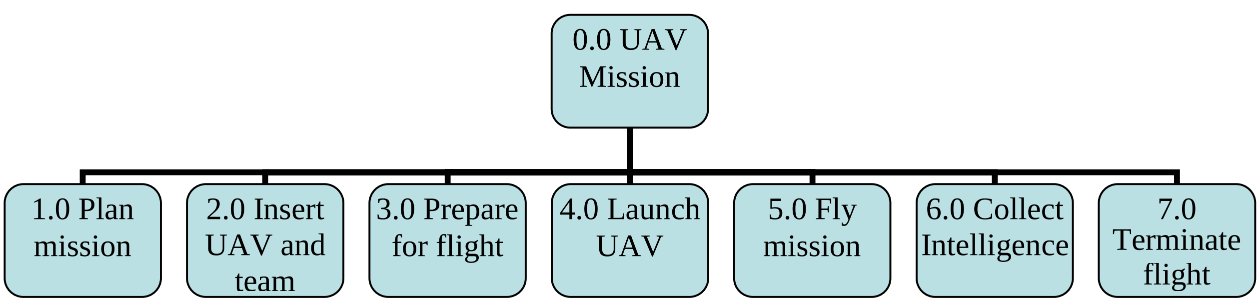

Figure 3-2: Decomposition of UAV Mission.

Agent roles can be represented in tabular form. These could relate a role to a specific grade and military occupational specialty (MOS) or to specific functions (Figure 3-3). Modeling HVs could, for example, involve checking that all required skills will be present in a given team.

Stakeholder	Primary Role(s)
Commander	**Define command intent**
G2 (Int Cell)	**Define intelligence objectives and target properties; analyse intelligence**
G3 (Ops Cell)	**Plan mission**
SO2 (Air)	**Prepare Air Tasking Order (ATO)**
ATC	**Accept ATO; Airspace control / deconfliction**
UAV IP	**Fly UAV**
UAV OP	**Manage payload; analyse imagery**
Ground	**Force Protection**
UAV Leader	**Command UAV Section**
UAV Tech	**Maintain UAV system components**
Met Office	**Provide meteorological information**

HV-D Roles		
Abbreviation	**Role Name**	**MOS**
PL 02	*Platoon Leader*	*11A*
PSG/VC E7	*Platoon Sergeant*	*11B40*
VC E6	*Vehicle Commander*	*11B30*
SL E6	*Squad Leader*	*11B30*
VC E5	*Vehicle Commander*	*11B20*
RBTIC E5	*Robotic*	*11B20*
TL E5	*Team Leader*	*11B20*
HC E4	*Health Care*	*68W10*
DVR E4	*Driver*	*11B10*
INF E4	*Infantry*	*11B10*
CCSW E4	Common Close Support Weapon	11B10
A/GNR E4	Gunner	11B10
A-Tank E4	Anti Tank	11B10

Figure 3-3: Roles X Functions.

Having defined necessary tasks and allocated tasks to agents, timing and sequencing could be specified to simulate different agent combinations. In this section, we consider modelling approaches to simulate such performance.

Critical path analysis can be used to develop approximate models. This technique is used in project management to consider planned activity in terms of elapsed time and dependencies between tasks. It offers a simple way to describe likely activity progress and can highlight potential performance bottlenecks. The use of critical path analysis is central to the Goals, Operators, Methods, Selection (GOMS) approach to human performance modeling (Olson and Olson, 1990; Gray et al., 1993; Baber and Mellor, 2001). West and Nagy (2007) have explored the potential uses of GOMS beyond individual performance to socio-technical systems. They suggest that primary issues relate to the need to include recursions and task scheduling at a system-level description. Figure 3-4 shows a critical path analysis which considers both task order and dependencies for an application involving mini-uninhabited aerial vehicles (UAVs). A dependency could be actor-defined (assuming that individuals will perform their tasks in sequence) or based on a task's information requirements (assuming that one task will need to be completed before another can start). Analysis of the system in Figure 3-5 shows that allocating tasks across different crew sizes and operating conditions implies that that the 2-person crew performs more poorly than the 8- or 17-person crew (except for replanning). The observation that increasing crew size beyond 8 or so makes little difference is similar to the result obtained by Walters et al. (2003). These researchers used MicroSAINT task-network modeling to predict the relationship between crew size and rotation schedule on operator workload and task performance in a tactical UAV. A key finding was that 6 skilled personnel was the minimum operating crew size for the operations centre, and increasing crew size beyond six had only minimal impact on overall performance. One could further examine how tasks might be assigned to different agents or task sequences re-arranged.

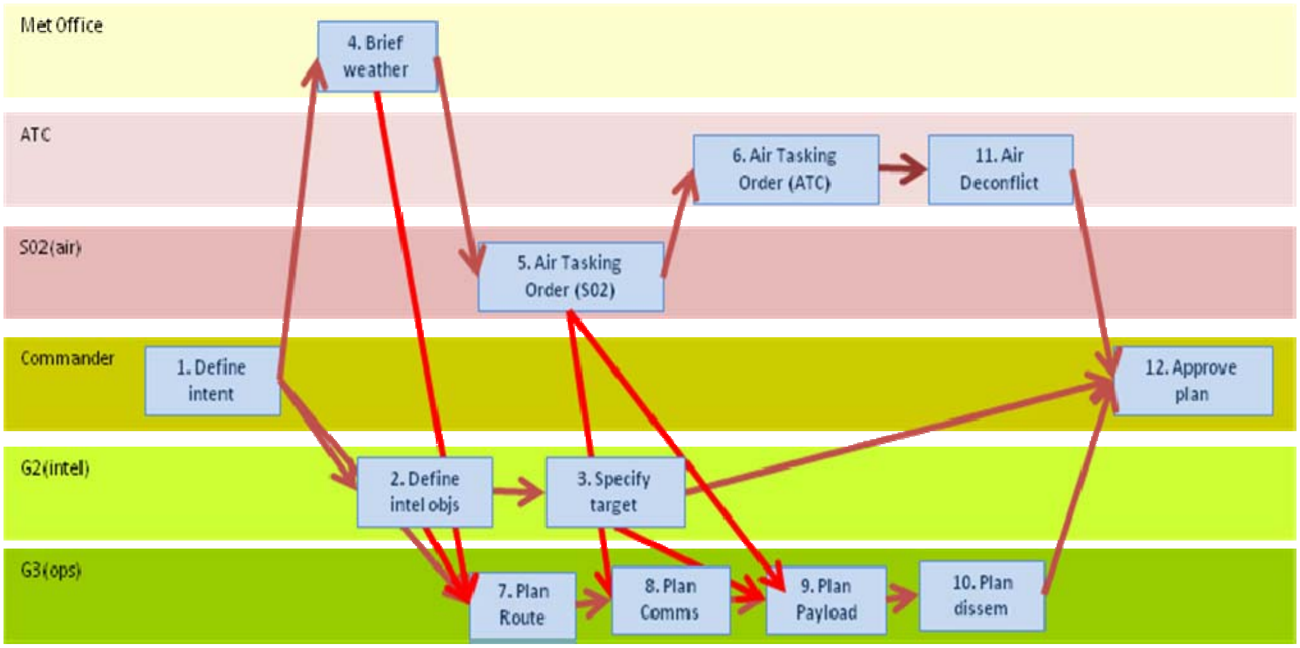

Figure 3-4: Extract from Critical Path Analysis.

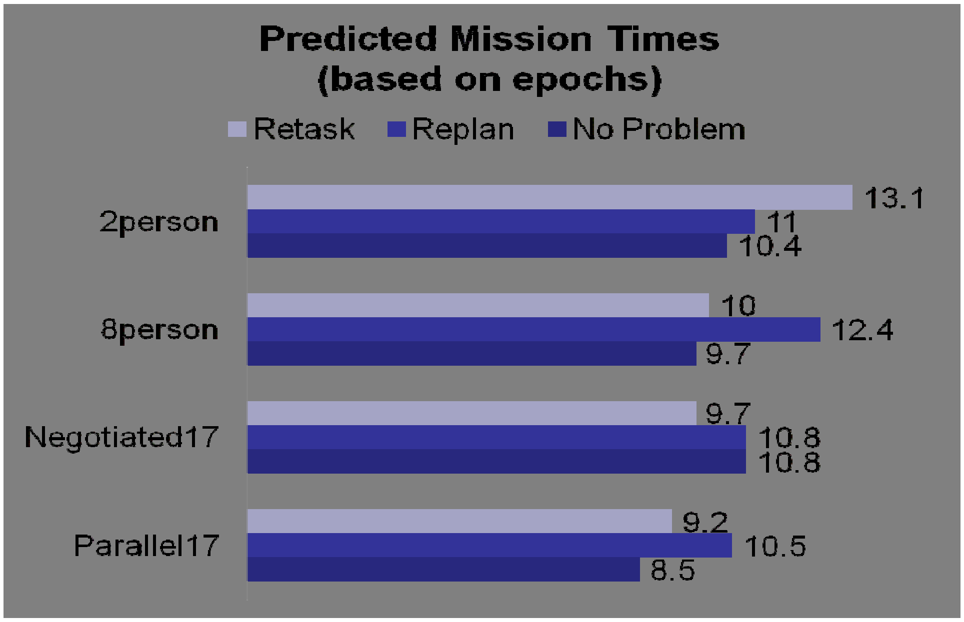

Figure 3-5: Predicted Mission Times.

Using a critical path analysis, one can produce a range of predicted mission times for alternative task allocation configurations (e.g., whether the mission is undertaken by 2, 8 or 17 person crews), or under different performance constraints (e.g., addressing a need to re-plan or re-task the mission). More detail is provided in Baber et al. (2009).

An approach that has proved useful in US, UK and Canadian military research involves the development of task-network models based on tools that have evolved from *MicroSAINT* (Laughery et al., 2006). For instance, Hou and Kobierski (2006) used the Integrated Performance Modeling Environment (IPME) to model UAV activities performed with and without the use of an Intelligent Adaptive Interface (IAI). Their model is shown in Figure 3-6. In a nutshell, IPME is a discrete-event simulation software that is created for supporting human behaviour representation and human performance modelling (Dahn et al., 1997). IPME operates in a similar manner to MicroSAINT, in terms of the analysis of time. However, there are differences in how these times are defined and fed into the models.

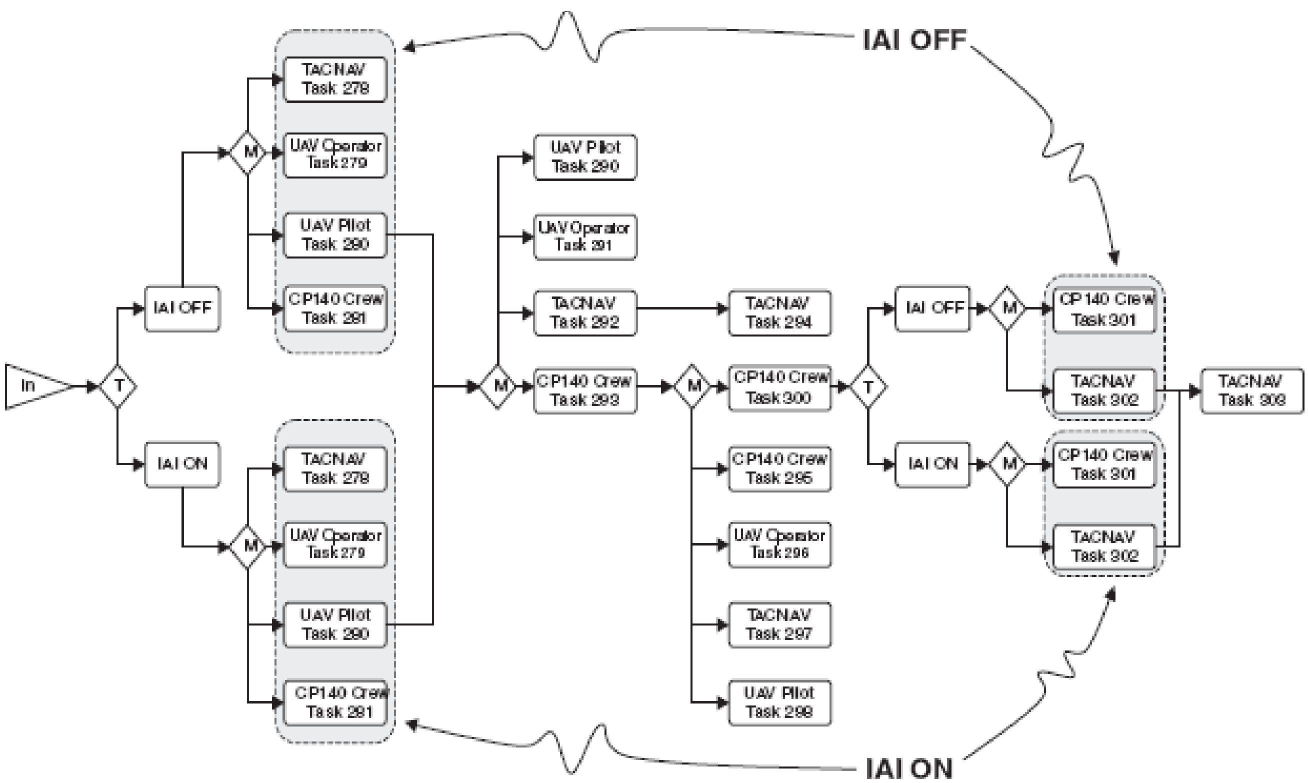

Figure 3-6: Task-Network Model of UAV With and Without IAI [Hou and Kobierski, 2006].

The aim of the task-network model in Figure 3-6 is to explore the potential benefits of intelligent adaptive interfaces (IAIs) for managing UAV operator workload. The Hou and Kobierski (2006) models indicate that the IAI reduces goal completion time, potentially making operator resources available for planning and communication.

McGovern-Narkevicius et al. (2009) examined the impact of refuelling teams on aircraft refuelling on the CVN-21 aircraft carrier. Their models used a combination of IMPRINT (Improved Performance Research Integration Tool) human performance models and the FOCUS model of launch and recovery rates for CVN-21. IMPRINT was developed by the US Army Research Laboratory to help system developers predict the impact of operator performance on system performance. Data are entered through task-network diagrams and underlying human performance algorithms perform the simulations. Performance can be optimized by building models representing alternative function allocations and comparing their output. Developers can use IMPRINT to predict how design decisions impact operator performance in a system (Mitchell, 2005). McGovern-Narkevicius et al. (2009)

observed that, "Changes in performance due to manpower, personnel, training or human factors changes can be modelled in the human performance model and then introduced in the process model. These proactive trade-offs are at the heart of successful HSI." (p. 46-8).

3.3.2 Simulations of Combinations of Human Views

Wang et al. (2008) reported the use of Canadian Forces (CF) occupational classifications to define operators in IPME. IPME allows an analyst to represent a human system using four component models. For example, human activities are mapped out in a task network model, operator characteristics are captured in a crew model, environmental stressors are described in an environment model, and the impact of performance moderators is represented in a performance shaping function model.

Several desirable features make IPME a useful platform for linking HVs to a human performance model. Firstly, existing IPME constructs (particularly its component models) map easily to several HVs. Specifically, HV-C (Tasks) can easily populate a task network model, HV-B6 (Human Characteristics), and HV-D (Roles) can be represented in a crew model, HV-B5 (Health Hazards) can be captured in the environment model, and HV-G (Metrics) can guide the system performance calculation. Secondly, IPME is a generic, re-configurable modelling platform. In addition to existing component models, one can create customized data constructs for accommodating other views. For example, the crew model can be extended to represent HV-E (Human Networks) quite easily. Thirdly, IPME uses a plug-and-play modelling philosophy and a modular approach to model construction. As a result, the data associated with HV products can be examined either independently within each IPME module, or as a subset of the entire IPME model. Analysts can test a particular module without needing to modify the entire model, providing flexibility.

Once completed, an IPME model can be executed as a discrete-event simulation. Since stochastic processes are implicit in the IPME model, one can study system performance bottlenecks or compare alternative system designs by examining the model's outputs. The interaction between the HV products can be examined using an IPME simulation model, helping to validate individual product data.

Wang et al. (2008) incorporated the CF military occupational characteristics into IPME. The intent was to populate an IPME model with a unique set of operator characteristics (i.e., an operator's knowledge and skills obtained through professional training). The occupational data come from the CF military occupational specifications (MOS), which are conventionally used to support human resources (HR) activities. The new linkage between IPME and MOS paves the way for incorporating the HV product most closely associated with personnel (HV-B, Constraints) into a simulation model. An operator is assigned activities in the task network. Occupational characteristics are assumed to define performance criteria required for tasks performed by a given rank in a duty area (e.g., Flight Engineer: Duty Area A – Ground Duties: AT001 – Perform aircraft pre-flight inspection). The task statement is defined in terms of level of capability required (e.g., from basic awareness to expert knowledge). Figure 3-7 is a sample screen shot of a MOS identifier (MOSID) interface which allows an analyst to specify the knowledge and skills of a virtual operator. Wang et al. (2008) showed how these capabilities were related to performance characteristics like time and error, in demonstrating how different crew mixes affect overall performance.

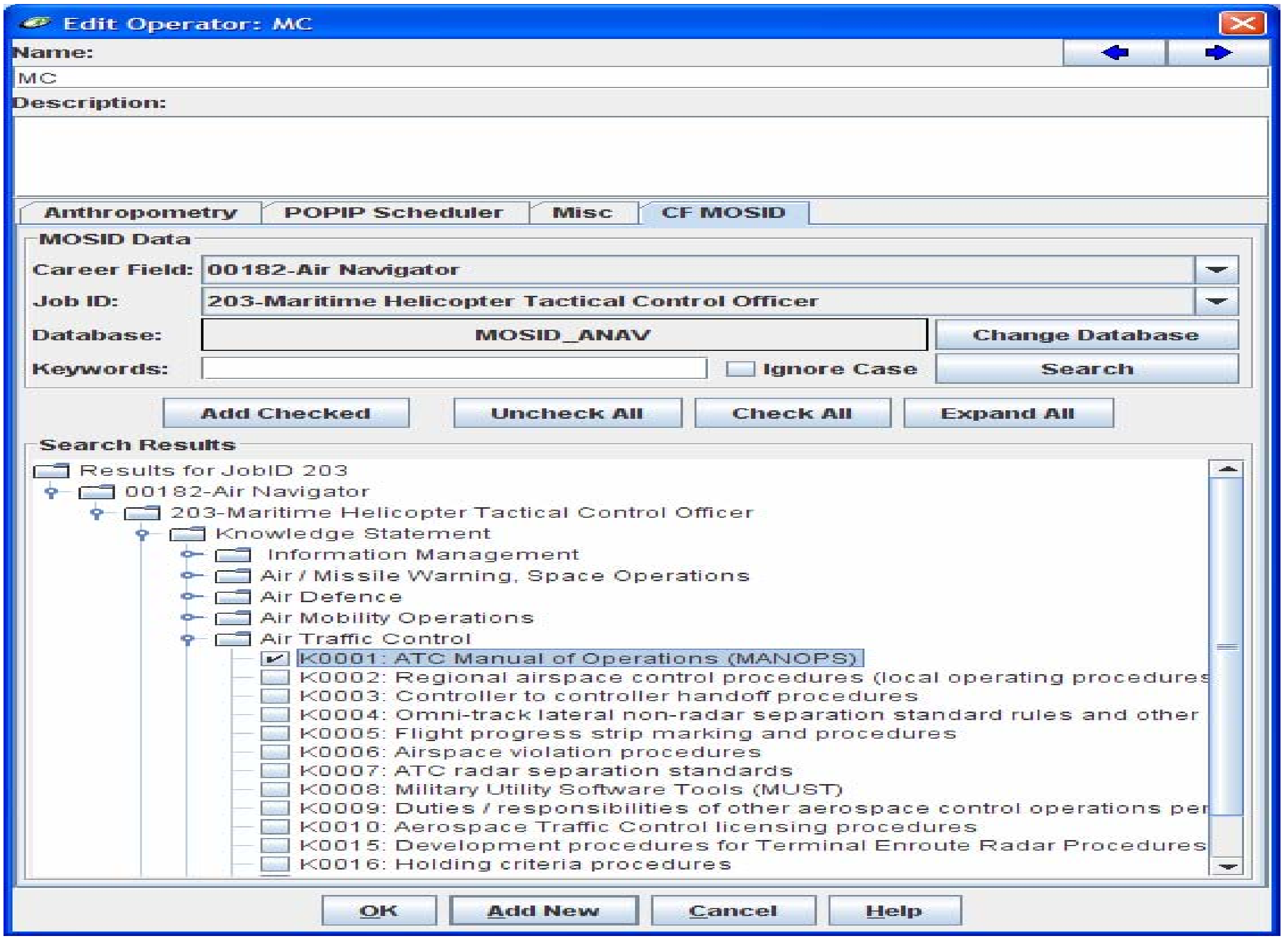

Figure 3-7: Screen Shot of a MOSID Interface in IPME.

3.3.3 Simulation of Performance: Case Study Using IMPRINT to Model Combined Human Views

Discrete-event models representing human-system interactions were discussed above. These models have also been configured to explore performance metrics for decision maker coordination and mission completion, (Handley, Zaidi and Levis, 1999). Typical models allow input parameters to be varied, constraints to be relaxed and other variables to be explored to evaluate the effect on model outcomes, and by inference, on the human system design. Using the same methodology, a preliminary schema for the interaction of individual HV components was created. Products HV-A to HV-G each capture a different set of human elements (task, role, network, etc.) However, relationships between elements are key to understanding system performance. The initial HV Dynamics schema is shown in Figure 3-8.

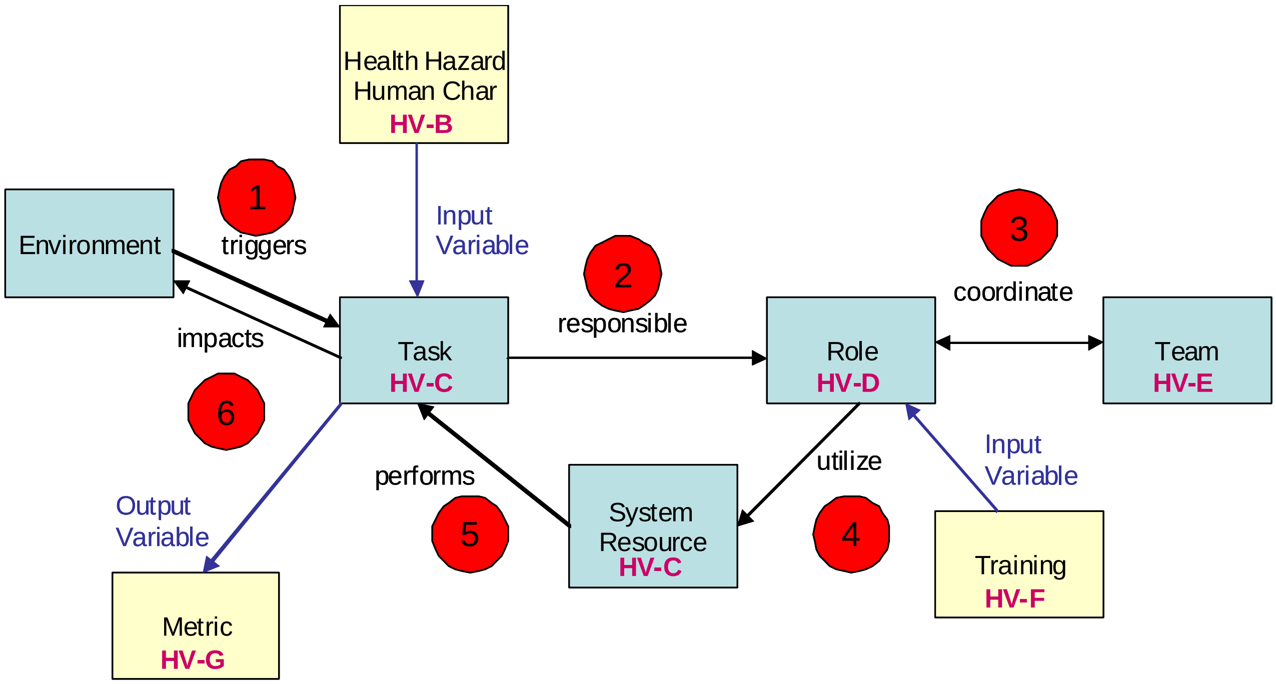

Figure 3-8: Initial HV Dynamics Schema.

The numbers in the red circles in Figure 3-8 show the data flow through the discrete-event model. An event from the environment triggers a task (HV-C). The role (HV-D) responsible for the task begins processing it, coordinating with team members (HV-E) to exchange information during task processing. The way the task is processed may depend on characteristics of the actual person fulfilling the role (HV-B), including training completed (HV-F). Use of a system resource (HV-C), e.g., a sensor, to complete the task is included in the model. Other constraints like health hazards (HV-B) may moderate the performance of the task. Once the task is completed; metrics (HV-G) are used to evaluate performance.

The modeling schema devised for HV Dynamics was implemented using IMPRINT. Analyses performed with IMPRINT provide the information required to evaluate the interaction of HV components. The model's input requirements can be mapped to HV product data, as shown in Figure 3-8.

Table 3-2: Mapping of HV Products to IMPRINT Data

Product	Description	IMPRINT Data
HV-A Concept	A high-level representation of the human component of the system.	– Hypothesis to be tested by the model
HV-B Personnel Constraints	Manpower Projections (HV-B1) – Predicted manpower requirements for supporting present and future systems. Establishment Inventory (HV-B3) – Current number of personnel by rank and job within each establishment.	*IMPRINT OUTPUT*: Number of desired MOS expected to be available per year. *IMPRINT OUTPUT*: Estimated number of soldiers needed.
HV-B Human Factors Constraints	Health Hazards (HV-B5) – Short- and long-term hazards to health that occur as a result of system operation, maintenance and support. Human Characteristics (HV-B6) – Operator capabilities and limitations with system operating requirements under various conditions.	– Stressors, such as heat, humidity, cold, wind, protective clothing, and fatigue. – Personnel Characteristics, such as intelligence test score composite and cut-off.
HV-C Tasks	– Identify human level tasks – Task knowledge, skill, and abilities (KSA) requirements – Task-role assignment matrix – Tools required to accomplish task – Information demands for specific tasks	– Function/task decomposition – Task to operator assignment – Tasks to system interfaces – Task demands (mental workload)
HV-D Roles	– List of roles – Role responsibility – KSA competencies	– Warfighters/Operators
HV-E Human Network	– Role groupings or teams formed – Interaction types – Team dependencies	– Team functions – Operator teams
HV-F Training	– Training resources, availability, and suitability – Training required to obtain necessary knowledge, skills, and ability	– Changing sustainment training frequency
HV-G Metrics	– Human performance requirements – Human task to metrics mapping – Target values	– Mission level time and accuracy criterion – Task level time and accuracy standards *IMPRINT OUTPUT*: Crew performance, crew workload

To assess validity, an experimental model was created using sample data from the US Army's Future Combat System. We used IMPRINT as a simulation environment to evaluate the dynamic aspects of the human system components captured in the static HV products. By creating an actual IMPRINT model using HV data, differences in terminology, level of detail, and content descriptions could be addressed. Table 3-3 shows the process used to create the model.

Table 3-3: Step-Wise Process to Create IMPRINT Model Using HV Data

STEP	IMPRINT MODEL	HV DATA
1	Operators	HV-D Roles
2	Mission Network Diagram	HV-C Tasks
3	Warfighter Assignment	HV-D Task-Role Matrix
4	Resource-Interface (RI) Pairs	HV-C System Interfaces
5	Task Time and Accuracy and Task Effects	HV-G Performance Standards/ Measures
6	Performance Moderators	HV-B Constraints
OUTPUTS	*Mission Results* *Task Performance* *Operator Workload*	*HV-G* *HV-G* *HV-G / HV-B*

While the HV products define necessary data elements, the relationships between elements are less defined. Relationships can therefore be modelled in different ways, subject to user needs and system requirements. While some relationships were not currently specified in the architecture viewpoint, the HV can be used to provide input. Also, the HV captures more extensive information on Networks (HV-E) and Training (HV-F) than is currently called for in the IMPRINT model example.

Once the model was created, a baseline simulation was executed to provide expected levels of mission performance parameters (time and accuracy). Task performance can be represented in terms of time to complete, percent steps correct, and task failure and its consequences. Operator activity can also be represented in terms of workload by considering resource conflicts, which indicate multiple operators or tasks accessing the resource. Thus, we used the following data categories:

- Mission Performance (mission completion time).
- Task Performance (time to complete, percent steps correct).
- Tasks that failed and the consequences of failure (task repeated, operator assignment for another task changed, time and/or accuracy on another task degraded, no effect, mission aborted).
- Channel (resource) conflicts, which indicate multiple operators or tasks accessing the resource.
- Operator workload (overall, single task demand, sum of data over time).

Some IMPRINT results for time and accuracy are listed in Figure 3-9. An example of an IMPRINT workload output is shown in Figure 3-10.

		Time		Accuracy	
Task	**Operator**	**Standard**	**% Met**	**Standard**	**% Met**
START	Platoon Leader	00:08:00.00	100.00	90.00	100.00
Initiate Road March	Platoon Leader	00:25:00.00	96.00	90.00	92.00
Move Along March Route	Driver	00:20:00.00	96.00	90.00	100.00
Report Control Measures	Team Leader	00:20:00.00	96.00	90.00	92.00
Maintain March Security	Platoon Sergeant	00:20:00.00	100.00	90.00	100.00
Conduct Scheduled Halts	Health Care	00:20:00.00	100.00	90.00	100.00
Platoon Arrives at Designated Coordinates	Vehicle Commander	00:20:00.00	100.00	90.00	96.00
Platoon Initiates Screen Operation	Squad Leader	00:20:00.00	92.00	90.00	96.00
Driver Reacts to Ambush	Driver	00:10:00.00	96.00	90.00	92.00
Vehicle Commander Reacts to Ambush	Vehicle Commander	00:10:00.00	100.00	90.00	96.00
Infantry Squad Reacts to Ambush	Squad Leader	00:10:00.00	100.00	90.00	92.00
Platoon Leader Reacts to Ambush	Platoon Leader	00:10:00.00	100.00	90.00	100.00
Evacuate Injured Personnel	Health Care	00:20:00.00	100.00	90.00	92.00
Disengage from an Enemy Force	Squad Leader	00:20:00.00	92.00	90.00	76.00
Treat and Evacuate Casualties	Health Care	00:20:00.00	100.00	90.00	92.00
Conduct Resupply Operations	Platoon Sergeant	00:20:00.00	100.00	90.00	92.00
Conduct Maintenance Operations	Vehicle Commander	00:20:00.00	100.00	90.00	96.00
Conduct Consolidation and Reorganization	Team Leader	00:20:00.00	92.59	90.00	92.59
Destroy Unit Vehicles and Equipment	Driver	00:20:00.00	100.00	90.00	96.00
Resume Original Mission	Platoon Leader	00:20:00.00	96.00	90.00	100.00
END	Platoon Leader	00:07:00.00	100.00	90.00	96.00

Figure 3-9: Predicted Task Time and Accuracy Measures.

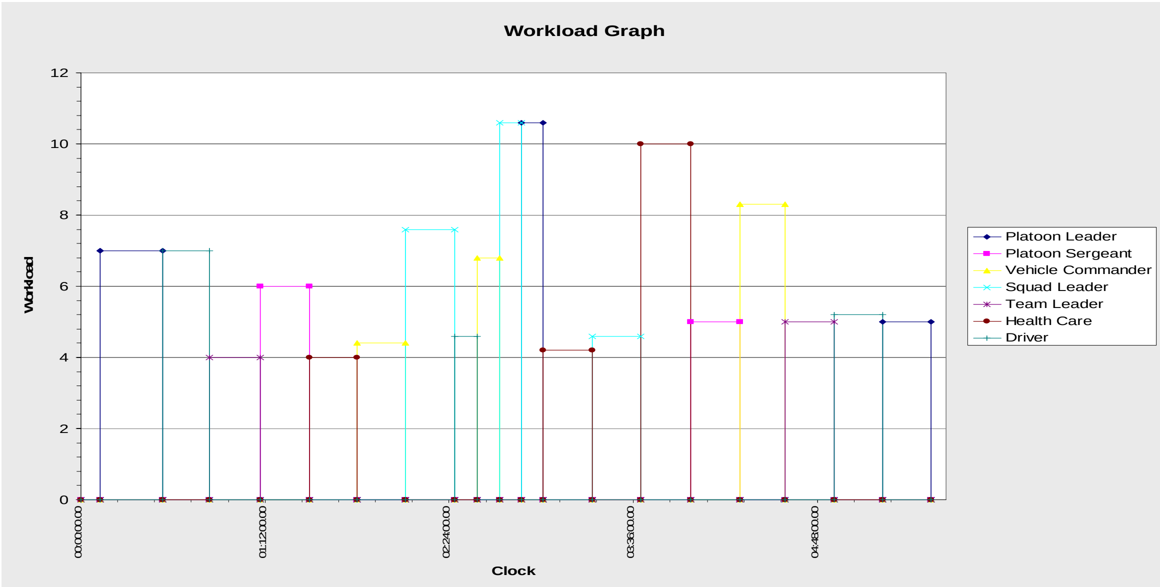

Figure 3-10: IMPRINT Workload Results.

Following baseline simulations, trade-off analyses can be performed. For example, different role-to-task allocations will impact task performance and operator workload – if one operator is over worked and another under worked, tasks can be reassigned. The assignment of system interfaces to tasks will affect channel conflicts, and thereby task performance and task failure. There is a direct relationship between the information captured in the HV product and model outcomes.

IMPRINT can be used to model effects associated with Constraints (HV-B). The effects of personnel characteristics like those measured by the composite and cut-off scores of the Armed Services Vocational Aptitude Battery (ASVAB) can be assessed. The effects of stressors (heat, cold, noise, lack of sleep), the Mission Oriented Protective Posture (MOPP) level, or training frequency can also be modelled. The IMPRINT dynamic model can help set realistic system requirements and operating conditions in particular situations.

Creating Human Dynamics (HV-H) within the model allows exploration of how changing parameters in one of the static products impacts other aspects of the human data. For example, by adjusting assignments made in the HV-D Task to Role Matrix, component, some roles may be overloaded, causing cascading effects in other parts of the model, i.e., other tasks not being completed because it required the completion of the over worked operator's tasks. Changing skill levels in HV-F (Training) can show how assigning an operator with less experience would lead to a failure to complete key tasks, affecting system performance. Ultimately the goal of Human Dynamics is to show how changes to factors affecting the human elements of a system impact on system performance.

3.3.4 HV-C Tasks, HV-D Roles and HV-E Human Networks: Modelling Collaboration and Communication Processes

To develop reliable models of real-life cooperative processes, empirical studies of these processes in realistic scenarios are essential. Empirical observation should help provide answers to the following questions:

- What are the activities?
- Who carries out each activity?
- When are activities carried out, and why?
- What information is gained through the activity and where is it needed?
- Which decisions are made and when?
- Which tools are used and when?
- Who cooperates and communicates with whom and when?

The K3 technique was developed using UML (universal markup language) activity diagrams (Killich et al., 1999; Foltz et al., 2000) to model cooperative processes. K3 is the German acronym for "cooperation", "coordination" and "communication". The basic elements of the graphical notation are *activity*, *information* and *tool*, as illustrated in Figure 3-11. Activities processed simultaneously by a organizational unit (which might be a single person or higher level unit like a group or a department) without synchronization or with an undefined order – both characteristics of weakly structured workflows – are represented using a *blob* structure. If two or more activities are processed in parallel by the working unit the *parallelization* element is used. Elements are connected by *control* and *information* flows. Cooperative communication is represented by *joining* and *forking* of control flows and *synchronized communication*. *Swim lanes* provide an overview of organizational units and assigned activities. They contain the activities, blobs and parallelization elements of the corresponding organizational unit and describe its behaviour. Kirwan and Ainsworth (1992) divide task analysis methods into collection, representation and simulation techniques. K3 can be used for collection and representation. The analyst can construct "should-be" processes in addition to the "as-is" state.

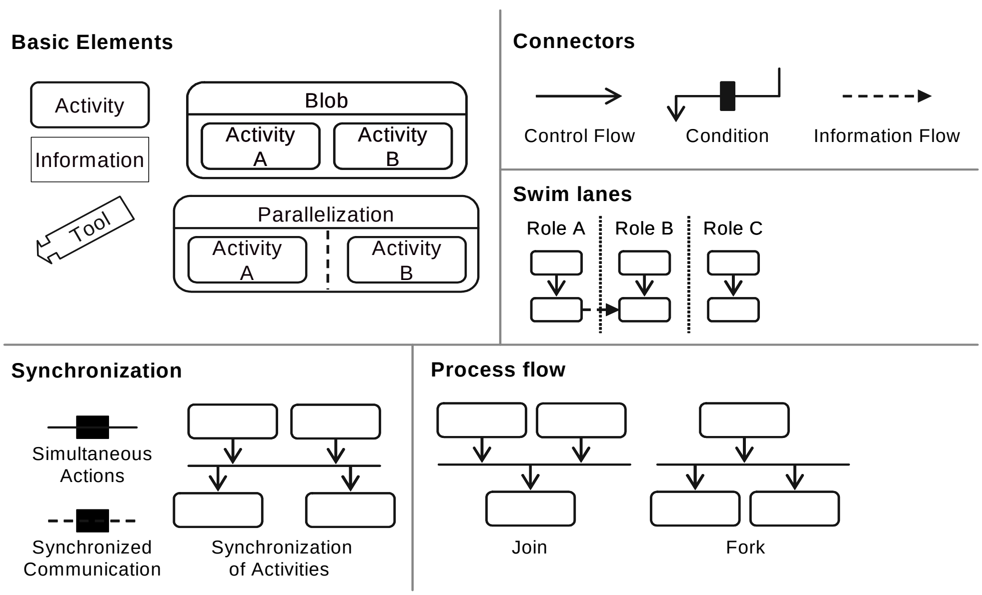

Figure 3-11: Elements of the K3-Technique for the Graphical Modeling of Cooperative Processes.

Process data can be acquired by real-life observation or by interviewing domain experts, a more common technique for system design. Figure 3-12 shows a K3 model describing UAV deployment, developed based on domain expert interviews. It highlights the large number of communication activities during mission preparation.

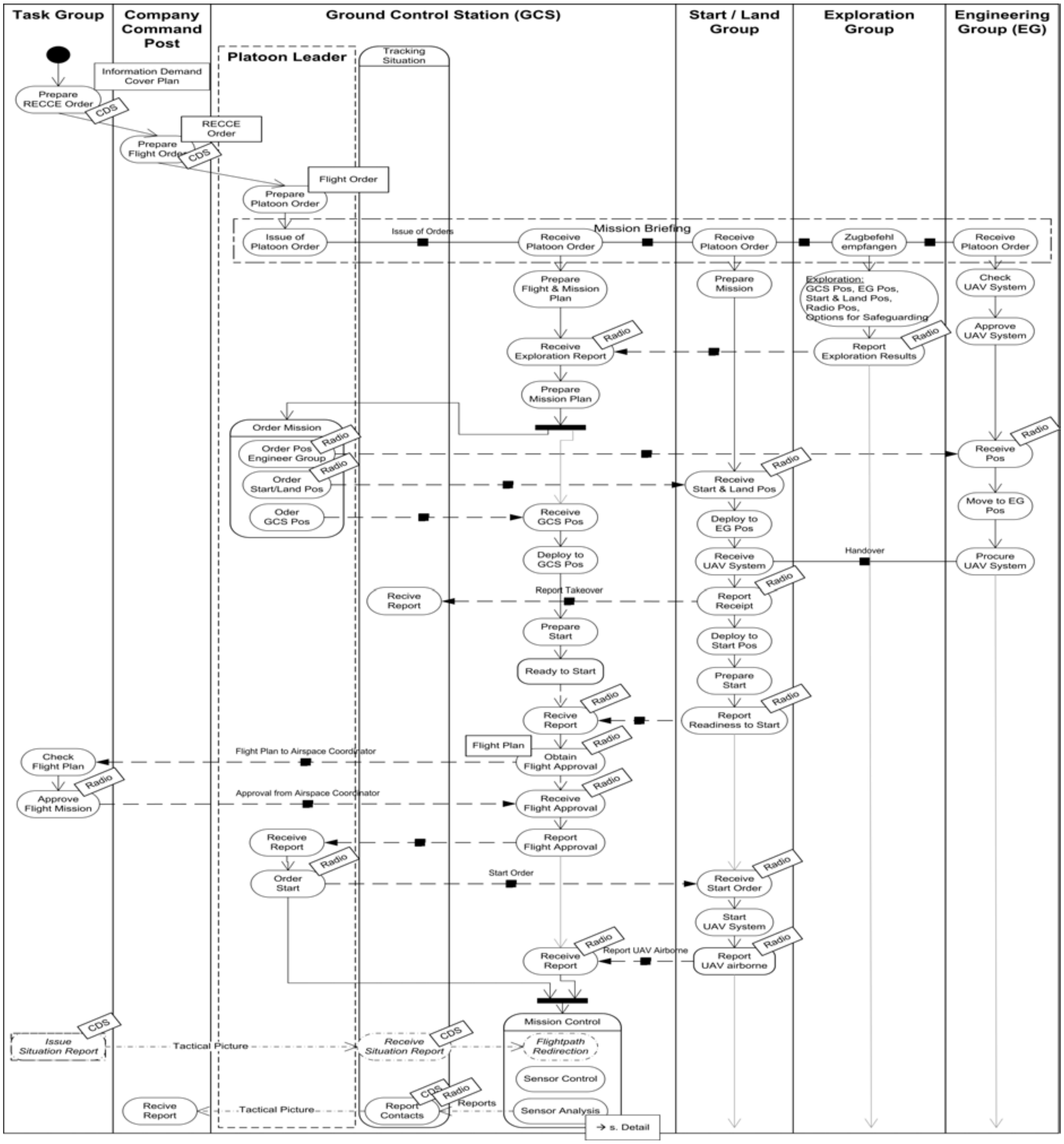

Figure 3-12: UAV Deployment Modelled Using K3.

3.3.5 HV-E Human Networks: Networks and Teams

For human networks, there has been growing interest in modelling C2 communication structure, particularly using social network analysis (Dekker, 2002; Houghton et al., 2007). Compared to a hierarchical structure, when networks become more highly-connected, their resilience to random attack should increase. If the attacks are targeted, network protocols need to anticipate the loss of specific nodes. At one level, this is a routing problem, and the solution would define efficient, adaptive routing protocols. At another level, this is a problem of each node's function. A service-oriented architecture approach might use nodes to offer specific services to the network and manage node loss through redundancy. In the UAV domain, we assume that personnel located in headquarters (e.g., G2, G3, So2(Air)), air management (e.g., ATC, CAOC, the UAV itself, e.g., mechanics, pilot, PO), leader, driver, and other personnel associated with ground cover are all part of force protection. By considering which personnel are allocated to what functions, one could model who might communicate with whom, who shares functions, and what knowledge is required by the system to achieve mission goals. By making assumptions about available communication channels one can propose alternative network structures. Figure 3-13 shows two examples.

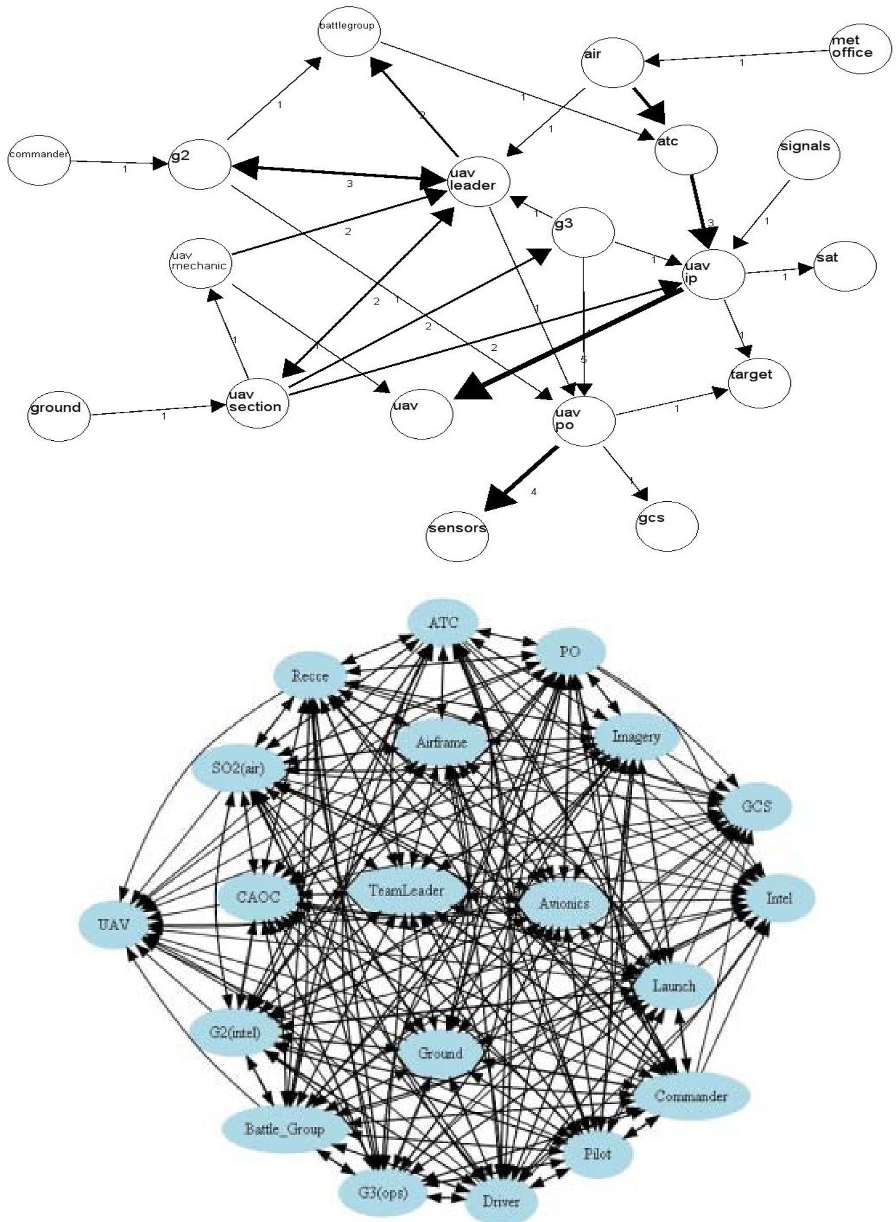

Figure 3-13: Social Network Diagrams. Mapping between actors as one-to-many (top) and many-to-many (bottom).

In the UK, Mathieson et al. (2005) developed the STORM team maturity model. The underlying algorithm combines Tuckman's (1977) team maturity process model and Noble's (2004) theory of knowledge enablers to model social and cultural characteristics of team performance. STORM can be used to determine which stage of Forming-Norming-Storming-Performing best represents a team. A team consists of agents with differing abilities, communication loading, etc. One might anticipate such modeling effects to provide useful insights into ad hoc team formation in coalition operations.

3.3.6 HV-E Human Networks and HV-C: Network Topologies

Dekker (2001, 2002) examined how communication structures affect command and control. In this analysis, the communication between units varied according to command structure. In Dekker's models, there is implicit definition of HV-D Roles (by the designation of agents) and HV-C Tasks (through functions allocated to each agent). Dekker was interested in exploring how different command structures performed a mission. The model was essentially an event-driven simulation, with targets appearing or disappearing at matrix nodes and Sq 1-4 agents traversing the network to find targets. Upon target detection, a message was passed to the intelligence unit, which then reported to the command unit. Command then issued a message to squadrons to attack the target (see Figure 3-14).

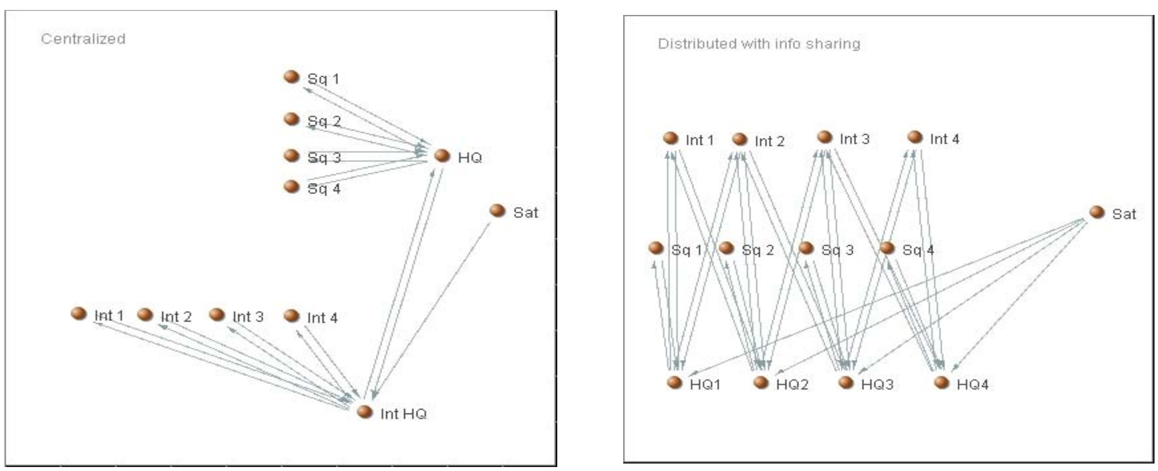

Figure 3-14: Examples of Different Network Structures (Dekker, 2001, 2002).

Dekker's models showed that different command structures led to demonstrable differences in performance. Dekker used a delay analysis and an intelligence analysis for his approach. Variations in the time it took messages to pass from one node to another (i.e., measures of delay in transmission), led to an *information flow coefficient*. This coefficient showed how well a given structure passes information from sensor to shooter to complete the task. A similar delay measure called the *coordination coefficient* applies to the exchange of information between shooter assets (e.g., to prevent multiple attacks on a target). Applying a simple decay function, the longer information takes to move through a network, the less 'up-to-date' it is and the lower the Intelligence Coefficient.

Figure 3-15 shows an 'idealised' space that is characterised by dimensions relating to the structure of the organisation and manner of communication of information and command. In order to relate Figure 3-15 to the work of Dekker (2001), we have mapped Social Network Analysis (SNA) to the dimensions. The Diameter of a network can be used to indicate the degree of closeness of members within a network and we assume that a network with a high diameter is likely to have many members connected to each other, and a low diameter to have a few members connected (possibly in a linear or hierarchical manner). Thus, we map the SNA metric of Diameter onto the SAS-050 dimension of Allocation of Decision Rights as these indicate whether a network is hierarchical (‘unity decision rights’) or distributed (‘peer-to-peer’ decision rights). The Density of network can be used to indicate the proportion of connections between members relative to the total number of possible connections, i.e., to indicate whether a network uses 30% or 70% of the available connections. Thus, we map the SNA metric of Density onto the SAS-065 dimension of Distribution of Information as these indicate whether information will flow along many connections (‘broad dissemination’) or on a few connections (‘tight control’). Finally, Centrality provides an indication of how well connected a member is to other members in the network and provides a rough measure of the influence that node might have on the network. We assume that an average Centrality for the entire network will correspond to the distribution of influence in the network, i.e., a network where all members have similar levels of influence will have a high average Centrality and a network in which influenced is held by a few members will have a low average Centrality. We map the SNA metric of Centrality onto the SAS-065 dimension of Patterns of Interaction to indicate whether a network have influence in a few members (‘fully hierarchical’) or across many members (‘fully distributed’). On the basis of these metrics, one can see that Figure 3-16 shows Dekker’s (2001) ‘Centralized’ network to occupy a similar space to that is shown as ‘Classic C2’ in Figure 3-15, and the other networks approaching the space are shown as ‘Edge organisation’ in Figure 3-15.

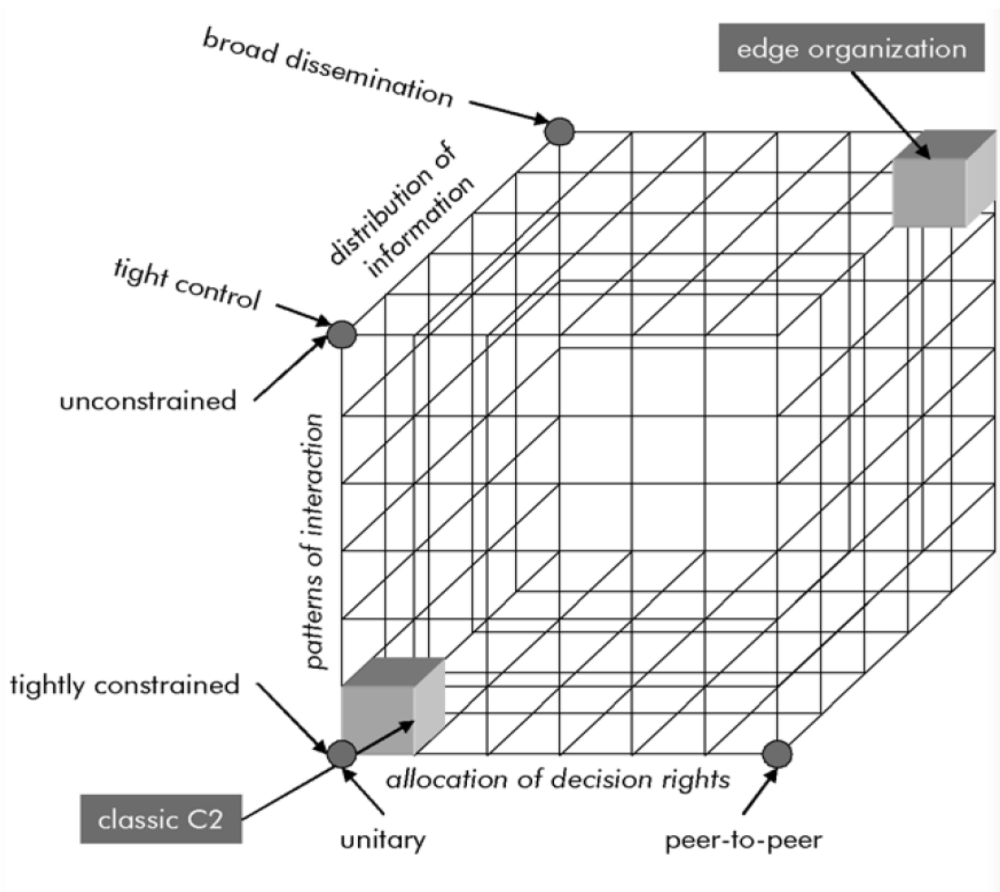

Figure 3-15: SAS-065 Space of Command and Control [from Alberts and Hayes, 2005].

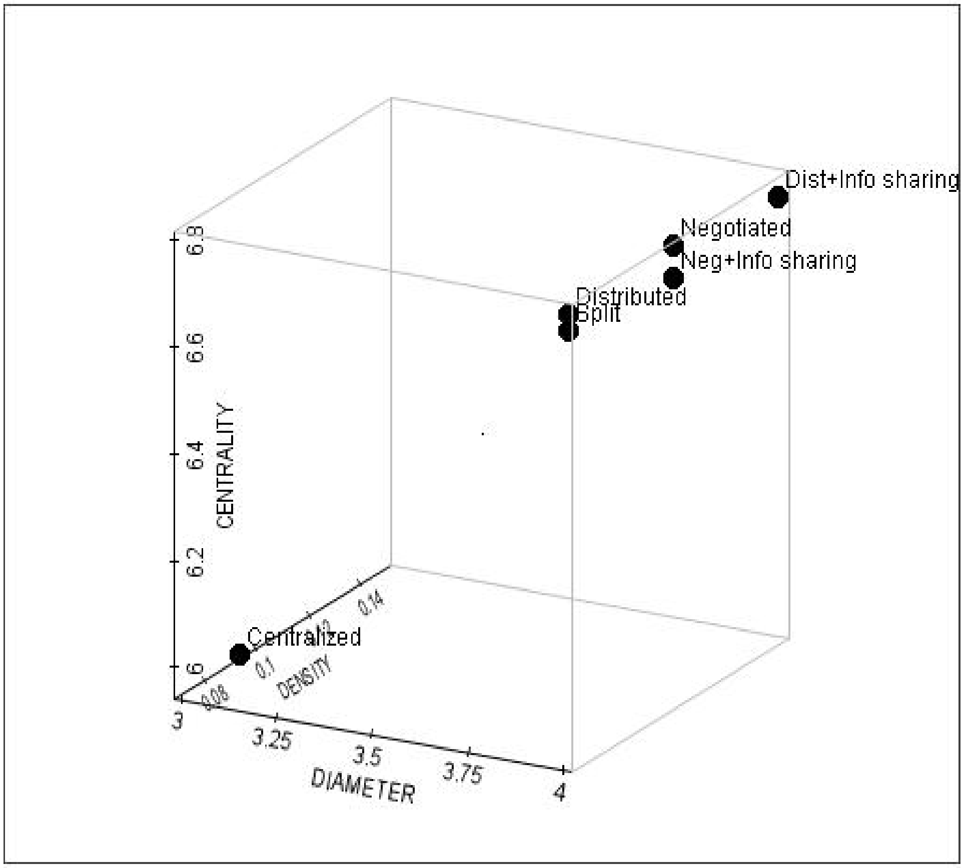

Figure 3-16: Mapping Dekker's Results to the SAS-065 Space of Command and Control.

3.3.7 Network Metrics: Packet Loss and Delay

Dekker argued that a command structure with many intermediary units between force, C2 and intelligence will likely be sluggish given the time delay associated with each message. However, command structures with many intermediary units usually build in redundant connectivity. This means that intelligence can be pooled and thus the reliability of that intelligence improved. Dekker used fairly small networks and time-based measures only. Baber et al. (2008) used OPNET (Optimised Network Evaluation Tool) to examine the effects of network structure and size on delay and packet loss metrics. OPNET is a network simulation package that allows nodes and links to be configured in different topologies. Each node is described as a state-machine, and nodes pass information according to defined link types. Figure 3-17 shows a model represented as a series of nodes connected by links. Data packets (made up of a string of digits contain the unique identifier of the packet, the time of generation and some error handling codes) are generated at the two ends of the event generation network (the top line of Figure 3-17), using two separate packet generators. The process of each packet generator is described by Figure 3-18. Packets are generated to ensure separation of packet generation from packet collision.

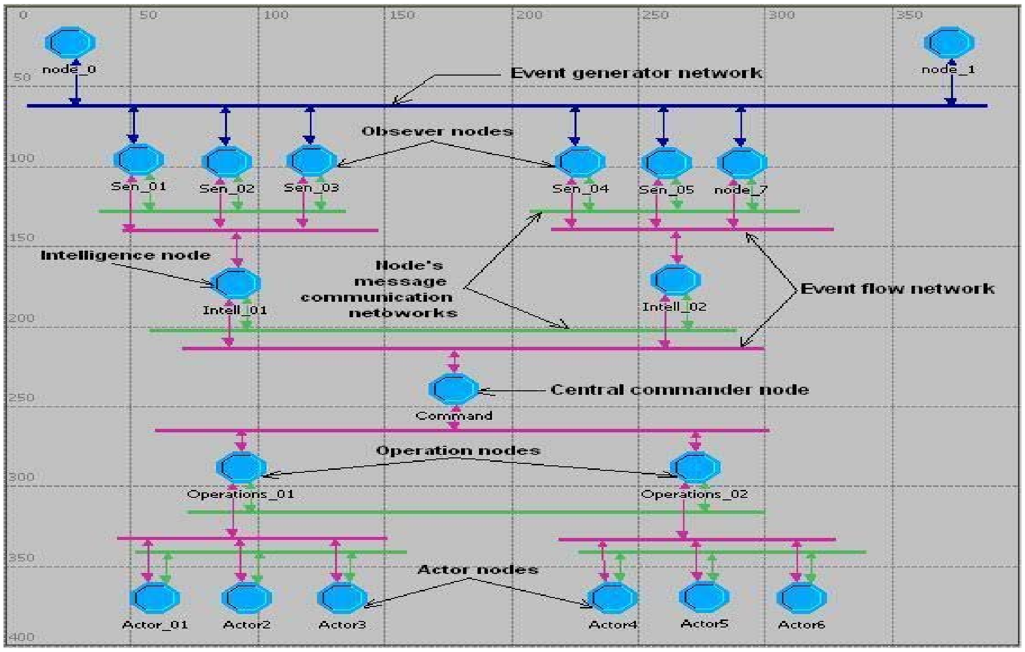

Figure 3-17: Converting the Hierarchical OODA.

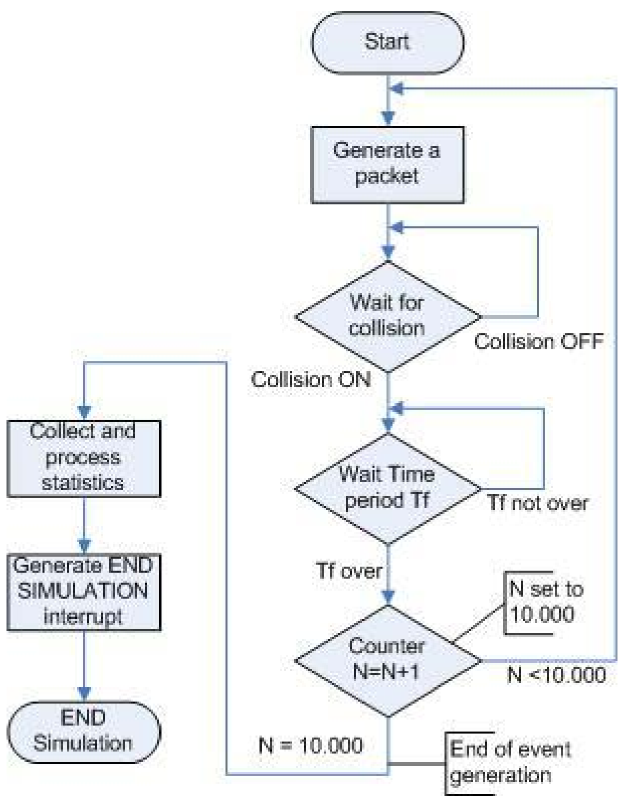

Figure 3-18: Operation Mechanism of Event Generator.

Packets are generated simultaneously and propagate along the bus in a mach 1 propagation delay. As Figure 3-19 indicates an 'event' is generated when packets collide, and this collision propagates back in both directions of the bus and is seen as a single event observed at slightly different times by the various Observer Nodes attached to next level of the network in Figure 3-17. The event generates a new packet (containing the ID of both of the collided packets and the time of collision) which is then passed through the network. In this manner, when the new packet reaches the Command Node in the network, the selection of which Operator Nodes to which to send a message can be determined by comparing the IDs in the packet with the Actor Nodes to which the Operator Nodes connect. In this way, the relationship between Observer Node and Actor Node can be managed. This assumes, for example, that the Observer Nodes and Actor Nodes operate on a similar location. Once the packet reaches the Actor Node, then the process terminates and a report is produced which contains the ID of the originating packets and the times at which various processes have been performed on them, i.e., collision, processing the Observer Node, Command Node, Operator Node and Actor Node. In this way, it is possible to determine the time delay between a packet being generated (on the top bus) and a response by made (on the bottom bus) of Figure 3-17. Some packets will not be processed, because Nodes will be occupied processing other packets when a new packet is available. In this instance, the new packet will move to the next node in line. However, if all nodes are occupied, then the packet will be lost (or rather it will be 'trapped' by an algorithm that is running to monitor the generation of each packet and its subsequent processing). Packets can be lost at different levels in the network. In this report we are combining all of the packet loss data into a single dimension rather than reporting the rate of packet loss at each level.

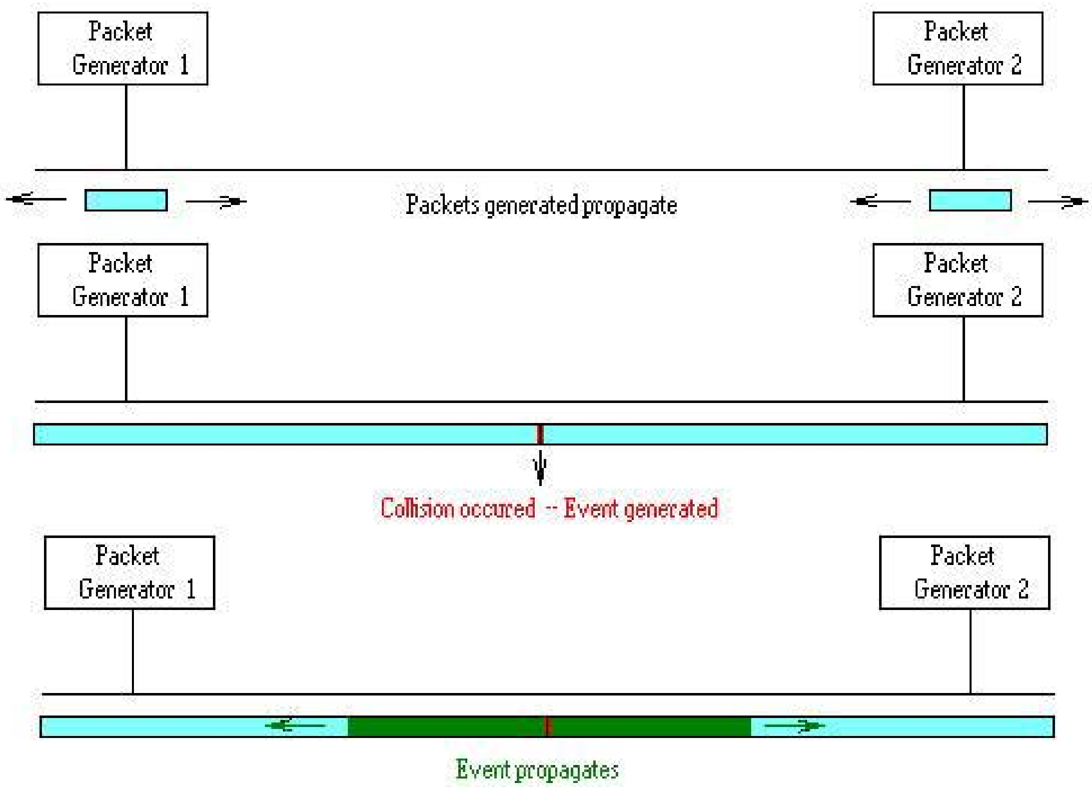

Figure 3-19: Event Generation Network.

Larger networks tend to fragment into collections of small networks of similar structures. By this we mean that the communication of packets within a network begins to synchronise across groups of nodes. In other words, some nodes become occupied and available at similar frequencies and so begin to change in a concerted manner. For example, assume there are four Observer Nodes on a bus: when the first packet arrive, the first Observer Node will respond to it and send a message to the Intelligence Node to which it is connected; when the second packet arrives, the first Observer Node is occupied and so the packet moves to the second Observer Node, which sends a message to the Intelligence Node to which *it* is connected and so on. If there are two separate Intelligence Nodes, then over time it is likely that Observer Node 1 and Intelligence Node 1 will synchronise their activity. In much bigger networks, this synchronisation is obviously a little more complex, but nevertheless it is possible to set increased activity in parts of the network at different times. From this one can assume that these areas of increased activity are, in effect, sub-networks that are working together. The performance of these sub-networks (in the models we have built) tend very much to take the form of hierarchical control, i.e., the information passes through the nodes in a linear manner with the rate being controlled by the Command Node (or at least the Node which has the most connections to it). In this manner, both Hierarchical and Distributed Networks begin to exhibit similar performance (as shown by Figure 3-20) and we believe that this is because of the fragmentation of both networks in these smaller, hierarchical sub-networks. Thus, the proposed advantages of Hierarchical or Distributed Networks are likely to be dependent on Network size (and that, with very large networks, we tend to see emergent structures which differ from those which were originally intended). This spontaneous fragmentation of large networks into small hierarchical networks can be considered analogous to the scale-free networks in which single nodes act as servers to clusters of nodes around them, with weak ties to other clusters.

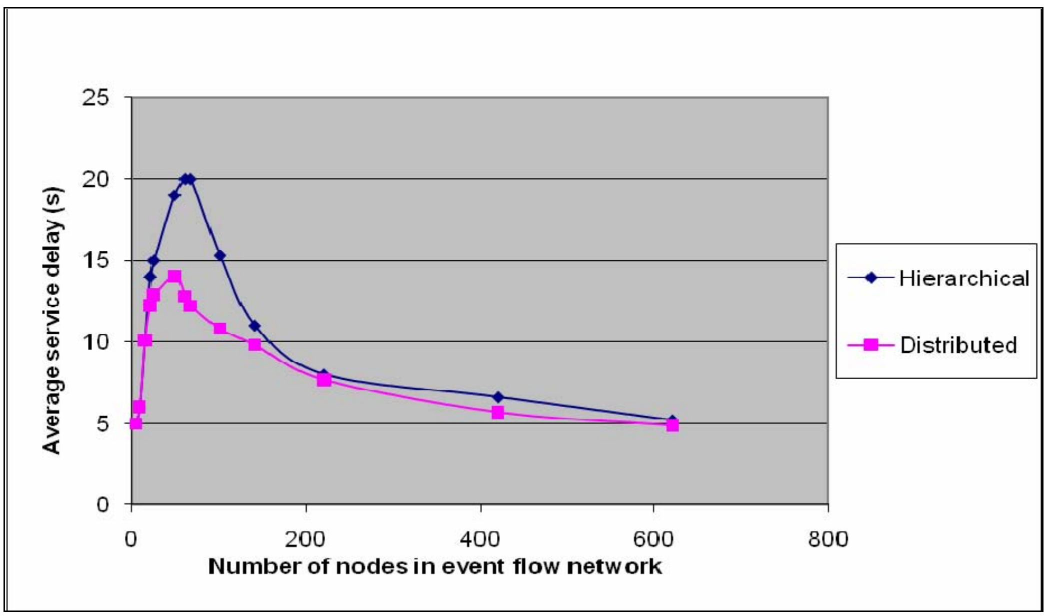

Figure 3-20: Service Delay Changes with Network Size Structure into an OpNet Model.

3.4 AGENT-BASED MODELING AND SIMULATION

In this section, we consider M&S approaches that reflect relationships among sets of HVs. The most common approaches to human performance modeling examine the relations between HV-C Tasks and other views, but there is also a growing set of approaches relating to HV-E Human Networks. HV-A Concept provides a 'big picture' overview of the CONOPS being described in the system architecture. In other words, it shows the setting in which operations take place, the actors involved and their relationships. An obvious M&S application would be to animate HV-A; that is, represent agent movement relative to the terrain and each other. This would require agent descriptions and the tasks required to perform the mission. For example, if HV-A is a map showing force lay-down and possible target locations, then one could perform target detection by flying a UAV over the terrain.

3.4.1 A Probabilistic Approach using Agent-Based Simulation

The number of possible system configurations that must be evaluated to achieve a complete system analysis (which should allow prediction of the optimal mission-specific system configuration) is so large as to be impossible to determine empirically. A promising approach would be to develop and apply probabilistic simulation models of complex work process dynamics, based on Bayesian network, Petri-nets or case-based reasoning methods. These may not provide precise predictions but they can specify the most probable range of values for dependent variables (e.g., detection rate), for given independent variables (e.g., sensor range). These approaches can apply to weakly structured work processes such as product development and project planning (Kausch et al., 2007; Duckwitz et al., 2008). Effectiveness and prediction accuracy can be increased by conducting simulation-based studies. Thus, the approach developed for the analytical evaluation of cooperative K3 concepts (see Section 3.3.4), was weakly structured given the wide spectrum of potential missions and scenarios (Pioro and Grandt, 2008; Pioro et al., 2008). The objective, however, using simulation was to estimate system performance under different configurations and operational conditions.

For process simulation, dependencies between all system components (i.e., the information flows), should be known. Precise estimates of the dynamic behaviour of system components (e.g., in terms of transfer functions), are very useful. This applies to simulations of any system, including those involving humans. However, due to the complexity of human behaviour, modelling approaches that aim to replicate human information processing mechanisms have achieved only limited success so far. A valid model of human information processing that captures the flexibility of human behaviour across the large variety of missions and scenario conditions may be unrealistic. To develop a simulation model that predicts the performance of a complex socio-technical system, we need to know how much information can be handled by a human operator within a certain timeline, including the quality of the actions or decisions taken. Thus, estimates of cognitive capacity and decision quality may be adequate; and, a complete account of underlying cognitive mechanisms is probably not necessary.

If the range of independent variables is understood, then human information processing can be represented by a transfer function between input and output variables within an information flow, as shown in Figure 3-21. This approach works best when:

- Human behaviour is predictable with regard to the potential outcomes of the transfer. This, in fact, applies only to skill-based or rule-based behaviour, and
- Transfer behaviour is expressed in terms of probability distributions (Jagacinski and Flach, 2003).

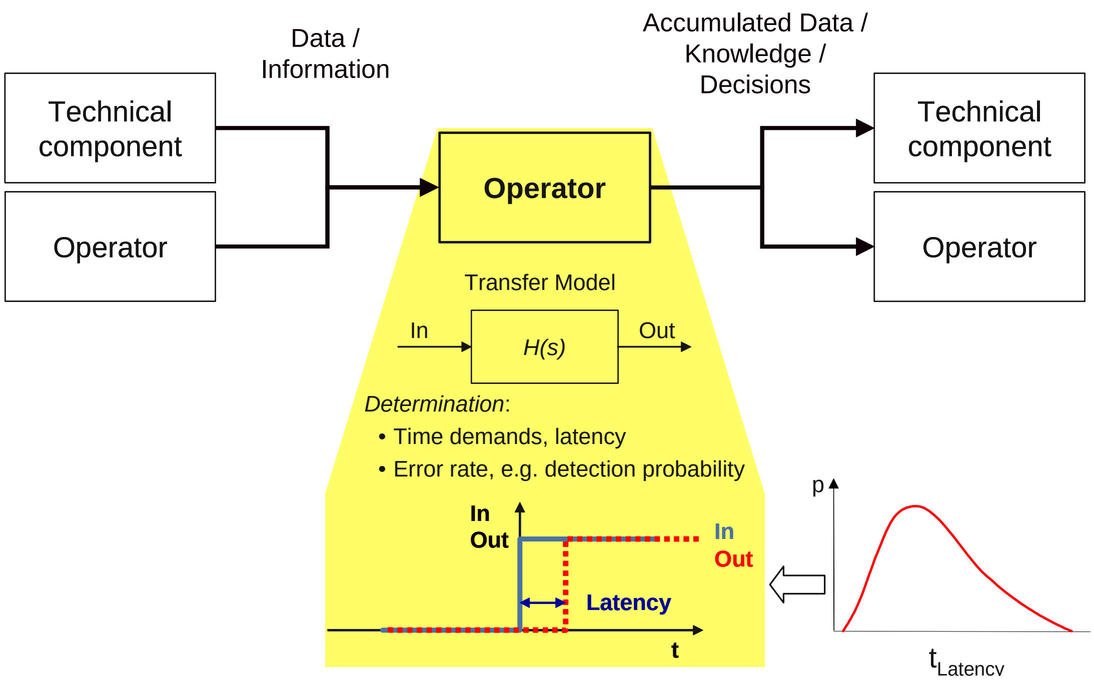

Figure 3-21: Human Information Processing as Probabilistic Transfer Model.

Under these premises, the transfer behaviour of the human operator is similar to that of technical systems. That is, it can be characterized by time demands, latency or lag, error probability, frequency of input and output assignments, or even missing outputs. Parameters of relevant probability distributions need to be determined empirically. In many cases these distributions are right-skewed for many variables in human information processing (e.g., response times). If there are significant correlations, e.g., between individual experience and latency, these higher level independent variables may be used instead.

In Petri-net based simulation models, this probabilistic behaviour can be implemented by a corresponding definition of state transitions. Transitions can contain probabilistic transfer models whose output is based on probability density functions. This way probabilistic behaviour like the effects of varying time demands, human error rates or reaction times can be fit into the simulation approach.

After the collaborative modelling process, the K3 model is transformed into a simulation model. From these matrices a Petri-net flowchart can be constructed using commercial Petri-net simulation tools. These provide a detailed specification of dynamic behaviour by adding own source code to the transitions of the Petri-net trajectory.

Following this approach, cooperative processes were investigated in the context of reconnaissance missions with a RECCE system incorporating multiple sensors including a UAV. At the very beginning a process assessment was carried out in order to identify the activities of the operators and the activity sequences on both the individual and group level, i.e. the resulting workflows within a team. This assessment was based on observations during exercises and subsequent interviews in which the workflows were constructed in a collaborative way together with the operators. Workflows were described by means of semi-formal K3 models (see Section 3.3.4). To transform the K3 model into a Petri-net simulation model, several matrices were derived from the K3 model describing roles, operational phases and activities. The workflow graph and these matrices were implemented into a simulation model using SeSAm (Shell for Simulated Agent Systems, University of Wuerzburg, Germany, http://ki.informatik.uni-wuerzburg.de/sesam/). The simulation model follows a person-centred approach (Licht et al., 2007). Thus, the agents representing human operators select tasks from a pool if they are in an idle state, or check the task pool for high priority tasks as they accomplish a task. A precondition for task selection is that the agent's competencies are compatible with task requirements. Thus, HV-C could be used to represent competencies for selection and could be based on a UML (Unified Modeling Language) sequence diagram. Other agents represent the different sensor systems, the vehicle which carries the soldiers, and the targets embedded in the military scenario.

As the UAV flies over a target it engages in a target detection process; that is, the sensor information is forwarded to an agent representing the human operator agent, who responds correctly or incorrectly after a certain latency, determined stochastically. Since all information is collected by the troop leader (agent) at this position within the simulation model, a tactical picture representing the (partially) reconnoitred scenario can be extracted. Figure 3-22 shows the simulation model's graphical output. The picture on the left displays the "real world" (i.e., the scenario data used as the basis for subsequent simulation). On the right the probably "reconnoitred world" calculated by the simulation model is shown.

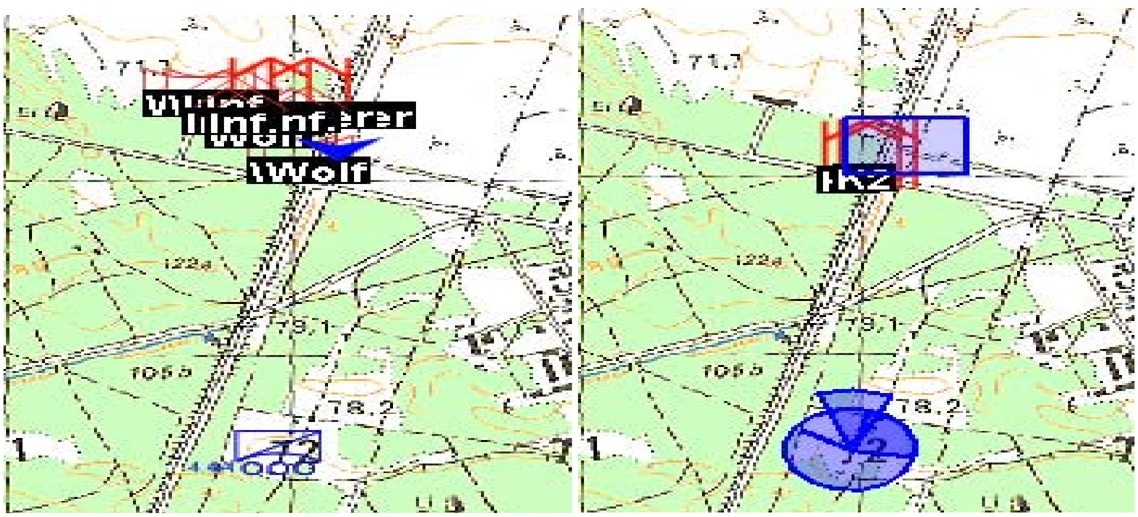

Figure 3-22: Visualization of a Single Simulation Run of an RECCE Mission with UAV Deployment (Pioro et al., 2008). Left: Underlying simulation scenario ("real world"), right: probably reconnoitred situation by the operational team.

3.4.2 Combining Agent-Based Simulations with Network Topologies

The Recursive Porous Agent Simulation Toolkit (REPAST) is an open-source modeling toolkit developed by Collier et al. (2003). It has three environments, and allows developers to build agent-based simulations supporting agent activity and networking. It is possible to build a REPAST model that enables agents to communicate in a defined network, and compare performance under different network structures. Agents can respond to environmental events. Importantly, one can combine both models so that agents respond to events *and* to communications from other agents.

Figure 3-23 shows the terrain in a REPAST model in which a UAV (highlighted on this figure by the red box) moves around the environment searching for targets. The terrain is imported from a GIS model (OpenWorld) to REPAST. The section in the top-left of the display shows the UAV ‘video feed’ (the portion of the background image over which the UAV is positioned). The main image shows an area around a building and the UAV is following a pre-defined search path to identify ‘targets’. In this simulation, a target is defined when the analyst designates a location by clicking on it and enters its parameters; during the run, parameters are returned to the UAV or other simulated agents (shown on the right-hand side of the display). Thus, UAV behaviour is managed by flight path and target locations. The flight path is generally predefined, but can be modified through commands from other agents). Changing the flight path (e.g., to reflect different search strategies, or different UAV capabilities) or target characteristics (e.g., occupied area or definition parameters) or UAV response (e.g., uncertainty associated with target detection) will impact system performance.

Figure 3-23: UAV Flying Around Environment in REPAST Model.

In this model, agent activity is a series of event-based modules. For example, the UAV follows a search path around the terrain (defined by the analyst as a series of waypoints), and when it flies over a target it reports a sighting to agents in the information chain. The analyst specifies each target using its location and a set of five parameters (abstract quantities to which different agents in the information chain respond). To develop an agent-based model of task performance, REPAST defines communication structures which interact with agent-based models. Network information flow is defined by how agents communicate with each other (Figure 3-24). An agent might respond differently under different network structures because the timing of information arrival differs. Consider two networks with different information chains. In the first network, the ‘Intel Officer’ waits for a message from the ‘Payload Operator’ before performing assigned tasks. In the second network, the ‘Intel Officer’ receives a message directly from the ‘UAV’, and thus begins the tasks earlier than in the first network.

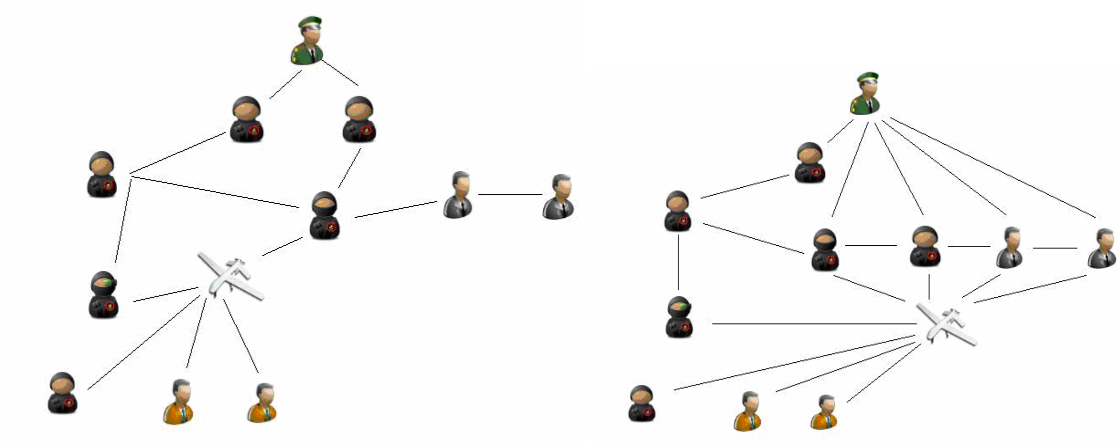

Figure 3-24: Alternative Network Structures Surrounding UAV.

Figure 3-25 illustrates how different network structures affect the time delay between target detection and complete processing of the target (allocating a threat level or response action to the target).

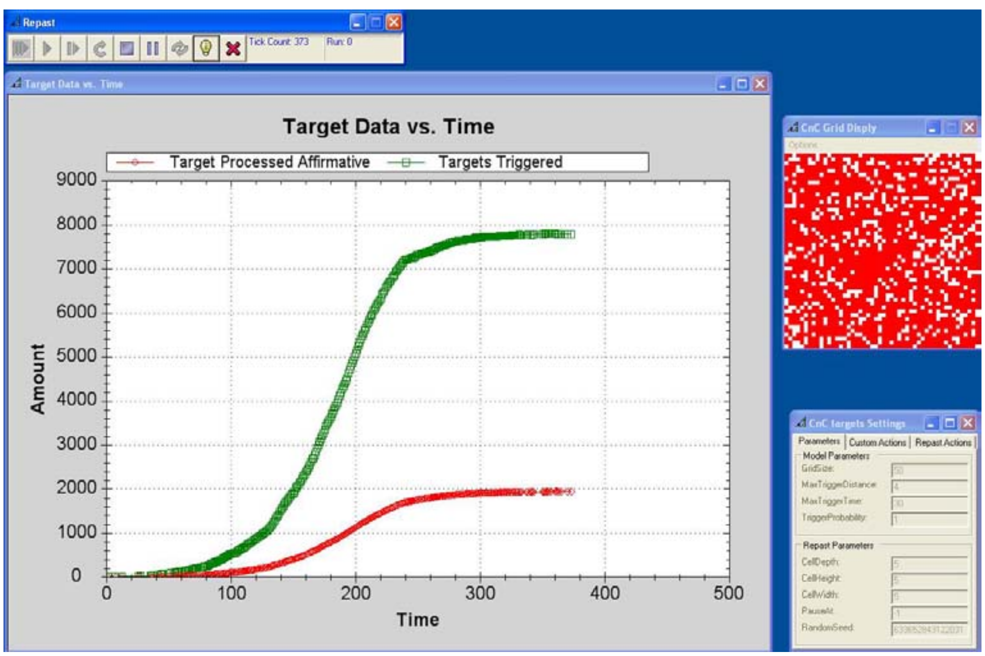

Figure 3-25: Difference in Timing between Target Detection and Processing.

3.5 CONCLUSIONS

The design of complex systems involves the management and coordination of a large number of unknown parameters that can be difficult to quantify. Parameters can arise as emergent properties from the interaction of system components. Without M&S, it can be difficult to resolve them so as to support efficient design activity and trade-off between options. M&S provides a means to explore these issues. Just as an architectural framework can help define the parameters of a system and their relationships, so the use of HVs can assist in the exploration of system concepts through Modeling and Simulation.

HVs provide a structure to help define simulations in much the same way as they are used for the development of system architectures. Conversely, M&S provides a means of testing assumptions underlying HVs and their interactions. Ultimately, one would anticipate a marriage of HVs with simulation tools so that Dynamic Views can be run through various HV combinations to allow 'what-if' testing of architectures under different operational constraints.

There exist similarities between the Probabilistic and Network Topology approaches discussed in this chapter. Both are based on an intent to use simulation models for consolidating data from various HVs. It is useful to point out that modeling solutions based on a single HV are also possible, but are not described here.

We have also discussed a range of simulation tools, (including K3, IMPRINT, IPME, MicroSAINT, OpNet, and REPAST), and modeling techniques like critical path analysis not usually associated with human factors. This broad selection is deliberate so as not to favour any one approach. The described analyses could be performed with most of these tools (if the problem was re-described to fit model requirements). The point of M&S HVs is not to demonstrate superiority of one approach over others.

The granularity of data captured in a model is a concern for any performance model. For example, to construct an IPME model, task data typically need to be defined at a specific level so that IPME's operator workload algorithms can be used. Task parameters like timing, the requirement for cognitive resources, etc., are important for an IPME model. However, not all projects require the level of performance assessment provided by IPME. It is questionable whether or not detailed level task data should be captured in the HVs at all.

As a generic modeling environment, IPME can be configured to incorporate a wide variety of HV data. How such data can be linked to operator performance predictions (e.g., how to formulate performance shaping functions for these types of data) is still, in many cases, an open research question.

A process model, on the other hand, does not require the micro-level task data, and the procedures for process mapping are likely already included in a typical system design. As a result, the process model approach tends to be more cost-effective, especially after considering the cost associated with model validations.

To sum up, the Probabilistic and Network Topology approaches can be considered complementary to each other. Each integrates a subset of the entire HVs data, and addresses different aspects of the system (e.g., performance vs. process). The selection of a particular approach depends not only on the nature of the system, but also the type of questions that need to be answered.

[Annex D, from Sweden, provides another perspective on the use of modeling and simulation for command and control environments.]

Chapter 4 – EXPERIMENTATION

4.1 INTRODUCTION

The ultimate goal of the transformation toward NNEC (NATO Network Enabled Capability) is to provide an operational advantage to the warfighter, in the form of what is known as Future Capable Forces (ACT, 2009). The development of a mature NNEC has a long way to go. The common understanding is that what needs to be done in terms of technological development is fairly well understood. The critical issues have to do with doctrine and policy, processes, and information exchange – which all involve the human. At the 2009 NATO NEC conference (ACT, 2009), Major General Gijsbers (from the Netherlands) stated that NNEC is all about people. Despite this, NNEC specifications are often formulated in technological terms. With the development of systematic and comprehensive HVs, there is now a systems engineering methodology to support the human-related NNEC elements. A challenge for positioning a HV upfront in integrated systems development is to demonstrate how human capabilities lead and drive the complex networked environments. One influential viewpoint holds that the human should not be seen merely as a limitation or as an operator pushing buttons, but instead should emphasize the human capabilities of organisation and creativity as the central driver in the network of uncertainty (McCann and Pigeau, 2000; Essens, Tanercan, Vogelaar and Winslow, 2002).

To understand complex situations and behaviours in networked operations, one needs to observe, assess, and measure the behaviours in realistic, more or less controlled, operational situations where new technologies and organisational structures are being tested. Human behaviour has dynamic, emergent properties that will be evident as they engage in complex, new work structures. Humans apply their creativity to accomplish tasks using available opportunities and facilities. Working in a network requires new skills and competencies, or will draw upon already existing competencies. Therefore, to uncover and understand networked behaviours and develop appropriate systems requirements we should develop system concepts by conducting experiments with human participants ('human in the loop' experimentation) working with prototype systems using the new work structures. Without understanding how humans operate and which new behaviours or demands emerge from the new work structures, it is difficult to realistically model, simulate, and predict future systems performance.

In most nations there are research initiatives to assess the critical factors of networked operations. Realistic experimental and exploratory studies generate useful scientific questions – if theory is still underdeveloped. Such studies are difficult to plan and implement. One can find exercises intended to experiment with NEC; however, assessment and measurement of human behaviour are usually not the primary focus and obtaining useful human performance data is difficult. More controlled laboratory experimentation relevant to NEC is also available in the literature, but there are only a few research programs looking at the human element of NEC in a systematic way. In an experiment on NEC development in joint operations in air defence, Berggren et al, 2008 (see also van Bezooijen and Essens, 2008) looked at how air defence crews interacted with networked parties to resolve operational situations. Berggren et al. tried to balance realism (military scenarios and participants) and control (experimental conditions, timed critical events, 1:1 ratio of subjects to observers). With only four crews available, Berggren et al. tried to take as many measures as possible, using multiple techniques. Although these were complex NEC experiments, Berggren et al. were interested in a systematic overview of NEC research, in particular how other researchers deal with realistic experimentation of NEC issues. They specifically addressed the status of human in the loop experimentation with NEC. Using this as a foundation, we framed our approach for the current effort. First, an example is provided that shows which human dimensions are critical for NNEC operations. Then, levels of realism and control in experimentation are discussed and a four-level categorization is proposed. Finally, literature is reviewed with respect to the categorization, the results summarized, and implications discussed.

4.2 HUMAN DIMENSIONS OF NEC

The development of information and communication networks has affected the way people interact with the world, obtain information, accomplish tasks, and work collaboratively within organizations. In military systems, the technological development began as 'automation' or 'optimization' of existing information flows in closed systems of military units. The result was faster teletype, facsimile and courier communications with little change in organizational structure or processes. The development and application of the World Wide Web made it easier to connect computers to a network and exchange information. The concept of virtually seamless coupling of systems and people, and the possibility of almost instant information push and pull of terabytes of data, triggered the NEC concept, which later was extended to NNEC in the coalition context. The major driver of NNEC transformation may not be the technical development, but the potential gain in flexibility, collaborative ability, and operational effectiveness. Applying the NNEC approach should result in:

- More appropriate and faster matching of operational capability to the dynamically evolving operational situation (including small scale, asymmetric opponents);
- Enabling virtually immediate information sharing between network entities, independent of hierarchical structure; and
- Enabling ad hoc collaboration among decision makers, helping them solve operational challenges and share resources.

In particular the last two gains reflect the critical factor in NNEC effectiveness – enabling people to use the opportunities that networked operations offer.

What kind of behaviours would typically emerge in a NNEC context? Let us first describe in more detail what a net centric operations context is. Figure 4-1 shows two military organisations for joint operations. On the left is a representation of a classic, hierarchical arrangement with vertical information flows aligned with the command structures. On the right is a networked environment in which units interact horizontally at all levels of command.

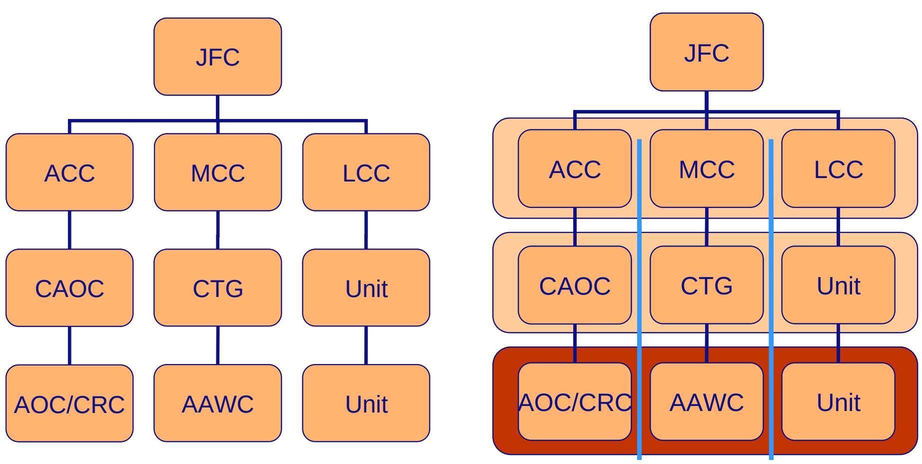

Figure 4-1: Abstract Representations of the Organisation of a Joint Operation with Air, Maritime and Land Components Commands.

The idea of NEC or networked operations is that networks connect the units at each level of command (van Bezooijen and Essens, 2008). Moreover, the idea is that units at lower command levels not only receive and provide information directly to connected units, but have also received the authority to act on it, from mission command and the operation's rules of engagement. That is, the bottom level components are not just connected to the highest level (Joint Forces Command). Formal institutions smooth the interaction between components; for example, Liaison Officers represent the commanders of other components. In addition, formal interaction plans can be developed that regulate direct interaction in operations between low-level units. The expectation for NNEC is that the operational environment's opportunities and threats can be exploited better and faster if there is:

- Direct information exchange and interaction support – the technical component;
- An ability to process and creatively integrate available information – the mental component;
- A collaborative attitude and thinking in networks – the social component; and
- Delegation of authority to act and collaborate at any level of the command chain – the organisational component.

A popular representation is the NEC value chain (Figure 4-2). This represents a chain of improvements over current work that can be achieved applying an information network. The assumption is that the availability of an information network will lead to better information sharing, better situation awareness, better collaborative decision making, and self synchronisation at the lowest levels, resulting in more effective missions.

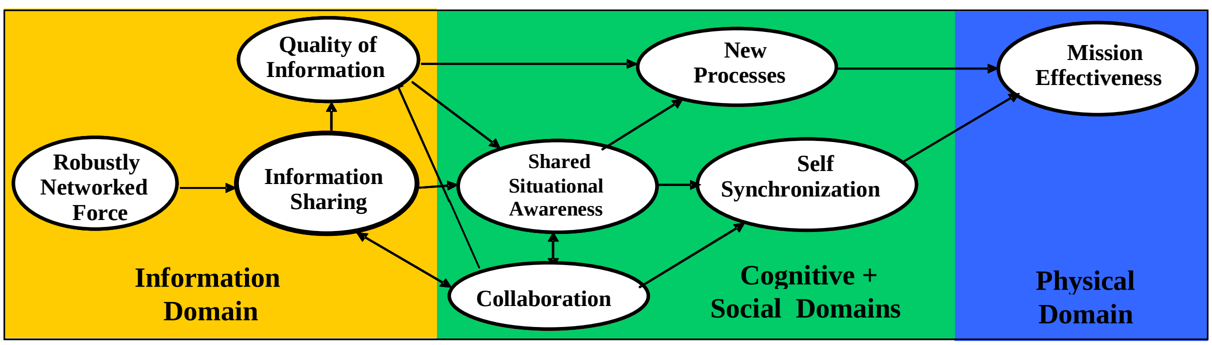

Figure 4-2: NEC Value Chain.

A number of human dimensions can be derived from these perspectives on NEC and networked operations. One dimension set relates to humans interacting with networked systems. These dimensions have been examined extensively in the human factors literature. Analyses of NEC address the complexity facing commanders and operatives resulting from networked information, networked people, and networked resources placed in ad hoc configurations (van Bemmel and Essens, 2005; Berggren, et al, 2008; van Bezooijen, Essens and Vogelaar, 2006; van Bezooijen and Essens 2007; van Bezooijen and Essens 2008a, b; Essens, Spaans, Treurniet, 2007; Essens and van Bezooijen, 2008; van de Ven, et al, 2007).

The human dimensions of NEC identified in these studies were:

- Information processing: Process large amounts of information from many information sources, filter and select information with direct and indirect relevance; search and find relevant information; combine information into integrated knowledge representations at multiple levels of command and from many sources;
- Reasoning: Reason at multiple (command) levels and from different perspectives;

- Creativity: Take initiative beyond one's own operational area in uncertain, complex situations, support initiatives from lower levels of command, provide lower levels with freedom of action and enforce if required; and
- Collaboration: Collaborate with less familiar partners, lead ad hoc groups who are sometimes distributed, bring together individuals having diverse interests to share information, align plans, while managing conflict, coping with diversity, and respecting conflicting interests.

If these abilities are well represented, then the added value and opportunities that NEC provide can best be exploited.

NNEC is a complex concept comprising multiple dimensions: technical, informational, human, and organisational. Human dimensions of NNEC can be proposed, but a true understanding of human behaviour as an emergent property of a socio-technical system requires that a working system is examined. In a literature review we looked at the state of the art in NEC research, how much research was performed, what human dimensions received the most attention and how they were measured.

4.3 EXPERIMENTATION IN NEC

Given its complexity, it is difficult to show the "value added" for NEC. For instance, providing satellite imagery to an intelligence analyst might provide the analyst with a better overview of the tactical situation, but if the analyst does have not the skills to decipher the imagery it will not add information and may lead to misinterpretation. Cooperation may better concentrate the means to effect an operation, but at the same time there is a cost to the extra communication, which might slow down the command process. Research that focuses on operational details in controlled experimental environments may help us understand how to harness the power of networked operations; however manipulated variables may prove to have unexpected effects when other factors vary. For instance, the representation of operational information from diverse sources (a so-called common operational picture) may be experimentally optimised for a particular operator. However, if other information sources are included, and the operator does not understand these, it generates different requirements for that representation. In operational contexts the integration of information sources might require completely different representations, or may require other parties to interact with the operators for interpretation. Also, since the whole is qualitatively different from the collective of the elements, the interactions are critical in this respect. In NEC the best arrangement of system boundaries is not yet well understood. Applying the results of experimentation to real network operations requires careful consideration of the impact of what was left out of the experimental design.

In an earlier study on C2 assessment, Rasker, Essens, and van Bezooijen (2008) discussed the issues involved in conducting scientific research in an operational context. Military practitioners might think that scientific rigour is something that scientists want for academic reasons. In fact, many studies have solved applied problems in laboratory conditions with high experimental control. Reduced control in operational conditions may be less valuable and less relevant for scientific understanding. Further, military practitioners may fail to see the importance of systematic manipulation of variables across a range to validate the robustness of an effect. Even the meaning of the term 'experiment' is confused: the experiment as a highly scientifically controlled setting versus the experiment as a demonstration or proof of concept. Both have their value, but for developing understanding of new, complex systems intermediate forms may be needed to bring practitioners and scientists together. At one side practitioners need to appreciate that certain scientific conditions are required to elevate the results above the incidental, at the other side laboratory-oriented scientist need to understand that certain operational conditions are required to capture the complexity of real socio-technical systems. To capture this distinction we propose four classes of NEC research: Lab, Lab+, Field+, Field (see Table 4-1).

Table 4-1: Definition of Levels of Experimentation and Selected Requirements

	EXPLORE	EVALUATE	EXPLAIN	PREDICT
Lab			Greater impact on: – Abstract scenario's (stimuli) – Large number of subjects – Balanced conditions	
Lab+		Greater impact on: – Systematic comparison multiple conditions – Model based hypotheses	Some impact on: (cause-effect relationships) – Model based hypotheses – Multiple conditions – Controlled scenario's – Performance and effectiveness measurement – Deep interviews/ questionnaires Greater impact on: – Representative set of subjects – Multiple conditions, random allocation – Repeated measurements	Some impact on: (prove cause – effect) – Predictive models – Controlled learning curves
Field+		Some impact on: – Base line measurement – Specific scenario events and scenario selection – Multiple measures; systematic observations – Expert opinions Greater impact on: – Comparison of few conditions – Balanced groups – Repeated measurements – Measurements before, during, and after – Structured interviews/ questionnaires – Multiple observers – Multiple representative scenario's – Coupling scenario events with defined behaviours		

	EXPLORE	EVALUATE	EXPLAIN	PREDICT
Field	Some impact on: – Guided access to all information, processes and operators – Insight in the scenario events – Semi-structured observations – Judgements of multiple domain experts – Existing assessment reports			

A 'Field' study is often characterized by the lack of control the researcher has. The challenge in such uncontrolled situations is to identify the constants and go beyond the accidental and anecdotal. 'Field+' is the setting in which some level of control is introduced intentionally while maintaining the naturalistic processes. In a Field+ setting, experienced operators are able to perform the tasks using their experience and expertise. The typical student subject would lack the skills to perform the tasks adequately. 'Lab' at the other end of the scale has maximal control but lower realism in tasks or stimuli. This allows for the manipulation of specific variables to examine fundamental, underlying mechanisms. A 'Lab+' study allows more complexity in stimuli and tasks, while relinquishing some experimental control. For a Lab+ study, the untrained student subject can perform the task (possibly requiring training). For Field+ and Field studies, domain specialists are needed. Whereas Lab+ differentiates from Field+ in the setting and the level of control that is possible, it is the Field+ that has the most face validity with the NEC community. For NEC experimentation, in general, we are most interested in analyses from Lab+ and Field+ settings, and well-documented Field studies because those are the ones that focus on realistic tasks.

Table 4-2: Categorization of Experimental Set-Ups

	Lab	Lab+	Field+	Field
Minimal Experience of Participants in Relation to the Experimental Task/Scenario	Naïve	Naïve	Experienced	Experienced
Experimental Task/ Scenario	Abstract tasks	Realistic task with abstract elements	Realistic field task	Normal operation or deployment
Control	Maximum	Good	Some	None
Realism	Low: Abstract stimuli	Representative: Scenario-based	Realistic: Scenario-based	Very high: Natural development

4.4 METHOD

A good source for NEC research literature is the International Command and Control Research Symposia (ICCRTS) organized by The Command and Control Research Program (CCRP) sponsored by the US Assistant Secretary of Defense. The maturity of human-relevant NEC research has improved with the increasing number of experimental studies over the years since the initial concepts were described (Alberts, Garska and Stein, 2000).

Therefore, we started the survey by reviewing each paper published in the last five years of the CCRP Proceedings. In a second round, a broader literature search was done by HFM-155 members (data up to October 2008). The following selection criteria were used:

- Reference to working in a network, NEC, or versions of that term.
- Measurement or description of human behaviours.
- Experimental setup or field study.

When there was more than one article describing the same experimental data, only the more extensive one was selected. Papers that did not include an analysis or reference to working in an NEC or networked operations environment were not selected for our analysis.

Each selected paper was analysed using eight questions:

1) What was the focus of the research?
2) What was the experimental classification (Lab, Lab+, etc.)?
3) What independent variables were manipulated?
4) What dependent variables were measured/observed?
5) What measurement instruments were used?
6) What scenarios were used?
7) Was a synthetic environment used? If so, what type?
8) What was the main conclusion?

Additional (telephone) semi-structured interviews were held (November – December 2008) with six prominent human factors researchers in applied military research from diverse research organizations in Australia, Canada, Netherlands, Sweden, Untied Kingdom, and the United States. The intention was to match these data with the literature data and to get insight in current activities and strategies in NEC research. Five questions were asked in the interview:

1) What are your research plans with respect to Human Factors issues in Networked Enabled Operations?
2) What type of research questions will you answer?
3) Where will you conduct your experimentation?
4) How much control do you have over field experimentation/exercises?
5) What type of methods or instruments do you use?

4.5 RESULTS

In total 750 papers were reviewed by the closure date (September 1, 2008). After selection, 38 of these matched the criteria. The results from Questions 2 – 7 are presented in the following paragraphs. Responses to Questions 4 and 5 and Question 6 and 7, respectively, were similar, and are reported together. Annex E contains the bibliography for those 38 papers.

4.5.1 Survey

4.5.1.1 Types of Experimentation

In Table 4-3 the clustering of studies by the Lab, Lab+, Field+ and Field classification are presented.

Table 4-3: Categorization of Relevant Studies on NEC Experiments (With Total Number of Identified Studies)

Lab	Lab+	Field+	Field
Bakken and Gilljam (2003) Dorneich et al. (2004) Dowse and Lewis (2007) Eggenhofer et al. (2008) Galster and Bolia (2003) Swan et al. (2003)	Artmann (1999) Chong et al. (2008) Drozdova (2008) Duncan and Jobidon (2008) Galster and Bolia (2004) Leweling and Nissen (2007) Lichacz (2005) Lospinoso and Moxley (2007) MacKinnon et al. (2007) Ruddy (2007) Smith (2008) Thomas (2008) Wright and Kaber (2003)	Adelman et al. (1998) Bezooijen and Essens (2008) Bowman and Thomas (2008) Bowman (2007) Cheah et al. (2007) Crebolder et al. (2007) Fielder, Baker, Winters (2006) Graham et al. (2004) Hazen et al. (2007) Hutchins et al. (2007) Klein et al. (2007) Luck et al. (2006) Shattuck and Woods (1997) Staal (2008) Thomas et al. (2007)	Adkins et al. (2008) Gonzales et al. (2005) Office of Force Transformation (2005) Warne (2008)
6	**13**	**15**	**4**

The following observations were made and conclusions drawn:

- A substantial number of papers not selected referred to or were about NEC or networked operations, but merely discussed theoretical issues or methodological instantiations and did not provide data on observed or measured behaviours.
- Lab+ and Field+ categories were most frequent.
- Lab studies (with naïve participants and abstract stimuli) that address human dimensions of NEC are apparently limited. This may reflect our limited understanding of NEC-related human behaviour, and the complexity of associated systems. Thus, focusing on one aspect of the network will provide little insight into the dynamics of networked operations.

- We propose two reasons for the low number of field studies. One is that access to realistic settings is difficult and costly to organise. Second, when access is granted, it is often in the context of an exercise having a different purpose (e.g., training, technology assessment). Thus, for training exercises, activities might be interrupted to provide feedback for participants. For testing new technologies, software, or tools, participants have not had much prior experience with the procedures, and so even though the participants may be skilled they are not performing their tasks in the usual way.

4.5.1.2 Independent Variables

Independent variables were placed into one of the following categories:

- Organizational structure;
- Information availability;
- Technology availability;
- People (skills and competencies); or
- Scenario/process.

Table 4-4 shows the results of the classification.

Table 4-4: Categorization of Independent Variables (Multiple Occurrences Noted in Parentheses)

Type	Lab	Lab+	Field+	Field
Organizational Structure	– Organizational design edge vs. hierarchical – Reward structure – Distributed vs. co-located	– Organizational design edge vs. hierarchical (6) – Organizational component structure	– Physical distance and social network distance – Distributed vs. co-located (2)	– Organizational structure (2)
Information Availability	– Information quality – Information availability (2)	– Information acquisition, assessment and decision support – Opponent postures, reliability – Information architecture (2)	– UAV sensor information (4)	– Net centric command decision service – Availability of specialized service – Information-centric concept of operation
Technology Availability	– Communication availability – Sensor coverage	– Visual range – Remote C2	– Interoperability of C2 system	
People (Skills and Competencies)	– Trust	– Demographic characteristics	– Communication skills – Team maturity	– Types of skills
Scenario/ Process		– Task difficulty – Opponent postures – Different vignettes, to correlate SA and confidence – Different effect based planning processes	– Different possibilities to complete a mission – Number and speed of events	

The following observations were made and conclusions drawn:

- Most experimentation appears to consider relatively small changes in technology and/or information availability, organizational change or scenarios in which a system will be used.
- Many older studies are focused on the availability of information and its effect on performance. More recent studies address organizational concepts rather than technology (e.g., ad-hoc teams, social networks, and organizational structures).
- Only a few studies address participant skills or competencies as independent variables.
- Several of the Field and Field+ categorized studies have no systematic variations of independent variables. In these experiments, a realistic scenario is used to study an organisational arrangement or clarify effects, without comparing two different conditions.

4.5.1.3 Dependent Variables

The dependent variables identified in Table 4-5 were classified as process-related or outcome-related variables (with reference to Command Team Effectiveness model; Essens et al., 2005). Outcome variables address the achievement of an end state or goal; process variables address the processes towards an outcome. For instance ‘information exchange’ is a process variable useful for achieving effective operations. Subcategories included task-focussed and team-focussed process measures, and task-focussed and team-focussed outcome measures, as well as individual measures.

Table 4-5: Categorization of Dependent Variables (Multiple Occurrences Noted in Parentheses)

Type	Lab	Lab+	Field+	Field
Task Focused Process Measures	– Strategy changes	– (Shared) situation awareness (4) – SA of commander's intent	– (Shared) situation awareness (6) – Decision making processes (2)	– (Shared) situation awareness (2) – Decision making processes – Individual sense-making
Team Focused Process Measures	– Team effectiveness and efficiency	– Information exchange (4) – Organizing activities – Team effectiveness, coordination – Communication (3) – Knowledge sharing (3) – Information richness	– Quality and number of communications (2) – Team awareness – workload (2) – Balanced roles and responsibilities – Team work – Self synchronisation (2) – Information exchange – Team collaboration, based on speech turns	– Team collaboration (2) – Information exchange – Information gathering and sharing – Communication – Interactions (2) – Shared-sense making – Degree of networking
Task Outcome Measures	– Time – Outcome and time (2) – Performance, # trials	– Outcome and time (5) – Outcome (3) – Team performance – Time	– Team performance (2) – Information quality (3) – Task performance (3) – Cost and availability of training – Response time and lag	– Quality of information – Task performance – Force effectiveness – tempo/agility/ synchronization (2)
Team Outcome Measures		– Confidence (2) – Trust (2)	– Trust (2)	
Individual Outcome Measures	– Workload, stress, arousal	– Military Development Score – Leadership – Workload – Learning	– Orders and intent, thinking aloud – Workload (2) – Competency – Trust in organization, process and technology – Narrative capture, afterwards	– Trust in system – Skills and competencies

The following observations were made and conclusions drawn:

- In general, there was more focus on process than on outcome measures. In many cases, it is assumed that task performance will be improved if processes are performed better.
- The number of (and variation among) dependent variables for an experiment increases from Lab to Lab+ to Field+ to Field.
- In Field+ and Field categories there is more use of subjective ratings made by expert observers.
- A small portion of the outcome measures are directly linked to military force effectiveness. In many cases, it is assumed that military force effectiveness will improve when outcomes or processes are

better. In earlier studies the assumption was that mission effectiveness should increase when task performance improves. In more recent studies the relation between mission effectiveness and task performance is examined.

4.5.1.4 Scenarios, (Synthetic) Environments, and Instruments

The final categorization (Table 4-6) was organised according to scenario, synthetic environment, and instruments used.

Table 4-6: Categorization by Scenarios, Synthetic Environments, and Instruments (Number of Occurrences in Parentheses)

Type	Lab	Lab+	Field+	Field
Scenario	1 Bargaining game 1 Trust game 1 Boat game 1 Mental rotation task 1 Robot game 1 Humanitarian task 1 Raid on objective scenario 1 Abstract problem solving	7 Counter terrorist scenario 1 Theatre defence task 1 GAAT scenario (military) 1 Robot game 1 Fire fighting 1 Pre-crisis situation 1 Coalition stabilization mission	1 Plan-execute-plan execute cycle 2 UGV terrain exploration 1 Personnel recovery mission 4 Air defence/warfare 1 Brigade operation (development of tactical operation orders) 1 Peace enforce scenario 2 Coalition convoy escort operation (UAV supported) 1 CTF NRF collaboration 1 Military planning 1 Homeland intelligence (threat) assessment 1 Heliborne operation 1 Maritime interdiction operation	1 Real command periods for Air Force ops 1 Middle East deployment 1 Coalition force operation during OIF 1 Small-scale contingencies scenarios
Synthetic Environ-ment	1 ELICIT 1 Air war game 1 specialized software 4 Dedicated programmed (virtual) environment	7 ELICIT 3 Dedicated programmed (virtual) environment 1 CPOF 1 Air war game 1 Paintball arena	8 Simulation exercise 1 Commercial gaming environment 1 Training simulator 1 Specialized program 2 Virtual battle experiment environment 1 ForceMate	2 Operational exercises 2 Deployment
Instruments Used	1 Questionnaire 2 TLX 5 Log files / Automated scenario event or outcome counting 1 IPA scale (team comms patterns) 1 Body physiology	7 Questionnaire 1 Demographic survey 5 Observation/ rating 2 Interviews 3 Comms log files 10 Log files / Automated scenario event or outcome counting 1 TLX 1 3D SART 1 Stopwatch	4 TLX 10 Questionnaire 5 Comms log file 4 Log files / Automated scenario event or outcome counting 5 Observation/rating 1 Body physiology 2 Think aloud protocols 1 QUASA method to measure SA	3 Questionnaire 2 Log files / Automated scenario event or outcome counting 3 Interviews

[Table 4-6 acronyms: CPOF = Command Post of the Future, CTF NRF = Coalition Task Force/NATO Reaction Force, ELICIT = Experimental Laboratory for Investigating Collaboration, Information-sharing and Trust, GAAT = General Agreement on Tariffs and Trade, IPA = Interaction Process Analysis, OIF = Operation Iraqi Freedom, QUASA = Quantitative Analysis of Situational Awareness, SART = Situation Awareness Assessment Technique, TLX = Task Load Index, UAV = Uninhabited Aerial Vehicle, UGV = Uninhabited Ground Vehicle]

The following observations were made and conclusions drawn:

- The measurement of dependent variables was not standardized, except for workload measures (TLX).
- A large range of measurement tools (used in one single experiment) was used for in Lab+ and Field+ studies. Lab studies used a small number of dependent variables. For Field studies, the constrained methodology limited the use of measurement tools. Thus, most data are gathered using interviews and observations.
- Only a few scenarios were used in more than one experiment. An exception, however, is the counter terrorist scenario that is used in the ELICIT environment. We offer two explanations for this limited re-use. Scenarios in Field and Field+ or were participant-specific, and therefore cannot be used more than once. Most NEC research programs started recently; only the first results of these programs are published. We expect more re-use of scenarios in future publications.

4.5.2 Interviews

The summaries from the six interviews are as follows:

1) *Research Plans in NEC*

   Research plans in networked operations address:

   - Human-human collaboration;
   - Effects of organisational structures on collaboration; and
   - Thinking and decision making in complex, multi-dimensional, situations.

   Also, the closer connection between or integration of particular military functions is mentioned, in particular of command and control and intelligence.

2) *Type of Research Questions*

   Research questions typically address:

   - Effective collaboration; how to measure it real time; and how it can be developed ‘on the fly’ while in operation;
   - How trust develops over time;
   - The perception and understanding of complex situations, nature of effects, other perspectives;
   - What good and bad decisions are; how we can train and support people to make better decisions; what the individual characteristics contribute; and
   - Effects of organisational structures and culture.

3) *Research Environment*

   There is agreement that understanding human behaviour in networked operations requires realistic field experimentation in complex, distributed environments. A common view is that field observation provides insight into emergent behaviours, and more controlled experiments can take the resulting concepts and test the underlying mechanisms. Modelling could provide additional insights difficult to achieve in natural situations.

An alternative strategy was proposed: The development of realistic, dynamic, interactive games with sufficient complexity. With games and simulations, one can create situations where one person or a small team cannot cope with a situation's complexity and must engage in collaborative decision making processes to mentally model the situation and reach a decision.

Some 'field laboratory' environments provide a good mix of complexity and control. Some suggested a sequential process in which data are collected in Field settings, and then Field+ or Lab+ experimentation is conducted. Scenarios should be developed in collaboration with operationally experienced domain experts, and should last 2 or 3 days, not just a few hours. Experimentation would benefit with international collaboration. The concentration of effort might overcome national budget limitations and might accelerate our understanding of human behaviour in NEC. Field observations and experimentation should be more appreciated by academic researchers as a valuable data source. However field data and methods are not highly valued there. We suspect that if it was more appreciated our understanding of NEC and associated theoretical developments would proceed more quickly.

4) Control in Field Experimentation

The common experience is that there is virtually no control in field experimentation or exercises. Even in military field laboratories the control is often limited to scenarios; the settings are designed for other or multiple purposes, and will usually not allow for replicable situations.

5) Methods or Instruments

Standard techniques are used, like questionnaires (individual background, attitude), observational techniques (what did they do) and cognitive interviews (what did they think). Communications during exercises are recorded and analysed semantically in automated fashion (based on words, or parts of sentences). Measures of the sociological characteristics of teams and team members, and questionnaires to assess trust between team members have been developed and used. Multidimensional measures (e.g., 'star plot') have been developed to assess operator behaviour on four dimensions, viz., on the sensory, tactical, operational and strategic level.

There is a need for less intrusive, automated instruments that could measure the level of communications among staff members on the fly, or measure how social networks are used. There has been a development of team or staff effectiveness (such as the NATO Command Team Effectiveness instrument; Essens et al, 2005, 2009) which are being increasingly used in field experimentation and exercises. The translation and validation of instruments for national application is a challenge. Despite the widespread use of English, a native language is preferred if non-technical topics (collaboration, trust, or morale) are assessed.

4.6 CONCLUSIONS AND RECOMMENDATIONS

We were interested in obtaining an overview of NEC research, and examining how other researchers conduct realistic experimentation on NEC issues. In our overview we identified thirty-eight published experiments or case studies that focus on the human dimension of networked operations or NEC. The number of identified papers is relatively small, and although we looked carefully, we cannot claim to have been exhaustive. Some studies may not have been published in the open literature. Case studies may appear as internal (defence) reports, and are sometimes classified. We did not evaluate a study's quality. It was good to see that there is a large number of what we have called Field+ studies. These combine realism and control, and should elevate the observations above the accidental.

There were relatively few lab studies, which may reflect the state of NEC theory. Interviewed researchers maintained that the basis for theory should come from observational field work where behaviours emerge in complex situations. From there, critical human-dimension factors and their interactions can be identified, abstracted, and tested in Lab+ or Lab environments. In addition to experimental studies, meta-studies that integrate experimental findings would also be useful.

The potential for discord between the scientific method and operational practice in military exercises is not merely a faulty impression. There seems to be a strongly-rooted dichotomy that is not easily bridged. It hinders however the development of improved assessment, and well founded investments in new organisations introducing new technologies. The HV in this report will help bridge this dichotomy.

Interestingly, studies from the information domain (e.g., what information to add and how) provided insight to the social and organisational domain (e.g., how can collaboration be improved/supported). In networked operations collaboration is the major force multiplier. It is not just 'getting the right information to the right person at the right time in the right format'. That maxim suggests the existence of a master plan that knows who is who and who wants what. This is not possible (or at least an operational challenge) in a complex, dynamic, adaptive system. Rather, to share information one needs to know what other parties might need and dynamic interaction to exchange information among relevant parties. The basis for this is collaboration and social networking. Information processing in complex operations remains an issue. There still seems to be too much information to process, and the communications network makes it worse. Effective collaboration and use of the social network may help solve these issues.

There are many measures and instruments available to assess performance. As the interviews showed, more automated data collection tools are needed to provide fast feedback. On the other hand, more holistic measures need to be developed, such as metrics for the effectiveness of staffs and organisations (NATO HFM-163 is addressing these questions). It is important that these instruments are applicable and usable during the operation or exercise, so that immediate feedback can be given. This may also improve the appreciation of scientific contributions to the exercise.

Synthetic environments provide particular settings for eliciting behaviours, and there are many different synthetic environments that can be used. On the other hand it can be useful to have well-studied environments where the particulars are well understood (e.g., ELICIT). To develop others will require international collaboration, because the effort to develop relevant synthetic environments for experimentation is extensive and therefore expensive.

The interviews provided a useful adjunct to the literature review. In particular the focus on the development of complex Field+ and Lab+ (gaming) environments to address complex issues is noteworthy. We can expect more studies that examine the human dimension of NEC and are relevant to the development of NEC theory. The development of more advanced NEC measurement instruments is likely. Given NEC's dynamic nature and the ad hoc nature of teams and organisations, we expect that 'on the fly' measures, direct feedback, and interventions in communication and interaction processes will be important.

Scientists should find better ways to provide direct scientific value for military exercises and operations. There is no ready-made solution, but in our experience, one needs a strong stakeholder to achieve this. In the perfect world, the scientist should be ready to deliver an assessment at the same rhythm as the military work takes place. If successful, valuable data from Field and Field+ studies could improve NEC theory and inform the design of Lab+ and Lab studies.

Chapter 5 – RECOMMENDATIONS

The goal of the HFM-155 Task Group was to focus on human-centric aspects of NEC and to use HSI processes and methods to identify, define, and document a solution to the challenges faced by NEC decision-makers. The NEC environment is highly uncertain and unpredictable, with coalition forces and multiple distributed units, operating Network-based with limited resources. HFM-155 outputs can help ensure that the human component is adequately considered in NEC capability development.

HFM-155 took a three-pronged approach to NEC human centric development:

1) An "HV" method was developed to inform defence system architecting and engineering processes for NEC;
2) Modeling and simulation approaches to address HSI issues in NEC were demonstrated; and
3) Human-in-the-loop experiment options and metrics were recommended to support NEC equipping decisions.

Draft characteristics and parameters for an HV component were developed to augment the systems architecture products required of system engineers responsible for the design of defence programs. Different modeling methods and simulation environments where human-system behavior could be evaluated at different tiers of information were explored. A taxonomy for different types of experimentation was developed, and extant NEC-related studies were classified.

HVs provide a means by which HSI activity is represented in systems engineering design and development. This provides an opportunity for the human factors engineer to 'talk the language' of the systems engineer. Some human-related considerations formerly deemed 'non-functional requirements' can now have an expression in systems engineering terms. We make three primary recommendations:

1) HSI activities, across all domains, should be described in terms amenable to HVs. This should not impose additional burden on the various domains and should allow conventional representations (e.g., diagrams, tables) to be included in the Data Repository (Figure 1-1) for consideration in the appropriate HVs. This would not only improve communication of recommendations and information from different HSI domains to the systems engineering community, but should also support communication among the various HSI domains.
2) System engineering should incorporate HVs into current practices surrounding Architecture Frameworks. This would provide an opportunity for the 'non-functional requirements' that often describe human factors to be given greater focus and attention.
3) In addition to proposing changes to the communication between HSI and systems engineering, the report suggests integrated roles for M&S and experimentation as vehicles for testing, exploring and developing operational concepts that have strong human factors foundations. This would not only require traditional approaches, but would ultimately see novel developments by which HVs would become central to experimental design or model specification.

The challenge for designing NEC capability is to achieve the proper mix of innovative technologies, organizational changes, and new human competencies to obtain the desired end state. NEC technologies assume quick and easy access to more information, better information quality, and near real-time shared understanding. The net result should be improved decision-making. The tools provided by HFM-155 should help capture HSI for NEC systems. The panel has provided methodologies on how to better consider the human in acquisition and engineering of NEC, how to visualize the integration of technology and human/social systems, and recommendations for better specifying operational requirements. By using an HSI approach, through the HV architecture, M&S options and the value of various experimentation techniques, NEC has the potential to expand the options available to Joint and Coalition force commanders so they can build and lead a networked, jointly integrated, power projection force.

Chapter 6 – REFERENCES

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Annex A – TECHNICAL ACTIVITY PROPOSAL (TAP)

ACTIVITY	RTG	Human Systems Integration for Network Centric Warfare											TBA
Activity REF. Number	HFM-155/RTG												
PRINCIPAL MILITARY REQUIREMENTS	1	2	3	4	5	6	7						
MILITARY FUNCTIONS	1	3	4	6	7	9	11	12	13	14			
PANEL AND COORDINATION	HFM												
LOCATION AND DATES	TBD												Open
PUBLICATION DATA	TR						2007				TBD		
KEYWORDS	Human Systems	Human Factors					Ergonomics				Human-Machine		
Coalition Systems Design													

A.1 BACKGROUND AND JUSTIFICATION (RELEVANCE TO NATO)

FORCEnet is the Navy's focus on Network Centric Warfare. It is an operational construct and architectural framework in the Information Age. It integrates Warriors, Sensors, Networks, Command and Control, Platforms, and Weapons into a networked, distributed combat force. It is the core of warfighting transformation to make NATO Network Enabled Capability (NNEC) an operational reality. NCW will support Joint and Coalition transformation by delivering new military capabilities that will greatly expand the sovereign options available to Joint and Coalition force commanders with the goal of building a networked, jointly integrated, power projection force. FORCEnet is recognized as the "glue" that will allow the application of Information Technology (IT) as a force multiplier for all other activities given effective Human Systems Integration.

A.2 OBJECTIVE (S)

Identify coalition human systems engineering data and processes to support the application of HSI techniques in developing and analyzing systems and doctrine, in order to influence their design and re-entry into the forces as more effective, human centric systems. Specifically our objectives are to:

- Establish a common framework to define the challenges and opportunities presented by NNEC as it is incrementally implemented throughout NATO, from the perspective of human systems integration.
- Align the work of the NATO nations across the spectrum of experimentation (laboratory to CDE) to coordinate, collaborate, and share HSI results.
- Conduct a cooperative technology demonstration on HSI and NNEC concepts.
- Explore interoperability and reuse of metrics and measures that support effective NNEC implementation and instantiation.
- Promote incorporation and adoption in the nations of the defined HSI NNEC-focused processes, tools, and activities through educational and learning activities.

A.3 TOPICS TO BE COVERED

Knowledge Engineering; Problem Solving behavior (Individual and Team); HSI design criteria, methods, and techniques; Training; Error Prevention; HSI/HCI metrics.

A.4 DELIVERABLE (E.G., S/W ENGAGE MODEL, DATABASE) AND/OR END PRODUCT

Technical Report, which includes the development of a common framework to define the challenges and opportunities that NNEC presents from a HSI perspective. Including also the identification of what impact the NNEC concept will have on the current state of HSI knowledge and capability.

A.5 TECHNICAL TEAM LEADER AND LEAD NATION

Ms. Dee Quashnock , SPAWAR San Diego, USA.

A.6 NATIONS WILLING TO PARTICIPATE

USA, NLD, GBR, DEU.

A.7 NATIONAL AND/OR NATO RESOURCES NEEDED (PHYSICAL AND NON-PHYSICAL ASSETS)

None.

A.8 RTA RESOURCES NEEDED (E.G., CONSULTANT FUNDING)

Access to RTO New Wise Workspace, Consultant Funding, Editing and Disseminating Final Report.

Annex B – TERMS OF REFERENCE

Human Systems Integration for Network Enabled Capability (Task Group HFM/ET-062)

References: HFMP, 2005/2007 Program of Work, approved TAP at 15th PBM. June 2005.

B.1 BACKGROUND

As the Militaries of NATO transform to a more networked, integrated capability of sensors, networks, command and control, platforms, and weapon systems, it is important to understand and effectively support the warfighter's role in these emerging distributed, scalable defence concepts. Throughout NATO, the transformations have different labels and some slight differences in definition, but there are commonalities which all NATO countries support. The Exploratory Team (ET) strongly supported the need for such a focused Research Task Group (RTG) effort. The ET went on to describe each of their national interests that supported the need for wide-spread coordination and cooperation.

For example, in the United Kingdom Networked Enabled Capability (NEC) is "… about the coherent integration of sensors, decision-makers, weapon systems, and support capabilities … (it) has implications for both the operational and non-operational environments…it will enable Shared Situation Awareness (SSA) and distributed collaborative working …" [NEC Handbook – JSP 777 Edn 1, 2004] In Canada, the Network Enabled Operations (NEOps) is "a concept that has the potential to generate increased combat power by networking sensors, decision makers and combatants to achieve shared battlespace awareness, increased speed of command, higher operational tempo, greater lethality, increased survivability, and greater adaptability through rapid feedback loops". [CF Strategic Operating Concept, 2004]. Canada states that "NEOps will offer the means to improve the ways that people throughout the system (i.e., the soldier, the diplomat, and the developer) work together, promoting information sharing and greater cooperation in a variety of defence, diplomatic and developmental contexts." [DRDC Toronto No. CR-2005-162, May 2005] The US, on the other hand, approaches network-centric operations as an operational construct and architectural framework for warfare in the information age which integrates warriors, sensors, networks, command and control, platforms, and weapons into a networked, distributed combat force, scalable across the spectrum of conflict from seabed to space, from sea to land. Regardless of the overall emphasis, the common set of tenets about network-centric operations are [CCRP- Power to the Edge, 2003]:

- Development of a robustly networked force improves information sharing.
- Information sharing and collaboration enhance the quality of information and shared situation awareness.
- Shared situational awareness enables self-synchronization.
- These, in turn, dramatically increase mission effectiveness.

The expectation is that network-centric operations will greatly expand the sovereign options available to Joint and Coalition force commanders – with the goal of building a networked, jointly integrated, power projection force.

The challenges then are the proper mix of innovative technologies, organizational changes, and new behaviors or competencies that will combine to achieve the desired end state. Technologies are oriented towards easy and quick access to more information with the assumptions that the information will be better and that there will be shared understanding and shared situation awareness, improved and faster decision-making, and better command, control and coordination of forces to achieve the commander's intent. What is unclear, of course, is whether or not the organizational changes and the human behavior adaptations needed to take full advantage of these new capabilities enabled by the transformation technologies are achievable.

Human Systems Integration (HSI) integrates human capabilities and limitations into system definition, design, development, and evaluation to optimize total system performance in operational environments. It is part of the total systems engineering approach to analysis, design, development, and testing. HSI has been defined as the integration of domains of personnel (skills), manpower (workload), training, human factors engineering, safety, survivability, and habitability to inform trade-offs during the systems engineering process. Increasingly, issues of organisation are being seen as integral to HSI, although there is still some debate about practical boundaries here. It is envisioned that the RTG will help to define some realistic boundaries.

The goal of ET-062 is to focus on those aspects of networked enabled capability and operations that are human centric and to use the processes and methods afforded by HSI as the means to identify, define, and document a solution approach for challenges faced by key decision-makers in the Defense enterprise (e.g., warfighters, policy-makers, capability specifiers, acquisition managers, system engineers). This solution approach includes appropriate focusing on the human-network issues in design as well as acquisition.

B.2 OBJECTIVES

B.2.1 Introduction

For the purposes of this TOR, the Task Group agreed to adopt the recently endorsed term NATO Network Enabled Capability (NNEC) which will align with the Studies, Analysis, and Simulation panel proposal for a follow-on group to SAS 050. NNEC, thus, will embody the common concepts described above. In this broader definition it includes not only warfighting but also public security and peacekeeping operations that require significant interaction with non-military organizations. In addition, the work of the HFM ET-063, which is exploring, defining and developing human performance concepts and metrics will be leveraged by the ET-062 Task Group; that is, the work of the panel will include, and not duplicate the work of the Human Performance ET-063.

The knowledge and perspective that is provided by the integration of a broad range of human disciplines will be critical to ensure that NNEC realizes its potential as a force multiplier. These disciplines include not only traditional HSI domains but also broader socio- and organizational elements (e.g., exploration of the characteristics of agile organizations or consideration of culture as a key component of implementing NNEC).

B.2.2 Scope

The Task Group agreed to the:

- Effective exchange of information across organizations;
- Development a common frame of reference within which various organizations can collaborate, coordinate, and compare their work and results; and
- Streamlining and standardization of the development, implementation, and reporting of HSI components of NNEC.

The Task Group agreed to focus its efforts on: Processes (HSI challenges in implementing NNEC), Experimentation (opportunities, whether in the laboratory or in Concept Development and Experimentation (CDE) exercise, to assess those HSI challenges), Metrics (HSI measures and methods that sufficiently quantify NNEC concepts), and Education (identification and sharing of best practices from countries successfully integrating the HSI processes in NNEC).

The objectives of the Task Group are to:

- Establish a common framework to define the challenges and opportunities presented by NNEC as it is incrementally implemented throughout NATO, from the perspective of human systems integration.
- Align the work of the NATO nations across the spectrum of experimentation (laboratory to CDE) to coordinate, collaborate, and share HSI results.
- Conduct a cooperative technology demonstration on HSI and NNEC concepts.
- Explore interoperability and reuse of metrics and measures that support effective NNEC implementation and instantiation.
- Promote incorporation and adoption in the nations of the defined HSI NNEC-focused processes, tools, and activities through educational and learning activities.

B.2.3 Products

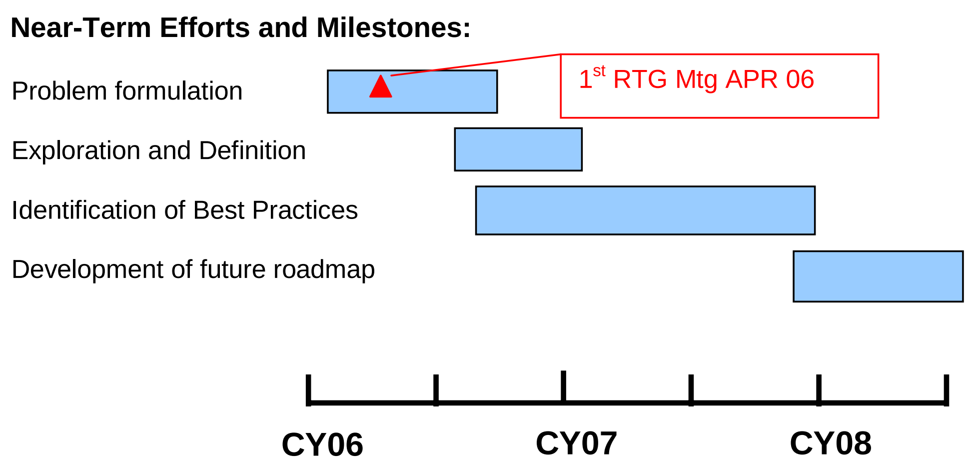
Consistent with the objectives, the products of the Task Group will include:

- Development of a common framework to define the challenges and opportunities that NNEC presents, from a HSI perspective, including the identification of what impact the NNEC concept will have on the current state of HSI knowledge and capability.
- As NNEC evolves, the current hierarchical nature of military organizations and military responses to events are changing. Concepts such as disbursed and distributed decision-making supports single warfighters as nodes on the network effecting employment of resources and assets. This imposes a different operational structure and organizational process then is currently implemented. Decision-centricity, decision superiority are stated as goals for this, but it is not clear how this will be implemented in a NNEC environment.
- Information overload is always assumed as the technology to identify and collect data improves. In NNEC, information access and availability is the key. More, however, does not necessarily mean better. Effective solutions and approaches that consider factors of degraded nodes, limited access (bandwidth, speed, delivery device constraints), and information assurance need to be addressed.
- A list of experimental concept development activities and opportunities within the participants' sphere of influence that can be aligned with the HSI-NNEC challenges.
- For experimentation, it will be necessary to realize that a continuum, from human-in-the-loop simulations using laboratory facilities to a technology demonstration and evaluation. A primary target for the results is the Atlantic Command Transformation (ACT). Working with ACT, it is planned to conduct focused demonstrations/experiments to address ACT issues/concerns.
- Experimental efforts to refine, develop, test, and measure various operational and organizational constructs are critical components to developing and applying new theories, concepts and even processes. For example, NNEC concepts such as "self-synchronization," distributed organizations (including so-called "reach-back" constructs) and commanders' intent are widely used but not well

understood. In order to truly understand, validate and effectively employ these constructs, further experimentation is required.

- Development of a set of common metrics for the HSI-NNEC challenges. This will include assessments that are frequently conducted across the various nations (e.g., usability), including the identification of measures of performance that support each HSI-NNEC activity/opportunity.
- Foundational to experimentation is the use of appropriate metrics and measures. The NATO nations use measures and metrics in independent assessments, HSI analyses, and human performance tests and evaluations. While these disparate assessment efforts have mutual goals, there is a need for active understanding and possible integration of HSI activities to accurately and completely track resources, performance measures, and assessment results. Efforts will be directed at ensuring HSI metrics for outcome (human performance), return on investment, and programmatic measures are identified.
- Educational forums communicating the results of the experiments and exercises for specific audiences (e.g., operators, decision makers, engineers and technical personnel).
- Initial activities will be directed at collecting and collating the state of the art knowledge of what each participant nation has regarding HSI-NNEC challenges. Efforts will expand to cataloging results from the Task Group efforts from modeling, simulation, experiments, and exercises, and synchronizing experimentation goals across nation activities. Results will be summarized into best practices. A list of recognized experts will be compiled and distributed to all NATO countries (This list will provide the nations a rich resource and promote the development of a community of practice.). The outcome from all the above will be compiled and summarized into a set of training and workshop materials for delivery to all NATO.
- Recommendations for new HSI-NNEC procedures, tools, and techniques, including, problem statement, understanding of need, appreciation, method, and business practices, both management and technical.

Near-Term Efforts and Milestones:



B.2.4 Duration

The Task Group will operate for three years.

B.3 RESOURCES

B.3.1 Membership

Task Group members will include serving military personnel and national experts in HSI, experimentation, field experiments, laboratory simulations, NATO operational requirements, and NNEC.

The Task Group anticipates participants from Canada, Germany, Italy, the Netherlands, the United Kingdom, and the United States. In addition, membership is open to non-defence organizations, such as, in the United States, the Coast Guard, the Federal Aviation Agency, Homeland Security, and similar organizations in the NATO nations.

Technical Group Leader: Ms. Dee Quashnock, SPAWAR.

HFMP Mentor: CAPT Paul Chatelier, USN (Ret).

B.3.2 National and/or NATO Resources Needed

The work of the Task Group will build on the experience and activities of national programs. Individual nation's resources will be required to support team members' time, travel, and participation in working meetings, as well as technical research and development, and such preparatory work as is agreed to during the TG.

Support will be also required for arranging meetings, workshops, and a symposium associated with a HFMP meeting.

Access to, and use of, education, training, and performance assets in nations and between nations, will also be sought. Specific support might also include access to NATO education, training, and performance aiding assets needed to facilitate co-operative efforts and agreements between nations and to provide operational military staff as the TG proceeds toward a CDE.

B.3.3 RTA Resources Needed

Traditional support will be requested to assist with announcements of meetings and other TG activities, posting of information on the RTO's websites, and access to information from the RTO's websites by TG members. Support for obtaining meeting rooms in Paris and NATO headquarters might also be required.

B.4 SECURITY CLASSIFICATION LEVEL

NATO UNCLASSIFIED (NU).

B.5 PARTICIPATION BY PARTNER NATIONS

Partner nations are invited and encouraged to participate in the Task Group.

B.6 LIAISON

Contact and collaboration will be sought with other NATO organizations (NTG), ACT, and HFM Panels and Groups. In addition, it is intended that the interim work products produced by the Task Group will be made available to the participating nations prior to formal publication.

Annex C – PAPERS AND PRESENTATIONS

Baber, C., Grandt, M. and Hougton, R.J., 2009, Models of Human Factors in a Network-Enabled Capability (NEC), In P.D. Bust (ed). *Contemporary Ergonomics 2009,* London: Taylor and Francis, 282-290.

Handley, H.A.H. and Smillie, R.J., 2008, Architecture Framework Human View: The NATO Approach, *Systems Engineering,* 11(2) 156-164.

Handley, H.A.H. and Smillie, R.J., 2009, Human View Dynamics – The NATO Approach, *Systems Engineering*, TBD.

Smillie, R.J. and Handley, H.A.H., 2009, Human-Centered Design Focus in Systems Engineering Analysis: Human View Methodology, In P.D. Bust (ed). *Contemporary Ergonomics 2009,* London: Taylor and Francis, 310-319.

Annex D – MEASURES OF EFFECTIVENESS AND MODELLING IN COMMAND AND CONTROL – SWEDISH EXPERIENCES

D.1 SUMMARY

Valid and reliable measures for performance and effectiveness assessment are of importance in the development of Command and Control-methods and systems, in evaluations of exercises and of training. Measures also form base for modelling of human performance in C2. Several reliable and valid measurement techniques are available, and others can be adapted to the C2-environment. The use of traditional instruments and new trends of developments are presented. The C2-environment is a dynamic and complex setting with complicated technical systems and teams of operators interacting to interdependently reach shared goals. Accordingly, dynamic changes or processes over periods of time are in focus, and process measures are called for as a complement to traditional instruments. Practicable techniques for dynamic measurement are demonstrated. Classical experimentation designs are insufficient in dynamic situations and designs adapted to naturalistic environments as simulations are discussed and illustrated. Modelling techniques based on multivariate statistics are basic tools in the development of reliable performance measures. Examples illustrating the usefulness of these techniques for the development of models of operator performance and operational measures are presented. Central aspects in the development of CD&E are situational awareness, situation assessment, understanding, attention, decision making, mental resources, information load, mental workload, skill, experience, insight, creativity, flexibility, motivation, will, and emotion. These concepts form base for our modelling efforts. Our development of performance measures and models are, to a large extent, performed in international co-operations (NATO RTO task groups, Tri-lateral NL-CA-SW, Bi-lateral USAF/RL). Different countries use measures and metrics differently, and a common framework and co-ordination of disparate assessment efforts are aimed at. As a background for our research efforts, the ‘human view’ of the Swedish Armed Forces will be illuminated.

D.2 INTRODUCTION

A main goal of this review is to put our national experiences, needs and desiderata on operational measurement of performance and effectiveness on the table. A second goal is to give examples of and compare the Swedish perspective on performance assessment with international perspectives, in particular the NATO-perspective, as in RTG-155-156. A third goal is to show how international experiences (in combination with our own) can be used in our research laboratories and exercises, and a final goal is to present contributions to the development of transnational measures of performance and effectiveness.

The revolution in information technology (IT) during the nineteen-sixties and seventies begat a revolution in military affairs (RMA), and information became the new fog of war. Bits and bites became strategically equated with bombs and bullets, and advances in networking and communications technologies dramatically changed the nature of, and how to handle a conflict. This ascertainment of Dr. Kenneth Boff (2006) is particularly true with respect to the speed and range of options available for military command and control whereby the speed of decision making has been pushed ever closer to the speed of thought. With respect to military human factors the network centric operations approach, raised the challenges and expectations for ‘human systems integration’. This is indicated by an unprecedented level of attention and financial support to understanding and enhancing situational awareness, information load, collaboration, decision making and human-system performance, and to resolving un-intended complexity arising as a consequence of clumsy implementation of IT (Boff, 2006).

Regardless of differences in the network centric operations approach of different countries, the challenges are the proper mix of innovative technologies, organizational changes, and new human behaviours or competencies that will combine to achieve the desired end states. Technologies are oriented towards easy and quick access to more and relevant information that will increase shared awareness and decision making, but also increase the risks for detrimental effects of human information overload. Important questions concern to what extent the organizational changes and the human behaviour adaptations needed to take advantage of these new capabilities enabled by the trans-formation technologies are achievable, and how these adaptations and changes are implemented and measured. Reliable and valid measures of performance and effectiveness play an important role in the achievement of human behaviour adaptations.

The future development of Command and Control systems of the Swedish Armed Forces will be based on Ministry of Defense Architecture Framework, MoDAF. Before this decision was made in 2008, a program for Command and Control systems development has been accomplished within the Swedish Armed Forces during 2002 – 2006.

The point of departure for the developmental program was the adjustment of the Armed Forces to Networked Based Defense (NBD), and the developmental framework program was to be launched and in use from 2010. Central functions of NBD are information handling and processing, command, and effects on the information arena. A main purpose of NBD is interoperability according to NATO standards on systems use and development.

Central foci of the C2 developmental program were technical systems, C2 methods, and the ‘human function’. An evolutionary, iterative, developmental process was the main principle for the systems development, a long series of experiments, tests, and demonstrations have been performed, and a centre for C2 research has been developed. A final evaluation of the developmental framework program was performed in 2006.

The architecture framework of the developmental program was to a large extent characterized by NATO standards, interoperability and EBO, and the end item was a common architecture for the development and evaluation of different systems of the Armed Forces.

The architecture framework comprised the complete C2-system, and not only its technical aspects. Accordingly, C2-methods, organizations, human aspects and personnel were to be developed in parallel with the technical systems development.

In order to achieve a harmonization of NBD to NNEC, the architecture framework development was performed in close co-operation with NATO in the revision of NATO C3 System Architecture Framework (NAF). An essential aspect of the program was a contribution to international C2 capability in terms of development of advanced movable C2 Force Headquarter (FHQ) for battle groups.

A third essential aspect of the systems development architecture framework was a human view named Man-System-Interaction (MSI) The area addresses how human factors and user perspectives (individuals, teams, and organizations) shall permeate the systems development and use.

Basic MSI assumptions were:

- System development shall be based on HF- or MSI-aspects.
- There are differences in human capabilities and in human ways of working – systems must be flexible and adaptable to these differences.

- Humans have to work individually as well as in teams.
- Human capabilities and needs vary, and are functions of physical, mental, emotional, and motivational aspects.
- Human resources in terms of flexibility, adaptability, intuition, analysis- and decision making capabilities must be illuminated. Routine tasks should be handled by systems, and non-routine tasks by humans.
- Manning systems and organizations shall based on qualified selection and training.
- Operators have to interact with individuals/groups as well as technical systems.
- Optimal systems efficiency is achieved with iterative development with ‘man in the loop’.

Important ‘MSI-principles’ to notice in the developmental program:

- Human capacities and limitations must be specified, and taken into consideration.
- Develop, collect and use knowledge on human decision making and performance (individual and group).
- Develop, test, and evaluate systems efficiency from theoretical and empirical points of human factors views.
- Balance human action to automation maintaining data systems stability and integrity.
- Develop and use conventional scientific methods, concepts, and measures (mental workload, situational awareness, and operational performance) on individual- as well as on team basis.
- Design, perform, and analyze experiments and exercises in operational settings.
- Educate and train personnel of the Armed Forces in user friendly systems developmental methods.
- Take into consideration the ‘human system’ and the ‘technical system’ in combination.
- Consider organizational, motivational, and social factors effects on systems efficiency.
- Optimize speed, security, and efficiency of the command and control processes during armed missions.

As noted in the objectives of RTG-155, HF/MSI can be defined as the integration of domains of personnel (skill), manpower (workload, situational awareness, and performance), training, human factors engineering, safety, and survivability. Techniques for measurement of concepts related to human performance are fundamental for scientific as well as practical reasons.

Valid and reliable measures for performance and effectiveness assessment and for systems Verification and Validation (V&V) have been proven to be prerequisite conditions for cost-effective development of aerial systems. In the same way, measures will be of central importance in the development of and operational use of Command and Control Systems. We will illustrate how measures developed for V&V of flight systems can be adapted to and useful in C2-research.

Available measurement techniques are centered on technical evaluations of systems, and systems of systems, and they are insufficient for evaluations on higher systems levels, i.e., interactions between systems and operators in operative settings (systems levels 0 – 1). It is, in itself, hard to evaluate a technical system of high complexity, and even at a low level of systems complexity it is hard to obtain reliable and valid measures of effectiveness. By adding another complex system, the operator (or teams of operators) to the technical systems, complicates the evaluations even further. Nevertheless, it is imperative to evaluate the total system, i.e., technical systems with 'man in the loop' under simulated as well as real operational conditions.

Accordingly, effective systems development implies systems evaluation in terms of valid and reliable measures of technical systems as well as of operators. Performance/effectiveness measures are important in evaluation of training, performance feedback, and for operator (and team) status assessments. For these reasons the development and adaptation of performance/effectiveness measures and integration of measures are needed.

Consequently, the focus of our work is on measures that capture the performance and effectiveness of C2-systems under operative conditions and with 'man in the loop'. It is a dearly-bought experience of ours as well as others that performance and effectiveness are multifaceted concepts hard to capture and measure. Notwithstanding, performance measures are decisive presumptions for systems development.

In the procedure of defining criteria of the very complex behaviour of command and control operators, there are obstacles to be overcome. There are skills, which are tacit, hidden, and imbedded. The operator's handling of the system may have a wide range of effects from immediate to gradual or remote and from trivial to critical. The outcome may be manifest by very simple actions or no action at all. There are at least four aspects to consider: hidden knowledge and embedded performance, lack of practicable theories of performance, lack of studies on measures validity, and of operational performance criteria (Vreuls and Obermayor, 1986; Svensson et al., 1998).

Human performance measures have to be considered on the individual, team as well as on the organizational levels. As noted, the criterion questions are critical: What manifest aspects or behavior imply effective performance? We have in earlier studies of performance assessment realized that we must focus on those actions and events that are of decisive importance for the outcome. The better these analyses, the better and useful are the measures developed. Detailed task or mission analyses are of vital importance for the assessment of these actions and events. A 'results-based' approach (instead of a 'wants-based' approach) must be applied to achieve the goals. The differences between desired (or criterion) performance and actual performance (i.e., gap-analyses) are critical. Furthermore, concrete and sturdy measures of performance are aimed at.

Techniques for performance assessment can be categorized in a number of ways. One aspect of categorization concerns the level of objectivity, i.e., whether the assessments derive from technical measurement systems or from human observations and statements. Even if this classification de facto is empty or insignificant, it is still in frequent use. The fundamental factors of all measures (independent of level of objectivity) concern their ***validity*** and ***reliability***, i.e., whether they measure the right aspects, and whether the measures are precise.

Operational performance measures must be developed in operational settings and with skilled personnel. By using known and operational C2-systems (as the Command and Control Centre of the Swedish Air Force) and operational and experienced staffs we can minimize sources of error and maximize reliability in the development of performance measures. These measures will provide optimal conditions for drawing correct conclusions in the development and testing of prototypical systems. An optimal procedure for development and use of performance measures is to switch between laboratory conditions (e.g., the CD&E Centre of the Swedish Armed Forces) and operational conditions (e.g., the operational Command and Control Centre of the Swedish Air Force).

The command and control environment is a dynamic and complex setting with complicated technical systems and teams of operators interacting to interdependently reach shared goals. Accordingly, another categorization deals with whether the techniques reflect a status at a certain time (or for a period of time) or they reflect dynamic changes or processes over periods of time. Both ways of measurements complement each other and reflect different aspects of the command and control processes. Both approaches are of value for the process oriented techniques in modelling of the interactions between operators and systems.

Modelling techniques based on multivariate statistics are basic tools in the development of valid and reliable performance measures. Most important is factor analysis which is an analytical technique that makes possible the reduction of a larger number of interrelated manifest and specific performance measures or markers to a smaller number of factors or groups of related measures with high reliability and construct validity. The factors can be considered as constructs laying behind and explaining the co-variation between their markers, and the constructs find their manifest expression in their markers. We will give examples of the usefulness of these techniques for the development of factor models and operational measures.

Performance measures have to be related to a criterion or different criteria. Ideally, the difference or gap between actual performance and the final criterion can be identified. However, most often we have to consider performance measures as relative measures, i.e., measures, the meaning of which is dependent on their relationships to other measures. In these situations relative change in performance over time (e.g., the extent to which performance have been better or worse since the latest measure performed) is a common metric. The performance measures dependence on mental workload is an obvious example of relative measures. High performance during high mental workload has a different meaning than the same performance during low mental workload.

Information complexity, mental workload, and situational awareness are central concepts influencing performance. The relative and sequential relationships of these factors to performance have been verified in a series of Swedish studies by means of structural modelling. By means of these models we can make analyses of the specific relationships between the measures. We can, e.g., estimate at what level the information complexity increases mental workload to a level that, in its turn, decreases situational awareness with decreased performance as a consequence. We will present studies reflecting the importance of this way of handling human performance measures.

We will state that experimental efforts to develop, test, refine, and measure various operational and organizational constructs are critical components to developing and applying new theories, concepts and processes, and the use of appropriate metrics and measures is fundamental to experimentation. It is also important to remember that experimentation is fundamental to the epistemological process, and it can, by no means, be correctly represented by simple ‘codes of best practice’.

The countries working with the network centric operations have different approaches and they use measures and metrics in independent assessments, HF/MSI analyses, and human performance tests and evaluations differently. There is a need for a common framework and coordination and integration of disparate assessment efforts, and there is a need of interoperability and re-use of metrics and measures. If we use the same metrics in different experiments and exercises comparisons can be made, and if the same measures are used repeatedly changes in system developmental status as well as increases in skill (e.g., as a function of training) can be evaluated.

D.3 CRITERIA FOR MEASURES

Measurement is of course of central importance in the process of testing such hypotheses. A series of requirements must be fulfilled in the development and use of measures:

Validity Problems – In crudest terms validity refers to the extent a variable measures what it is presumed to measure. Content validity refers to the degree a measure assesses appropriate, domain-specific knowledge or behaviour. It gives (often multiple) meanings to a variable. At least three different aspects of validity are important: Factorial or construct validity is based upon factor analysis. From theoretical reasoning and empirical research it is reasonable to conclude that mental workload, operator performance, as well as situational awareness are multifaceted concepts or constructs (i.e., factors). The validity of a manifest measure of one of these constructs or factors is indicated by its correlation with the factor, which is its factor loading. The correlation indicates to what extent the specific measure represents the construct. Both predictive and concurrent validity are expressed by the correlation between a criterion variable and a specific measure (criterion validity). Face validity is related to acceptance of a variable and is of special importance when measuring subjective experience.

Reliability Problems – According to the reliability theory, reliability can be defined as the proportion of the total variance of a measure that is true variance. An obtained measure or score is assumed to be the sum of a true measure and an error component. Test-retest reliability (stability) refers to the capability of a measure to provide the same results when the exact conditions are replicated on two or more separate occasions. Internal consistency refers to the extent different measures are similar with respect to factorial content. Cronbach's Alpha is an index of internal consistency. Generally validity criteria can be considered more important than reliability criteria. A valid measure can be useful even if its reliability is moderate or low.

Sensitivity – The sensitivity of a measure is closely related to its reliability (relationship between true and total variance). It indicates a measure's capability to distinguish between different conditions of interest imposed on an operator. For example, the sensitivity of a mental workload measure would increase with the technique's capacity to measure mental workload variations during a mission. Sensitivity is a very important criterion and critical in the selection of empirical measures. Furthermore, sensitivity is fundamental for dynamic measures.

Diagnosticity – Diagnosticity refers to the extent a measure expresses not only overall assessments but also gives information about specific components of that assessment. The essence of the notion of diagnosticity is to be able to identify the specific mechanism (sensory, perceptual, cognitive, and psychomotor), the process involved during the performance of a particular task and which part of an interface an operator has problems with.

Applicability – This criterion refers to the ability of a measure to reproduce in the field the same results obtained in the laboratory and the ability of the measure to produce valid results over a wide range of situations (e.g., variations in information load).

Implementation Requirements – The criterion of implementation requirements concerns practical aspects of necessary equipment and procedures (hardware such as EPOG measurement systems, recorders of psycho-physiological data, computers, and software for data reduction, statistical analyses, and procedures for the presentation of results). Physical space requirements, portability of equipment, and integration of the equipment into a simulator or a real system are all vital for the collection of valid and reliable data.

Intrusiveness – Intrusiveness refers to the degree to which a measure interferes with the normal or prescribed activities of a situation. For example, an intrusive measure can interfere with a pilot's flight performance or its mere presence may impose additional load.

Operator Acceptance – Operator acceptance is related to intrusiveness. The operator's acceptance of empirical devices may affect performance outcome. The assessment procedures may be ignored or inadequately performed, if acceptance is low. From our own experiences we consider the operator's acceptance of measurement procedures very important. A measure perceived as bothersome and unnecessary may affect the outcome of all other measures.

D.4 THE CONCEPT OF VARIANCE

Variance and change is the matrix of science. Without variation within and between phenomena no comparisons can be made, and no conclusions about differences can be drawn. If two or more phenomena vary (i.e., are variables), and they vary in systematic and concordant ways, we have co-variances or inter-correlations between the variables. The 'first generation' statistics concerns comparisons and tests of changes and differences between variables. The 'second generation' statistics concerns co-variations, multivariate statistical techniques including factor analysis and structural equation modelling.

Inter-Individual Variance – Differences between cases or individuals are the main source of variance in classical behavioural experimentation. Typically, groups with a large number of cases are measured after different forms of treatment. For instance, the performance of groups of subjects can be measured and compared after different kinds of training, or their performance in different system designs can be compared. In these analyses the variances induced by the different treatment conditions are compared and the probabilities for statistically significant differences are calculated. However, the probability values indicate only whether treatments have significant effects or not. It does not tell to what extent treatments or training regimes have effects. In analyses of high statistical power (i.e., studies with a large number of cases in the groups), e.g., significant differences are achieved even if the differences in the means of the groups are tiny, and practically insignificant. Accordingly, classical experimental designs based on inter-individual variance have a restricted explanatory power.

Intra-Individual Variance and Repeated Measurement Designs – In repeated measurement designs, intra-individual variance is added to the inter-individual variance. As compared to inter-individual variance, intra-individual variance, to a larger extent reflects experimental or external influences. This is due to the reduced proportion of inter-individual variance in repeated measures designs. Furthermore, and most important, repeated measurement designs make possible descriptions of changes over time or over consecutive phases of a task. Accordingly, from the consecutive changes of different variables, co-variation measures, e.g., correlations, and proportions of common variance can be estimated.

Figure D-1 presents an example of the variation of two variables (variable A and variable B) as a function of time or phases of, e.g., a C2-mission. The variables can, e.g., represent system information complicity (A) and operator mental workload (B), respectively, i.e., one variable representing the dynamics of the technical system and one representing the dynamics of the operator. Technical variables are often continuous and genuinely dynamic. In the same way, psycho-physiological measures as, e.g., heart rate (an indirect measure of mental workload) are continuous. However, it is harder to represent the dynamics of cognitive variables as workload, situational awareness, and performance. In order to mirror the dynamics of different psychological aspects we use repeated measures, i.e., the subjects are asked to rate, e.g., mental workload repeatedly every 5th minute or after phases of work.

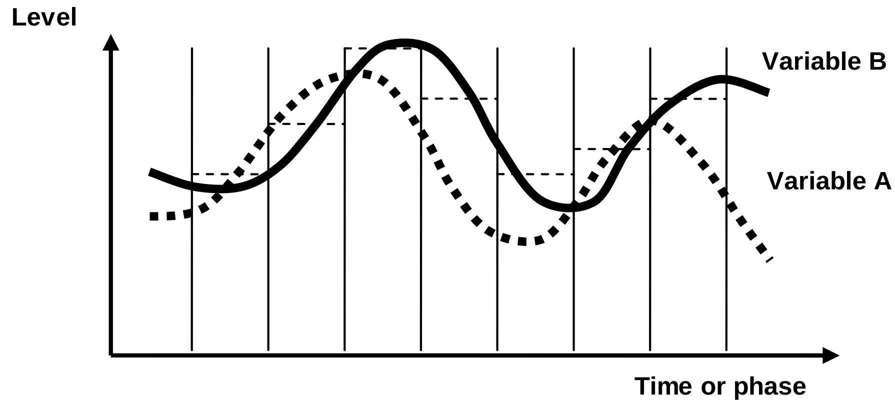


Figure D-1: A Generic Example of the Variation of Two Variables (Variable A and Variable B) as a Function of Time or Phases of, e.g., a C2-Mission. The variables can, e.g., represent system information complicity (A), and operator mental workload (B), respectively. Vertical lines represent a series of phases. Horizontal broken lines represent subjects' estimates.

If, e.g., the vertical lines of Figure D-1 represent a series of phases the subjects are asked to repeatedly estimate their workload during the last phase (the horizontal broken lines may represent the levels of the subjects' estimates). We call the resulting series of these estimates as quasi-dynamic measures. The correlation between variables A and B of Figure D-1 is .52, i.e., the common variance is 27 percent. However, as can be seen, there is a lag of about one phase between the variables, indicating that, e.g., the operators changes in workload (B) are delayed in relation to the changes in information complexity of the technical system (A). If we, by means of time series analyses, correct for the lag, the correlation increases to .87, i.e., 76 percent of the variance in workload can be explained by the variance in systems information complexity.

Figure D-2 represents an example of the variation of a multiplicity of systems- and operator variables as a function of time or phases of, e.g., a simulated C2-mission. As can be seen, the complexity is high and it is hard to penetrate the relationships and aspects lying behind the relationships. By means of data reduction techniques the multiplicity can be reduced and by statistical modelling techniques causal relations between underlying dimensions can be demonstrated and confirmed.

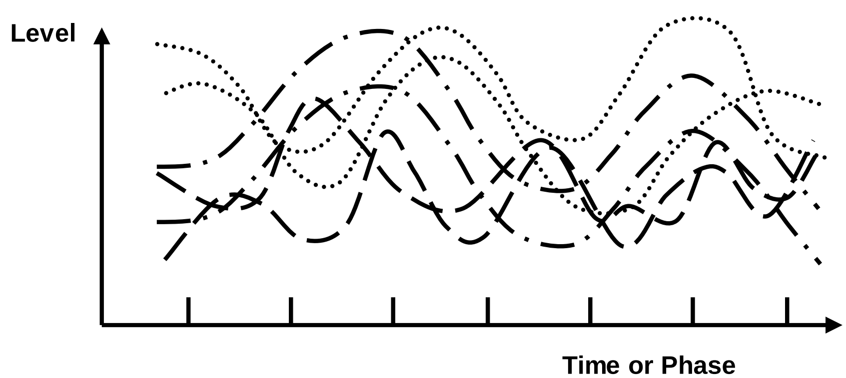


Figure D-2: A Generic Example of the Variation of a Multiplicity of Variables as a Function of Time or Phases of, e.g., a Simulated C2-Mission.

D.5 THE ROLE OF MEASUREMENT IN PRACTICE

D.5.1 Concept Development and Experimentation

Translated to the relatively complex context of military experimentation the concepts successively being formed in development processes can be regarded as equivalent to hypotheses in terms of being “best guesses” of how one should be operating in the future. These concepts should be made explicit and tested empirically as early as possible in a developmental cycle. The alternative that changes in an organizational system will be based on trial and error or collection of anecdotes is of course possible, but progress will be unsure, and relatively slow (Alberts and Hayes, 2005).

D.5.2 During Operations

Evaluation must be executed continuously in order to make minor adjustments to the plan and to establish that the ongoing activities are in accordance with established end states in an operation. It is vital to establish measurements for all the different activities in an operation in order to measure the overall effect. This might include measuring attitudes and perception in the local population in an area of operation in order to see whether opinions are changing to the better or worse for own forces. Thereby it is possible to create measures that indicate if it is necessary to take action in order to secure force protection. By establishing performance and effectiveness measurements for normal conditions it is then possible to develop measurement techniques to detect changes. Evaluations of technical systems are as important as evaluation of the human dimension. It is important to have information of which sensors that are active and passive and whether transmission of information is secure.

Evaluation has to be synchronized and coordinated in order to appraise all different activities in an operation. Further, it has to be well defined so that it is possible to collect information which it could be based upon.

Evaluation on an operational level is executed in many different staffs and processes. For example in the CJOC (Combined Joint Operation Centre) there are representatives from J1-J9 which contributes with information for their different activities. There are important parameters from all different services that need to be weighted in order to appraise the overall situation. Depending of which activities that needs to be coordinated evaluation has to be made both in the short and long run. Depending of time horizon and level of threat different measurement techniques might have to be developed.

D.5.3 Methodological Considerations

An important notion is that dynamic environments need dynamic measures, but it has been difficult to assess and measure how people perform in dynamic and complex environments. Measuring performance is important when you want to validate systems or evaluate effects of training on performance.

Even at a low level of complexity it has proved to be difficult to reach solid and reliable assessments of C2 processes. Both technical and human aspects of C2 have to be considered. The different systems, technical and human (i.e., a team of operators), are complex and difficult to evaluate. When operators in an operational environment are assessed, where they interact with other operators as well as technical systems, the assessment becomes even more difficult. Therefore it is important to find measurement techniques that in a reliable and valid way can capture and measure the dynamics of this complexity.

It is not feasible to conduct studies with a classical experimental design if you are interested in the dynamics of the situation – the complexity is simply too great and if you impose too much control the dynamics and realism of the scenario are lost. Sometimes it is desirable or necessary to assess experts in their natural, dynamic environment, for example during a training session or field exercises. In these cases you are rarely allowed to interfere with active manipulations, consequently the methods have to be adjusted accordingly. Consequently, it is difficult to apply the experimental method as conceived in science. Experimental control is hard as the complexity is manifested in variables, which exceed the number of available data points. In addition, it is seldom possible or suitable to have random assignment of participants to treatments as organizational units often must be constructed according to considerations on competence.

Two methodological research traditions have been utilized. Research traditions, as multifactor case studies and action research, take advantage of natural variance and uncertainty instead of reducing or excluding it.

Multifactor case studies assume that the studied system, irrespective of its complexity, has a reasonably simple structure which is possible to study and evaluate. Instead of using the "randomized assignment to treatments" and "laboratory control" models as research design, phenomena are studied in their real context. Measurement normally involves an array of different variables, thus using these as a set of indicators of the behaviour of the phenomena in the studied context. As replication of studies might be a problem, generalization of findings is based on theoretical considerations. In a practice, case studies might be appropriate when different solutions are contrasted to each other such as comparing two command and control systems.

Action research is similar to experiments as it tries to manipulate the studied system based on theoretical considerations. The 'action-research model' is an iterative sequence of actions: theorizing, intervening, gathering data on the effects of the intervention, and then checking the theory prior to the next intervention. Whether or not the predicted consequences occur becomes a test of the initial theory.

There are great similarities between the approaches, a series of case studies might be considered as an action-research approach and theoretical considerations are of course also important in action research. The main point is that these two research traditions have addressed the theoretical and practical problems present in military experimentation.

D.5.4 The Role of Experts in the Definition of Measures

Experts or instructors are often required to evaluate the participants' performance in complex training sessions. The problem is that it is, due to economical and practical restrictions, almost impossible to have sufficient instructors. One way to handle this problem is to let the operators assess their own performance. Several studies have shown that there are manifest correlations between operators own assessment of performance and objective- and instructor measures of performance, respectively

This should be contrasted to the traditional way to define theoretical structure and methods for measurement in science, that is, by studying relevant literature on the subject. However, this approach effectively excludes the clients from the problem analysis. It is the clients' "best guesses" that should be tested and not the analysts'. In many cases there are also a lack of relevant research on command and control, especially if the problem is interdisciplinary. Finally, the literature-based problem analysis is time consuming. We argue that relevant literature should support, not be the core of, the problem analysis. We suggest an approach for problem analysis based on modelling where the relevant clients and domain competences are engaged.

The practical consequence is that considerations on scale of measurement must be embedded in the procedure of modelling of experimental design in an effort integrating the clients. In such an undertaking, the model for evaluation must in every case be empirically specified to enable empirical evaluation, i.e., there has to be a definition of the set of empirical elements and the relations between them that corresponds to the model's conceptual terms. Consider the example of a causal model (where A causes B) as shown in Figure D-3.

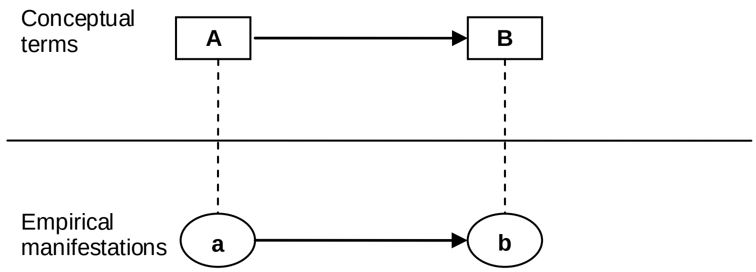


Figure D-3: Example of a Causal Model.

D.5.5 Defining What to Measure – Performance Criteria

In the procedure of defining criteria of the very complex behavior of operators of complex systems, there are some obstacles to be overcome. There are skills, which are tacit, hidden, and imbedded. The operators´ handling of the system may have a wide range of effects from immediate to gradual or remote and from trivial to critical. The outcome may be manifest by very simple actions or no action at all.

The four "fundamental problems" that Vreuls and Obermayor (1986) identify are not by a long way solved. The four problems are briefly described below:

1) Hidden knowledge and embedded performance as mentioned above.

2) Lack of theories of performance means that investigators are driven to collect a large amount of, sometimes less useful, data for a given task and environment. In the absence of theories to guide selection of performance measures, one is driven to the alternative of measuring as much as reasonably possible.

3) Studies of measurement validity as well as reliability are usually lacking which is connected with the fact that researchers seldom know enough of operational performance criteria.

4) Operational performance criteria. Researchers seldom know the operational meaning of a performance change in their experiment. It is rare to find other criteria differentiating between novices and experts than a number of something, e.g., hours in the system. They conclude that these metrics are useful to describe experience, but they are not performance criteria.

It is important to focus on actions of decisive importance for the outcome, events that discern a success from a failure. The so called objective criteria are not enough due to the problem of hidden knowledge, embedded performance, and to the fact that the outcome could be manifest by very simple actions or no action at all. Questions to and answers from observers and participants are even more important, as almost all important behaviour is cognitive.

Our evaluation methods, as well as development of practicable concepts hinge to a great deal on the participation of experts on the job. It is a common experience that Subject Matter Experts (SMEs) and experiences from former and operational systems are utilized quite too little. Seen in the rear-view mirror, the development of C2-systems in Sweden makes an example of this failure.

D.6 SOME MULTIVARIATE STATISTICAL METHODS FOR DATA REDUCTION

To identify operational measures of concepts as well as measures of complex system in a systematic way call for techniques to reduce the complexity of the data set. A number of methods are available.

D.6.1 Data Reduction – Factor Analysis (FA)

Factor analysis (FA) is an analytical technique that makes possible the reduction of a larger number of interrelated manifest variables to a smaller number of latent variables or factors. The FA technique is based on the co-variation between manifest measured variables, and the goal of the technique is to achieve a parsimonious and simplified description by using the smallest number of explanatory concepts needed to explain the maximum amount of common variance in a correlation matrix (i.e., a table showing the inter-correlations among the variables to be factored). The factors can be considered as hypothetical constructs (concepts) laying behind and explaining the co-variation between their markers, and the constructs find their manifest expression in their markers (Gorsuch, 1974; Hair, Anderson, Tatham, and Black, 1998).

Figure D-4 illustrates how the underlying explanatory concepts or factors can be extracted from the inter-correlations between a larger numbers of manifest measures. In the example, the markers or measures for mental workload can be perceived or rated workload and heart rate; for situational awareness the markers can be self-rated SA and a measure of eye point of gaze; and for performance the measures can be perceived performance and an objective performance indicator. It is important to notice that the arrows in the figure are directed from the factors to the manifest variables. This shows that the correlations between the manifest variables are explained by the latent or underlying variables or factors.

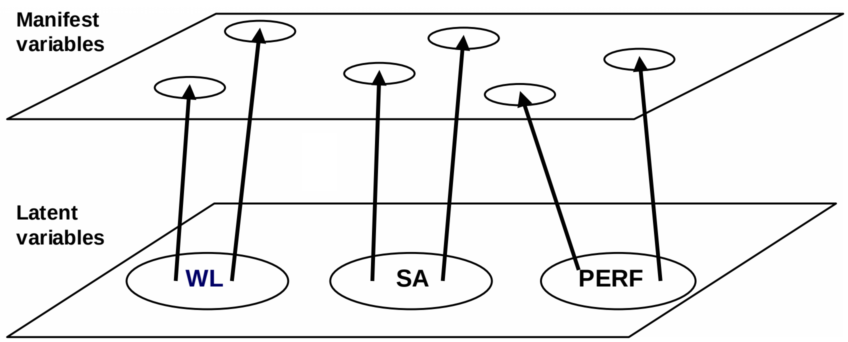


Figure D-4: A Generic Example of a Data Reduction by Means of Factor Analysis. The upper plane represents manifest variables or measures. The lower plane represents latent, underlying variables or factors [in this example the factors workload (WL), situational awareness (SA), and performance (PERF)].

Factor analysis is a central technique in the development of questionnaires or inventories measuring behavioural and psychological aspects. By means of the technique items of the questionnaires can be optimally selected with respect to their power as markers of underlying concepts or factors. The reduction of a larger number of questions to a smaller number of underlying factors makes possible a simple and powerful description of results.

Table D-1 gives an example a data reduction by means of factor analysis. A post mission questionnaire of about 70 items has been reduced to 9 factors by means of factor analysis. The questionnaire has been used in operational studies at wings of the Swedish Air Force and is in use at the Swedish Air Force Flight Simulation and Training Center (FLSC). The reliability has been analyzed by means of Cronbach's Alpha. As can be seen, the reliabilities of the factors ensure that the factors are consistent and have high construct validity (Svensson, Angelborg-Thanderz and Wilson, 1999).

Table D-1: An Example a Data Reduction by Means of Factor Analysis; a Post Mission Questionnaire of about 70 Items was Reduced to 9 Factors. PeP = Perceived Performance, SC = Situational Awareness, DIFFIC = Task Difficulty, EFF = Mental Effort, PMWL = Pilot Mental Workload, CAPAC = Reduction in Mental Capacity, MOTIV = Motivation, COMP TSD = Complexity of Information in Tactical Situation Display, and COMP TI = Complexity of Information of Target Display. The Cronbach's Alpha coefficients indicate the reliabilities of the factors.

Index	Chronbach's alfa
Percieved Performance (PeP)	.74
Situational Cognizance (SC)	.80
Difficulty (DIFFIC)	.84
Mental Effort (EFF)	.86
Pilot Mental Workload (PMWL)	.87
Ment. Capacity Red. (CAPAC)	.77
Motivation (MOTIV)	.84
Comp.Inform. TSD (COMP TSD)	.92
Comp.Inform. TI (COMP TI)	.93

It is important to realize that the reliability and validity values of single items or measures are just a fraction part of the corresponding quality indices for factors, and the measurement precision of single items is generally to low to be reliable and of practical value. Accordingly, factors (instead of single items) should be used as measures of concepts as mental workload, situational awareness, and performance. Compilation of items or variables into factors is necessary to achieve valid and reliable measures. Unfortunately, factors have, so far, seldom been used as measures in C2-studies, systems development and in evaluation of exercises.

Figure D-5 presents, from the example in Table D-1, how a series of markers representing different significant aspects of situational awareness in air operations form a factor.

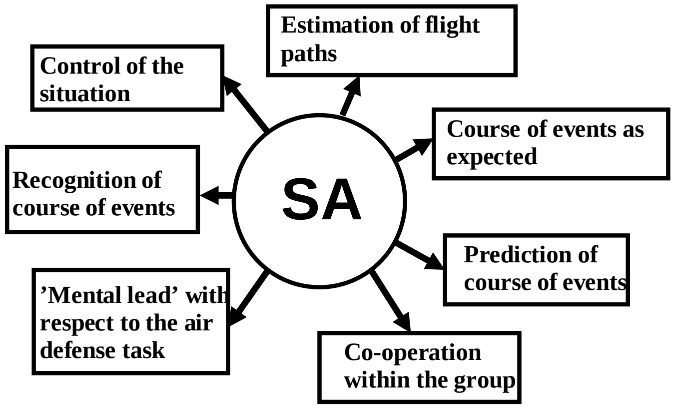


Figure D-5: Markers of the Factor Situational Awareness (SA) of an Air Operations Performance Questionnaire. Cronbach's Alpha = .80. (The factor is called Situational Cognizance in Table D-1, above).

The concept or factor was developed and formed in the following way: The concept situational awareness in air operations was discussed by SMEs and us, and a series of different aspects of the concept were presented. The multitude of aspects was then used in operational studies and reduced, by means of factor analysis, and the most potent aspects formed the markers of the factor.

It is of interest to notice that the markers, to a large proportion, represent recognition and prediction of the near future. It is also interesting to notice that co-operation within the air operation group is an important aspect of situational awareness in the air. Accordingly, there are similarities between air operations and C2-operations with respect to situational awareness and its measurement. The procedure is to be recommended in the development of concepts and their measurement, in C2-systems development, and evaluations of training and exercises.

D.6.2 Structural Equation Modelling (SEM)

Multivariate statistical techniques are important tools for analyzing multiple relationships and application of experimental designs in applied situations. By means of 'second generation' multivariate statistics we can analyze causal relationships and the relative effects of different causal factors. The techniques are based on correlational statistics, i.e., the linear relationships between variables, and the common variance between the variables forms the basis for the analyses. Accordingly, the techniques present the degree of relationship between variables in terms of explained variance.

In the LISREL model, the linear structural relationship and the factor structure are combined into one comprehensive model applicable to observational studies. The model allows

1) Multiple latent constructs indicated by observable explanatory variables;
2) Recursive and non-recursive relationships between constructs; and
3) Multiple latent constructs indicated by observable response variables.

The connections between the latent constructs compose the structural equation model; the relationships between the latent constructs and their observable indicators or outcomes compose the factor models. All parts of the comprehensive model may be represented in a path diagram and all factor loadings and structural relationships appear as coefficients of the path. LISREL gives a series of Goodness of Fit measures of the whole model (Jöreskog and Sörbom, 1993).

The databased modelling approach is primarily based on empirical data, and, accordingly, the resulting models represent the empirical relationships between concepts making statistical tests of causal flow models possible. Causal explanations represent the most fundamental understanding of the processes studied, and such knowledge is invariant over time. It is more important to know that one phenomenon is a cause of another than merely to know that these phenomena appear together. The techniques are especially suited for non-experimental research and data. The major characteristic of non-experimental research is that the experimenter cannot strictly manipulate the relevant variables. This is often the case in applied research in operative settings (e.g., studies of operator performance in C2-centras).

We have, since the eighties, performed a series of studies on modelling of operator performance in real as well as simulated situations (Svensson, Angelborg-Thanderz, Sjöberg and Olsson, 1997; Svensson, Angelborg-Thanderz and Wilson, 1998; Vinthec II, 2003; Nählinder and Berggren, 2002; Borgvall, Nählinder and Andersson, 2002; Rencrantz, Lindoff, Svensson, Norlander and Bergren, 2006). In theses studies we have, by means of structural equation modelling, developed and found strong support for the following model of operator performance.

From Figure D-6 we can se that an increase in information complexity results in an increase in mental workload, and an increase in mental workload reduces, in its turn, situational awareness, and a decrease in situational results in a decrease in performance. There are curve-linear relations between information complexity and workload, and workload and situational awareness, respectively. There is a linear relation between situational awareness and performance. Situational awareness acts as a mediating factor between workload and performance.

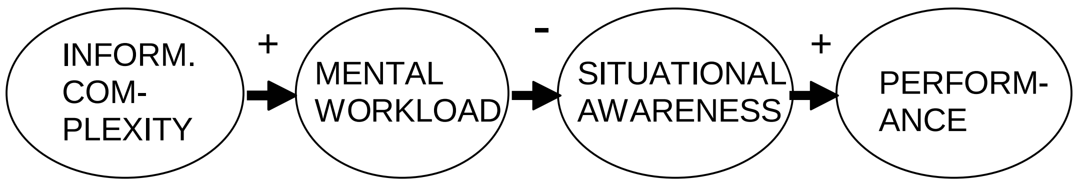


Figure D-6: A Generic Structural Model of the Sequential Relationships Between Information Complexity, Mental Workload, Situational Awareness, and Performance. The model has been verified in a series of empirical studies (+ indicates positive effect and – indicates negative effects).

The model gives support not only for the sequential relations but also for the concepts mental workload, situational awareness and performance. By using these concepts or factors and their relationships in our studies, we can better evaluate and understand operators' performance in complex systems and settings.

D.7 EXPERIMENTATION IN SWEDEN

In 2002, the Swedish Armed Forces (SAF) launched a transformation process aiming at developing a network based defence. The program was undertaken as a number of interrelated programs controlled by the Armed Forces Head Quarter. One important part of the program was the initiation of a development centre now having a central role in the SAFs CD&E process.

The development centre (SwAF Joint CD&E Centre), located in Enköping, some 70 km west of Stockholm, was initiated under the management of the Swedish Defence Material Administration (FMV) and handed over to the SAF early in 2007. SwAF Joint CD&E Centre is organized in two basic units, one for development of concepts and doctrines and one for method development and experimentation.

An important undertaking for the centre is experimental exercises in which concepts are tested, developed and demonstrated. Initially these were labelled DEMO and held twice a year. These undertakings will continue to have a central role in the years to come as the SAF have decided to use the CD&E approach for development. Annual development exercises will replace the earlier DEMOs as a mean for experimentation on concepts under development. In the near future the aim is to further develop the SAF development of abilities according to the CD&E approach and with SAF UtvC as a coordinative centre. Concept development will focus on ‘joint effects’, ‘logistics’ and “effect based approach operations”.

An important part of implementing the SwAFs Joint CD&E Centre has been to develop appropriate methods for the CD&E process. Methods and approaches have been successively refined. Work has focused on developing a “practice” for concept development and experimentation – the road from conceptual thinking to implemented practice – based on the scientific procedure. In the context of the Defence Forces’ progressive development of command and control the ambition has been to maintain a scientific rigor in the experimentation activities.

The ambition has been to have an ability to empirically test the organization’s “best guesses” with a limited amount of resources as regards time, money, training, and technical aids, while still gaining knowledge from experimentation. An important part of the work has been to make data collection in a setting of distributed command and control systems as efficient as possible by using different technical solutions.

When the first exercises, then labelled DEMOs, were held at the SAF development centre (UtvC) in 2003 there were no thoroughly elaborated procedures for how to conduct military CD&E in such an environment. In fact, the Code of Best Practice for Experimentation (Alberts and Hayes, 2002) was published the year before. The “code” and subsequent undertakings in the international military community has been of central importance for the Swedish ambitions to develop a CD&E process.

Still there had been earlier work in the SwAF R&D process focusing on methodological issues. The ambition of the work, carried out in a number of different projects, was to develop knowledge on tools and procedures to support current and forthcoming experimentation processes. These experiences were the extended and developed to fit into the context of SAF UtvC.

The basic premise was to try to adapt the scientific approach into “plans for execution and analysis” of experiments. As the work was supposed to be undertaken by a coordinated interdisciplinary team of scientists, officers and technicians, “plans for execution and analysis” of experiments were viewed as analogical to the plans for a military staff. Data from experiments were supposed to be processed directly after each session of data collection by the analytical team. The purpose was to be able to present and interpret preliminary results while the exercise was in progress. An important component of realizing such an ambition is relevant technique for efficient data collection and administration. Consequently, besides developing procedures it has also been important to develop such technical aids.

D.7.1 Case Studies at the Command and Control Centre of the Swedish Air Force (StriC) – Dynamic Measures

The measurement techniques can reflect a status at a certain time (or for a period of time) or they can reflect dynamic changes or processes over periods of time. Both ways of measurements complement each other and reflect different aspects of the command and control processes. Here we present a technique that reflects the dynamic changes of the C2-situation.

The command and control environment is a dynamic and complex setting with complicated technical systems and teams of operators interacting to interdependently reach shared goals. To know when such teams and systems are performing well is crucial both in terms of system verification and validation, and when it comes to training C2-teams.

We will here give an example of attempts to assess the dynamics of different aspects of performance in an operational C2-situation. Two studies have been performed at the Command and Control Centre of the Swedish Air Force (StriC in Uppsala). The first study was a pilot study which aimed to test and develop the methodology of dynamic measures. The second study built upon lessons learned form the pilot study and focused on further developing the methodology as well as focusing on aspects related to interoperability. The participants were C2-operators from the Swedish Air Force working in a peace support operation scenario (DONFOR) in an operational setting. They operated in two different staffs, i.e., CRC and CAOC. Representatives from the Netherlands and Canada also participated in the study and some of them as C2-instructors and specialists with respect to NATO standards and routines. Data was collected quasi-dynamically during the scenario by means of Personal Digital Assistants (PDA) questionnaires and heart rate measurement. Data was also collected through digital questionnaires after each scenario as well as by the means of observation protocols. We will present the results on performance assessment by means of dynamic measures.

Accordingly, the purpose was to test and develop an evaluation technique for complex environments. More specifically we describe a study that was conducted in an operational C2-environment where expert operators, with different roles, tasks and sub goals, had to work as a team. Focus is on describing how the central concepts workload, situational awareness and performance change over time. The measures are not genuinely dynamic (as, e.g., heart rate) and therefore we call them quasi-dynamic. The technique has been used in former studies and in validation studies of military aircraft systems of the Swedish Air Force.

Dynamic environments need dynamic measures, but it has been difficult to assess and measure how people perform in dynamic and complex environments. Measuring performance is important when you want to validate systems or evaluate effects of training on performance.

Even at a low level of complexity it has proved to be difficult to reach solid and reliable assessments of C2 processes (Essens, Vogelaar, Mylle, Blendell, Paris, Halpin and Baranski, 2005). Both technical and human aspects of C2 have to be considered. The different systems, technical and human (i.e., a team of operators), are complex and difficult to evaluate. When operators in an operational environment are assessed, where they interact with other operators as well as technical systems, the assessment becomes even more difficult. Therefore it is important to find measurement techniques that in a reliable and valid way can capture and measure the dynamics of this complexity.

It is not feasible to conduct studies with a classical experimental design if you are interested in the dynamics of the situation – the complexity is simply too great and if you impose too much control the dynamics and realism of the scenario are lost. Sometimes it is desirable or necessary to assess experts in their natural, dynamic environment, for example during a training session or field exercises. In these cases you are rarely allowed to interfere with active manipulations, consequently the methods have to be adjusted accordingly.

Experts or instructors are often required to evaluate the participants' performance in complex training sessions. The problem is that it is almost impossible to have sufficient instructors due to economical and practical restrictions. One way to handle this problem is to let the operators assess their own performance. Several studies have shown that there are manifest correlations between operators' own assessment of performance and objective- and instructor measures of performance, respectively (Berggren, 2005).

D.7.1.1 Method

The study was conducted in an Air Command Operations Centre in Uppsala, Sweden, as part of a trilateral cooperation between the Netherlands, Canada and Sweden. The purpose was to:

1) Develop evaluation methodology for complex environments; and
2) Study interoperability in a NATO setting.

This paper focuses on the first purpose. The second purpose is only mentioned here so the reader understands that the operators worked in a slightly different organization than they were used to.

Participants – The participants in the study were officers from the Swedish Air Force operating in a Control and Reporting Centre (CRC) or in a Combined Air Operation Centre (CAOC). The CRC was composed of one master controller, one fighter allocator, two fighter controllers and two track production officers. CAOC consisted of one current ops and one chief current ops. There was also one person representing the land component, i.e., SAM-allocator. Altogether nine people (eight male and one female) participated in the study. The participants were all experienced officers that do similar tasks in their daily work. Navy and other air and land components were simulated by game personnel.

Apparatus – The study was conducted with regular systems and simulation equipment. Each operator has his own platform which consists of two computer screens, keyboard, a mouse, and communication devices. These platforms are linked so that each operator can access information from each other and from the system. The system is equal to what they use on a daily basis. A questionnaire consisting of six short questions was answered on HP Pocket PC 4700 and Qtec Pocket PC 9090.

Scenario – The study required cooperation between different staffs in different countries in order to execute a peace support operation. The scenario was based on a conflict between two countries that escalated during the week and ended in full scale war. At the beginning of the week there were many non-critical incidents, i.e., routine events that the operators faced more or less on a daily basis.

Procedure – The study was conducted during four days. Day one was for preparation and training, and the remaining three days for data collection. Data was collected by the means of digital questionnaires that was answered by the participants every 10 minutes on PDAs. This enabled quasi-dynamic measurements that indicated how the scenario and the situation developed and affected the participants' SA, workload and performance. The questions chosen were extracted from former studies and related to the complexity of the scenario, workload, situation awareness (SA), performance, sharing of information, and team coordination. The questions were answered on a scale from 1 (very low/bad) to 5 (very high/good).

D.7.1.2 Results

The quasi-dynamic data (from the PDA) was collected from each participant at a total of 48 times during the scenario. The six markers that where used were; 'mental workload', 'scenario information complexity', 'SA', 'individual performance', 'team coordination' and 'information sharing'. By means of factor analysis, and structural equation modelling (LISREL) (Jöreskog, and Sörbom, 1993) a causal model was created out of the data. This model shows the causal relations between the three factors mental workload, individual performance, and team performance (see Figure D-7). The reliability (Cronbach's Alpha) is .83 for workload,

.81 for individual performance and .85 for team performance. Workload correlates negatively with individual performance and individual performance correlate positively with team performance. That is, if an operator has a high workload it affects his/her individual performance negatively, which, in turn, affects team performance negatively. The Weighted Least Squares Chi-Square equals 7.37 and has a p-value of 0.39. The standardized root mean square residual (RMR) equals 0.031. The Goodness of Fit Index (GFI) was 0.99, and the Adjusted Goodness of Fit Index (AGFI) was 0.96. Accordingly, the adjustment of the model is almost perfect and the correlations between the six different markers could fully be explained by the three different factors and their causal relationships.

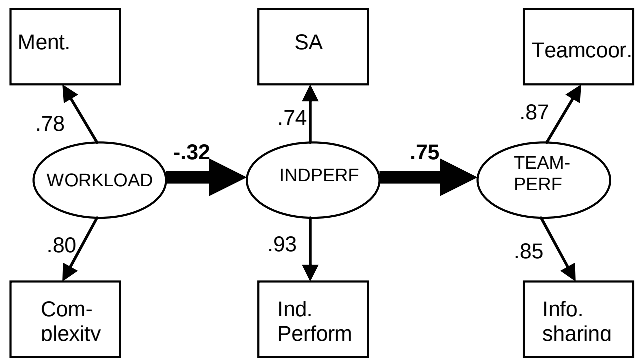


Figure D-7: Model of the Causal Relations Between Mental Workload (WORKLOAD), Individual Performance (INDPERF), and Team Performance (TEAMPERF).

Figure D-8 illustrates the dynamic changes in the workload and performance measures. It can be seen that there is an inverse relation between workload and the performance measures: performance increases when workload decreases, and vice versa. The figure illustrates the close relationship between the performance measures, which is caused by the strong effect (.75) of individual performance on team performance.

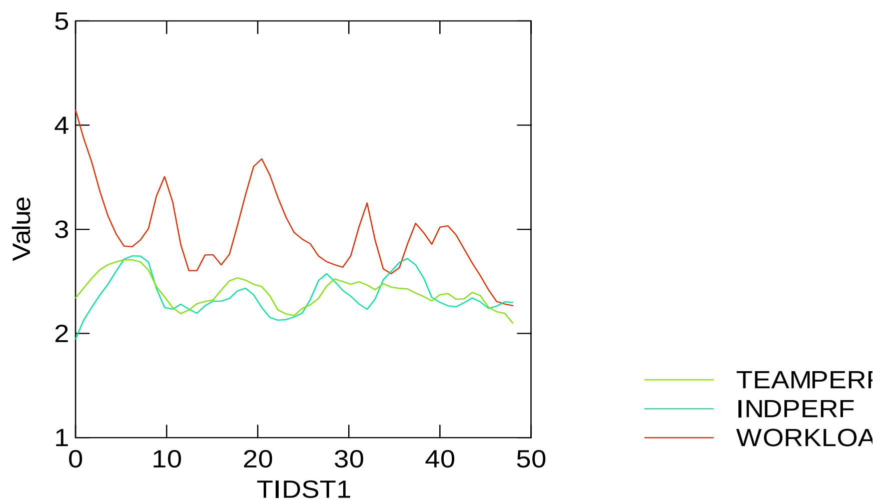


Figure D-8: Changes in Workload (WORKLOAD), Individual Performance (INDPERF), and Team Performance (INDPERF) as a Function of Time (TIDST1) and Complexity of the Situation. The curve has been smoothed by means of distant weighted least squares regression.

An index of the operator's efficiency is derived from the quotient of individual performance and workload measures, i.e., the higher the performance in relation to mental workload the higher the efficiency index. Figure D-9 shows that the index of efficiency improves significantly (r = .16; p = .008) during the scenario, i.e., the operators become more efficient even though the scenario is becoming more complex over time. The increase is especially noticeable in session 1 (time between 1 and 10), session 3 (time 21 – 31) and session 5 (time 40 – 48). During session 3 the correlation between index and time of measurement is .31, (p = .007). For session 5, the correlation is .38 (p = .003).

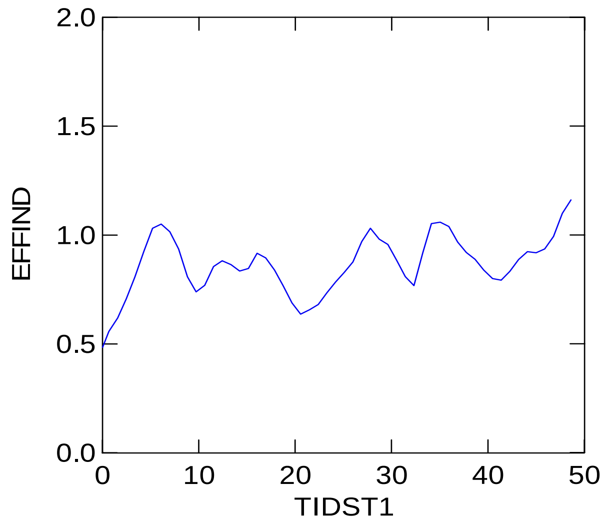


Figure D-9: Changes in Efficiency Index (EFFIND) Over Time (TIDST1) as a Function of the Demands of the Situation. The graph shows means for all operators. The curve has been smoothed by means of distant weighted least squares regression.

From correlation analyses we found that there is a clear connection between experience and performance: the experienced operators have better performance especially in situations with high workload. Correlation analyses also show that experience, e.g., time spent in the system, correlate significantly with individual and team performance. The correlation is dependent of the complexity of the task. If all situations are included in the analyses (even situations with low workload) the correlation between experience and team performance is .18, p = .004. When correlations are made without situations with low workload (where estimations on the PDA are 1 and 2) the connection is even stronger .31, p < .001.

D.7.2 Discussion

The use of semi-dynamic measurements has proved to be successful. Using PDA questions every 10 minutes of the scenario have proved to be a practicable way for measuring a complex dynamic event. By means of data reduction and modelling we have comprised the dynamics of the scenario and been able to describe how performance changes over time in an intelligible way. The causal relationships between workload, situational awareness, and operative performance have been demonstrated in a series of studies (Svensson, Angelborg-Thanderz, and Wilson, 1999; Svensson, Angelborg-Thanderz, Sjöberg, and Olsson, 1997; Svensson, and Wilson, 2002; Nählinder, Berggren, and Svensson, 2004).

The measurements have also enabled description and outlining of training effects. Index of efficiency is improved during the scenario even though the scenario is getting more complex. This can mainly be explained by the fact that operators' workload decreases over time. A reasonable explanation for this is that the operators are becoming more familiar with the scenario and the setup and thereby getting more skilled at their tasks even if the scenario became more complex and with an increasing number of acts of war.

From Figure D-8 we can see that during and after increases in workload decreases in performance will emerge. In the same way, decreases in workload are followed by increases in performance. It is interesting to notice that there are sometimes delays in the recovery in performance when the workload decreases.

We found a clear correlation between experience and performance, the correlation is especially strong during complex tasks but it is evident even in situations with low workload. A plausible conclusion is that the importance of experience, in relation to performance, increases with the complexity of the task. Easy tasks require less of the operator and can be managed correctly by operators with limited experience.

To conclude, the results from our study show that quasi-dynamic measures, i.e., repeated subjective ratings, are feasible in complex C2 environments to capture the workload, performance and dynamics of the situation. However, there is still a need to continue the development of these measures and try to supplement them with objective performance measures in order to get an overall efficient and effective performance assessment.

The method and modelling technique reported of might be a valid and successful way for verification and validation purposes, and also for training and performance assessment in complex environments.

D.8 GENERAL CONCLUSIONS

As compared to several other countries human aspects have been involved in and emphasized in the developmental processes of the Swedish Armed Forces. However, technical factors will, for several reasons, often dominate and human aspects are still disregarded with suboptimal systems function as a consequence.

Since long (the 1960s) performance assessment has been of central importance in our research. Accordingly, we have developed different evaluation techniques for experimental and operational situations. Classical experimentation is not feasible in experimentation in the wild as, e.g., simulation. As a consequence, we use quasi-experimental designs in which dynamic measures are of specific interest. In classical experimentation the inter-individual variance is the main variance source. In our studies we optimize the intra-individual variance portion – we are more interested in how SMEs react to changes of the situation than in differences between them.

As a consequence of our approach, 'second generation' statistics in terms of structural equation modelling have been indispensable. By means of these techniques we develop, empirically based, models of human performance.

As compared to other countries we have easy access to research platforms as well as operators of the Armed Forces. Accordingly, we can use SMEs operating in real situations, with valid results and conclusion as a consequence.

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Annex E – BIBLIOGRAPHY FROM EXPERIMENTATION SURVEY

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The NATO RTO HFM-155 Human View Workshop

Abbreviated Designation

RECORD OF CHANGES

Identification of Changes, Reg, No. (if any), and Date	Date Entered	NATO Effective Date	By whom Entered (Signature; Rank; Grade or Rate; Name of Command)

Current changes may be obtained from the custodian through your national chain of command. Proposed changes should be forwarded through your national change of command to the custodian.

RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATIONS BY NATIONS
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Abbreviated designation

RECORD OF RESERVATIONS

NATION	RESERVATIONS

ORIGINAL

OBJECTIVE

The NATO RTO HFM-155 Human View Workshop was convened to discuss and propose a cross-national *Human View*; that is an architectural viewpoint that focuses on the human as part of a system. Progress on the idea of a human view had already been made by several different groups working in different countries. The purpose of the workshop panel was to evaluate these emerging human view concepts, propose a candidate human view construct, and develop an outline of a NATO-wide Human View Handbook. This handbook is composed of the outcomes of the workshop and describes the draft Human View suggested by the panel members. The proposed human view was purposely designed to be independent of any specific architecture framework and adaptable to different implementation processes.

This handbook first reviews the three prevalent architectural frameworks (DoDAF, MoDAF, and DNDAF), as differences in perceptions of the current state of the human in the architecture framework lead to differences in the concept of the human view. It then describes the initial work that was done by different organizations to propel the idea of a human view. Finally the handbook describes the eight products that compose the human view that were designed by the workshop panel. This initial list of products is described only at a high-level, leaving flexibility for interpretation by individual users. The handbook concludes with a way ahead for continued development. The appendices add supplementary development work. In this way the handbook represents a compendium of the development and research that supports the evolution of the Human View. The accompanying *NATO Human View Quick Start Guide* provides a practioner's approach for completing the Human View.

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Kar Chan, United States
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INTRODUCTION

As a result of information technology and acquisition reform in 1996, the United States Department of Defense Architecture Framework (DoDAF) emerged as the structure for development of a systems architecture or enterprise architecture. DoDAF approaches are applicable to large systems with complex integration and interoperability challenges and are used by the engineering and acquisition communities to describe the overall system. Using DoDAF as the basis, similar approaches outside the US evolved, including the NATO Architecture Framework (NAF), the Canadian Department of National Defense Architecture Framework (DNDAF), and the United Kingdom Ministry of Defence Architecture Framework (MODAF). While these frameworks have continued to evolve to include new concepts in System Engineering, the portrayal of the human as a unique part of the system has not been broached. A Human View is required to explicitly represent the human and to document the unique implications humans bring to the system design.

The Human View enables an understanding of the human role in systems/enterprise architectures. It provides a basis for decisions by stakeholders by providing a structured linkage from the engineering community to the manpower, personnel, training, and human factors communities. It provides a way to integrate human system integration into the mainstream acquisition and system engineering process by promoting early and often consideration of human roles. The development of the Human View, if timely, can assist in evaluating the overall system performance. It provides early coordination of task analysis efforts by both system engineering and human factors teams. A universally accepted Human View enables consistency and commonality across service elements and international forces. By capturing the necessary decision data in the Human View and integrating this view with the rest of the architecture framework, the improved framework provides a complete set of attributes of the system data.

The NATO Human View Handbook provides a complete description of the Human View development. It provides the initial concept of the Human View and extensive appendices that represent additional progress on developing the viewpoint, the products, and the interrelationships.

ARCHITECTURE FRAMEWORKS

An architecture framework defines a common approach for development, presentation, and integration of architecture descriptions. It is intended to ensure that architecture descriptions can be compared and related across organizational boundaries (including Joint, inter-agency and multi-national). The application of a framework enables architectures to contribute more effectively to building interoperable systems, as well as providing a mechanism for understanding and managing complexity. Newer architecture framework versions are addressing Net-centric, System of Systems, and System/Services concepts. Frameworks capture much more than abstract/functional decomposition of large systems. The products can be used to capture multiple aspects of a complex system. These views can then be integrated together to recreate the system. Executable models that are used to evaluate performance measures can then be created from the information captured in the products.

The US Department of Defense Architecture Framework (DoDAF) defines different perspectives or views that logically combine to describe system architectures. DoDAF views are organized into four basic sets: overarching All View (AV), Operational View (OV), Systems View (SV), and the Technical Standards View (TV). AV products provide overarching descriptions of the entire architecture and define the scope and context of the architecture. OV products provide descriptions of the tasks and activities, operational elements, and information exchanges. SV products provide graphical and textual descriptions of systems and system interconnections that provide or support functions. TV products define technical standards, implementation conventions, business rules and criteria that govern the architecture. Each of the four views depicts certain architecture attributes. Some attributes bridge two views and provide integrity, coherence, and consistency to architecture descriptions.

The Ministry of Defence Architecture Framework (MODAF) has been adapted by the United Kingdom Ministry of Defence (MoD) from the DoDAF. The original four DoDAF Views have been extended into six MODAF Viewpoints. Along with the All View, Operational View, Systems View, and Technical Standards View, MoDAF adds the Strategic View (StV), which consists of views that articulate high level requirements for enterprise change over time, and the Acquisition View (AcV), which consists of views that describe programmatic details to guide the acquisition and fielding processes. The Canadian Department of National Defense Architecture Framework (DNDAF) is also closely based on DoDAF. DNDAF provides a Common View (CV), Operational View (OV), System View (SV), and Technical View (TV), all similar to the four DoDAF views, but also includes an Information View (IV) and Security View (SecV).

Architecture products are graphical, textual, and tabular items that are developed in the course of building a given architecture description and describe characteristics pertinent to the purpose of the architecture. It is important to distinguish between an architecture view and an architecture product. A view represents a perspective on a given architecture, while a product is a specific representation of a particular aspect of that perspective. Thus, a view will consist of one or more architecture products. At the lowest level of the framework, the architecture data elements are basic building blocks for inclusion in each architecture product. An integrated architecture insures that data elements defined in one product are the same as architecture data elements in another product. This creates common points of reference linking together architecture data elements ensuring relationships between the architecture products as well as linkages between the views.

EMERGENCE OF THE HUMAN VIEW

In the 2004 DoDAF Deskbook, there was an initial attempt to represent humans in the operational view products by including the role of the human and human activities associated with a system. In addition, analytical efforts in both Canada and the United Kingdom have been concerned on how to include human activities in an architecture framework. By including human activities, the domain of Human Systems Integration (HSI), in particular manpower, personnel, training, and human factors engineering, could begin to be addressed. Along with static representations of the humans, various efforts have also been exploring dynamic human views needed to support system development.

This section describes a selected set of emerging human view concepts. Some approaches used a top down method by analyzing human gaps in existing architecture frameworks, while other approaches were based on specific needs that evolved during the course of architecture development to capture specific human view data. Different architecture frameworks also spawned different human view approaches, as the level of decomposition down to the human level differs among the frameworks' operational and system view products. However, most approaches had the same core human elements, indicating a loose alignment between the proposed human views.

STATIC HUMAN VIEW CONCEPTS

1. Human View for Ministry of Defense Architecture Framework (MoDAF) United Kingdom

A detailed assessment of all MODAF Views was performed in order to identify a list of potential MODAF shortcomings that may lead to Human Factors Integration (HFI) problems if not addressed. The resulting list included items such as: HFI trends and standards are not captured; Human performance metrics, targets, and limitations are not specified; Human role/job/organisational design is insufficiently captured; Allocation of function decisions/ information requirements specifications may be technology-lead; and Team activity and team requirements are insufficiently captured. A Human View (HV) was suggested that is complementary to the existing MODAF Views and explicitly specifies the HFI elements that need to be considered in the design of socio-technical systems. By identifying specific HFI design elements in relation to the technological elements, HFI analysis, assessment, and management activities can be related better to enterprise design concerns. The suggested Human Views for MODAF include:

- HV-A: Capability Constraints: Maps the impact of design changes and constraints in relation to requirements and design variables; design constraints include subsequently required HFI activities (e.g. training).
- HV-B: HFI Quality Objectives and Metrics: Provides a repository for human-related priorities, values and performance criteria, from high-level quality criteria to metrics and targets.
- HV-C: Social Network Structure: Captures the structure of human role networks and the need for frequent (or critical) information exchanges; can include technical systems.
- HV-D-a, b, c: Organizational Dependencies: Clarifies organizational concepts by defining additional organizational properties and relationships (e.g. part-whole structures, rank structures, interaction types).
- HV-E: Human Function Definitions: Specifies human functions and activities in relation to system definitions, as part of detailing solutions beyond the operational functional decomposition.
- HV-F-a, b, c: Human Functions to Role and Competency Mapping: Specifies requirements and high-level solutions for Human Resources.
- HV-G: Human Performance Dynamics: Creates predictions for dynamic aspects of human behaviour for individuals and teams – as the basis for design and performance assessment.

The majority of the HVs are located conceptually and practically between the OVs and SVs. The intent of this Human View is to (1) expand MoDAF to capture all the elements for designing socio-technical systems; and (2) provide models for human design requirements that support human factors and are not captured by the architecture elements and representations.

2. Human View Extensions to the DOD Architecture Framework Canada

The Canadian approach presents an extension to the existing DODAF/DNDAF in the initial form of a limited set of Human View architecture products that specifically target decision makers interested in the HSI areas of manpower, career progression, and training; additional HSI domains will be developed at a later date. These domains collectively define how the human component will impact system or capability performance (e.g. mission performance, safety, supportability, and cost). Conversely, the HSI domains also define how the system impacts the human component (e.g. trade structures, skill gaps and training requirements, manning levels, career progression, selection and retention, workload and morale). Collectively, the proposed HSI supplements are intended to help define and describe the role of the human within a system. The Canadian Human View products are:

- The Manpower Projections (HV1) illustrates the predicted manpower requirements for supporting present and future projects (and programs) that incrementally contribute to the larger CF capabilities.
- The Career Progression Roadmap (HV2) illustrates career progression within a particular job field as well as the essential tasks, skills, and knowledge (and proficiency level) required for a given job.
- The Individual Training Roadmap (HV3) architecture product illustrates the instruction or education, and on the job or unit training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements.
- The Establishment Inventory (HV4) architecture product defines the current number of military personnel by rank and job within each CF establishment.

These four products are interdependent. The HV4 can be used in conjunction with forecasting results presented in the HV1 architecture product to facilitate decision makers in dealing with manpower requirements definition and to readily identify anticipated ‘gaps’ in personnel. The direct relationship between existing manpower levels and proposed programs may be addressed through closer examination of the HV2 and HV3 products as tradeoffs between existing career paths and anticipated requirements, as well as alterations to training programs may prove to address ‘gaps’.

3. Maritime Headquarters with Maritime Operations Center (MHQwMOC) Concept Based Assessment United States

The objective of this effort was to augment the Capabilities Based Assessment (CBA) of the US Maritime Headquarters with Maritime Operations Center (MHQwMOC) with the impact of Human System Integration (HSI) issues. This project established a relationship between the DoDAF views and personnel requirements and as part of the effort to organize and standardize maritime operations. As a result, an initial realization was developed of a Human View. This project produced actual view products based on a subset of twenty-seven activities defined in the emerging MHQwMOC Decide Node Tree (OV-5) and twenty-two corresponding roles identified in the Organizational Relationships Chart (OV-4). The products developed included:

- HV-A Responsibility Matrix: Mapping of activities (functional responsibilities) to roles.
- HV-A1 Activity to UNTL Alignment: Provided metrics for performance assessment of the human activities based on definitions of functions from other sources.
- HV-B KSA per Activity: Identified the knowledge, skills, and abilities (KSAs) associated with each activity.
- HV-C Role Requirements: Summary of the KSAs required for range of mapped activities.
- HV-D Role Training: Identified the gap in current training due to differences in current training and role requirements.
- HV-E Workload: Assessment of role performance under different organizational structures.
- HV-F1 Locations and Reach-back: Defined variables to evaluate the impact of reach-out and reach-back roles on organizational performance.
- HV-F2 Organizational Structures: Impact of organizational escalation and reduction on role responsibilities and relationships.
- HV-G Doctrine (TPPs, etc): Guiding principles for human roles and activities.

Table 1. Comparison of Static Approaches

Theme	Human Views for MODAF	Human View Extensions Canada	MHQw/MOC Human Views
Doctrine and Policy			✓
Constraints	✓		
Objectives & Metrics	✓		✓
Interacting Roles and Nodes	✓		✓
Organizational Groups and Changes	✓		✓
Allocation of Functions to Roles	✓		✓
Functions and Competencies	✓	✓	✓
Performance Analysis and Assessment	✓		✓
Individual Training		✓	✓
Manpower Projections		✓	
Establishment Inventory		✓	

DYNAMIC HUMAN VIEW CONCEPTS

1. Royal Netherlands Navy (RNLN) Manning Program

While there is no explicit Human View being developed, human issues in architecture design are being explored through IPME (Integrated Performance Modelling Environment). Different variations of crew concepts using current and future technologies are being compared. Human integration issues are being evaluated at different levels: Micro (adaptive automation), Meso (adaptive teams) and Macro (overall system).The manning model explicitly represents the organization, the human, and the technology. The design process includes conceptual, functional and detail levels; trade-offs are made at the design level between investment and effectiveness. The aim of the research is to develop a conceptual framework that is able to come up with viable team configurations which are in accordance to the goals and restrictions of a mission and the expected events in the environment, while taking several human factors guidelines into account. This configuration specifies the necessary education and competencies of the crew members, the responsibilities of the crew member and the expected workload. This framework will not be restricted to human teams, but can also be used for a human-computer team or a hybrid (human - intelligent autonomous systems) collaborative team.

2. Human Systems Integration Human View Dynamic Architect (HSI HVDA) – United States

The Human View Dynamic Architect (HVDA) addresses the issue that traditional system engineering architecture techniques have failed to produce the behavior insights needed to account for human information processing. The Human View Dynamic Architecture provides a critical tool to visualize and manage the expected system behavior by using pictorial and dynamic flow description of system behavior, functionality, and information sharing attributes, including the human. In this way it captures how the total system responds to events occurring within the operational environment, it shows how the operators interact with the system to achieve the mission, and it provides views as branches and sequels in context. By synthesizing the mission concept of operations, functions, information and dynamics into a single blueprint or architecture, it tells the story of how the user will interact with the system. The nominal, alternative, and exception/problematic interaction with the system can be defined, and the impact the human system interaction will have on the system design. It answers the question, “Can this warfighter, as part of this unit, with this training, in this environment, perform these tasks, using this equipment?” HVDA is a prelude to prototyping, which graphically tells the use case story as a “proof of concept” so that the warfighter can experience and adjust the vision early in the design phase. It provides a tangible metric of requirements evolution and a sanity check for system requirements.

THE NATO HUMAN VIEW

The purpose of a human view is to capture the human requirements and to inform on how humans interact with systems. The Workshop panel developed the following set of human view products by first grouping the existing human view elements into related themes. The number of themes was then reduced to create a manageable set of products for the human view. These products were then evaluated to determine if each product should be a discrete product in the human view, should be included in another human view product, or should be suggested as a supporting element to another existing view. Suitable terminology was then agreed upon to identify the human view products. The final set of products that composes the NATO Human View is listed below:

HV-A Concept
HV-B Constraints
HV-C Tasks
HV-D Roles
HV-E Human Network
HV-F Training
HV-G Metrics
HV-H Human Dynamics

HV-A CONCEPT

The HV-A is a conceptual, high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components. It serves as both the single point of reference and departure to depict how the human will impact performance (mission success, survivability, supportability, and cost) and how the human will be impacted by the system design and operational context (personnel availability, skill demands, training requirements, workload and well-being). The HV-A has a close relationship with other architecture products that provide high-level concepts.

The elements of the HV-A may include:

- Pictorial depictions of the system and its human component
- High level indicators of where human system interactions may occur
- A textual description of the overall human component of the system
- A use case which describes the human process

Figure 1 depicts the human roles superimposed over the interconnected nodes of a combat system.

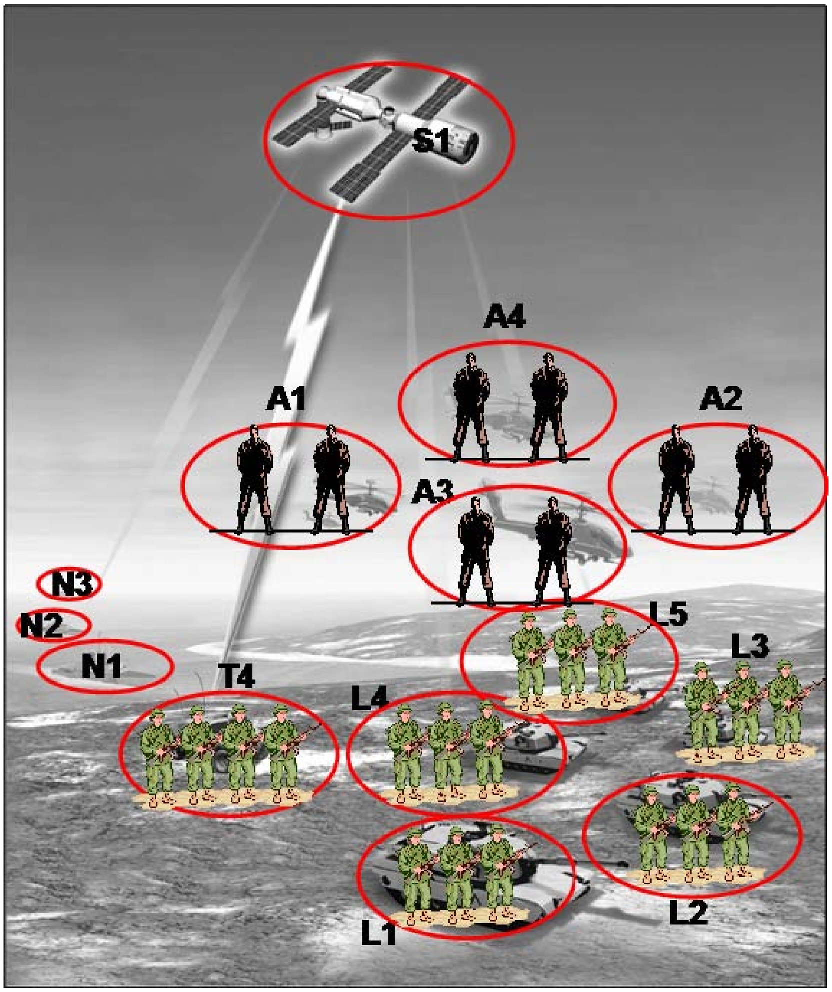


Figure 1. Concept (HV-A) Example [Baker, Pogue, Pagotto, & Greenley, 2006]

HV-B CONSTRAINTS

Not only is the human the most important and unique system within the system-of-systems, but it can also be the weakest link or highest risk in that system. Therefore expressing the capabilities and limitations of the human in the system is required. The HV-B contains the set of data elements that are used to adjust the expected roles and tasks. It acts as a repository for different sets of constraints that may affect parameters of different views that may impact the human system. If a system requires a human interface, then the system must be designed to accommodate the human in such a way as to account for the human limitations, and to support/maintain the human to at least a minimum acceptable level.

Due to the range of information captured in the HV-B, six sub-products capturing specific subsets of data have been defined for the HV-B. These are broken into two subsets, Personnel, containing four sub products, and Human Factors, containing two sub products.

Personnel Sub Products – information about personnel available to participate in the roles:

- Manpower Projections (HV-B1) - illustrates predicted manpower requirements for supporting present and future projects that contribute to larger capabilities.
  - Understand manpower forecasting to allow initial adjustments in training, recruiting, professional development, assignment and personnel management
  - Anticipate impacts (and timeframe) related to number(s) of personnel, personnel mix, Military Occupational Structure Identification (MOSIDs), Rank/level distribution, and, postings/relocation(s) of personnel.
  - Ensure sufficient number of personnel with necessary Knowledge Skills Abilities (KSAs) are 'ready and able' to support fielding of future program.

Figure 2 depicts an example of manpower projections for a capability package into future years to anticipate the number of personnel, personnel mix, rank/level distribution and Military Occupational Structure Identification (MOSIDs) requirements.

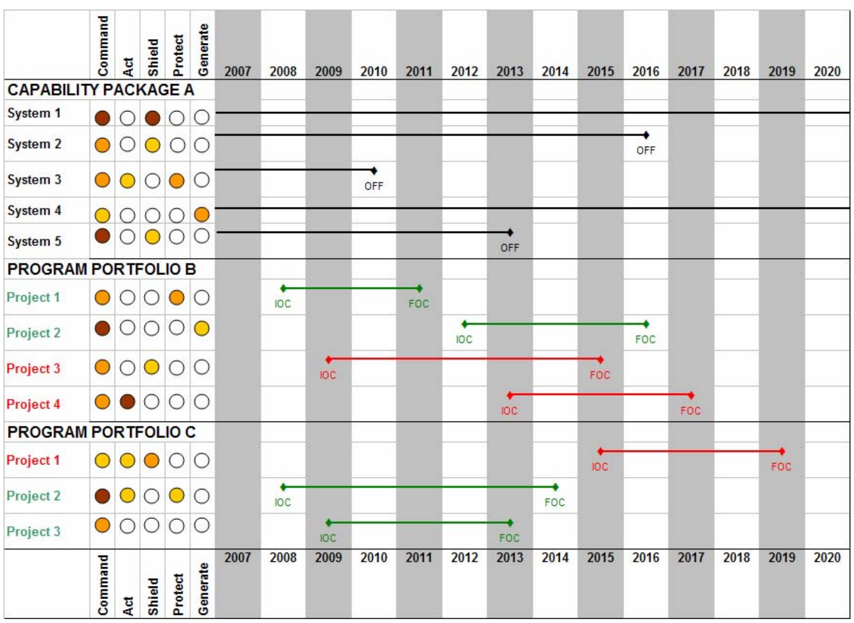
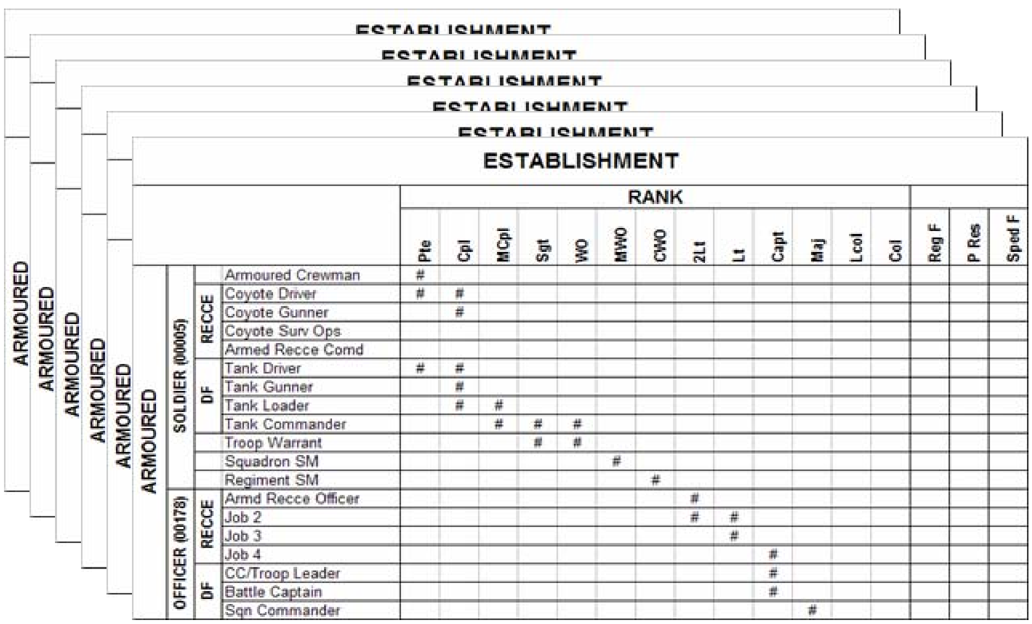


Figure 2. Manpower Projections (HV- B1) Example [Baker, 2007]

- Career Progression (HV-B2) - illustrates career progression as well as the essential tasks, skills, and knowledge (and proficiency level) required for a given job.
  – Address impacts of alternative system and capability designs on career progression;
  – Determine jobs available given an individual's current job and occupation;
  – Assess competencies required for each individual job; and
  – Support personnel planning by identifying availability of individuals with necessary competencies early in acquisition process.

- Establishment Inventory (HV-B3) - Defines current number of personnel by rank and job within each establishment.
  – Supports forecasting of trained effective strength.
  – Supports predicting number of people that must be trained, recruited, etc. to fill gaps required for 'out years'.

Figure 3 depicts and example of an establishment inventory to support forecasting of trained effective strength and to predict the number of people that must be trained and recruited to fill predicted gaps.


ESTABLISHMENT

				RANK															
				Pte	Cpl	MCpl	Sgt	WO	MWO	CWO	2Lt	Lt	Capt	Maj	Lcol	Col	Reg F	P Res	Sped F
ARMOURED	SOLDIER (00005)		Armoured Crewman	#															
		RECCE	Coyote Driver	#	#														
			Coyote Gunner		#														
			Coyote Surv Ops																
			Armed Recce Comd																
		DF	Tank Driver	#	#														
			Tank Gunner		#														
			Tank Loader		#	#													
			Tank Commander			#	#	#											
			Troop Warrant				#	#											
			Squadron SM						#										
			Regiment SM							#									
	OFFICER (00178)	RECCE	Armd Recce Officer								#								
			Job 2								#	#							
			Job 3									#							
		DF	Job 4										#						
			CC/Troop Leader										#						
			Battle Captain										#						
			Sqn Commander											#					

Figure 3. Establishment Inventory (HV- B3) Example [Baker, 2007]

- Personnel Policy (HV-B4)
  – Defines the various department policies dealing with (governing) HR issues
  – Ensures that personnel are fairly considered, properly treated, well looked after and supported in a legal, moral and ethical manner while employed with the department
  – HR documents, such as policies, doctrine, laws, benefits, pay, SOPs, etc.

Human Factors Sub Products - data related to the capabilities of the humans assigned to roles:

- Health Hazards (HV-B5)
  - Considers the design features and operating characteristics of a system that can create significant risks of illness, injury or death.
  - Aims to eliminate minimise or control both short- and long-term hazards to health that occur as a result of system operation, maintenance and support.
  - Hazards may include system, environmental or task hazard assessment; air quality control assessment; noise/vibration pollution evaluation; impact force, shock protection; WHIMS evaluation of tasks; radiation/LASER protection; CB protection; extremes of temperature, etc.
  - It may include aspects of survivability, i.e. limiting the probability of personal injury, disability or death of personnel in their interactions with the system. This can include providing protection from attack, and reducing detectability, fratricide, system damage, personnel injury and cognitive and physical fatigue.

- Human Characteristics (HV-B6)
  - Considers the physical characteristics of an operator and movement capabilities and limitations of that operator under various operating conditions.
  - Aims to compare operator capabilities and limitations with system operating requirements under various conditions to match or eliminate operating capabilities.
  - It may include aspects such as anthropometrical/medical data; reach data; range of motion data; physical strength data; visual and auditory assessment; speed or duration of activity data; cognitive workload; working memory capacity; ability to be security cleared; personality, motivation, etc.

HV-C TASKS

The HV-C describes the human-specific activities, i.e., the tasks that have been assigned to the humans in a system over its entire life cycle. It also considers how the functions are decomposed into tasks. (The term *task* in this product refers to a piece of work that can be assigned to a person).

The HV-C may also:

- Clarify the human-related functions in a system
- Provide a justification for the allocation of functions between the humans and machines
- Decompose these functions into a set of tasks that can be mapped to the roles identified in HV-D
- Describe these tasks in terms of various criteria and the KSA requirements
- Produce a task-role assignment matrix
- Depict the inter-dependencies between different tasks, particularly across functional groupings
- The information demands to perform specific tasks
- The tools required to accomplish a task
- Create interface design guideline on the basis of task requirements

The HV-C is very broad and can be used to capture all aspects of the human-related tasks in a system, including the allocation of tasks between humans and systems. This product is also closely related to the HV-D Roles, which will be described in the next section. There may be some overlap between the definition of tasks, roles and the assignment between them. More often, there may be multiple HV-C products representing different aspects of the human tasks in the architecture. In this case, the multiple products can be labeled consecutively within the HV-C context. Figure 4 depicts an example of tasks assigned to individuals, as well the requirement to interface to system tasks.

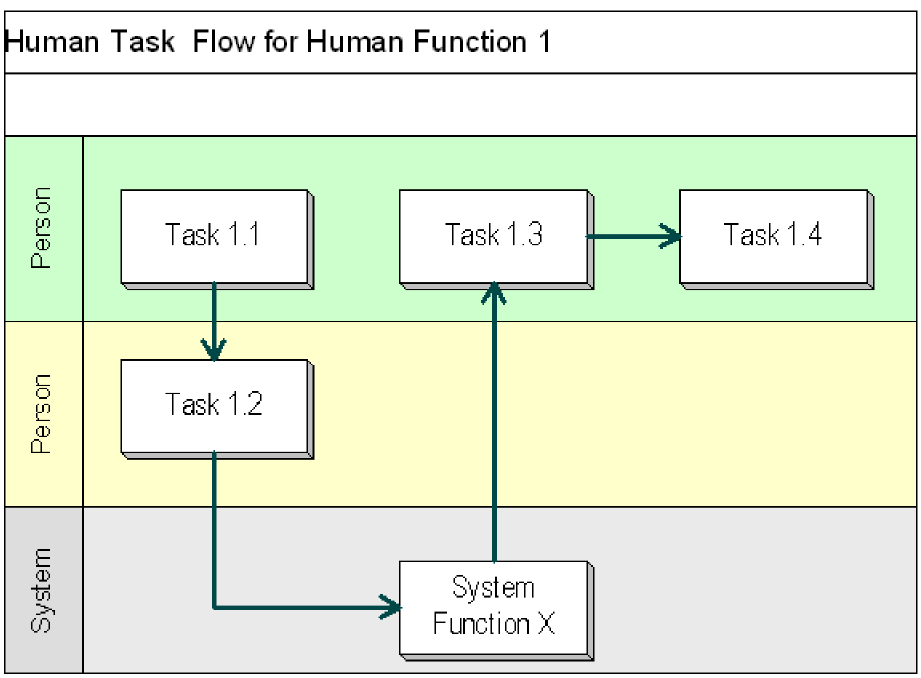


Figure 4. Tasks (HV-C) Example [Bruseberg, 2007]

HV-D ROLES

The HV-D describes the roles that have been defined for the humans interacting with the system. A role represents a job function defining specific behavior within the context of an organization, with some associated semantics regarding the authority and responsibility conferred to the user in the role, and *competencies* required to do the job. The role structure can be mapped to the human task decomposition to define the organizational responsibilities, and relationships between roles can be defined which provides the basis of the organizational structure.

The HV-D may define additional attributes of a role including:

- Responsibility - a form of accountability and commitment; roles are generally defined by their responsibilities.
- Authority - is the access ability of an individual user to perform a specific task
- Competencies - the quality of being able to perform; a combination of knowledge, skills and attributes; these should be trainable and measurable.
- Multiplicity - a role may be performed by a human user or by many human users at the same time.

The HV-D is closely related to the HV-C, as the identified tasks need to be allocated to roles, and competencies for the roles defined based on the assigned tasks. The HV-D can also be extended to include a "concept of work" to describe the distribution of responsibilities among humans and specific requirements for those responsibilities. Figure 5 depicts the interrelationships of roles that have been defined by a functional analysis for a military vessel.

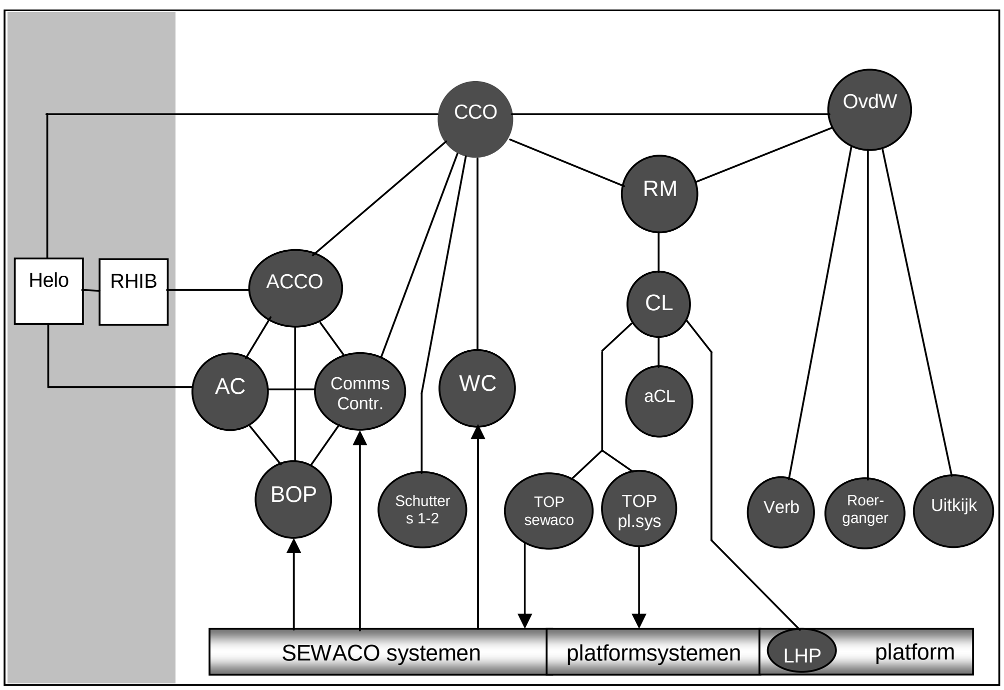


Figure 5. Roles (HV-D) Example [van den Broek, 2007]

HV-E HUMAN NETWORK

The HV-E captures the human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time.

Elements of the HV-E may include:

- Role groupings or teams formed, including the physical proximity of the roles and virtual roles included for specific team tasks.
- Type of interaction – i.e., collaborate, coordinate, supervise, etc.
- Team cohesiveness indicators - i.e., trust, sharing, etc.
- Team performance impacts - i.e., synchronization (battle rhythm), level of engagement (command directed)
- Team dependencies - i.e., frequency/degree of interaction between roles
- Communication/Technology impact to the team network - i.e., distributed cognition, shared awareness, common operational picture, etc.

Figure 6 depicts the collaboration requirements of a distributed military team.

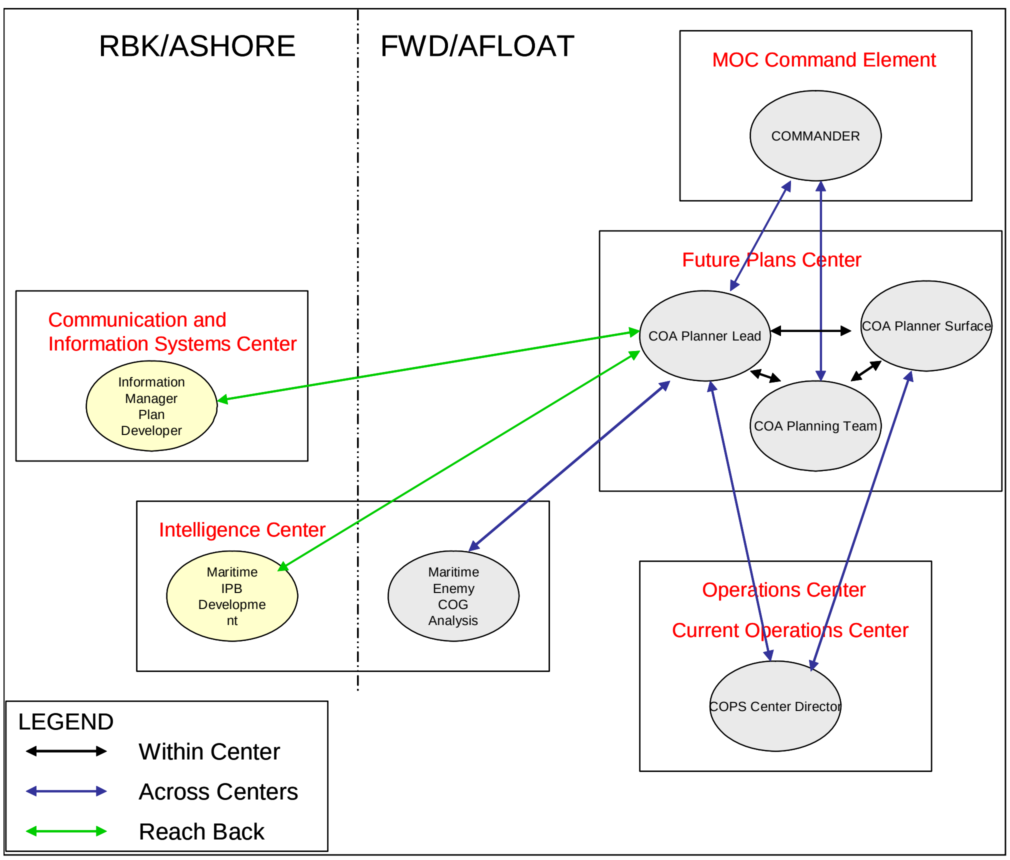


Figure 6. Human Network (HV-E) Example [Handley, 2007]

HV-F TRAINING

HV-F is a detailed accounting of how training requirements, strategy, and implementation will impact the human. It illustrates the instruction or education and on-the-job or unit training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements. This view can also address the development of additional training programs to meet the requirements of new capabilities.

Data elements of the HV-F may include:

- As-is training resources, availability, and suitability
- Risk imposed by to-be operational and system demands
- Cost and maturity of training options for tradeoff analysis
- Address impacts of alternative system and capability designs on training requirements and curriculums
- Determine training required to obtain necessary knowledge, skills, and ability to support career progression
- Differentiation of basic, intermediate, or advance job training; operational vs. system specific training; and individual vs. team training

Figure 7 illustrates the career progression and training levels required for a given job within a particular MOSID. This supports personnel planning by identifying availability of individuals with necessary competencies early in acquisition process.

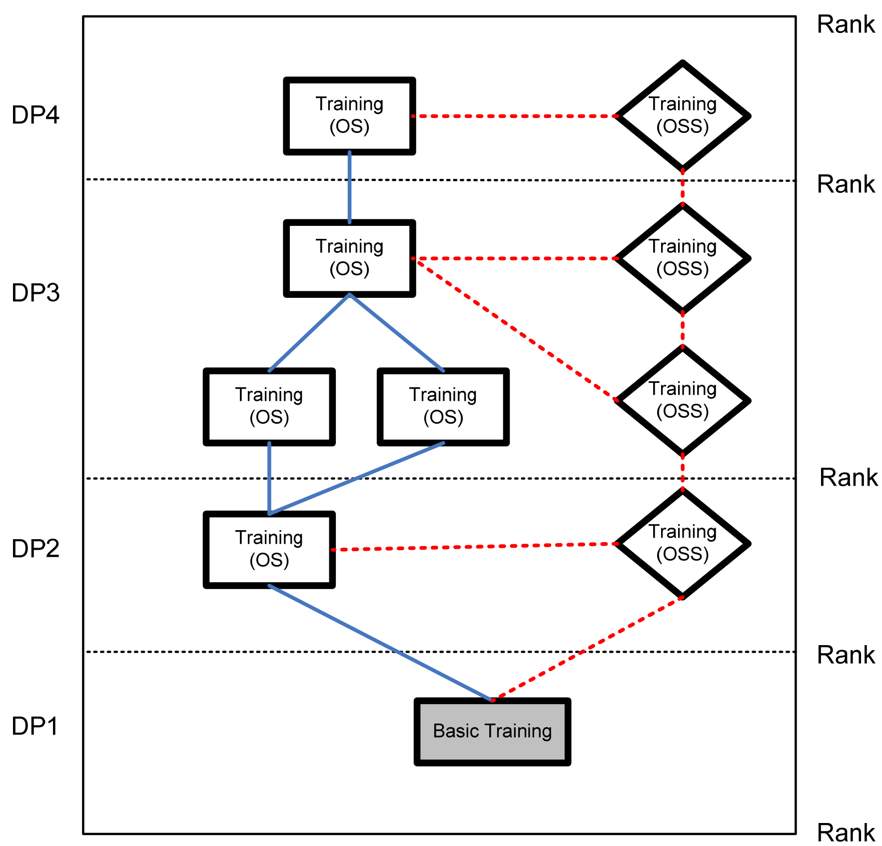


Figure 7. Training (HV-F) Example [Baker, 2007]

HV-G METRICS

The HV-G can be its own product or incorporated into another architecture metric view, such as the SV-7 (in MoDAF and DoDAF). It provides a repository for human-related values, priorities and performance criteria, and maps human factors metrics to any other human view elements. It may map high-level (qualitative) values to quantifiable performance metrics and assessment targets or it may map measurable metrics to human functions, i.e., human performance specifications. It provides the basis for any human factors assessments to underpin enterprise performance assessments and the foundation for requirements tracking and certification. For example, it may include task standards as well as performance measures.

Elements of HV-G may include:

- Human Factors Value definitions level 1…n
- Human Performance Metrics (what is to be measured)
- Target Values (what quantifiable value is acceptable)
- Key Performance Parameters
- Human Task to Metrics mapping
- Value to design element mapping
- Methods of compliance

Figure 8 depicts a taxonomy of human performance metrics.

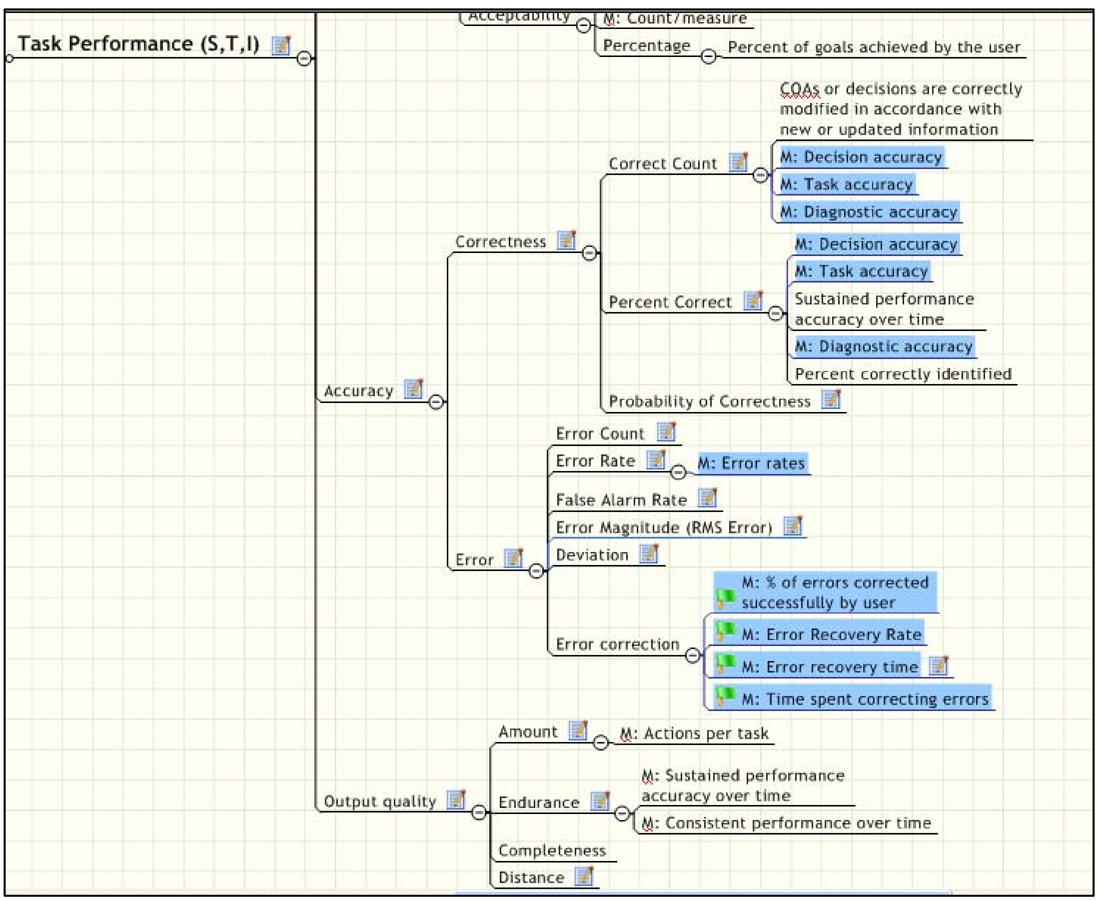


Figure 8. Metrics (HV-G) Example [Pester-Dewan, Oonk, Paris, Reynolds, & Smith, 2006]

HV-H HUMAN DYNAMICS

The HV-H captures dynamic aspects of human system components defined in other views. These are dynamic aspects in the sense that states, conditions, or performance parameters may change over time, or as a result of triggering events. It pulls together definitions from across the Human View to be able to communicate enterprise behaviour. It provides inputs to human behaviour and executable models that may be supported by simulation tools. There are many different human models and simulations that can be used to develop dynamic models; this view can provide stimuli and design aspects for these models.

Features of the HV-H may include

- States (e.g. snapshots) and State Changes, e.g.
  - Organisational/team structure
  - Task/Role assignments to people
  - Team interaction modes
  - Demands on collaboration load (e.g. need to spend effort in building shared awareness, consensus-finding, communicating)
  - Task switches/interruptions
- Conditions (e.g. triggering events or situations; scenarios)
  - Critical / frequent / representative / typical scenarios
  - Operational constraints (e.g. extensive heat stress)
  - Time conditions: sequence, duration, concurrency
- Performance outcomes (observed or predicted), e.g.
  - Workload
  - Decision speed
  - Team interaction/collaboration style
  - Trust in commanders intent
  - Quality of shared awareness/coordination/implicit communication

Figure 9 depicts the output of a simulation tool that indicates workload for individuals and teams that are part of a larger system. Appendix G includes a comprehensive example of the Human Dynamics.

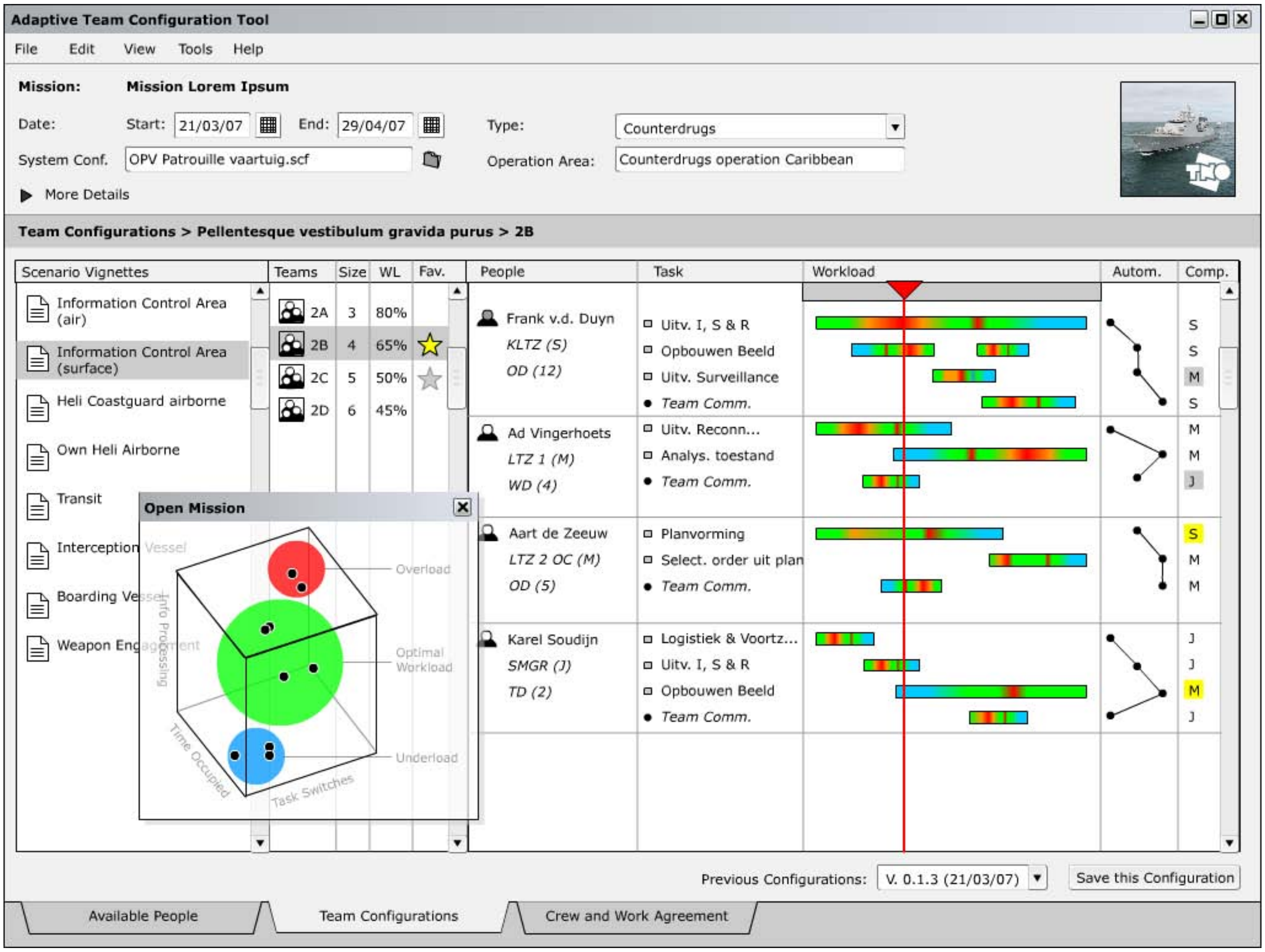


Figure 9. Human Dynamics (HV-H) Example [van den Broek, 2007]

THE WAY AHEAD

The outcomes of the NATO RTO HFM-155 Human View Workshop have been captured in this handbook, which outlines the vision of the NATO Human View through the accompanying eight human view products. This is the first step in the development of a complete design of the human view. Follow on work has been specified to complete the development, this work will be included in this initial volume as appendices. The tasks and status are indicated in Table 2.

Table 2. Follow on Tasks and Status

Task	Status	Notes
1. Continue to refine the draft handbook to more fully explain the view and products.	Complete	Additional templates provided in Appendix E
2. Increase the number of examples that provide visualization of the products.	Complete	Included Appendix A with Commander's Update Brief
3. Define the data elements that are needed to populate the view.	Complete	Included Appendix C with Data Definitions
4. Use the data elements to derive the intra-relationships between the Human View products and the inter-relationships to other architectural views and products.	Complete	Included Appendix B with product relationships
5. Supply guidelines to practioners on a process to develop the Human View, and define how this fits with current processes to develop architecture framework products.	Complete	Included Appendix D that depicts the integration of the Human View with DoDAF product preparation
6. Further Development of the Human View Dynamics	Complete	Appendix G more fully defines the role of simulation
7. Employ the human view for real systems applications	Complete	Future Combat System Examples Included as Appendix H
8. Publish and peer-review the Human View Handbook.	Complete	Article accepted in Systems Engineering Journal

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APPENDIX A: COMPREHENSIVE EXAMPLE COMMANDER'S DAILY UPDATE BRIEF PROCESS

INTRODUCTION

This appendix presents a comprehensive example of the human view products that describe the Commander's Daily Update Brief Process. The Commander's Daily Brief is an operational brief that provides updates regarding the readiness and operational assets throughout the command, with a focus on the previous 24 hours and the next 24 hours. A Commander's Daily Update Brief Process is in place in virtually every US military command. The staff process that produces the brief includes analyzing data sources, creating Microsoft Power Point slides, and numerous review cycles. This process was detailed in support of Trident Warrior 2005 and describes the baseline system used to produce the Commander's Daily Update Brief using the Integrated Interactive Data Briefing Tool (IIDBT).

Historically, the production of the brief has been a manual, staff intensive process that often resulted in static information, which was often several hours old. Prior to the implementation of the IIDBT, this process consumed staff members working the night shift, while the day shift's personnel devoted the morning to its production (Pester-DeWan, Moore & Morrison, 2003). The IIDBT automated the data gathering process using Web services that pull data directly from authoritative sources; the automation of these formerly manual processes saved the staff an estimated 3.5 hours a day while at the same time allowing them to present more current information (Higgins and Hall, 2004). While production time has been cut significantly, the process is still largely stove-piped along functional area divisions. Coalescing the information for the brief typically requires 15 to 20 warfighters and numerous reviewers from various functional areas to create a series of Power Point slides that are organized into a single presentation that is catered to the admiral's information requirements (Handley & Heacox, 2005).

The process described and the models produced can help evaluate the efficiency of the baseline system in the briefing production cycle. These provide a foundation for determining projected time and staff savings when integrating new technologies and processes into the briefing production cycle. This appendix presents the Human View products that augment the previously captured Operational and System View products.

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Higgins, E. & Hall, J. (Summer 2004). The IIDBT Meets the Demands of Modern Warfare with Speed and Accuracy. *Chips Magazine*.

Pester-DeWan, J., Moore, R. & Morrison, J. (2003). Knowledge Engineering for Command and Control Transformation at United States European Command (USEUCOM). Technical Report. Pacific Science & Engineering Group, San Diego, CA.

HV-A CONCEPT

The concept adds the role of the humans into the high-level representation of the process.

Figure A.1. Concept Diagram for Commander's Daily Update Brief

HV-B Constraints

The constraints are used to adjust the expected roles and functions of the humans.

This view is currently unavailable.

HV-C TASKS

Part 1. Activities and Task Decomposition

The activities from the operational view are further decomposed into tasks that can be assigned to humans.

1.0 Identify new information for assigned topics	2.0 Create assigned slides	3.0 Approve slides at cell level	4.0 Compile the briefing form posted slides	5.0 Approve slides at command level	6.0 Brief commander and staff
▪Select topics for briefing content	▪Obtain templates for briefing	▪Advise reviewers of readiness	▪Access slides posted by assigned cells	▪Advise reviewers of readiness	▪Send Link for collaborative session
▪Review previously submitted data	▪Import data	▪Review slides	▪Assess if all slides have been posted	▪Review slides	▪Access Session
▪Identify data sources for relevent updates	▪Create slide	▪Provide updates and comments	▪Notify appropriate cell staff that slides are due	▪Provide updates and comments	▪Initiate Collaborative session
▪Access sources & identify information	▪Revise slides and notes	▪Review comments	▪Access status of requrested slides	▪Review comments	▪Take roll call
	▪Assess currency of information	▪Assess need for more info	▪Notify BWC to proceed without slides	▪Access & revise slides	▪Present the brief
	▪Assess accuracy of fields and spelling	▪Access sources & identify new information	▪Arrange posted slides in order for briefing	▪Post reviewed slides	▪Discuss issues and implications
	▪Revise slide fields and spelling	▪Import data		▪Ensure order and content of posted slides	▪Determine action items
	▪Assess need to make changes to notes	▪Assess need to make changes to slides			▪Distribute action items
	▪Revise slide notes	▪Access and revise slides			
	▪Assess need for sharing with foreign partners	▪Post reviewed slides			
	▪Assess compliance of daa with disclosure policies				
	▪Post completed slide				

Figure A.2. Activities and Task Decomposition for Commander's Daily Update Brief

Part 2. System Interface Matrix

The systems that are utilized to complete the tasks are identified.

Tasks	Systems	C2F CaS Crisis Action Page	Digital ROE	SIPRNET	Electronic Bookmarks	IIDBT	Cells Shared Folder	Email or other direct comms	SameTime or IWS
1.1 Select topics for briefing content		✓	✓						
1.2 Review previously submitted data		✓							
1.3 Identify data sources for relevent updates				✓					
1.4 Access sources & identify information				✓	✓				
2.1 Obtain templates for briefing						✓			
2.2 Import data				✓					
2.3 Create slide						✓			
2.4 Revise slides and notes						✓			
2.5 Assess currency of information									
2.6 Assess accuracy of fields and spelling									
2.7 Revise slide fields and spelling						✓			
2.8 Assess need to make changes to notes									
2.9 Revise slide notes						✓			
2.10 Assess need for sharing with foreign partners									
2.11 Assess compliance of data with disclosure policies								✓	
2.12 Post completed slide							✓		
3.1 Advise reviewers of readiness								✓	
3.2 Review slides							✓		
3.3 Provide updates and comments								✓	
3.4 Review comments								✓	
3.5 Assess need for more info									
3.6 Access sources & identify new information				✓	✓				
3.7 Import data					✓				
3.8 Assess need to make changes to slides									
3.9 Access and revise slides						✓			
3.10 Post reviewed slides		✓							

Figure A.3. System Interface Matrix for Commander's Daily Update Brief

Tasks	Systems	C2F CaS Crisis Action Page	Digital ROE	SIPRNET	Electronic Bookmarks	IIDBT	Cells Shared Folder	Email or other direct comms	SameTime or IWS
4.1 Access slides posted by assigned cells		✓							
4.2 Assess if all slides have been posted									
4.3 Notify appropriate cell staff that slides are due								✓	
4.4 Access status of requrested slides									
4.5 Notify BWC to proceed without slides								✓	
4.6 Arrange posted slides in order for briefing						✓			
5.1 Advise reviewers of readiness								✓	
5.2 Review slides		✓							
5.3 Provide updates and comments								✓	
5.4 Review comments								✓	
5.5 Access & revise slides						✓			
5.6 Post reviewed slides		✓							
5.7 Ensure order and content of posted slides						✓			
6.1 Send Link for collaborative session									
6.2 Access Session									✓
6.3 Initiate Collaborative session									✓
6.4 Take roll call									✓
6.5 Present the brief		✓							
6.6 Discuss issues and implications									✓
6.7 Determine action items									✓
6.8 Distribute action items								✓	

Figure A.4. System Interface Matrix for Commander’s Daily Update Brief, Continued

HV-D ROLES

Part 1. Role Definition

The roles that are required for the process, and selected attributes, are defined.

Code	Title	Multiplicity	Team	Competency	Authority
J00	*Commander*	Individual		GW36 - Guiding Directing, and Motivating Subordinates	Level 0
J1	Director of Manpower and Personnel	Individual	Cell Directors	GW36 - Guiding Directing, and Motivating Subordinates	Level 1
J1X	Update Development Staff	Group	CFMCC Staff	GW09 - Analyzing Data or Information	Level 2
J2	Director of Intelligence	Individual	Cell Directors	GW36 - Guiding Directing, and Motivating Subordinates	Level 1
J2X	Update Development Staff	Group	CFMCC Staff	GW09 - Analyzing Data or Information	Level 2
SSO	*Special Security Officer*	Individual		GW07 - Evaluating Information to Determine Compliance with Standards	Level 2
J3	*Director of Operations*	Individual	Cell Directors	GW33 - Coordinating the Work and Activities of Others	Level 1
J3X	Update Development Staff	Group	CFMCC Staff	GW09 - Analyzing Data or Information	Level 2
J33	*Current Operations (COPS)*	Individual		GW26 - Communicating with Supervisors, Peers, or Subordinates	Level 2
BWC	*Battle Watch Captain*	Individual		GW26 - Communicating with Supervisors, Peers, or Subordinates	Level 2
J4	Director of Logistics	Individual	Cell Directors	GW36 - Guiding Directing, and Motivating Subordinates	Level 1
J4X	Update Development Staff	Group	CFMCC Staff	GW09 - Analyzing Data or Information	Level 2
J5	Director of Planning	Individual	Cell Directors	GW36 - Guiding Directing, and Motivating Subordinates	Level 1
J5X	Update Development Staff	Group	CFMCC Staff	GW09 - Analyzing Data or Information	Level 2
J6	Director of C4I	Individual	Cell Directors	GW36 - Guiding Directing, and Motivating Subordinates	Level 1
J6X	Update Development Staff	Group	CFMCC Staff	GW09 - Analyzing Data or Information	Level 2
J7	Director of Training	Individual	Cell Directors	GW36 - Guiding Directing, and Motivating Subordinates	Level 1
J7X	Update Development Staff	Group	CFMCC Staff	GW09 - Analyzing Data or Information	Level 2
J9	Director of Experimentation	Individual	Cell Directors	GW36 - Guiding Directing, and Motivating Subordinates	Level 1
J9X	Update Development Staff	Group	CFMCC Staff	GW09 - Analyzing Data or Information	Level 2

Figure A.5. Roles for Commander's Daily Update Brief

Part 2. Task Responsibility Matrix

The tasks from the activity decomposition are assigned to the available roles. Note that some tasks are assigned to role “teams” while others are assigned to individual roles.

Tasks	Responsibility							
	Director of Operations	CFMCC Staff	Cell Directors	Special Security Officer	Battle Watch Captain	J33	Remote Staff	Commander
1.1 Select topics for briefing content	✓							
1.2 Review previously submitted data		✓						
1.3 Identify data sources for relevent updates		✓						
1.4 Access sources & identify information		✓						
2.1 Obtain templates for briefing		✓						
2.2 Import data		✓						
2.3 Create slide		✓						
2.4 Revise slides and notes		✓						
2.5 Assess currency of information		✓						
2.6 Assess accuracy of fields and spelling		✓						
2.7 Revise slide fields and spelling		✓						
2.8 Assess need to make changes to notes		✓						
2.9 Revise slide notes		✓						
2.10 Assess need for sharing with foreign partners		✓						
2.11 Assess compliance of data with disclosure policies				✓				
2.12 Post completed slide		✓						
3.1 Advise reviewers of readiness		✓						
3.2 Review slides			✓					
3.3 Provide updates and comments			✓					
3.4 Review comments		✓						
3.5 Assess need for more info		✓						
3.6 Access sources & identify new information		✓						
3.7 Import data		✓						
3.8 Assess need to make changes to slides		✓						
3.9 Access and revise slides		✓						
3.10 Post reviewed slides		✓						

Figure A.6. Task Responsibility Matrix for Commander’s Daily Update Brief

Tasks	Responsibility							
	Director of Operations	CFMCC Staff	Cell Directors	Special Security Officer	Battle Watch Captain	J33	Remote Staff	Commander
4.1 Access slides posted by assigned cells					✓			
4.2 Assess if all slides have been posted					✓			
4.3 Notify appropriate cell staff that slides are due					✓			
4.4 Access status of requested slides		✓						
4.5 Notify BWC to proceed without slides		✓						
4.6 Arrange posted slides in order for briefing					✓			
5.1 Advise reviewers of readiness					✓			
5.2 Review slides			✓					
5.3 Provide updates and comments			✓					
5.4 Review comments		✓						
5.5 Access & revise slides		✓						
5.6 Post reviewed slides		✓						
5.7 Ensure order and content of posted slides					✓			
6.1 Send Link for collaborative session						✓		
6.2 Access Session	✓		✓		✓		✓	✓
6.3 Initiate Collaborative session						✓		
6.4 Take roll call					✓			
6.5 Present the brief	✓							
6.6 Discuss issues and implications								✓
6.7 Determine action items								✓
6.8 Distribute action items					✓			

Figure A.7. Task Responsibility Matrix for Commander's Daily Update Brief, Continued

HV-E HUMAN NETWORK

Part 1. Role Groupings

The roles are grouped into different functional teams.

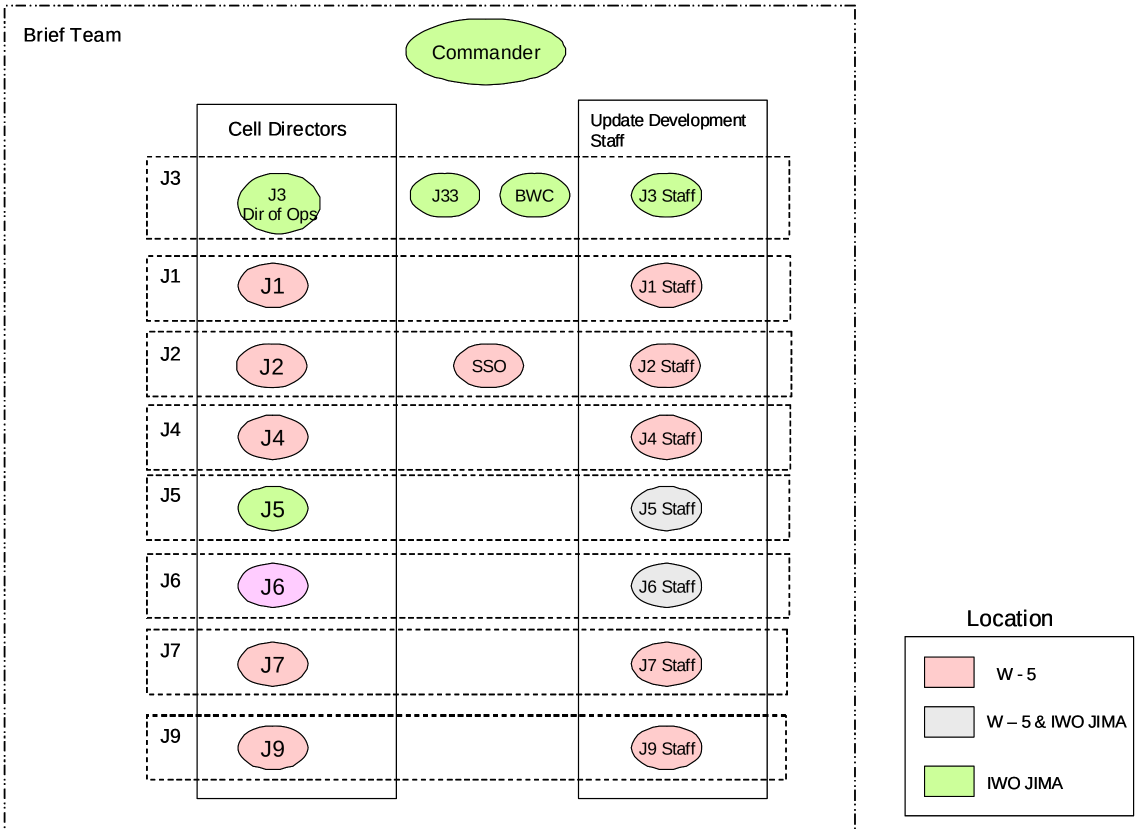


Figure A.8. Role Groupings for Commander's Daily Update Brief

Part 2. Team Interactions

The interactions of the teams across physical locations are indicated.

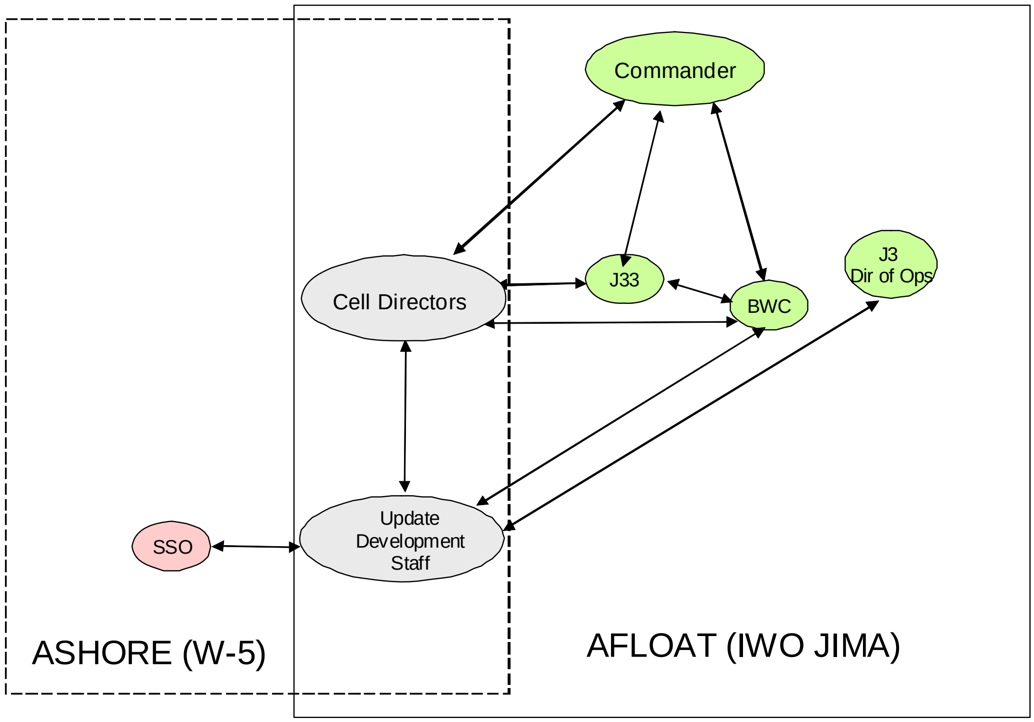


Figure A.9. Team Interactions for Commander's Daily Update Brief

Part 3. Information Requirements

The information requirements between the teams are captured.

Operations/Tasks in this Activity	*Technology/Applications*	*Information Flow*	
		From	*To*
1.1 Select topics for briefing content	Routine: CAS Web (Battle Rhythm) Special: e-mail, chat	Dir of Ops	CFMCC Staff
1.2 Review previously submitted data	CAS Web (view previous posting), e-mail, chat	(CFMCC Staff work in progress)	
1.3 Identify data sources for relevent updates	DISA Federated or other search tool, electronic bookmarks, e-mail, chat	(CFMCC Staff work in progress)	
1.4 Access sources & identify information	DISA Federated tool, SIPRNET	(CFMCC Staff work in progress)	
2.1 - 2.3 Import data into templates		(CFMCC Staff work in progress)	
2.4 - 2.9 Ensure accuracy of information & presentation, and post updated info	IIDBT, PowerPoint, Cell's private shared folders, Public shared folders	(CFMCC Staff work in progress)	
2.10 Assess need for sharing with foreign partners	e-mail, chat	CFMCC Staff	SSO
2.11 Assess compliance of data with disclosure policies	Public shared folders, e-mail chat	SSO	CFMCC Staff
2.12 Post completed slide	DISA Federated or other search tool, electronic bookmarks, e-mail, chat, Public shared folders, SIPRNET, IIDBT, Cell's private shared folders	(CFMCC Staff work in progress)	
3.1 Advise reviewers of readiness	e-mail, chat	CFMCC Staff	Cell Director
3.2 - 3.3 Conduct cell-level review and provide feedback	Public shared folders, e-mail, chat	Cell Director	CFMCC Staff
3.4-3.10 Review feedback, revise materials per review as necessary and re-post	DISA Federated or other search tool, electronic bookmarks, e-mail, chat, Public shared folders, SIPRNET, IIDBT, Cell's private shared folders	(CFMCC Staff work in progress)	

Figure A.10. Information Flow for Commander's Daily Update Brief

Operations/Tasks in this Activity	*Technology/Applications*	*Information Flow*	
		From	*To*
4.1 - 4.2 Assess if required material has been posted	Public shared folders	(BWC work in progress)	
4.3 Request additional materials	e-mail, chat	BWC	CFMCC Staff
4.4 - 4.5 Develop additional material per request, re-post and notify	DISA Federated or other search tool, electronic bookmarks,e-mail, chat, Cell's private shared folders, Public shared folders, SIPRNET, IIDBT	CFMCC Staff	BWC
4.6 Arrange posted slides in order for briefing and notify reviewers	Public shared folders, e-mail, chat	BWC	Cell Directors
5.1 - 5.3 Conduct command-level review and provide feedback	Public shared folders, e-mail, chat	Cell Directors	CFMCC staff, (copy BWC)
5.4 - 5.5 Review feedback, revise materials per review as necessary, re-post and notify	DISA Federated or other search tool, electronic bookmarks, e-mail, chat, Cell's private shared folders, Public shared folders, SIPRNET, IIDBT	CFMCC Staff	BWC
5.6-5.7 Finalize and post material for briefing	Public shared folders, CAS Web, e-mail, chat	BWC	J33
6.1 Send link for collaborative session	e-mail, chat	J33	Dir Ops, Cell Dirs, Cdr, Remotes, BWC
6.2 Access session	VOIP/VTC, CAS Web, SameTime, IWS, e-mail, chat	Dir Ops, Cell Dirs, Cdr, Remotes, BWC	J33
6.3 Initiate collaborative session	VOIP/VTC, SameTime, IWS	J33	Dir Ops, Cell Dirs, Cdr,
6.4 Take roll call	VOIP/VTC, SameTime, IWS	BWC	Dir Ops, Cell Dirs, Cdr,
6.6-6.7 Present the brief, discuss implications	VOIP/VTC, CAS Web, SameTime, IWS	Dir Ops, Cell Dirs, Remotes	Cdr
6.7 Determine COA	VOIP/VTC, CAS Web, SameTime, IWS	Cdr	Dir Ops, Cell Dirs, Remotes, BWC
6.8 Distribute decision/ action items	e-mail, chat	BWC	Dir Ops, Cell Dirs, Remotes, Cdr

Figure A.11. Information Flow for Commander's Daily Update Brief, Continued

HV-F TRAINING

Part 1. Existing Skill Inventory

Attributes of the personnel currently filling the roles is documented.

Code	**Title**	**Name**	**Rank**	**Designator**	**Billet Ref**		**Clearance**	**Location**
J00	*Commander*	FITZGERALD	O-9	1310	JTF-001	JFMCC-001	TS	IWO
J1	Director of Manpower and Personnel	LANE	O-5	1315	JTF-2201	JFMCC-1901	S	W-5
J2	Director of Intelligence	HOPPA	O-6	1630	JTF-1501	JFMCC-1101	TS/SCI	W-5
SSO	*Special Security Officer*	SMITH	E-6	CTA	JTF-1504	JFMCC-1201	TS/SCI	W-5
J3	*Director of Operations*	GOULDING	O-6	1110	JFMCC-020	JTF-501	TS/SCI	IWO
J33	*Current Operations (COPS)*	GRAY	O-5	1147	JFMCC-301	JTF-801	TS	IWO
BWC	*Battle Watch Captain*	MAYO	O-4	1320	JFMC-403	JTF-903	TS	IWO
J4	Director of Logistics	FALLON	O-6	3100	JFMCC-1501	JTF-2401	S	W-5
J5	Director of Planning	PETIT	O-5	1310	JFMCC-771	JTF-603	TS	IWO
J6	Director of C4I	BURKE	O-6	1120	JFMCC-2001	JTF-2501	TS	W-5
J7	Director of Training	VACANT						
J9	Director of Experimentation	VACANT						

Figure A.12. Existing Skill Inventory for Commander's Daily Update Brief

HV-G METRICS

Human performance metrics are defined for the tasks.

Tasks	Objectives	Indicators	Risks
1.0 Identify new information for assigned topics	1. Relevant new information is identified; 2. Requests for breifing, both standard and special are acted upon		
1.1 Select topics for briefing content		Brief development is started within time targets	Missed trigger to begin process
1.2 Review previously submitted data			
1.3 Identify data sources for relevent updates		Information identified is the most up-to-date available	Topical requirements are misunderstood
1.4 Access sources & identify information		Information identified is relevant to the situation.	Data sources are not accessible
2.0 Create assigned slides	1. All available information required to respond to situation is included; 2. Preparation is within time limits		
2.1 Obtain templates for briefing			
2.2 Import data			There is a lack of connectivity to sources
2.3 Create slide		Information on the slide is relevant to the situation	Data updates are not imported
2.4 Revise slides and notes			
2.5 Assess currency of information		Information on the slide is the most up-to-date available	
2.6 Assess accuracy of fields and spelling			The request for a special format is missed
2.7 Revise slide fields and spelling			
2.8 Assess need to make changes to notes			
2.9 Revise slide notes			
2.10 Assess need for sharing with foreign partners			
2.11 Assess compliance of data with disclosure policies			
2.12 Post completed slide		Slide preparation is within time limits	Development schedule is not followed

Figure A.13. Human Performance Metrics for Commander’s Daily Update Brief

Tasks	Objectives	Indicators	Risks
3.0 Approve slides at cell level	1. Adherence to the development schedule is maintained; 2. The review process results in higher quality slides		
3.1 Advise reviewers of readiness		Reviewers are available when needed	Reviewers are not available
3.2 Review slides		Requested slides are posted and accessible	Review is a technicality
3.3 Provide updates and comments		Accuracy of information is improved	
3.4 Review comments			
3.5 Assess need for more info			
3.6 Access sources & identify new information		Information identified is relevant to the situation.	Data sources are not accessible
3.7 Import data			
3.8 Assess need to make changes to slides			
3.9 Access and revise slides			
3.10 Post reviewed slides		Slides are reviewed and changed within time targets	
4.0 Compile the briefing form posted slides	1. Adherence to the development schedule is maintained; 2. The compliled brief contains all requested slides		
4.1 Access slides posted by assigned cells		Requested slides are posted and accessible	Posted slides are inaccessible/ incompatible
4.2 Assess if all slides have been posted			
4.3 Notify appropriate cell staff that slides are due			Missed trigger to begin brief development process
4.4 Access status of requested slides		Requested slides are posted and accessible	
4.5 Notify BWC to proceed without slides			
4.6 Arrange posted slides in order for briefing		Brief is completed within time targets	

Figure A.14. Human Performance Metrics for Commander’s Daily Update Brief, Continued

Tasks	Objectives	Indicators	Risks
5.0 Approve slides at command level	1. Adherence to the development schedule is maintained; 2. The review process results in higher quality slides		
5.1 Advise reviewers of readiness		Reviewers are available when needed	Reviewers are not available
5.2 Review slides		Requested slides are posted and accessible	Review is a technicality
5.3 Provide updates and comments		Accuracy of information is improved	
5.4 Review comments			
5.5 Access & revise slides			
5.6 Post reviewed slides		Slides are reviewed and changed within time targets	
5.7 Ensure order and content of posted slides		Brief is compiled within time targets	
6.0 Brief commander and staff	1. Briefing schedule is maintained; 2. Commander gains up to date SA of the situation; 3. Follow-on tasks are assigned		
6.1 Send Link for collaborative session		The brief is conducted within the time target	Delays cause the briefing to be late
6.2 Access Session		All staff are able to access the session	Staff are unable to access the brief
6.3 Initiate Collaborative session			
6.4 Take roll call		All requested staff are present	
6.5 Present the brief		Current information is presented	The most current information is not presented
6.6 Discuss issues and implications		Relevant information is presented	
6.7 Determine action items		Action items are developed	
6.8 Distribute action items			Action items are not relayed

Figure A.15. Human Performance Metrics for Commander’s Daily Update Brief, Continued

HV-H Human Dynamics

Part 1: Dynamic Model

Sample pages from two different dynamic models of the Commander's Daily Update Brief are presented with the relationships to Human View products noted. The first was created with Colored Petri nets, a graphical, discrete event modeling and simulation tool that is applicable for a range of modeling application. The second was created with MEGA, a business process modeling (BPM) software.

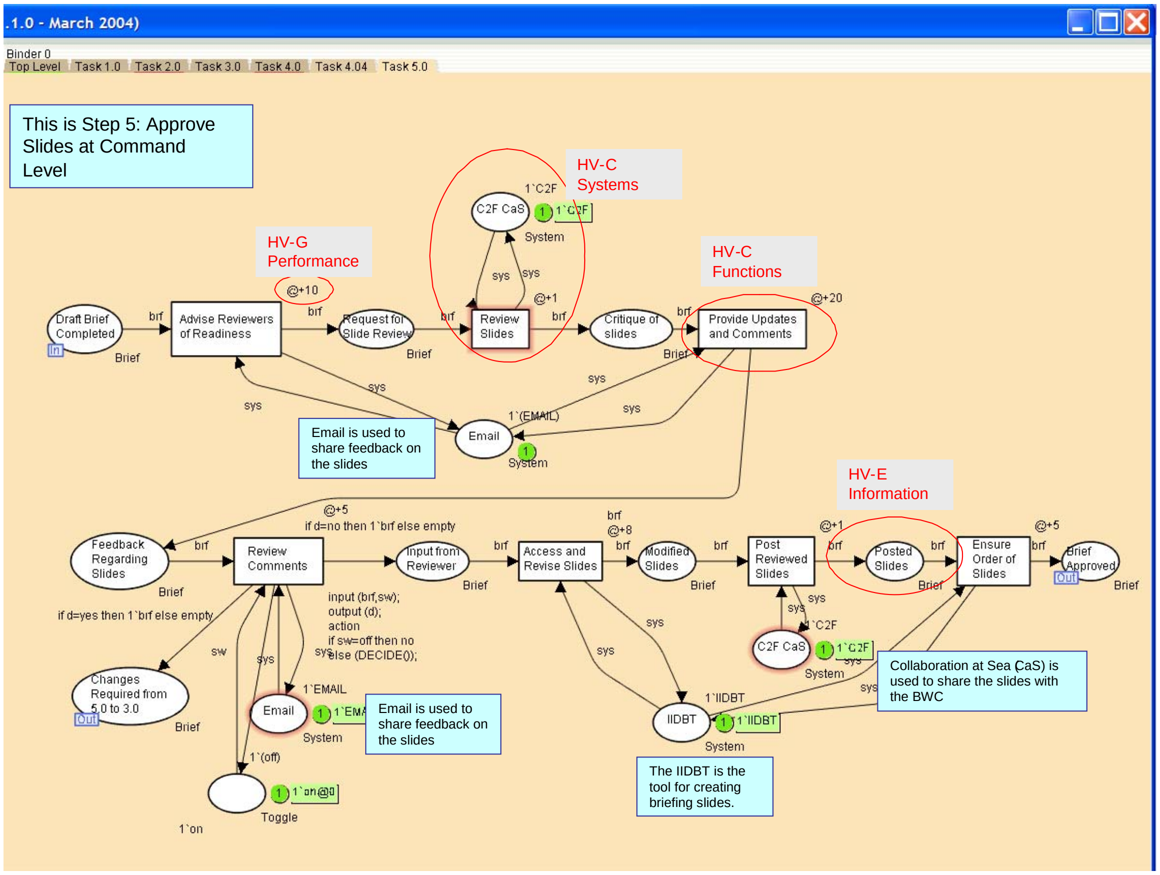


Figure A.16. Colored Petri net Model Sample Page for Commander's Daily Update Brief

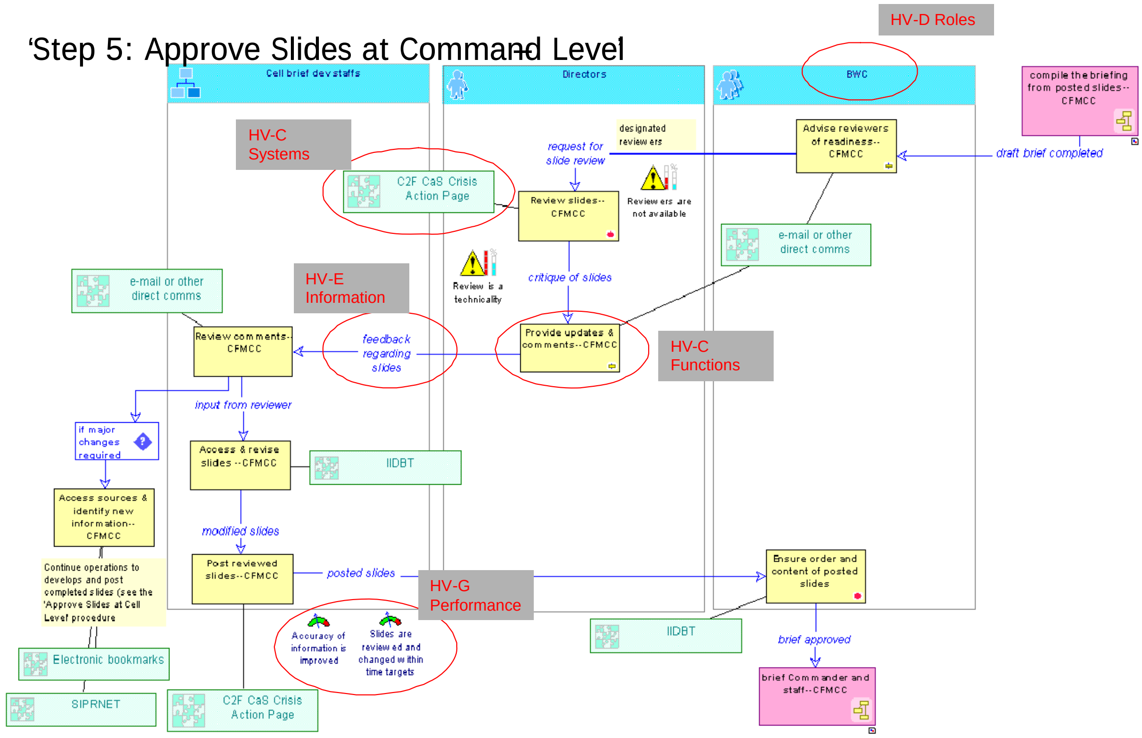


Figure A.17. MEGA Model Sample Page for Commander's Daily Update Brief

Part 2. Experimental Conditions and Outcomes

The different conditions under which the dynamic model will be run and the outcomes to be measured are defined.

Model with DIIDBT		Model without DIIDBT		Performance Measured
Operational Tempo	Bandwidth/ Connectivity	Operational Tempo	Bandwidth/ Connectivity	Brief Completion Time
LOW	LOW	LOW	LOW	TBD
LOW	HIGH	LOW	HIGH	TBD
HIGH	LOW	HIGH	LOW	TBD
HIGH	HIGH	HIGH	HIGH	TBD

Operational Tempo – The rate at which information is available

Connectivity – The number of communication channels available for information exchange

Figure A.18. Experimental Conditions and Outcomes for Commander's Daily Update Brief

Part 3. Model States

The different states of execution for the dynamic models are depicted graphically.

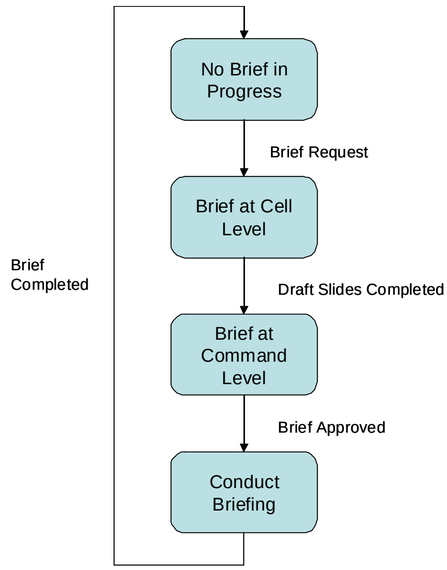


Figure A.19. Model States for Commander's Daily Update Brief

Product Summary

The complete set of Commander's Daily Update Brief Human View products and their relationship with the existing DODAF architectural products is shown in the figure below.

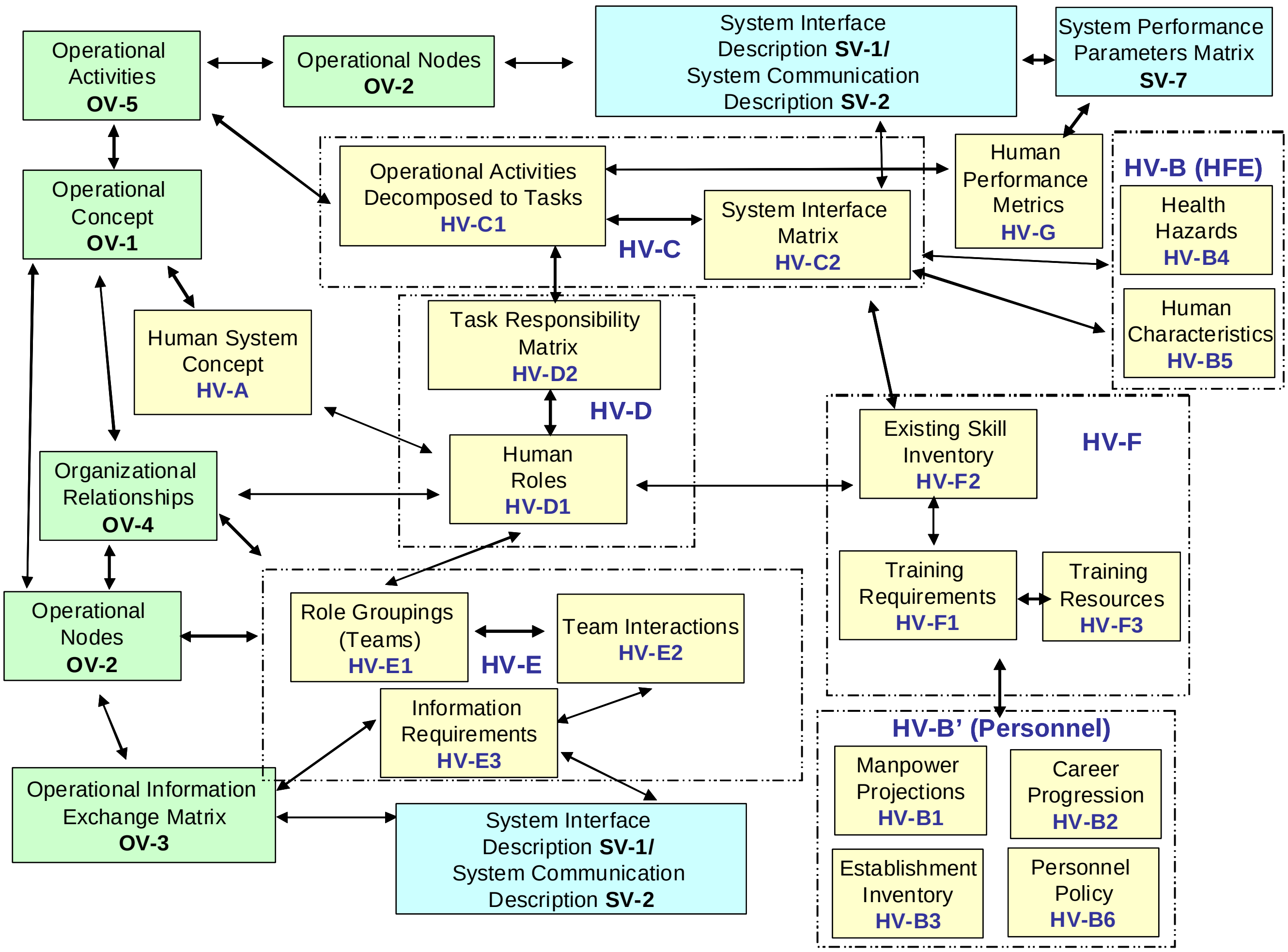


Figure A.20. Human View Products for Commander's Daily Update Brief

APPENDIX B: ARCHITECTURE PRODUCT RELATIONSHIPS HUMAN VIEW PRODUCTS AND DODAF

INTRODUCTION

This appendix summarizes major relationships among the NATO Human View products and select US Department of Defense Architectural Framework (DoDAF) products. The relationships are evolved sequentially and then summarized at the end of the appendix. These relationships were discovered during the Commander's Daily Update Brief example described in Appendix A.

HV-A CONCEPT

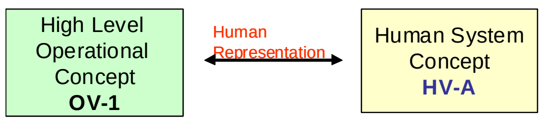


Figure B.1. Concept Relationships

HV-B CONSTRAINTS

Sub views:

- HV-B1 Manpower Projections
- HV-B2 Career Progression
- HV-B3 Establishment Inventory
- HV-B4 Personnel Policy
- HV-B5 Health Hazards
- HV-B6 Human Characteristics

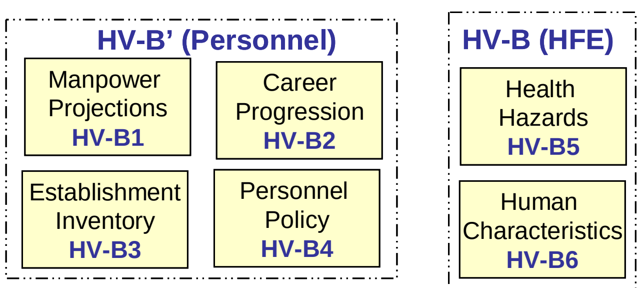


Figure B.2. Constraint Relationships

HV-C TASKS

Sub views:
HV-C1 Operational Activities to Tasks
HV-C2 System Interface Matrix

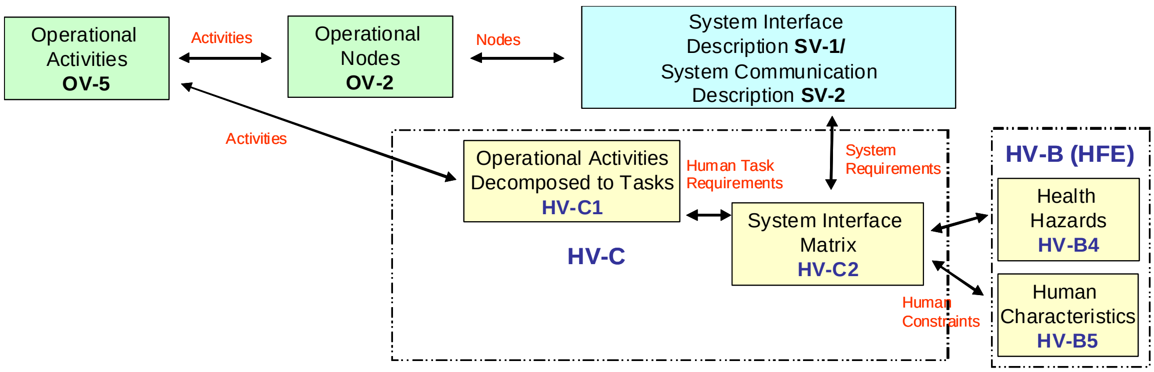


Figure B.3. Tasks Relationships

HV-D ROLES

Sub views:
HV-D1 Operational Activities to Tasks
HV-D2 System Interface Matrix

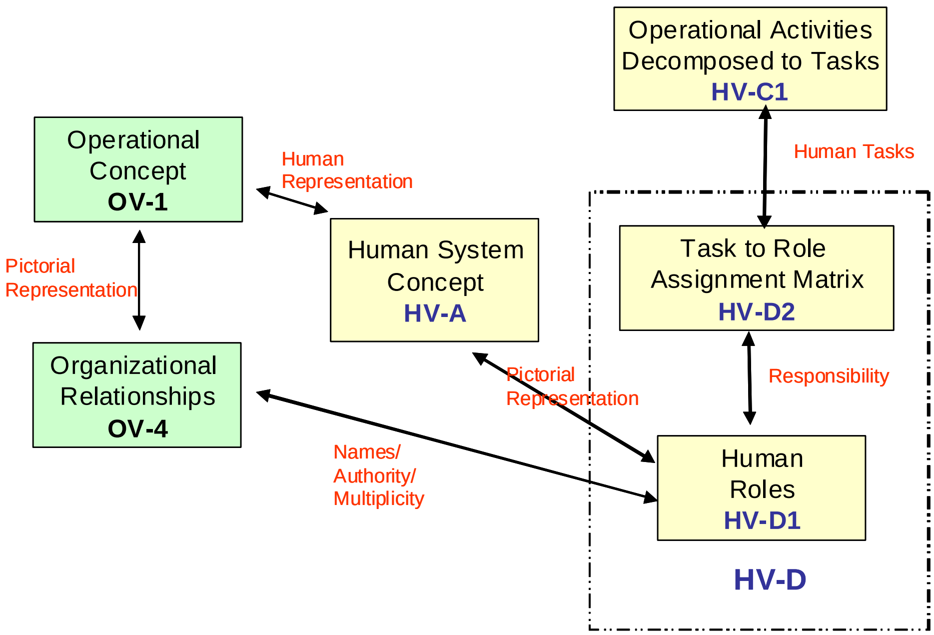


Figure B.4. Roles Relationships

HV-E HUMAN NETWORK

Sub views:

HV-E1 Role Groupings (Teams)
HV-E2 Team Interactions
HV-E3 Information Requirements

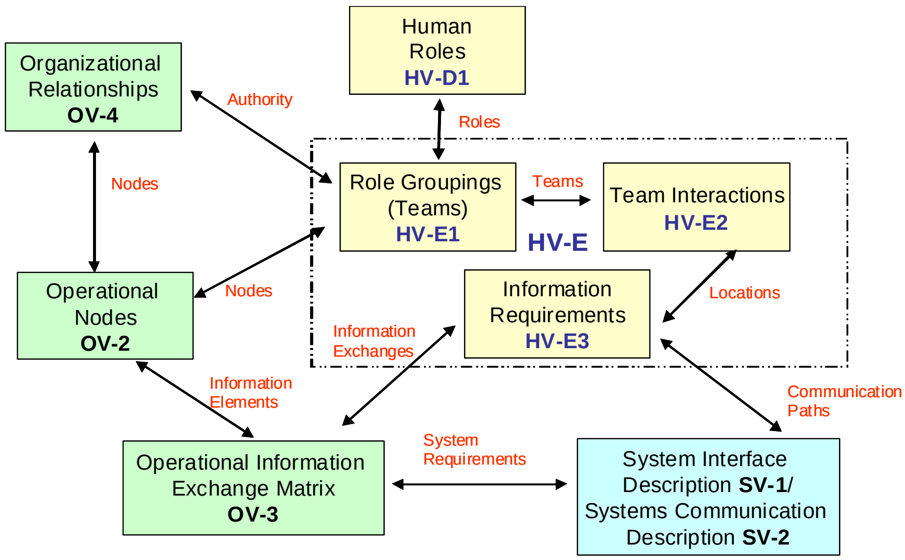


Figure B.5. Human Network Relationships

HV-F TRAINING

Sub views:

HV-F1 Training Requirements
HV-F2 Existing Skills Inventory
HV-F3 Training Resources

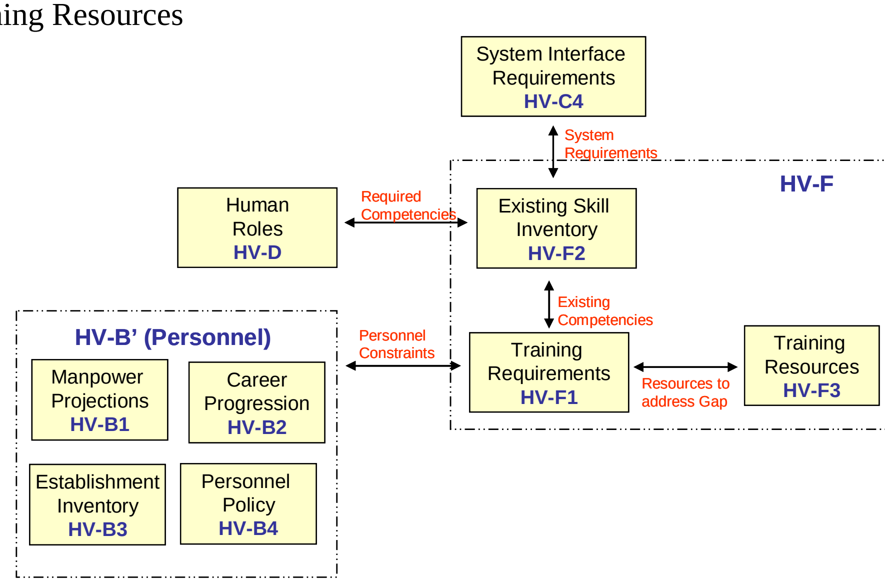


Figure B.6. Training Relationships

HV-G Metrics

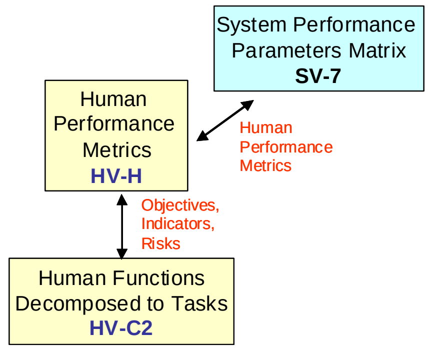


Figure B.7. Metrics Relationships

Summary of Static Product Relationships

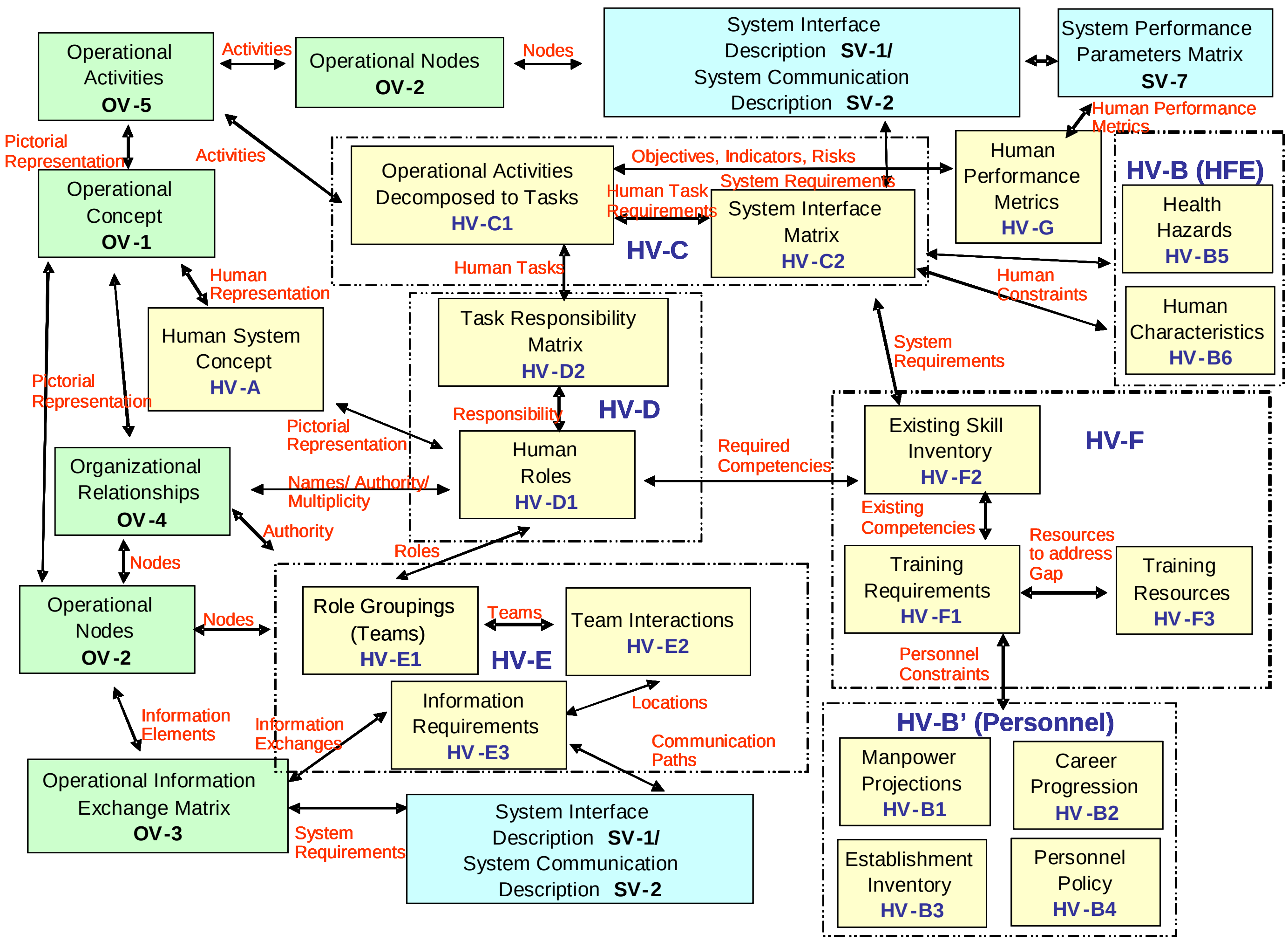


Figure B.8. Static Product Relationships

HV-H Human Dynamics

Subviews:
- HV-H1 Scenario
- HV-H2 Controls
- HV-H3 Performance Evaluation

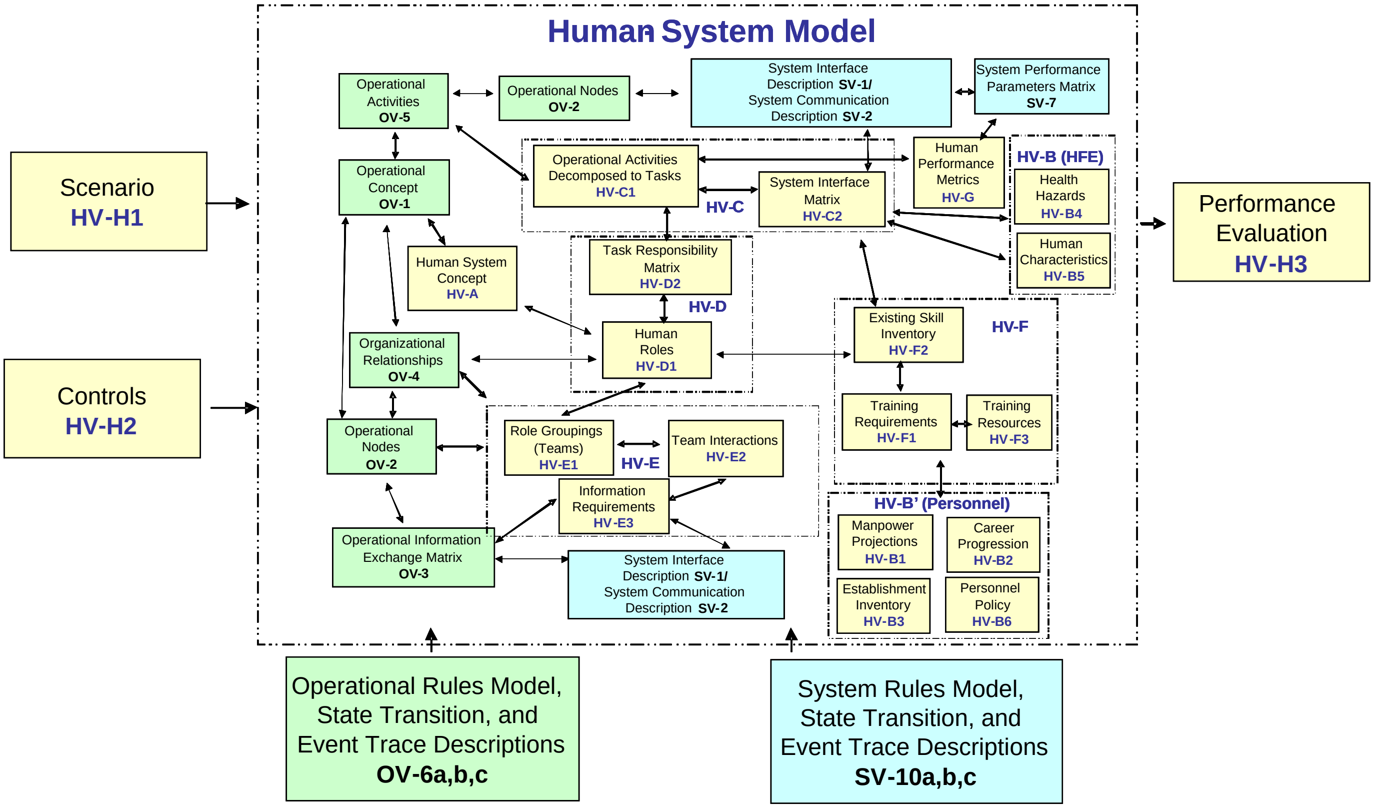


Figure B.9. Human Dynamics

APPENDIX C: DATA DEFINITIONS TABLES AND DATA MODELS
HUMAN VIEW ELEMENTS AND RELATIONSHIPS

HV-A CONCEPT

Product Definition: The HV-A is a conceptual, high-level representation of the human component of the enterprise architecture framework.

Table C.1. Data Elements for Concept (HV-A)

Data Elements	Attributes	Example Values/Explanations
Referenced Elements		
Asset Icon		See OV-1 Definition Table
Line		See OV-1 Definition Table
Role		See HV-D Definition Table
Team		See HV-E Definition Table
Interaction		See HV-E Definition Table
Relationships		
Asset Icon may represent a Role		
	Asset Icon Name	Name of the icon
	Role Name	Name of the role represented by the icon
Asset Icon may represent a Team		
	Asset Icon Name	Name of the icon
	Team Name	Name of the team represented by the icon
Line represents an Interaction		
	Line Name	Name of the connection
	Interaction Name	Name of the interaction represented by the line
Line connects to Asset Icon		
	Line Name	Name of the line connecting asset icon
	Asset Icon Name	Name of the asset icon

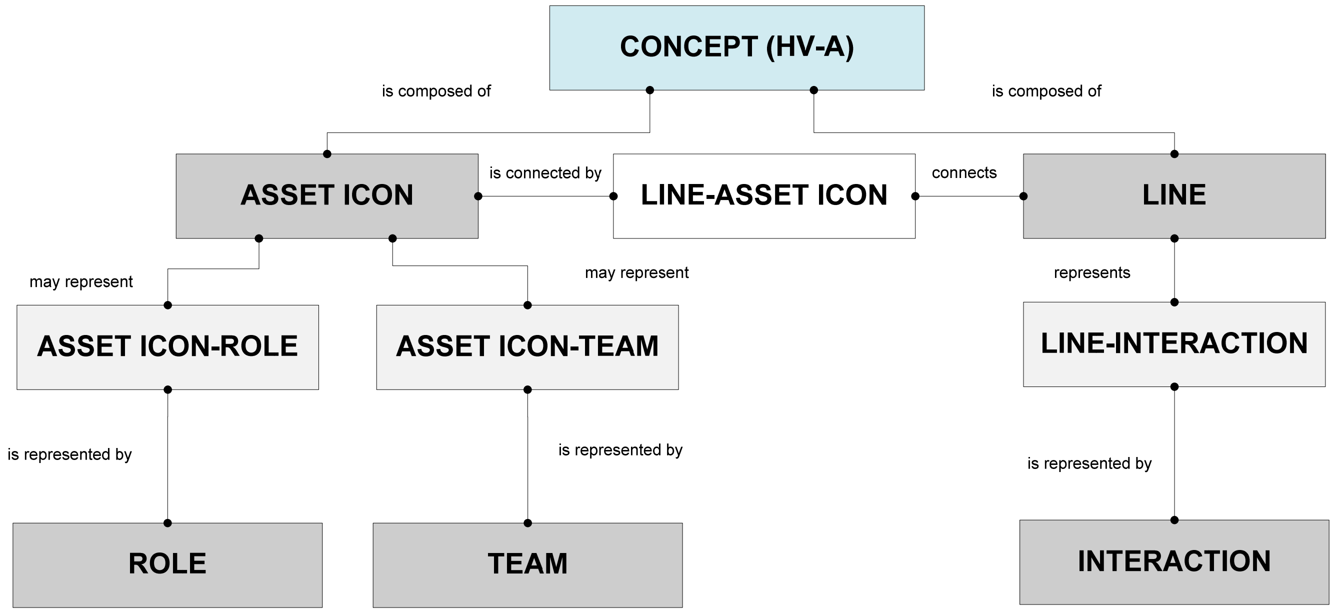


Figure C.1. Data Model for HV-A Concept

HV-B CONSTRAINTS

Product Definition: The HV-B provides a repository for different sets of constraints that may impact the human system.

Table C.2. Data Elements for Constraints (HV-B)

Data Elements	Attributes	Example Values/Explanations
Defined Elements		
Constraint Type		
	Name	Name of type of constraint, i.e., manpower, health, etc.
	Description	Description of the type of constraint
	Source	Reference to the source document for the constraint type
Constraint		
	Name	Name of specific constraint
	Description	Description of constraint
	Parameters	Constraint parameters
	Source	Reference to the source document for the specific constraint
Referenced Elements		
Task		See HV-C Definition Table
Role		See HV-D Definition Table
Team		See HV-E Definition Table
Interaction		See HV-E Definition Table
System		See SV-1 Definition Table
Relationships		
Constraint Type includes Constraint		
	Constraint Type Name	Name of the constraint type
	Constraint Name	Name of the constraint
Task has Constraints		
	Task Name	Name of the task from HV-C.
	Constraint Name	Name of the constraint
Role has Constraints		
	Role Name	Name of the role from HV-D
	Constraint Name	Name of the constraint
Team has Constraints		
	Team Name	Name of the team from HV-E
	Constraint Name	Name of the constraint
Interaction has		

Constraints		
	Interaction Name	Name of the interaction from HV-E
	Constraint Name	Name of the constraint
System has Constraints		
	System Name	Name of the system name from SV-1
	Constraint Name	Name of the performance parameter set

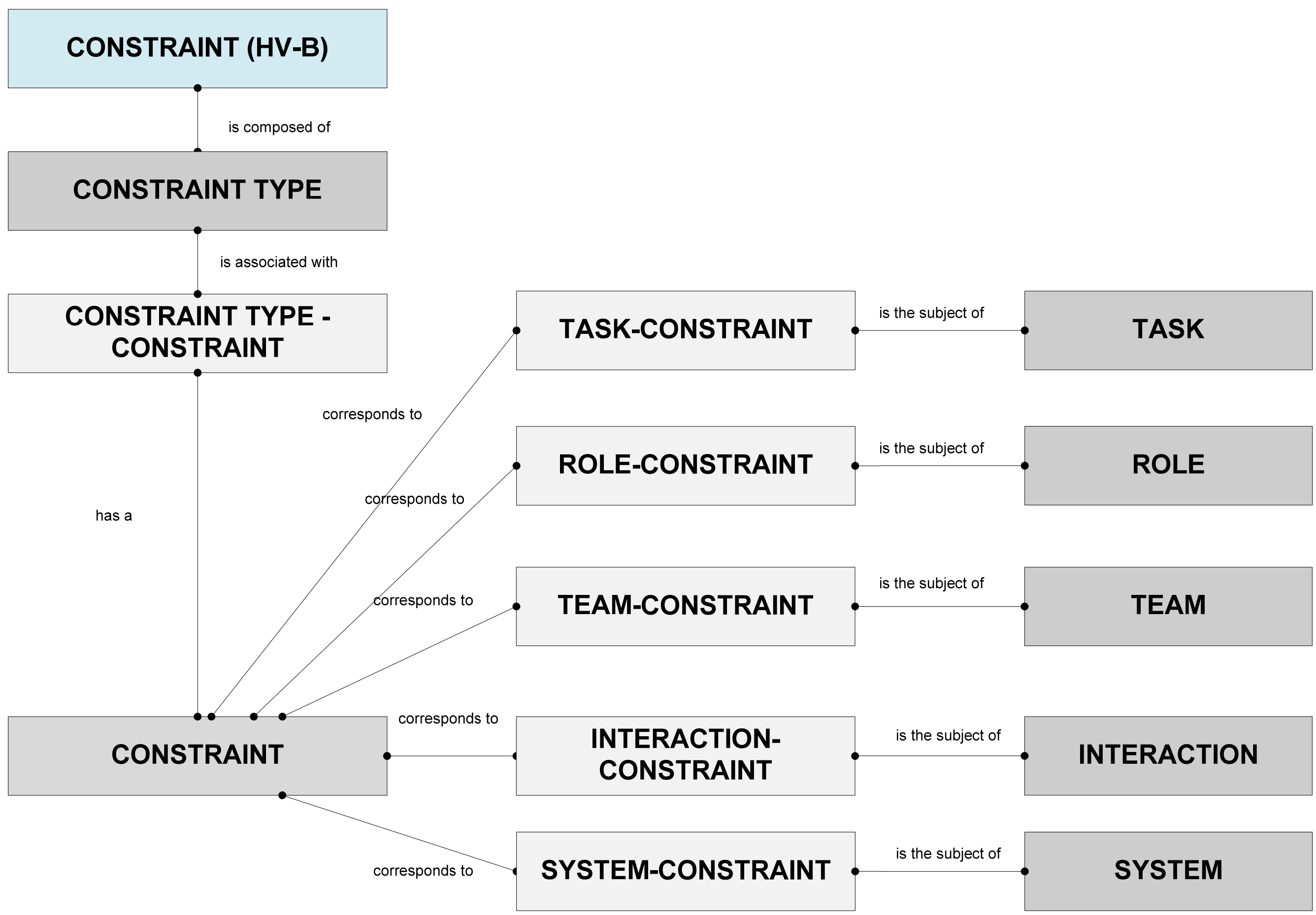


Figure C.2. Data Model for HV-B Constraints

HV-C TASKS

Product Definition: The HV-C describes the assigned human activities and describes how the functions are decomposed into tasks.

Table C.3. Data Elements for Tasks (HV-C)

Data Elements	Attributes	Example Values/Explanations
Defined Elements		
Task		
	Name	Name of the task
	Level Identifier	Identifier that corresponds to the task's place in the activity hierarchy
	Flow Identifier	Identifier the corresponds to the task's place in the activity flow
	Description	Description of the task
	Objective	Output of the task
Referenced Elements		
Operational Activity		See OV-5 Definition Table
System		See SV-1 Definition Table
Relationships		
Operational Activity is decomposed into Tasks		
	Operational Activity	Name of the operational activity from the OV-5
	Task	Name of the task
Task has relationship to other Tasks		
	Task	Name of the Task
	Task	Name of the Task
		(Note this can be precedence, hierarchical, etc)
Task requires System		
	Task	Name of the task
	System	Name of system from SV-1

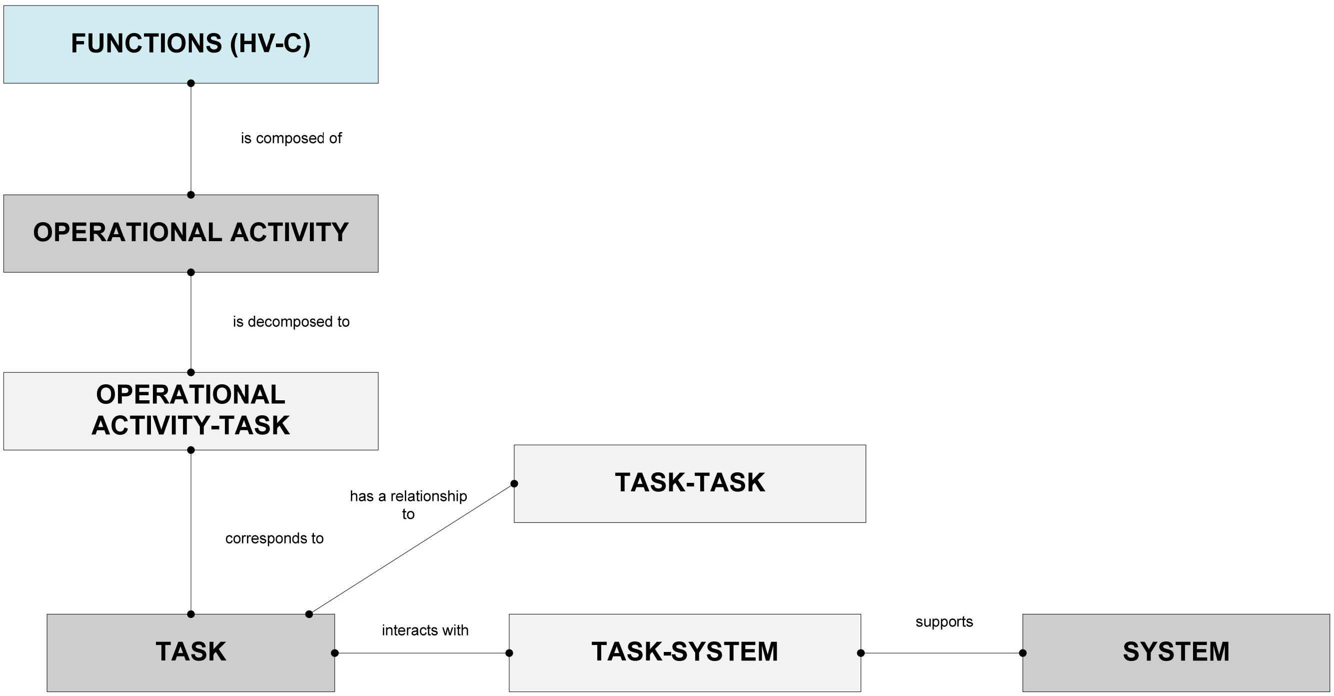


Figure C.3. Data Model for HV-C Tasks

HV-D ROLES

Product Definition: The HV-D describes the roles that have been defined for the humans interacting with the system.

Table C.4. Data Elements for Roles (HV-D)

Data Elements	**Attributes**	**Example Values/Explanations**
Defined Elements		
Role		
	Title	The title of the role
	Code	Organizational representation of the role.
	Multiplicity	Number of human user performing the role at the same time.
Responsibility		
	Name	Name of responsibility acquired when assigned to task
	Description	Description of responsibility
Authority		
	Name	Name of authority granted by hierarchical position
	Description	Description of authority
Location		
	Name	Name of the physical location of the role
	Code	Code for the representation of the location
Referenced Elements		
Task		See HV-C Definition Table
Competency		See HV-F Definition Table
Human Role		See OV-4 Definition Table
Organizational Relationship		See OV-4 Definition Table
Relationships		
Task that Role performs		
	Task Name	Name of the task from HV-C
	Role Name	Name of the role
Competency required to perform Task		
	Competency Name	Name of competency (or KSAs) from HV-F
	Task Name	Name of the task from HV-C
Responsibility induced by Task		
	Responsibility Name	Name of responsibility
	Task Name	Name of the task from HV-C
Role is associated		

with a Human Role		
	Role Name	Name of the role
	Human Role	Name of the human role from the OV-4
Human Role has an Organizational Relationship		
	Human Role	Name of the human role from the OV-4
	Organizational Relationship	Name of the organizational relationship from the OV-4
Authority induced by Organizational Relationship		
	Authority Name	Name of authority
	Organizational Relationship Name	Name of the organizational relationship from the OV-4

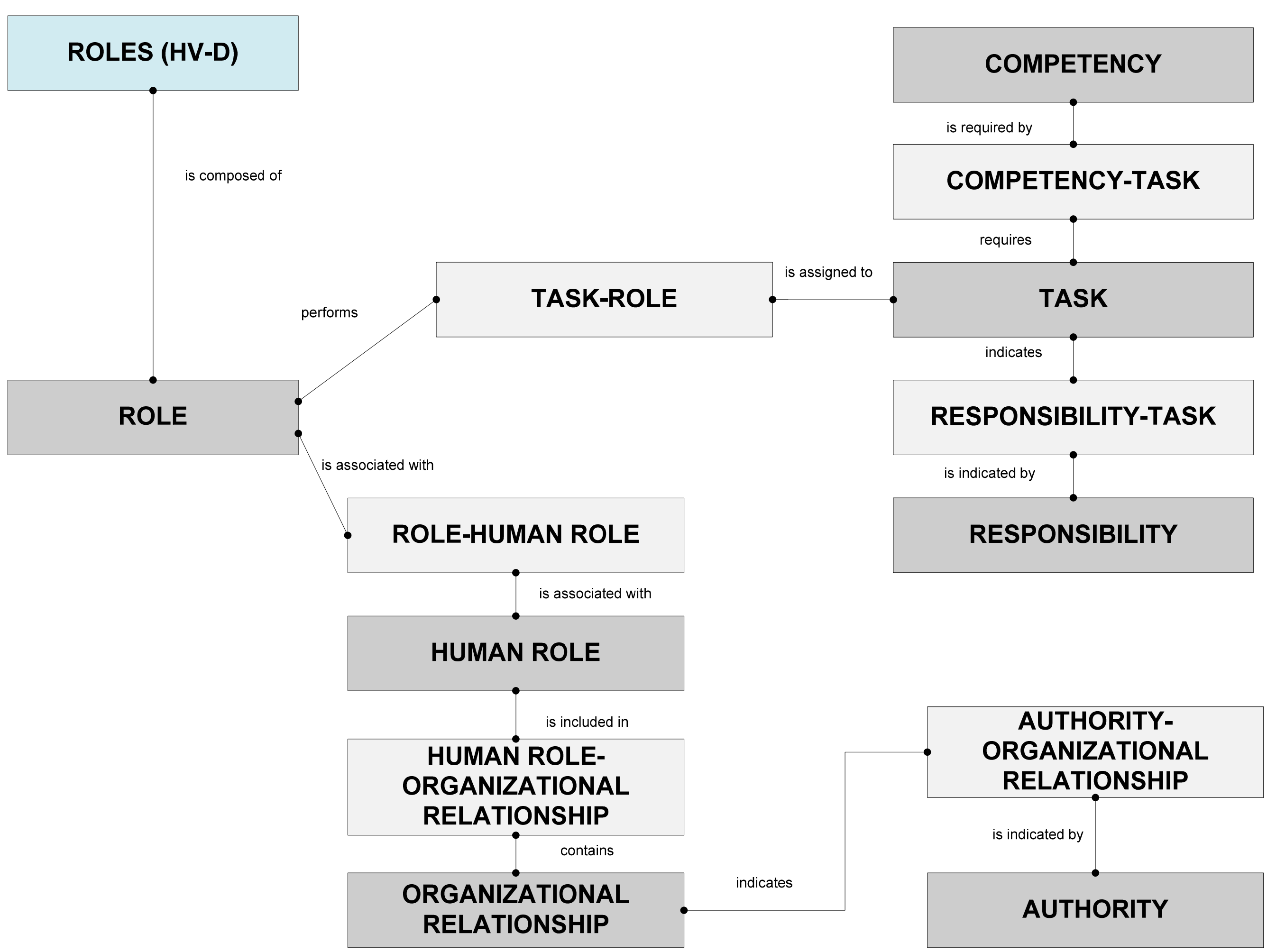


Figure C.4. Data Model for HV-D Roles

HV-E Human Network

Product Definition: The HV-E captures the human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time.

Table C.5. Data Elements for Human Network (HV-E)

Data Elements	Attributes	Example Values/Explanations
Defined Elements		
Team		
	Name	Name of the team
	Description	Description of the team
Interaction		
	Name	Name of the interaction
	Description	Description of the interaction
	Type	Type of the interaction, i.e., inter or intra team
	Requirements	System or network requirements to support the interaction
	From	Name of the role/team that is the initiator of the interaction
	To	Name of the role/team that is the receiver of the interaction
Location		
	Name	Name of the physical location of the role
	Code	Code for the representation of the location
Referenced Elements		
Role		See HV-D Definition Table
Task		See HV-C Definition Table
System		See SV-1 Definition Table
Information Exchange		See OV-3 Definition Table
Relationships		
Team is composed of Roles		
	Team	Name of the team
	Role	Name of the role from HV-D
Role has a physical Location		
	Role	Name of the role
	Location	Code for the location
Task requires Interaction		
	Task	Name of the task from HV-C
	Interaction	Name of the interaction
Interaction requires System		
	Interaction	Name of the interaction
	System	Name of system from SV-1

Interaction may be Information Exchange		
	Interaction	Name of the interaction
	Information Exchange	Name of information exchange from OV-3
Roles may have Interaction		
	Role	Name of the role from HV-D
	Interaction	Name of the interaction
Teams may have Interaction		
	Team	Name of the team
	Interaction	Name of the interaction

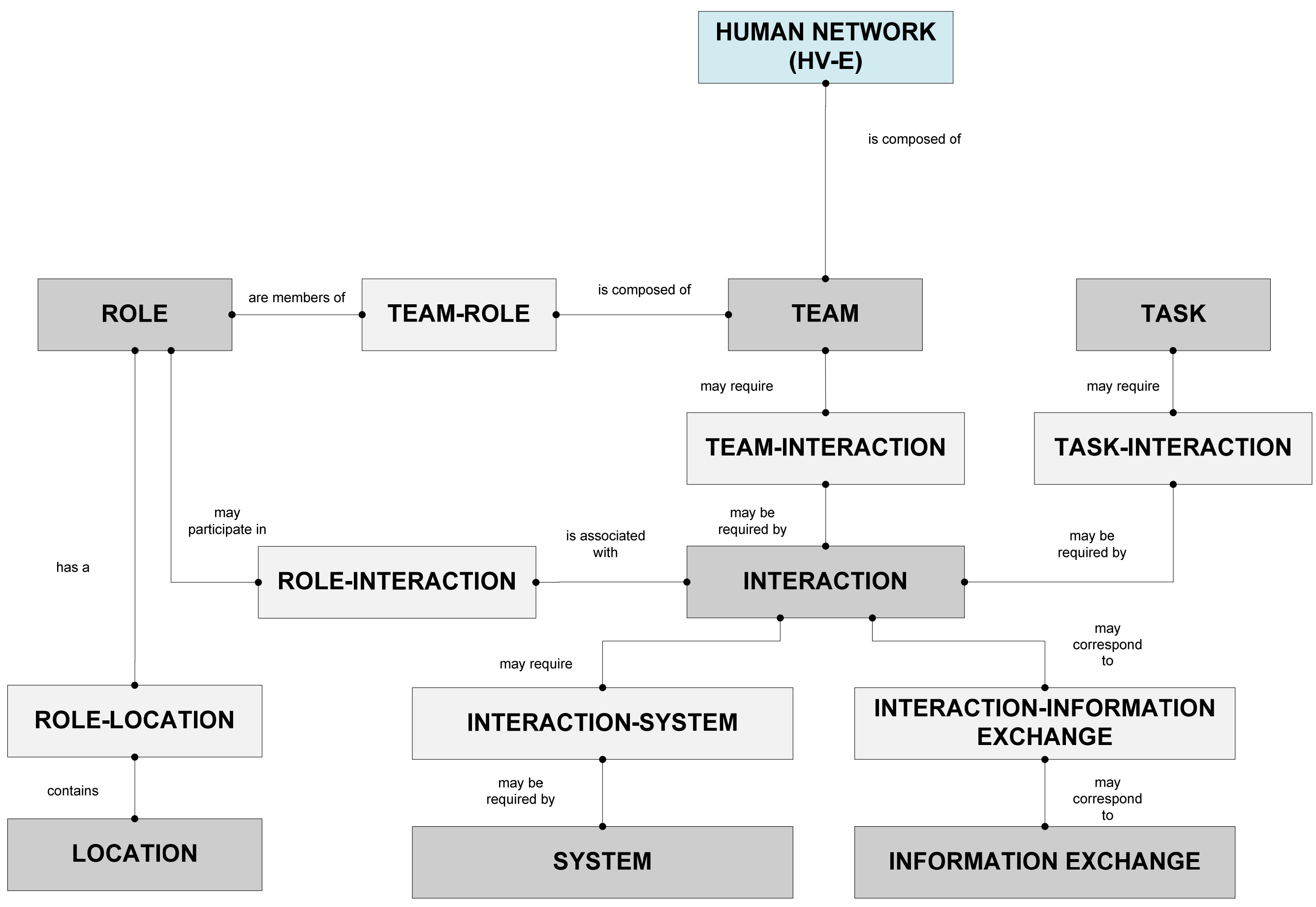


Figure C.5. Data Model for HV-E Human Network

HV-F TRAINING

Product Definition: The HV-F provides a repository for different sets of constraints that may impact the human system.

Table C.6. Data Elements for Training (HV-F)

Data Elements	**Attributes**	**Example Values/Explanations**
Defined Elements		
Training Requirement		
	Name	Name of the training requirement,
	Description	Description of the training requirement
	Timeframe	Timeframe for meeting training requirement
Training Resource		
	Name	Name of training resource
	Description	Description of training resource
	Location	Location of the training resource
Training Type		
	Name	Name of training type, i.e., basic, system specific, etc
	Description	Description of training type
Competency		
	Name	Name of competency acquired when training requirement fulfilled
	Description	Description of competency
	Date	Date competency acquired
Referenced Elements		
Task		See HV-C Definition Table
System		See SV-1 Definition Table
Role		See HV-D Definition Table
Constraint		See HV-B Definition Table
Relationships		
Training Requirement requires a Training Resource		
	Training Requirement Name	Name of the training requirement
	Training Resource Name	Name of the training resource
Training Requirement is a Training Type		
	Training Requirement Name	Name of the training requirement

	Training Type Name	Name of the training type
Training Requirement invoked by Task		
	Training Requirement Name	Name of the training requirement
	Task Name	Name of the task from HV-C
Training Requirement invoked by System		
	Training Requirement Name	Name of the training requirement
	System Name	Name of the system from SV-1
Training Requirement invoked by Role		
	Training Requirement Name	Name of the training requirement
	Role	Name of the role from HV-D
Training Requirement provides a Competency		
	Training Requirement Name	Name of the training requirement
	Competency Name	Name of the competency
Role acquires a Competency		
	Role	Name of the role from HV-D
	Competency	Name of the competency
Training Requirement may invoke a Constraint		
	Training Requirement Name	Name of the training requirement
	Constraint Name	Name of the human constraint from HV-B

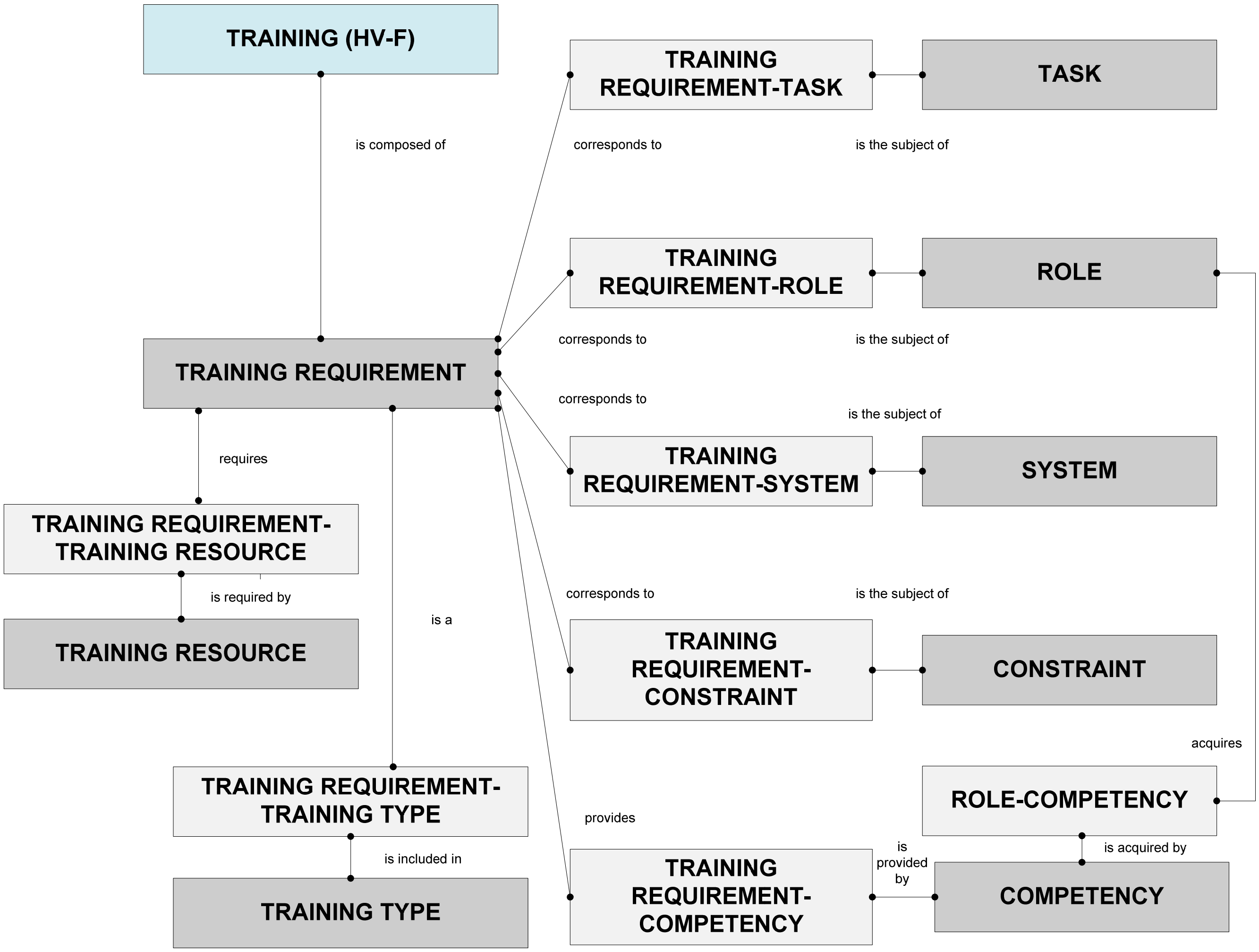


Figure C.6. Data Model for HV-F Training

HV-G METRICS

Product Definition: The HV-G provides a repository for human-related values, priorities and performance criteria, and maps human factors metrics to any other human view elements.

Table C.7. Data Elements for Metrics (HV-G)

Data Elements	**Attributes**	**Example Values/Explanations**
Referenced Elements		
Performance Parameter		See SV-7 Definition Table
Performance Parameter Type		See SV-7 Definition Table
Performance Parameter Range		See SV-7 Definition Table
Task		See HV-C Definition Table
Role		See HV-D Definition Table
Team		See HV-E Definition Table
Interaction		See HV-E Definition Table
Relationships		
Task has Performance Parameter		
	Task Name	Name of the task from HV-C.
	Performance Parameter Name	Name of the performance parameter
Role has Performance Parameter		
	Role Name	Name of the role from HV-D
	Performance Parameter Name	Name of the performance parameter
Team has Performance Parameter		
	Team Name	Name of the team from HV-E
	Performance Parameter Name	Name of the performance parameter
Interaction has Performance Parameter		
	Interaction Name	Name of the interaction from HV-E
	Performance Parameter Name	Name of the performance parameter
Performance		

Parameter has Performance Parameter Type		
	Performance Parameter	Name of the performance parameter
	Performance Parameter Type	Name/identifier of performance parameter type
Performance Parameter has Performance Parameter Range		
	Performance Parameter	Name of the performance parameter
	Performance Parameter Range Identifier	Name/identifier of performance parameter range

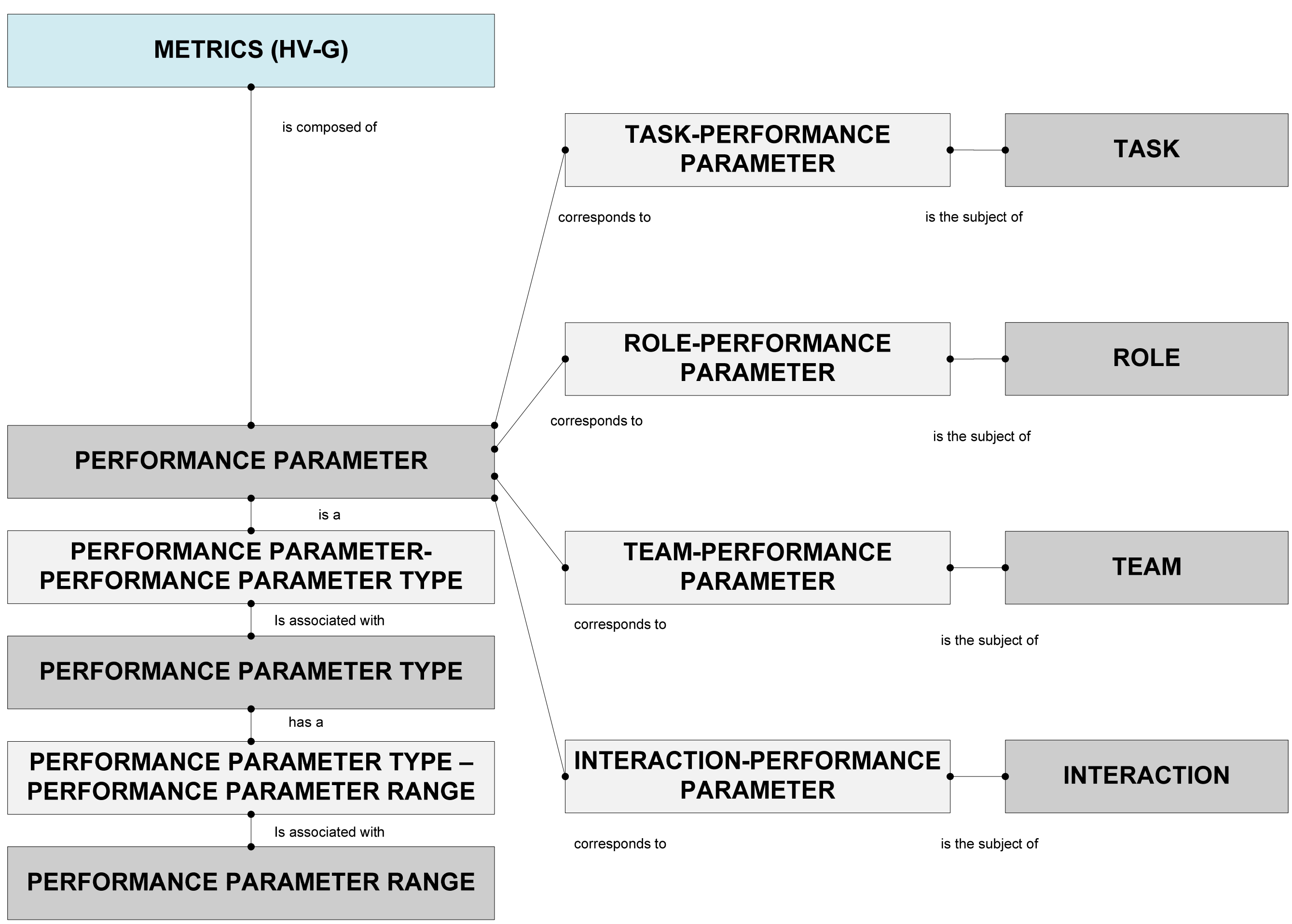


Figure C.7. Data Model for HV-G Metrics

HV-H HUMAN DYNAMICS

Product Definition: The HV-H captures dynamic aspects of human system components defined in other views. This can be used to configure an executable model of the Human System.

Table C.8. Data Elements for Human Dynamics (HV-H)

Data Elements	Attributes	Example Values/Explanations
Referenced Elements		
State		See OV-6b Definition Table
Transition		See OV-6b Definition Table
Action		See OV-6b Definition Table
Event		See OV-6b Definition Table
Guard		See OV-6b Definition Table
Task		See HV-C Definition Table
Constraint		See HV-B Definition Table
Interaction		See HV-E Definition Table
Relationships		
State has associated Action		See OV-6b Definition Table
Action is associated with Transition		See OV-6b Definition Table
Event triggers Transition		See OV-6b Definition Table
Transition has a Guard		See OV-6b Definition Table
Action maps to a Task		
	Action	Name of the action
	Task	Name of the task from HV-C
Event maps to an Interaction		
	Event	Name of the event
	Interaction	Name of the interaction from HV-E
Guard maps to a Constraint		
	Guard	Name of the guard
	Constraint	Name of constraint from HV-B

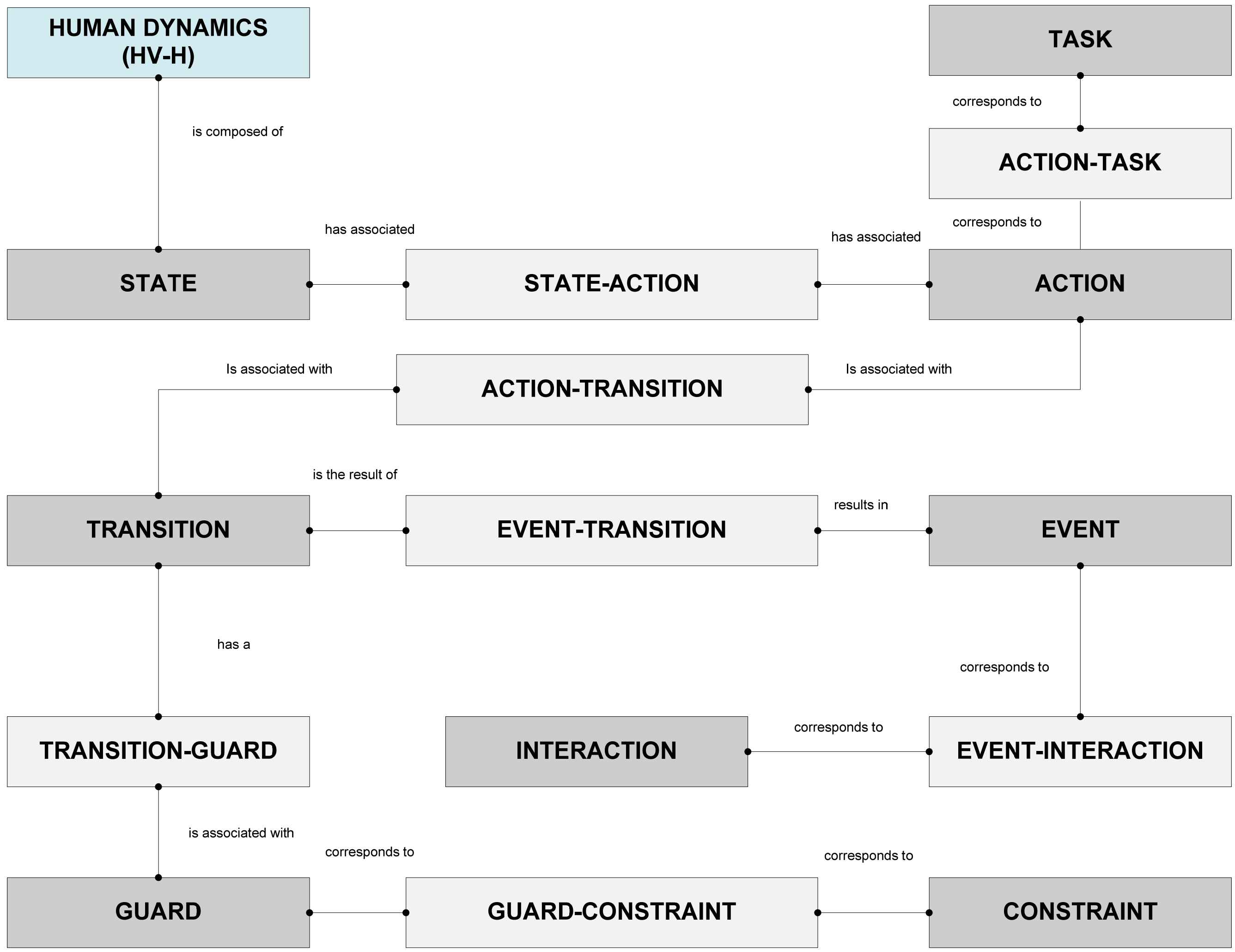


Figure C.8. Data Model for HV-H Human Dynamics

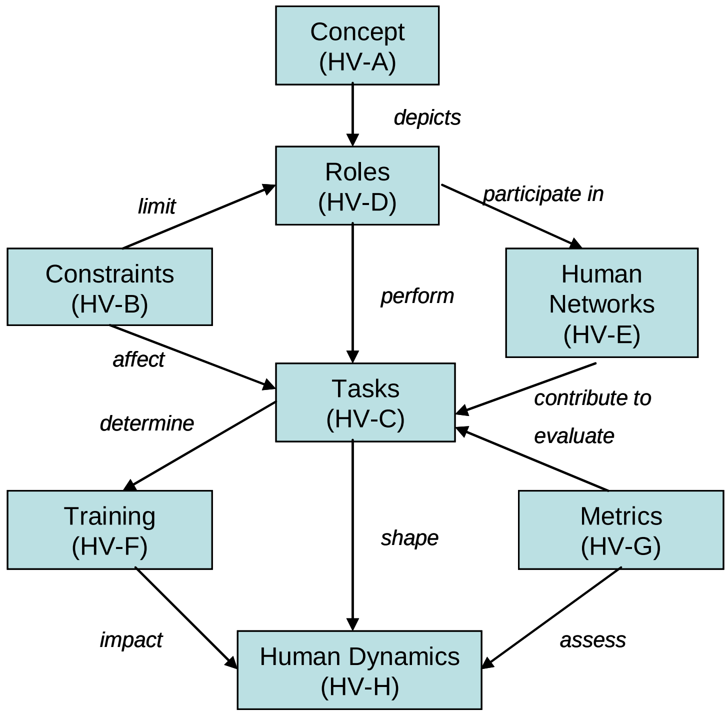


Figure C.9. Meta Model for NATO Human View

APPENDIX D: INCLUDING THE HUMAN VIEW PRODUCTS IN EXISTING PROCESSES

I. Including Human View Products in the Architecting Process

An approach to develop the DoDAF architecture products based on the traditional Structured Analysis approach has been defined[1]. At each stage of the five step process several of the DoDAF products are completed. By understanding the relationship between the DoDAF products and the Human View, as depicted in Appendix B, the appropriate stage to produce the Human View products can be identified and included in the process.

Process Stage	DoDAF Products Completed	Human View Products to be Completed	Purpose
Stage 1: Develop the operational concept that guides the remaining stages.	OV-1 Operational Concept Graphic	HV-A Concept	Includes human roles into high-level representations
Stage 2: Determine which organizations to include in the architecture and the command relationship that will exist between them	OV-4 Command Relationship Chart	HV-B Constraints	Constraints adjust expected roles and functions of the humans
		HV-D (Part 1) Role Definition	Roles that are required with selected attributes
		HV-F (Part 1) Existing Skill Inventory	Attributes of personnel currently in roles
Stage 3: Determine the functions that need to be performed and organize them into a functional decomposition, as well as capturing the desired behavior of the architecture.	OV-5 Activity Model OV-6 a&b Operational Rules and State Transition Models OV-7 Logical Data Model	HV-C (Part 1) Task Decomposition	The operational activities are decomposed into human tasks
		HV-D (Part 2) Task Responsibility Matrix	The tasks from the activity decomposition are assigned to available roles.
Stage 4: Create the initial physical architecture composed of system nodes and allocate system functions to perform operational activities. Additionally	OV-2 Operational Node Connectivity Description OV-3 Operational Information Exchange Matrix SV-5 Operational Activity to System	HV-E (Part 1) Role Groupings	Roles are grouped into functional teams
		HV-E (Part 2) Team Interactions	Interactions of the teams across physical locations
		HV-E (Part 3) Information Requirements	Information Exchanges across the teams

[1] Wagenhals, L.W., Shin, I., Kim, D., & Levis, A. H. (2000). C4ISR Architectures: II. A Structured Analysis Approach for Architecture Design. Systems Engineering 3(4) pp. 248-287.

the activities are allocated to the operational elements and nodes.	Function Traceability Matrix SV-11 Physical Data Model SV-4 Systems Functionality Description	HV-C (Part 2) System Interface Matrix	Systems that are utilized to complete tasks
Stage 5: Complete the design of system architecture by defining the system nodes and the system information elements that flow between and the required system interfaces.	SV-1 System Interface Description SV-2 System Communication Description SV-3 Systems[2] Matrix SV-6 System Information Exchange Matrix SV-8 System Evolution Description SV-9 System Technology Forecast SV-7 System Performance Parameter Matrix	HV-F (Part 2) Training Requirements	Training required to provide personnel essential knowledge and skills for tasks.
		HV-F (Part 3) Training Resources	Instruction, education, on-the-job or unit training available
		HV-G Metrics	Human performance metrics defined

The interaction of the DoDAF and Human View products is shown graphically in the figure below.

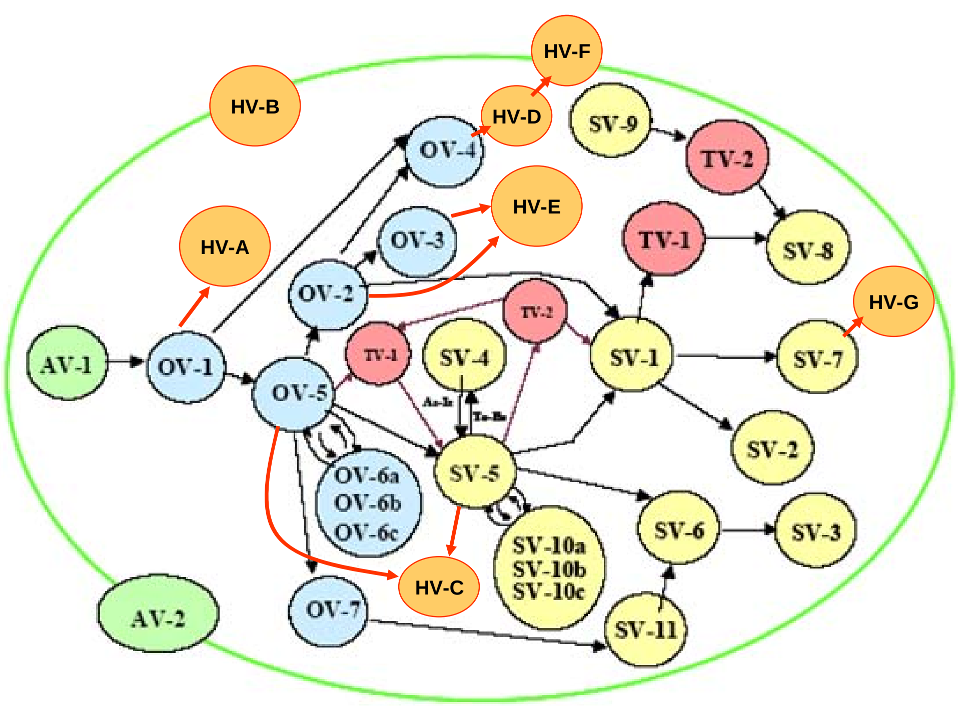


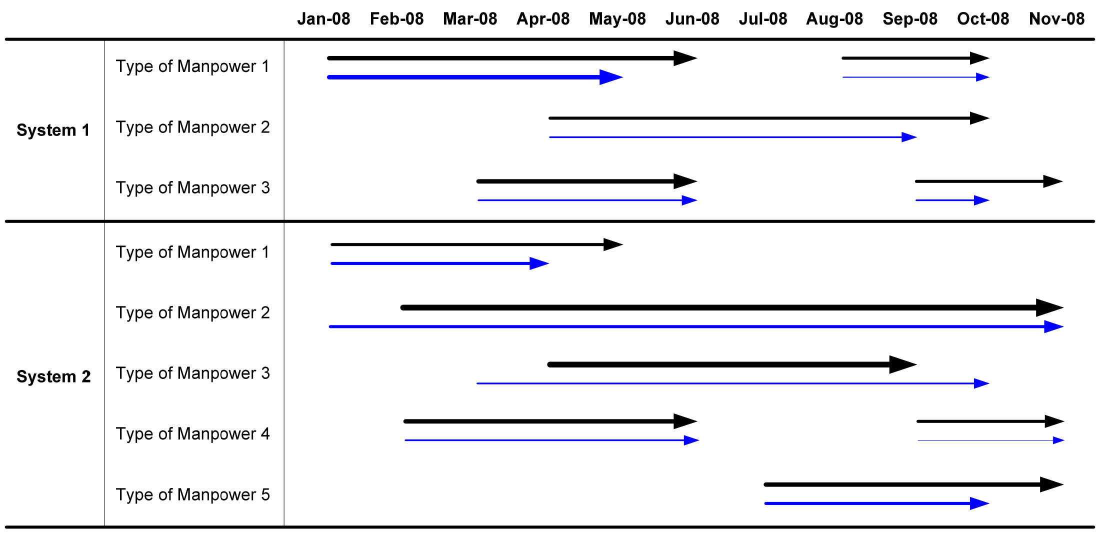
Figure 2.2-2. Data-Centric Build Sequence *
Augmented with Human View Products

* DoD Architecture Framework Version 1.0, Deskbook, 9 February 2004, p. 2-5.

APPENDIX E: SAMPLE PRODUCT TEMPLATES[2]

HV – B: CONSTRAINTS

HV-B1: Manpower Projections



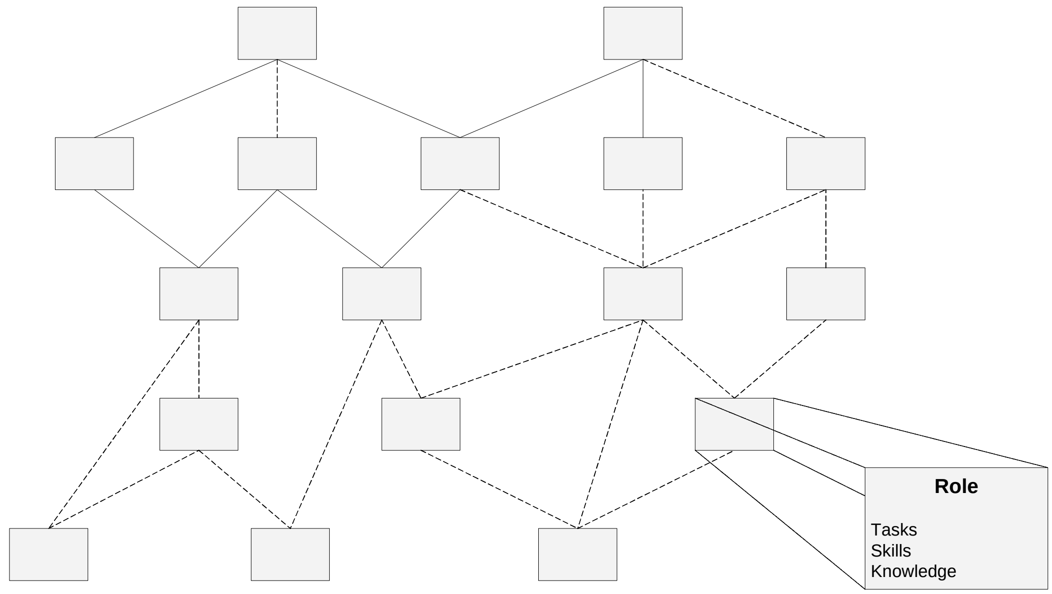
Legend
Black line = current manpower requirements
Blue line = projected manpower requirements

Description:

- The thickness of the lines represents the amount of manpower required; thus, thicker lines require more manpower of that type while thinner lines require less manpower.
- Type of manpower could include: technician, IT, engineer, administrator/coordinator, manager, soldier, etc.
- Systems could include: Infantry Carrier Vehicle (ICV), MULE (Countermine), Medical Vehicle Treatment (MV-T), etc.
- Rationale: FCS highlights the reduction in soldiers; thus, with this type of visualization, the user can easily identify the reduction in amount of manpower (thinner lines) and time of manpower (shorter lines) used.

[2] The graphics and descriptions for Appendix E were supplied by Linda Wu, Human Factors Engineer, Pacific Science & Engineering Group.

HV-B2: Career Progression



Description

- Career progression is a network of roles (rectangles). The roles are connected by lines illustrating how an employee can move from role to role as he/she gains skills and knowledge. Even though not illustrated within each rectangle, an example of the possible contents within it is displayed in the bottom right corner. Under the tasks, skills and knowledge categories, a list of items for that role is provided.
- Roles could include: technician, IT, engineer, administrator/coordinator, manager, soldier, lieutenant, captain etc.
- Tasks could include: repair electrical systems on land manned systems, design unmanned aerial vehicles, coordinate and manage projects, etc.
- Skills could include: repair electrical systems, design and manage network architectural structures, manage personnel, logistics and resource allocations, etc.
- Knowledge could include: network infrastructure training, military data processing and interpretation experience, human factors skills, etc.
- Rationale: for the starting roles (rectangles at the bottom), there are fewer and more general tasks, skills and knowledge. As the individual progressed up the chain, the roles become more difficult and more specific towards a certain domain or job. This increase in difficulty and specificity are illustrated by the growing list of tasks, skills and knowledge. The items under each tasks, skills and knowledge category should share similar items as the roles below it. E.g. an IT Manager role would have the same tasks, skills and knowledge as an IT Support role but with additional management qualifications under those categories. Furthermore, the graph can be divided into a left and right side where each side promotes towards different areas (i.e. left side promotes towards management while right side promotes towards technical lead).

HV-B3: Establishment Inventory

		Rank							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Job	**Job 1**	-	# #	-	#	# #		#	# # #
	Job 2	#	-		-	# # #		-	-
	Job 3	# # # #	-	#	# #		-	# #	
	Job 4	-	# # #		-	# #	# # #	-	#
	Job 5	#	-	# #			# #	#	
	Job 6	# #		# #	-	-		# # #	#
	Job 7	-	# #		# # #	-	# #	-	

Legend

#	= <10
# #	= 10 - 19
# # #	= 20 - 29
# # # #	= 30 - 39
RED	= need *many* more people
YELLOW	= need *some* more people
GREEN	= *do not* need more people
-	= no people are needed
(blank)	= do not have any people and need people

Description:

- Rationale: the # symbol indicates the current people inventory for a certain job/rank while the colors of the symbols indicate how many more people are still needed for that category. The dash (-) indicates that there is not corresponding inventory for that certain job/rank. The only thing this table does not address is the quantity of people needed for a job/rank that currently does not have any people in it (a blank cell).
- Alternative 1: instead of the # symbol, use letters to represent domain or systems, or any other tie shared between rank and job. E.g. M for manned systems, such as Mounted Combat System (MCS) or Medical Vehicle Treatment (MV-T), A for unmanned aerial vehicles such as Class II, and G for unmanned ground vehicles the MULE or ARV Aslt.
- Alternative 2: instead of indicating the number that each # symbol represent, it can indicate a percentage or a general quantitative number of people.

HV-B4: Personnel Policy

	Human Resources Documents									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Employee 1	✓	-	✓	✓	-	✓	-	✓	✓	✓
Employee 2		✓	✓	✓		-		-	-	-
Employee 3	✓	✓	-	✓	-		✓	✓	✓	-
Employee 4	-	✓	✓	✓	-		✓	✓		-
Employee 5	✓	-		✓	✓	✓		-	✓	✓
Employee 6	✓	✓				✓	✓			
Employee 7	-	✓	✓	✓	-		✓	✓		-
Employee 8			✓	✓			-	✓	✓	✓
Employee 9	✓	-		✓	✓	✓		-	✓	-
Employee 10	✓	✓	✓		-		✓	✓	-	-

Description:

- Human resources documents could include: policies, doctrines, laws, benefits, pays, SOPs, etc.
- Rationale: the check marks (✓) indicate that HR has created a document for an employee while the dash (-) indicates that the document is not require for that employee. The blank cells can thus indicate to the user which documents have not been created for an employee.
- Alternative 1: colour the check marks to indicate that HR has reviewed the document with the employee. I.e. black check mark (✓) for a document that exists for an employee while green check mark (✓) for a document that has been reviewed with the employee.
- Alternative 2: colour the check marks to indicate the employees ratings/feedback on their treatment in that area of HR governance. I.e. green check mark (✓) for total employee satisfaction, yellow check mark (✓) for medium employee satisfaction, and red check mark (✓) for employee dissatisfaction.

HV-B5: Health Hazards

	Description	**Risk Level** R / Y / G	**Length** Long-term (L) / Short-term (S)	**Solution**	**Resolved** Y / N
Health Hazard 1	Describe hazard	R	L	Describe solution	Y
Health Hazard 2	Describe hazard	R	L	Describe solution	N
Health Hazard 3	Describe hazard	R	S	Describe solution	N
Health Hazard 4	Describe hazard	Y	L	Describe solution	Y
Health Hazard 5	Describe hazard	Y	S	Describe solution	Y
Health Hazard 6	Describe hazard	G	S	Describe solution	N
Health Hazard 7	Describe hazard	G	L	Describe solution	Y

Description:

- Health hazard could include: system, environmental, task, air quality, noise/vibration, pollution, force/shock, radiation, temperature, etc. or anything that are risks of illnesses, injuries or deaths.
- The description of the hazard describes in detail what it is, the cause and effects of it and the human risks associated with the hazard.
- The risk level is divided into three categories: (R)ed, (Y)ellow, and (G)reen indicating the seriousness of the hazard towards humans. Interpretation of the different categories can be defines relatively to the project but in general:
  - R = serious hazard
  - Y = moderate hazard
  - G = mild hazard
- Risks of long-term hazards will stay with the person forever or for a really long time (1+ years, or some other quantitative length of time), while short-term hazards will stay with the person for less than 1 year (or some other quantitative length of time).
- Alternative: the risk could identify the length of time it takes for the hazard to come into effect (e.g. mild air pollution may pass air safety standards but may not display any hazard to the user until after five years of being exposed to it).
- Rationale: The health hazards are written like requirements with properties so they can easily be listed in a table. The hazards can be organized by risk (where the most serious hazards are at the top so they are addressed first), length, or if they have been resolved or not (where the ones that are unresolved are at the top so they can be addressed first).

Alternative HV-B5: Health Hazards

	System								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Health Hazard 1	X			X			X	X	
Health Hazard 2		X		X	X			X	
Health Hazard 3	X		X	X		X	X		X
Health Hazard 4	X			X			X		X
Health Hazard 5		X	X			X			
Health Hazard 6	X		X	X			X	X	
Health Hazard 7		X			X		X		X

Description:

- Rationale: this table helps the user visualize the relationships between the health hazards and the systems (or design alternatives of the system, etc.). The X symbol indicates the presence of a hazard towards a system; thus, with this table the user can identify which hazards are common towards what type of systems (e.g. ARVs are prone to vibrational hazards), or what hazards a certain system has (e.g. C2V has many hazards while RSV has few hazards).

HV-B6: Human Characteristics

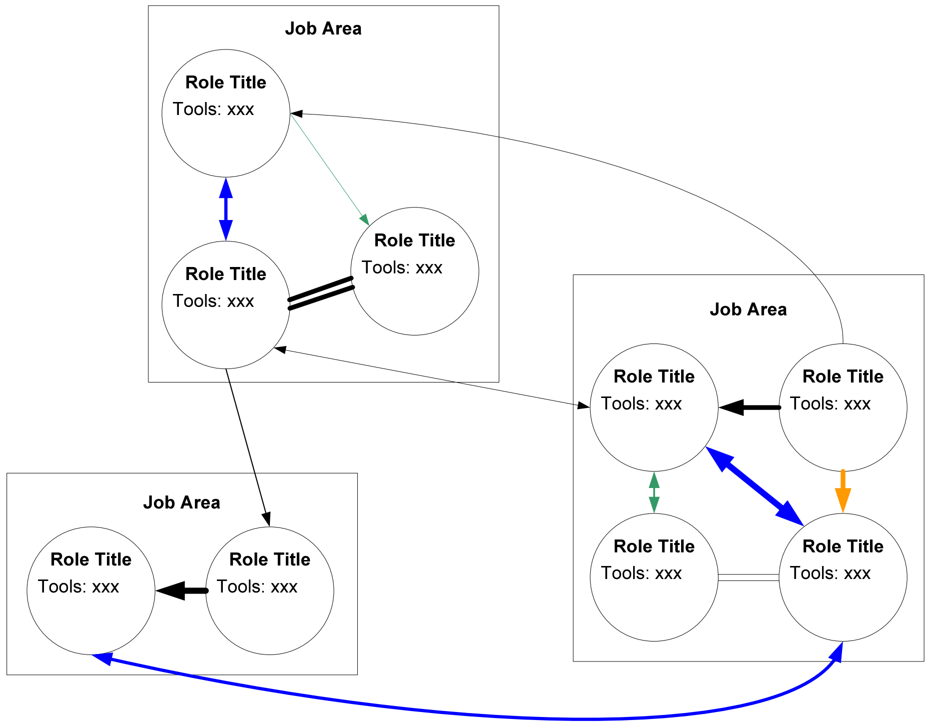
		Description of Characteristic	System				
			1	2	3	4	5
Category 1	Characteristic 1		✓	-		✓	-
	Characteristic 2		-	✓	-		✓
	Characteristic 3		-		✓	-	✓
	Characteristic 4			✓	✓	-	-
	Characteristic 5		✓	-	-	✓	
Category 2	Characteristic 1		-	✓	-	✓	-
	Characteristic 2		✓	-		-	✓
	Characteristic 3		✓		✓	-	-
	Characteristic 4		-	✓	-	✓	
	Characteristic 5		-		✓	-	✓

Description:

- Categories could include: physical, visual and auditory, cognitive, memory, personality/motivation, etc.
- Characteristics could include: strength, length, height, weight of person (for physical); visibility rangers, size of font, intensity of sound (for visual and auditory); reaction time, situation awareness (for cognitive), etc.
- Description of characteristic describes in detail what it is and the requirements of the characteristics (e.g. physical design of the system should accommodate 5^{th} – 95^{th} percentile of male and females).
- Rationale: the check marks (✓) indicate that the system meets the characteristic requirement while the dash (-) indicates that the system does not require to meet the characteristic requirement. The blank cells can thus indicate to the user which systems still need to address certain characteristic requirements. Furthermore, the characteristics are grouped by categories for easier finding as well as to help detect if a characteristic is missing by analyzing if a category has all the characteristics it needs.

HV – C FUNCTIONS

HV-C1: Operational Activities and Decomposed to Tasks



Description:

- Tasks could include: repair electrical systems, design IT architecture, software development, fly Class IV helicopters, coordinate and manage projects, etc.
- Criteria is anything that is necessary to perform the task. It could include: completion of a certain task, use of a certain tool or software, requirement that a type of data has been collected, etc.
- KSA is the knowledge, skills and abilities required to do the task. It could include: repair electrical systems, design and manage network architectural structures, manage personnel, military data processing and interpretation experience, human factors skills, network infrastructure training, etc.
- Roles could include: technicians, electrical engineer, administrator/coordinator, IT manager, soldier, lieutenant, captain etc.
- Rationale: the visualization is presented in the unit of tasks, which are grouped into functions through colour coding. The flow from top to bottom represents the inter-dependencies between tasks where the top tasks need to be completed before starting the bottom ones. Furthermore, the circular tasks are for humans while the rectangular tasks are for machines. This way, the user can easily see the flow and relationship between human and machine interactions among the tasks. For each task, the criteria and knowledge/skill/abilities to complete it is detailed along with the role suitable for the task.

HV-C2: System Interface Matrix

	Requirement	Description	Systems									
			1	2	3	4	5	6	7	8	9	10
Category 1	1		✓	-	✓	✓	-	✓	-	✓	✓	✓
	2			✓	✓	✓		-		-	-	-
	3		✓	✓	-	✓	-		✓	✓	✓	-
	4		-	✓	✓	✓	-		✓	✓		-
	5		✓	-		✓	✓	✓		-	✓	✓
Category 2	1		✓	✓				✓	✓			
	2		-	✓	✓	✓	-		✓	✓		-
	3				✓	✓			-	✓	✓	✓
	4		✓	-		✓	✓	✓		-	✓	-
	5		✓	✓	✓		-		✓	✓	-	-

Description:

- Categories could include: physical, visual and auditory, cognitive, memory, personality/motivation, etc.
- Requirements are the specific requirements of the interface.
- Descriptions are the descriptions of the requirements. It answers what it is, why it is useful and provides explanations and suggestions for design.
- Systems could include: Infantry Carrier Vehicle (ICV), MULE (Countermine), Medical Vehicle Treatment (MV-T), etc.
- Rationale: for the FCS example, most of the interface references are associated with requirements for the interface. Therefore, with this table the user can easily see which systems met the requirements, as indicated by the check marks (✓), which systems do not need to meet certain requirements, as indicated by the dash (-), and which systems has yet to fulfill its requirements, as indicated by blank cells. . Furthermore, the requirements are grouped by categories for easier finding as well as to help detect if a requirements is missing by analyzing if a category has all the requirements it needs.

Alternative HV-C2: System Interface Matrix

Task	**Supported by**	**System**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Situational Awareness	✓	-	✓	✓	-	✓	-	✓	✓	✓
2	Colour, Commonality		✓	✓	✓		-		-	-	-
3	Commonality	✓	✓	-	✓	-		✓	✓	✓	-
4	Situational Awareness, Colour	-	✓	✓	✓	-		✓	✓		-
5	Physical Space, Visual Alert	✓	-		✓	✓	✓		-	✓	✓
6	Audio Alert	✓	✓				✓	✓			
7	Colour, Physical Space	-	✓	✓	✓	-		✓	✓		-
8	Visual Alert, Audio Alert			✓	✓			-	✓	✓	✓
9	Situational Awareness, Commonality	✓	-		✓	✓	✓		-	✓	-
10	Physical Space	✓	✓	✓		-		✓	✓	-	-

Description:

- Tasks could include: detect a warning signal, locate a target, typing on the keyboard, etc.
- The supported by column indicates which interface design category supports the task. E.g. colour and commonality supports transition between multi-system use, audio alert facilitates the detection of a notification/warning signal, etc.
- Systems could include: Infantry Carrier Vehicle (ICV), MULE (Countermine), Medical Vehicle Treatment (MV-T), etc.
- Rationale: this visualization is task based as opposed to the one previously that is requirement based. Thus, the ability to accomplish a task, or function (as this view is called), is the main focus of this visualization. As with the other C2 visualization, check mark (✓) indicates that the system supports the task, dash (-) indicates that the system does not need to support the task, and blank cells indicates that the system does not support the task. Furthermore, this visualization provides a clear view of which system supports what tasks (or the majority of the required/desired tasks).
- Alternative: tasks could be grouped into domains or categories, i.e. types of interfaces such as physical workspace, GUI, user input, etc.

HV – D: Roles

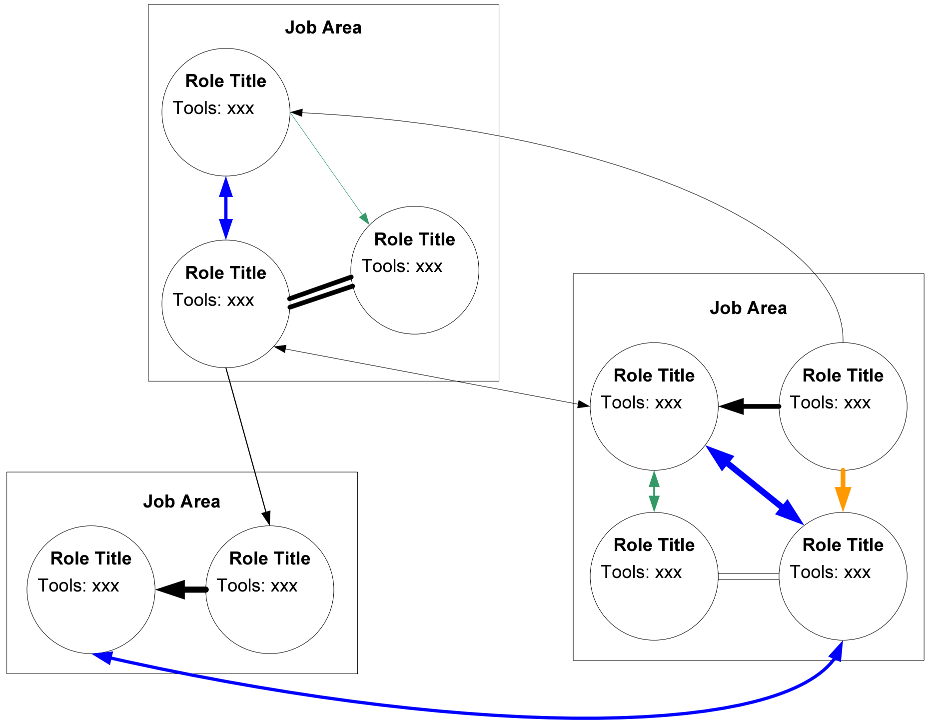
Human Tasks	Job Area				
	1	2	3	4	5
Task 1	**Role Title** R: xxx A: xxx C: xxx			**Role Title** R: xxx A: xxx C: xxx	
Task 2		**Role Title** R: xxx A: xxx C: xxx			
Task 3			**Role Title** R: xxx A: xxx C: xxx		**Role Title** R: xxx A: xxx C: xxx
Task 4	**Role Title** R: xxx A: xxx C: xxx **Role Title** R: xxx A: xxx C: xxx		**Role Title** R: xxx A: xxx C: xxx		
Task 5				**Role Title** R: xxx A: xxx C: xxx	

Legend
R = Responsibility. Responsibility outlines the accountability and commitment of the role.
A = Authority. Authority is the access ability of an individual user to perform a specific task.
C = Competency. Competency is the quality of being able to perform the role. It is a combination of knowledge, skills and attributes.

Description:

- Job area is the department which the role or role group belongs. It could include: administrative, hardware, software, legal, management, IT, repair, etc.
- Role title is the title of the role or role group, which is a general role title instead of a specific one, for example: technicians, electrical engineer , IT manager, soldier, lieutenant, captain etc.
- Human tasks are the tasks that need to be performed. It could include: repair electrical systems, design IT architecture, software development, fly Class IV helicopters, coordinate and manage projects, etc.
- Rationale: Roles are needed to perform certain tasks; thus, it is important that those tasks are identified and clearly mapped with their respective roles. The mapping is presented by job area so that it identifies how many different of roles from a certain area are needed to perform a task. It also portrays multiplicity of a task by identifying several roles under a category. This identification can be a precursor to role group and team interactions for HV-E as well. Since the roles are listed by job area, the details of each role such as its title, responsibility, authority and competency is then listed within each job-task mapping.

HV – E: HUMAN NETWORK



Legend

Type of Interaction		**Type of Cohesiveness**	
A ——► B	A supervised B	Blue	= sharing
A ◄——► B	A and B coordinate	Green	= trust
A ═══ B	A and B collaborate	Orange	= caution

Description:

- Job area is the department which the roles belongs. It could include: administrative, hardware, software, legal, management, IT, repair, etc.
- Role title is the title of the role or role group, which is a general role title instead of a specific one. Role title could include: technicians, electrical engineer, IT manager, soldier, lieutenant, captain etc.
- Tools are communication / technology tools used that could impact teamwork by providing shared awareness among roles, common operational picture, distributed cognition, etc.
- Rationale: Each individual circle represents a role. The dashed circle represents a virtual role used for specific team functions. Job areas show role groups / teams formed. Role title distinguishes the individual roles and any details for that role, such as tools used, can be indicated. The details allow users to compare similarities and differences between the roles, such as common tools, similar operations, shared situational awareness, etc., providing information for assessing the interaction between them. The physical location of the roles is a scales representation of the physical proximities of them in reality. Also, the type of interaction between the roles are indicated by connecting symbols where the thickness of the symbols indicate the frequency of the interactions (thicker lines = more frequent, thinner lines = less frequent). Lastly, the colour of the connecting symbols indicates the cohesiveness of the roles.

HV-F: TRAINING

HV-F1: Training Requirements

Requirement	Skills Gained									
	1	2	3	4	5	6	7	8	9	10
1	✓	-	✓	✓	-	✓	-	✓	✓	✓
2	-	✓	✓	✓	-	-	-	-	-	-
3	✓	✓	-	✓	-	-	✓	✓	✓	-
4	-	✓	✓	✓	-	-	✓	✓	-	-
5	✓	-	-	✓	✓	✓	-	-	✓	✓
6	✓	✓	-	-	-	✓	✓	-	-	-
7	-	✓	✓	✓	-	-	✓	✓	-	-
8	-	-	✓	✓	-	-	-	✓	✓	✓
9	✓	-	-	✓	✓	✓	-	-	✓	-
10	✓	✓	✓	-	-	-	✓	✓	-	-

Description:
Rationale: the training requirements are listed and the skills to be gained either corresponds to the requirements, via a check mark (✓), or does not, via a dash (-).

HV-F2: Existing Skill Inventory

	Skills	Job or Employee				
		1	2	3	4	5
Category 1	1	-	✓	✓	✓	-
	2	✓	✓	✓	-	-
	3	✓	-	✓	✓	✓
	4	-	-	-	-	✓
	5	✓	✓	✓	✓	-
Category 2	1	✓	✓	✓	✓	✓
	2	-	-	✓	-	✓
	3	-	✓	✓	-	-
	4	-	-	✓	✓	-
	5	✓	-	-	-	✓

Description:
- Categories could include: administrative, hardware, legal, management, software, etc.
- Skills could include: repair electrical systems, design and manage network architectural structures, manage personnel, logistics and resource allocations, etc
- The job or employee indicates the specific job or employee that has those skill sets. Job could include: technician, IT, engineer, administrator/coordinator, manager, soldier, lieutenant, captain etc. Employee would include the names of the actual employees.
- Rationale: this table connects skills to a job or employee. The user can easily see which skill sets are abundant or lacking within their inventory, and which job or employee has the most skills. Furthermore, the skills are grouped by categories for easier finding as well as to help detect if a skill is missing by analyzing if a category has all the skills it needs.

HV-F3: Training Resources

Resource	Job or System				
	1	**2**	**3**	**4**	**5**
1	A	M	A	A, L	L
2	S	-	M, S	-	S
3	H	H	-	-	H
4	L	-	H	L, M	M
5	S	S	-	S	-

Legend
A = Administrative
H = Hardware
L = Legal
M = Management
S = Software

Description:

- Resources are the different training resources available; they could include: virtual simulation stations, guest speakers, help manuals, etc.
- The job or system indicates specific job or system that this type of training will influence. Job could include: technician, IT, engineer, administrator/coordinator, manager, soldier, lieutenant, captain etc. System could include: Infantry Carrier Vehicle (ICV), MULE (Countermine), Medical Vehicle Treatment (MV-T), etc.
- The legend indicates the type of skill gained from training, which relates resources to jobs/systems. E.g. resource 1 can be used to train job 1 for administrative tasks.
- Rationale: this table help visualize which training resources are available and which systems they support. Also, it indicates the type of skill gained from the resources (i.e. management, hardware, etc.) with respect to the job/system.
- Alternative: the type of skill can be dual coded to with different colours for easier interpretation.

HV-G: METRICS

Tasks	**Objective**	**Risks**	**Standards / Guidelines Used**	**Status** (P)ass / (F)ail
Task 1				F
Task 2				F
Task 3				F
Task 4				P
Task 5				P

Description:

- Tasks are human performance tasks that are analyzed to evaluate the performance of humans using the system. They can include: performing a certain task within a time frame, situational awareness of a display change, ability to move comfortably within the system space, etc.
- Objectives are the rationale of why that task is used to assess human performance, as well as describing a suitable pass is for that task. E.g. assess situational awareness by evaluating if the operator can detect notification and warnings on the user interface display in a timely manner to make appropriate decisions and take effective action. The outcome of the situation needs to be an effective and efficient resolution to the problem.
- Risks are the dangers of not being able to complete the tasks (i.e. a fail of the system's ability to perform that task). They can include: danger to system and/or operator, risk of national security, physical harm or health hazard, etc.
- Alternative to risk: risks can be colour coded as well, such as (R)ed = serious risks, (Y)ellow = moderate risks, and (G)reen = mild risks, for easier interpretation.
- Standards or guidelines used may or may not be applicable to every task. If a certain standard or guideline was used as the basis of or foundation for the task, it should be referenced here. I.e. MIL-STD-1472F, SMI Standard D786-11012-1, etc.
- The status is used to indicate if the system passed or failed the task.
- Rationale: to assess human performance, a series of tasks are created based on human performance requirements and the system is evaluated against those tasks. Furthermore, the requirements that did not pass should be listed first so that they can be addressed first.
- Alternative: The tasks can be grouped by categories such as interface, human characteristics, training, etc., as well as into even smaller categories such as cognitive, memory, anthropometric, etc. for human characteristics.

APPENDIX F: COMPARISON OF NATO AND UK HUMAN VIEW APPROACHES[3]

Part 1: NATO Human View Compared to UK Approach

NATO Human View		
Page #	**HV-A CONCEPT**	**UK Reference**
There is no equivalent UK product that captures a high-level representation of the human in the system		
9	Conceptual, high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components.	
9	It serves as both the single point of reference and departure to depict how the human will impact performance (mission success, survivability, supportability, and cost) and how the human will be impacted by the system design and operational context (personnel availability, skill demands, training requirements, workload and well-being).	
9	Pictorial depictions of the system and its human component	
9	High level indicators of where human system interactions may occur	
9	A textual description of the overall human component of the system	

NATO Human View		
Page #	**HV-B CONSTRAINTS**	**UK Reference**
The UK view "HV-A Personnel Availability" is the most closely matched to this product		
10	contains the set of data elements that are used to adjust the expected roles and functions	
10	repository for different sets of constraints that may affect parameters of different views that may impact the human system	
10	human interface of the system must be designed to accommodate the human in such a way as to account for the human limitations, and to support/maintain the human to at least a minimum acceptable level	
10	**Manpower Projections (HV-B1)** - illustrates predicted manpower requirements for supporting present and future projects that contribute to larger capabilities. - Understand manpower forecasting to allow initial adjustments in training, recruiting, professional development, assignment and personnel management – Anticipate impacts (and timeframe) related to number(s) of personnel, personnel mix, Military Occupational Structure Identification (MOSIDs), Rank/level distribution, and, postings/relocation(s) of personnel. – Ensure sufficient number of personnel with necessary KSAs are 'ready and	HV-A

[3] The information provided in Appendix F was supplied by Linda Wu, Human Factors Engineer, Pacific Science & Engineering Group.

	able' to support fielding of future program.	
11	**Career Progression (HV-B2)** - illustrates career progression as well as the essential tasks, skills, and knowledge (and proficiency level) required for a given job. – Address impacts of alternative system and capability designs on career progression; – Determine jobs available given an individual's current job and occupation; – Assess competencies required for each individual job; and – Support personnel planning by identifying availability of individuals with necessary competencies early in acquisition process.	HV-A
11	**Establishment Inventory (HV-B3)** - Defines current number of personnel by rank and job within each establishment. – Supports forecasting of trained effective strength. – Supports predicting number of people that must be trained, recruited, etc. to fill gaps required for 'out years'.	HV-A
11	**Health Hazards (HV-B4)** – Considers the design features and operating characteristics of a system that can create significant risks of illness, injury or death. – Aims to eliminate minimize or control both short- and long-term hazards to health that occur as a result of system operation, maintenance and support. – Hazards may include system, environmental or task hazard assessment; air quality control assessment; noise/vibration pollution evaluation; impact force, shock protection; WHIMS evaluation of tasks; radiation/LASER protection; CB protection; extremes of temperature, etc. – It may include aspects of survivability, i.e. limiting the probability of personal injury, disability or death of personnel in their interactions with the system. This can include providing protection from attack, and reducing detectability, fratricide, system damage, personnel injury and cognitive and physical fatigue.	HV-A
12	**Human Characteristics (HV-B5)** – Considers the physical characteristics of an operator and movement capabilities and limitations of that operator under various operating conditions. – Aims to compare operator capabilities and limitations with system operating requirements under various conditions to match or eliminate operating capabilities. – It may include aspects such as anthropometrical/medical data; reach data; range of motion data; physical strength data; visual and auditory assessment; speed or duration of activity data; cognitive workload; working memory capacity; ability to be security cleared; personality, motivation, etc.	HV-A
12	**Personnel Policy (HV-B6)** – Defines the various department policies dealing with (governing) HR issues – Ensures that personnel are fairly considered, properly treated, well looked after and supported in a legal, moral and ethical manner while employed with the department – HR documents, such as policies, doctrine, laws, benefits, pay, SOPs, etc.	

NATO Human View		
Page #	**HV-C TASKS**	**UK Reference**
The UK view "HV-E Human Functions and Tasks" is the most closely matched to this product		
13	describes the human-specific activities, i.e., the functions that have been assigned to the humans in a system over its entire life cycle. It also considers how the functions are decomposed into tasks. (The term task in this product refers to a piece of work that can be assigned to a person)	HV-E
13	Clarify the human-related functions in a system	HV-E
13	Provide a justification for the allocation of functions between the humans and machines	HV-E
13	Decompose these functions into a set of tasks that can be mapped to the roles identified in HV-D	HV-E
13	Describe these tasks in terms of various criteria and the KSA requirements	HV-F
13	Produce a task-role assignment matrix	HV-E
13	Create interface design guideline on the basis of task requirements	HV-E
13	Depict the inter-dependencies between different tasks, particularly across functional groupings	HV-E

NATO Human View		
Page #	**HV-D ROLES**	**UK Reference**
The UK view "HV-F Roles and Competencies" is the most closely matched to this product		
14	describes the roles that have been defined for the humans interacting with the system. A role represents a job function defining specific behavior within the context of an organization, with some associated semantics regarding the authority and responsibility conferred to the user in the role, and *competencies* required to do the job.	HV-F
14	Responsibility – a form of accountability and commitment; roles are generally defined by their responsibilities.	
14	Authority – is the access ability of an individual user to perform a specific task	
14	Competencies – the quality of being able to perform; a combination of knowledge, skills and attributes; these should be trainable and measurable.	HV-F HV-E
14	Multiplicity – a role may be performed by a human user or by many human users at the same time.	

NATO Human View		
Page #	**HV-E Human Network**	**UK Reference**
The UK view "HV-C Human Interaction Structure" is the most closely matched to this product		
15	captures the human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time	HV-C
15	Role groupings or teams formed, including the physical proximity of the roles	HV-C

	and virtual roles included for specific team functions.	
15	Type of interaction – i.e., collaborate, coordinate, supervise, etc.	HV-D
15	Team cohesiveness indicators - i.e., trust, sharing, etc.	
15	Team performance impacts - i.e., synchronization (battle rhythm), level of engagement (command directed)	
15	Team dependencies - i.e., frequency/degree of interaction between roles	
15	Communication/Technology impact to the team network - i.e., distributed cognition, shared awareness, common operational picture, etc.	HV-A

NATO Human View		
Page #	**HV-F Training**	**UK Reference**
The UK view "HV-A Personnel Availability" is the most closely matched to this product		
16	how training requirements, strategy, and implementation will impact the human	HV-A
16	instruction or education and on-the-job or unit training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements	HV-A
16	As-is training resources, availability, and suitability	
16	Risk imposed by to-be operational and system demands	
16	Cost and maturity of training options for tradeoff analysis	
16	Address impacts of alternative system and capability designs on training requirements and curriculums	
16	Determine training required to obtain necessary knowledge, skills, and ability to support career progression	HV-A
16	Differentiation of basic, intermediate, or advance job training; operational vs. system specific training; and individual vs. team training	HV-A

NATO Human View		
Page #	**HV-G Metrics**	**UK Reference**
The UK view "HV-B Quality Objectives and Metrics" is the most closely matched to this product		
17	repository for human-related values, priorities and performance criteria, and maps human factors metrics to any other human view elements	HV-B
17	may map high-level (qualitative) values to quantifiable performance metrics and assessment targets or it may map measurable metrics to human functions	HV-B
17	It provides the basis for any human factors assessments to underpin enterprise performance assessments and the foundation for requirements tracking and certification	HV-B
17	- Human Factors Value definitions level 1…n - Human Performance Metrics (what is to be measured) - Target Values (what quantifiable value is acceptable) - Human Function to Metrics mapping - Value definition links - Value to design element mapping	(in order) HV-B HV-B HV-B HV-B HV-B

	- Methods of compliance	- HV-B

NATO Human View		
Page #	**HV-H Human Dynamics**	**UK Reference**
The UK view "HV-G Dynamic Drivers of Human Behavior" is the most closely matched to this product		
	captures dynamic aspects of human system components defined in other views. Dynamic aspects in the sense that states, configurations, or performance parameters may change over time, or as a result of varying conditions or triggering events	HV-G
	inform other design aspects (when capturing 'as-is' behavior aspects) and to assess design decisions (by modeling 'to-be' behavior)	HV-A
	States (e.g. snapshots) and State Changes, e.g. – Organizational/team structure – Function/Role assignments to people – Team interaction modes – Demands on collaboration load (e.g. need to spend effort in building shared awareness, consensus-finding, communicating) – Task switches/interruptions	HV-G
	Conditions (e.g. triggering events or situations; scenarios) – Critical / frequent / representative / typical scenarios – Operational constraints (e.g. extensive heat stress) – Time conditions: sequence, duration, concurrency	HV-G
	Time Units – Timeline – Defined mission phases; sequence of consecutive tasks	HV-G
	Performance measures (observed or predicted), e.g. – Workload – Decision speed – Team interaction/collaboration style – Trust in commanders intent – Quality of shared awareness/coordination/implicit communication	HV-G

Part 2: UK Human View Compared to NATO Approach

UK Human View		
Page #	**HV-A Personnel Availability**	**NATO Reference**
The NATO products "HV-B Constraints" and HV-F Training" are the most closely matched to this view		
25/30	Defines the requirements and processes to ensure that personnel with the right characteristics, and in the right numbers are available for posts/jobs.	HV-B1 & 3
30	Captures essential components of the Personnel and Training DLOD (and the	HV-F1

	personnel, manpower and training HFI Domains).	
30	Defines the requirements for establishing suitable formal processes, as part of operational practice, to ensure that sufficient personnel suited to roles is available	HV-B3
30	Captures different types of personnel-related trends, fixed constraints, and process definition requirements	HV-B1 & 3
30	Provides an overview of essential dependencies between design factors concerning personnel and training provision	HV-F2
30	Describes concrete aspects to ensure the presence of human 'actors' in the enterprise	
30	Trend and Development Forecasts;	HV-B1
30	Personnel Characteristics (e.g. current/future; available/required);	HV-B1 & 3
30	Personnel Numbers (e.g. current/future; available/required);	HV-B1 & 3
30	Formal Personnel Development Structure and Processes, including: • Career progression plans and structures (e.g. to ensure formal experience progression); • Training processes and structures (e.g. to make skills available); • Recruitment and Retention plans (e.g. to avoid fluctuation); • Mechanisms to support learning (e.g. technical, practical, social); • Health and Safety provision (e.g. to avoid absence); • Personnel Policy (e.g. legal/moral/ethical support; duty of care; pay).	(in order) HV-B2 HV-F1 HV-B2 HV-F3 HV-B4 HV-B6
33	Visualization • Proportional comparison of demand and supply for relevant personnel characteristics (e.g. education level) over applicable time scales; • Cause-effect diagrams showing enterprise-specific dependencies (e.g. Influence Diagrams; Bayesian Networks); • Tables capturing relevant human characteristics in suitable categories (e.g. skills/qualifications, intellectual abilities, physical attributes); • Databases capturing essential workforce parameters as-is vs. to-be; • Annotated organizational charts (OV-4; HV-D) showing • Trends (e.g. opportunities for carrier progression); • Requirements (e.g. training needs); • Local effects (e.g. opportunities for social learning).	(in order) HV-B3 & F1 - HV-B1 & 5 HV-H HV-B2, F1

UK Human View		
Page #	**HV-B Quality Objectives and Metrics**	**NATO Reference**
The NATO product "HV-G Metrics" is the most closely matched to this view.		
25, 36	Provides a repository for human-related performance criteria, including qualitative values and quantifiable metrics with measurable targets.	HV-G
36	Provides the basis for HFI evaluations to underpin enterprise performance assessments.	HV-G
36	Captures non-functional requirements to complement functional requirements at all levels of abstraction.	

36	Provides a formal record for organization high-level qualitative value objectives to complement capability definitions.	
36	Provides means to quantify value objectives without loosing context by capturing quantifiable metrics in relation to qualitative value definitions.	
36	Captures HF performance criteria as the basis for human behavior assessments at any scope (e.g. individual, team, organization).	HV-G
36	Provides a mapping of HFI metrics to Human Functions/Tasks.	HV-G
36	Provides the foundation for HFI requirements tracking and certification	HV-G
36	May include mappings of values and metrics to methods of compliance (e.g. how to measure targets and present evidence).	HV-G
36	May map required improvements of performance targets for different timescales where appropriate.	
36	HFI Value definitions (level 1 to n)	HV-G
36	HFI Value definition relationships (between different levels)	HV-G
36	Human Performance Criteria and Metrics (i.e. what is to be measured)	HV-G
36	Target Measures (i.e. which quantifiable amount is acceptable)	HV-G
36	Methods of Compliance	HV-G
36	Time/Epoch (for metrics that should improve over set periods)	
39	<u>Visualization</u> • Breakdown of HFI values to quantifiable performance metrics and targets; • Human Function/Task to Metrics mapping (through table/matrix); • Metrics to Methods of Compliance mapping (through table/matrix); • Mapping of Target Measures to Timescales (table or annotated timeline).	(in order) HV-G HV-G HV-G HV-G -

UK Human View		
Page #	**HV-C Human Interaction Structure**	**NATO Reference**
The NATO product "HV-E Human Networks" is the most closely matched to this view.		
25, 43	Captures the structure of human networks supported by technology, including the operational dependencies and the purposes and constraints of information handling requirements based on human operational dependencies.	HV-E3
	Captures human-specific purposes and constraints underlying the technological networks enabling information flows.	
	Structures operational activities by purpose, based on dependencies requiring interaction (e.g. task/team relations).	HV-E3
	Details interaction implementation and constraints from a human task perspective, including physical and location constraints (e.g. remoteness; distribution; environment).	HV-E3

	Creates a conceptual link between OV-2, OV-4, SV-1, and HV-F.	
	Captures interaction requirements due to structural boundary definitions (e.g. virtual team) at different levels of abstraction	HV-E3
	Data Elements • Purposes of information manipulation (e.g. access, transmission, sharing) • Locations • Human Roles • Systems	

UK Human View		
Page #	**HV-D Organization**	**NATO Reference**
The NATO product "HV-D Roles" is the most closely matched to this view.		
25	Defines organizational properties and relationships, including fixed and task-organized structural dependencies besides organizational policies, values and procedures.	HV-D1 HV-B6
52	Provides distinctions between organizational structure definitions that express fixed dependencies (e.g. part-whole vs. rank structure).	
52	Provides a repository for formal post/job definitions (as organizational concepts) that fulfill roles (as functional concepts).	HV-D1
52	Defines formal definitions of organizational processes and values that underpin organizational structures and determine organizational behavior.	HV-D1
52	Distinguishes fixed structures from formal task-organized configurations, which implement mission-specific working structures as formally defined alternative set-ups.	
52	Organizational units (e.g. posts/roles; department)	HV-B3
52	Organizational relationships • Part-whole • Rank/authority structures	HV-D1
52	Formal task-organized configurations	
52	Formal process and value definitions	

UK Human View		
Page #	**HV-E Human Functions and Tasks**	**NATO Reference**
The NATO product "HV-C Tasks" is the most closely matched to this view.		
25, 60	Specifies human functions and activities in relation to system definitions, as part of detailing solutions beyond the OV-5 requirements.	HV-C1
60	Creates a critical link between OV-5 and SV-4 where initial decisions about the types of resources (e.g. human, technological, biological) are translated into requirements for the functions they need to fulfill.	HV-C1
60	Makes decisions as to whether functions are defined as uniquely	HV-D2

	human or technology-based.	
60	Instantiates the first level of Allocation of Function (AoF) definitions by describing human-specific activities to be carried out by human resources – without specifying the exact nature and structure of the resources.	HV-C1
60	Avoids technology-focused AoF decisions by capturing the human functions explicitly, and alongside the system functions, thus complementing definitions of system functions.	HV-C2
60	Identifies the need for human-computer interfaces as a functional system requirement.	HV-C2
60	Is the basis for human role and competency specifications underlying post/job definitions and personnel requirements.	HV-D2
60	Data Types • Human Functions/Tasks • Human Task Decomposition • System Functions • Human-System Interface Requirements	HV-C1 HV-D2 - HV-C2

UK Human View		
Page #	**HV-F Roles and Competencies**	**NATO Reference**
The NATO product "HV-D Roles" is the most closely matched to this view.		
25, 66	Specifies requirements for concrete human resources – by linking human tasks, competencies, and roles.	HV-D1 & 2
66	Maps human functions/tasks to definitions of roles and competencies.	HV-D1 & 2
66	Provides a dedicated repository to capture requirements for defining boundaries of human structures at a detailed level, which can be related to definitions of systems and their components	HV-C1
66	May require several iterations – from an initial mapping to existing and standardized structures, to a final mapping of tasks to changed structures, depending on re-design requirements	
66	It is suggested here to distinguish three different types of mappings: • Role-Task Mapping; • Competency-Task Mapping; • Role-Competency Mapping.	HV-D1 & 2
66	Data types • Human Functions/Tasks • Roles • Competencies • Function-Role-Competency Dependencies	(in order) HV-C1 HV-D1 HV-D1 HV-D1 & 2
68	<u>Visualization</u> • Task/Function flow diagrams with annotations (roles, competencies) or swimlane overlays. • Matrix mappings. They may be simplest to produce and ensure a comprehensive approach is taken.	HV-D1 & 2 (for all)

	• Table format: a number of competency requirements are listed for each Function/Task. • Relationship Graphic: each Function/Task may be attached to a number of (grouped) competency requirements.	

UK Human View		
Page #	**HV-G Dynamic Drivers of Human Behavior**	**NATO Reference**
The NATO product "HV-H Human Dynamics" is the most closely matched to this view.		
25, 71	Captures the factors that affect, constrain and characterize human behavior as the basis for performance predictions at the level of individuals, teams, or organizations. It creates a bridge between static architectural definitions and behavior predictions outside the architecture, such as executable models	HV-H
71	Provides descriptors of the dynamic factors that drive and influence what people are likely to do.	HV-H
71	Describes the drivers for how human actors will conduct their tasks, and interact with other people, organizations, equipment, and the physical environment.	
71	Identifies behavior-shaping constraints on performance in relation to the static definitions of enterprise structures and processes defined in other Views.	
71	Describes dynamic parameters in the sense that configurations, task requirements, or behavioral states may change either over time, or because of varying conditions and triggering events.	HV-H
71	Extends OV-6 and SV-10 towards Human Resource specific concerns.	
71	Conditions, including: • Operational constraints (e.g. extensive heat stress) • Triggering events or situations • Time conditions (e.g. sequence, duration, concurrency, patterns, rhythm) • Task Rules (e.g. strategies, procedures, priorities for role assignment)	HV-H
71	Representative Scenarios – i.e. a combination of conditions (e.g. critical, frequent, typical situations)	HV-H
71	Time Units • Timeline • Defined mission phases; sequence of consecutive tasks	HV-H
71	States (e.g. snapshots, stable configurations) and Configuration/State Changes, e.g. • Task-based changes of organizational configurations • Flexible use of resources (e.g. role switches, adaptive automation)	HV-H
71	Dynamic behavior properties/characteristics	
71	Performance measures (as indicators of expected behavior)	HV-H

	Visualization • State and configuration changes can be shown graphically where changes are shown through color coding and arrows. • Behavior characteristics (e.g. strength of relationship) can be captured graphically (e.g. through line thickness variations on arrows). • Dynamic behavior properties can be shown attached to timelines or mission phases (table or graphic). • Scenarios may be captured in table format where details for different types of conditions are specified, depending on relevance.	-

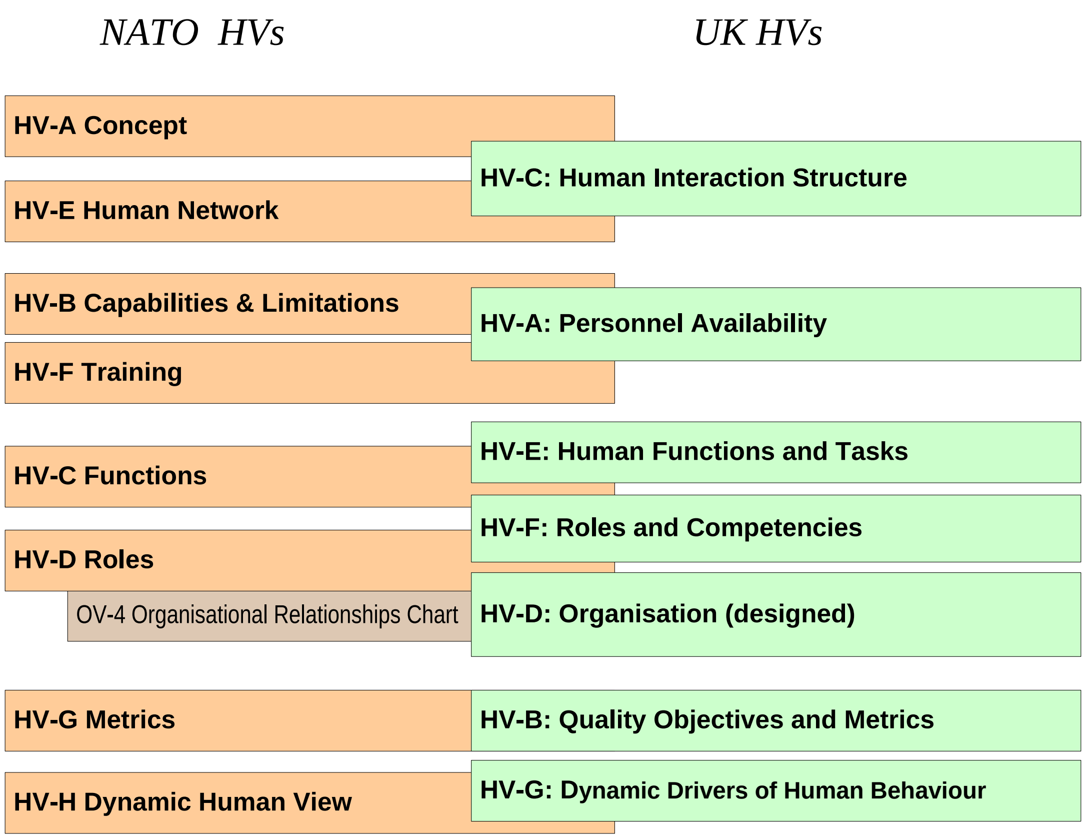


Figure F.1. Overlap of NATO HV and UK HV

APPENDIX G:
HUMAN VIEW DYNAMICS

1. Introduction

The eighth Human View product in the framework was termed "Human View Dynamics." The workshop panel was divided on whether this product should capture the static information pertinent to the dynamics, i.e., state diagrams, business rules, etc, or the instantiation of an actual dynamic model derived from the other static products. An example system, based on a subset of the US Army's Future Combat System, was captured with the Human View static products, and then successfully transferred into an executable environment and simulated. A task network type model, The Improved Performance Research Integration Tool (IMPRINT) made available by the US Army Research Laboratory was used as the simulation environment. As a result, a mapping was created between the constructs of the Human View products and the IMPRINT model.

These views have been used to capture the human elements of an example system based on a subset of the Army's Future Combat System [Mitchell & Brennan, 2008][4]. The capabilities and limitations of an Infantry Platoon and the resources available in the Infantry Carrier Vehicle were documented using the Human View products. Included were the tasks involved in conducting a tactical road march and reacting to an ambush, the different roles the platoon members assume during these operations (i.e., Platoon Leader, Driver, etc.) and the interaction types between the platoon members and their technologies. These figures are shown in the Appendix H.

2. Human Dynamics

The intent of the Human Dynamic (HV-H) product was to capture dynamic aspects of human system components defined in other views. In one sense it was designed to provide a repository for stimuli and design aspects, such as states, conditions or performance parameters, which may change over time or as a result of triggering events. On the other hand, it is entirely feasible for this product to be an actual simulation model based on the static information captured in the other products. It can range from simple process diagrams to sophisticated executable computer simulations of human system interactions. The model can be used to answer questions on whether a system architecture can meet performance expectations give the type of human resources allocated.

The objective of the Human Dynamics (HV-H) product then becomes to capture the interaction of the human system components defined in the other products (HV-A to HV-G). The design decisions recorded in the static Human View products can be evaluated through a dynamic evaluation of the human system performance using the HV-H. Trade off analyses can also be conducted to determine the impact of system parameters on human performance metrics. A comprehensive model, which easily maps to the defined Human View products, is desired to evaluate the spectrum of human view parameters. This relationship is shown in the figure below.

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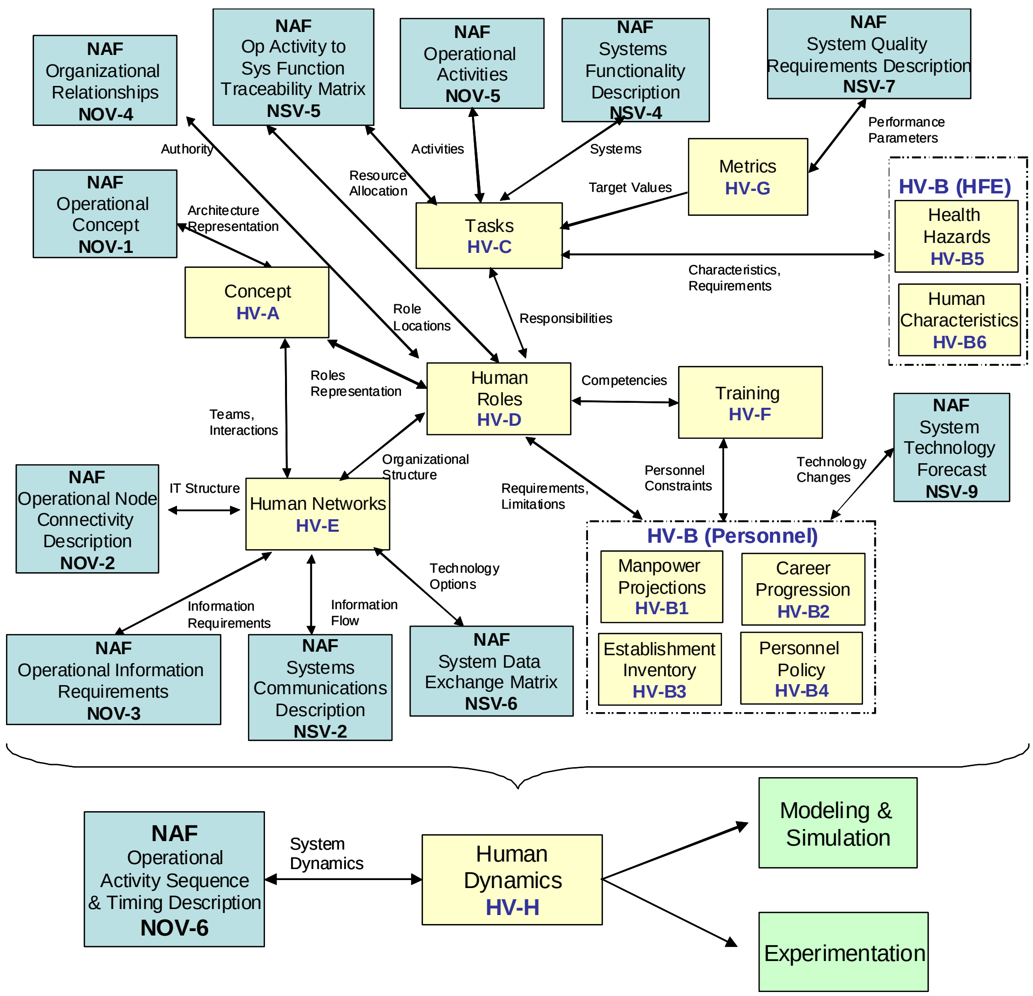
[4] Mitchell, D. & Brennan, G. (2008). Mission Centered Human System Analysis Using FCS Vignettes, Army Research Laboratory, February 6, 2008.



Relationship of Human Dynamics to Human View Static Products

Discrete event models representing the interactions of humans with system components have previously been designed. Using basic components of decision-makers (humans), tasks, and platforms (system resources), these models have been configured to explore performance metrics of decision maker coordination and mission completion [Handley, Zaidi & Levis, 1999][5]. Typical models allow input parameters to be varied, constraints to be relaxed and other variables (possibly) affecting the human system performance to be explored in order to evaluate the effect on the model outcomes, and by inference, on the human system design. Using the same type of methodology, a preliminary schema of the interaction of the individual Human View components was created. The human view products (HV-A to HV-G) each capture a different set of human elements, i.e., task, role, network, etc. However, it is the relationships between the elements that impact the performance of the system. The initial Human View Dynamics schema is shown in the figure below.

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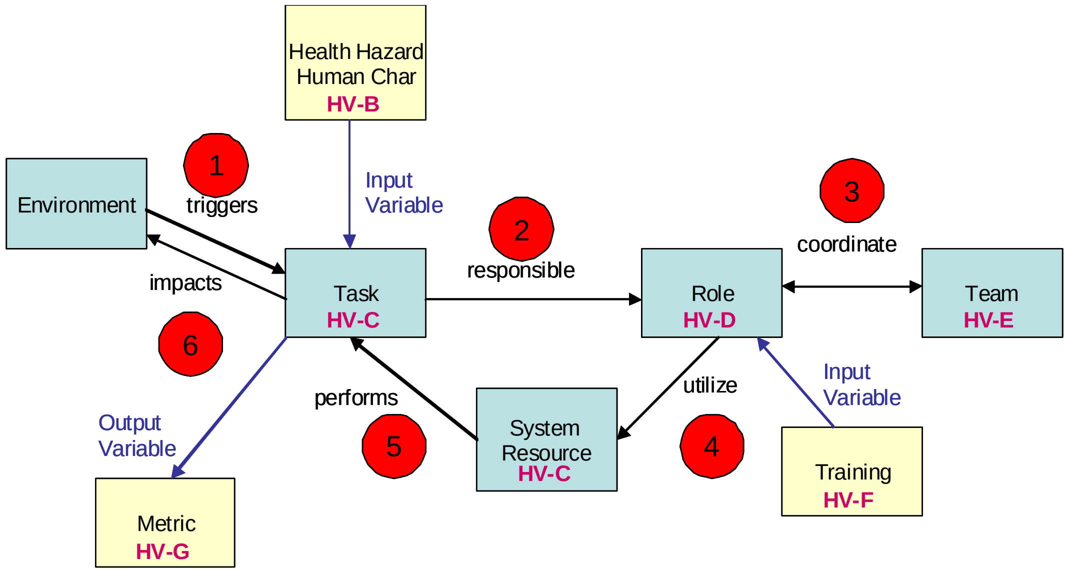
[5] Handley, H.A.H, Zaidi, Z.R., & Levis, A.H. (1999). The use of simulation models in simulation driven experimentation, *Systems Engineering*, 2 (2) 108-128.



Initial Human View Dynamics Schema

The numbering of the figure shows the flow of data through the discrete-event model. An event from the environment triggers a task (HV-C). The role (HV-D) responsible for the task begins processing it. The role may coordinate with team members (HV-E) for information exchange during processing. The way the task is processed may depend on traits of the actual person fulfilling the role (HV-B) and training completed (HV-F). Use of a system resource (HV-C) to complete the task is included in the model. Additionally, other constraints, such as human characteristics and health hazards (HV-B) may moderate the performance of the task. One the task is completed; metrics are used to evaluate the task performance.

3. Modeling Methodology

The Improved Performance Research Integration Tool (IMPRINT)[6] is a human performance modeling tool developed by the US Army Research Laboratory to help system developers predict the impact of operator performance on system performance. Data is entered through task-network diagrams and underlying human performance algorithms are used to perform simulations. The performance can then be optimized by building models representing alternative human and system function allocations. Developers can use IMPRINT to predict the impact of design decisions on the performance of the operators of a system [Mitchell, 2005][7].

The modeling schema devised for the Human View Dynamics was implemented using the IMPRINT modeling tool. The analyses that can be performed in IMPRINT provide the types of information that are required to evaluate the interaction of the Human View components. The model input requirements

[6] http://www.arl.army.mil/ARL-Directorates/HRED/imb/imprint/Imprint7.htm
[7] Mitchel, D.K (2005). Enhancing system design by modeling IMPRINT task workload analysis results in the Unified Modeling Language, *Human System Integration Symposium*, Arlington, VA, June 2005.

can be mapped to the data captured in the Human View products. An initial mapping of the data requirements of IMPRINT to the Human View products is shown in the table below

Mapping of Human View Products to IMPRINT Data

Product	Description	IMPRINT Data
HV-A Concept	A high-level representation of the human component of the system.	- Hypothesis to be tested by the model
HV-B Personnel Constraints	Manpower Projections (HV-B1) - Predicted manpower requirements for supporting present and future systems. Establishment Inventory (HV-B3) - Current number of personnel by rank and job within each establishment.	*IMPRINT OUTPUT*: Number of desired MOS expected to be available per year. *IMPRINT OUTPUT*: Estimated number of Soldiers needed.
HV-B Human Factors Constraints	Health Hazards (HV-B5) - Short- and long-term hazards to health that occur as a result of system operation, maintenance and support. Human Characteristics (HV-B6) - Operator capabilities and limitations with system operating requirements under various conditions.	- Stressors, such as heat, humidity, cold, wind, MOPP, and fatigue. - Personnel Characteristics, such as ASVAB composite and cutoff.
HV-C Tasks	- Identify human level tasks - Task KSA requirements - Task-role assignment matrix - Tools required to accomplish a task - Information demands for specific tasks	- Functions/Tasks decomposition - Task to operator assignment - Tasks to System Interfaces - Tasks demands (mental workload)
HV-D Roles	- List of Roles - Role Responsibility - KSA Competencies	- Warfighters/Operators
HV-E Human Network	- Role groupings or teams formed - Interaction types - Team dependencies	- Team functions - Operator teams
HV-F Training	- Training resources, availability, and suitability - Training required to obtain necessary knowledge, skills, and ability	- Changing sustainment training frequency
HV-G Metrics	- Human Performance Requirements - Human Task to Metrics mapping - Target Values	- Mission level time & accuracy criterion - Task level time & accuracy standards *IMPRINT OUTPUT* : Crew Performance, Crew Workload

In order to evaluate the validity of this approach, an experimental model was created in IMPRINT using sample data based on the Army's Future Combat System. The objective of this investigation was to evaluate IMPRINT's use as a simulation environment to evaluate the dynamic aspects of the human system components captured in the static Human View products. By creating an actual IMPRINT model using Human View data, issues with differences in terminology, level of detail, and content descriptions could be addressed. The process used to create the model is described in the table below.

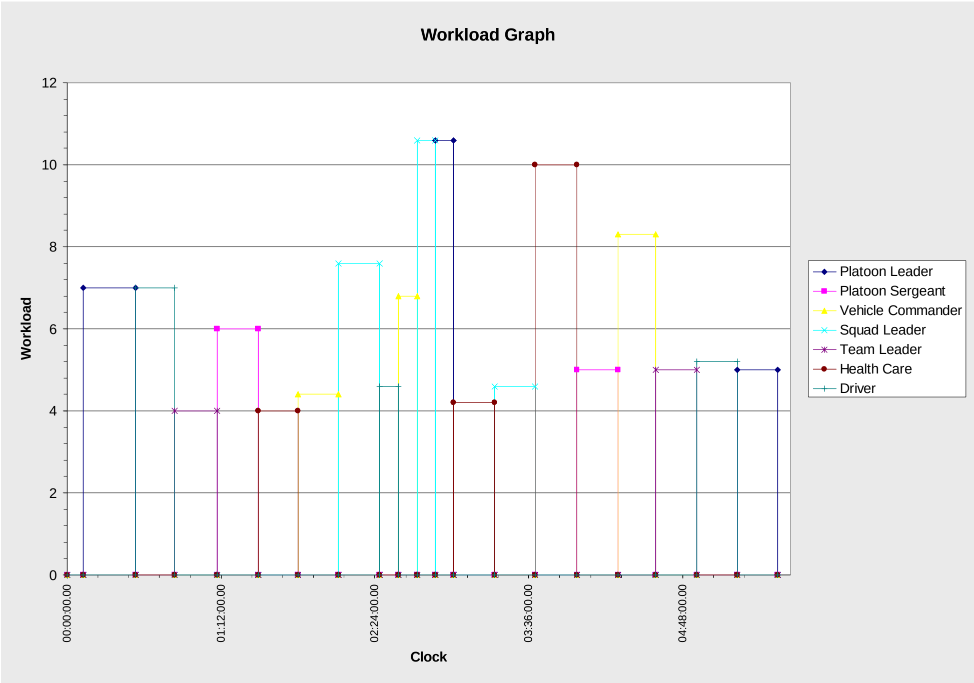
Step-wise process to create IMPRINT model using Human View Data

STEP	IMPRINT MODEL	HUMAN VIEW DATA
1	Operators	HV-D Roles
2	Mission Network Diagram	HV-C Tasks
3	Warfighter Assignment	HV-D Task-Role Matrix
4	Resource-Interface (RI) Pairs	HV-C System Interfaces
5	Task Time and Accuracy and Task Effects	HV-G Performance Standards/ Measures
6	Performance Moderators	HV-B Constraints
OUTPUTS	*Mission Results* *Task Performance* *Operator Workload*	*HV-G* *HV-G* *HV-G / HV-B*

While the Human View definitions explicitly define the elements to capture in each product, relationships defined between the different elements is subject to the user needs and system requirements. While some of the relationships required by the IMPRINT model were not currently specified in the architecture viewpoint, it is not outside the scope of the Human View to create these tables. Also, the Human View captures more extensive information on Networks (HV-E) and Training (HV-F) than is currently called for in the IMPRINT model. Future enhancements to IMPRINT may be able to capitalize on this data.

Once the model was created, a baseline simulation was executed to provide expected levels of mission performance parameters of time and accuracy. The IMPRINT results file gives data on the following categories:

- Mission Performance in terms of mission completion time
- Task Performance in terms of time to complete and percent steps correct
- Tasks that failed and the consequences of failure – task repeated, operator assignment for another task changed, time and/or accuracy on another task degraded, no effect, and mission aborted.
- Channel (resource) conflicts, which indicate multiple operators or tasks accessing the resource.
- Operator workload, both overall, single task demand, and sum of data over time. An example of an IMPRINT workload output is shown in the figure below.



IMPRINT Workload Results

Following the baseline simulations, tradeoff analyses can then be performed between different aspects of the model. For example, different role to task allocations impact task performance and operator workload. The assignment of system interfaces to tasks impacts channel conflicts also impacts task performance and task failure. There is a direct relationship to the information captured in the Human View product relationships to the model outcomes.

IMPRINT also has some limited ability to model the impact of Constraints (HV-B). The impact of changes in personnel characteristics of ASVAB[8] composite and cutoff scores, stressors of hot, cold, noise, sleepless hours, MOPP[9] level, and training frequency on task timeliness and accuracy can be assessed. The IMPRINT dynamic model can help set realistic system requirements and operating conditions.

Creating the Human Dynamics allows the exploration of how changing parameters in one of the static products impacts other aspects of the human data. For example, by adjusting the assignments made in the HV-D Task to Role Matrix, the overloading of some roles may occur causing cascading effects in other parts of the model. Also the ability to change skill levels in the HV-F (Training) may cause an operator with less experience or ability to perform key tasks, affecting system performance. Ultimately the goal of the Human Dynamics is to show that failing to consider human issues in system design can have an impact on system performance.

[8] Armed Services Vocational Aptitude Battery
[9] Mission Oriented Protective Posture

APPENDIX H:
FUTURE COMBAT SYSTEM EXAMPLES

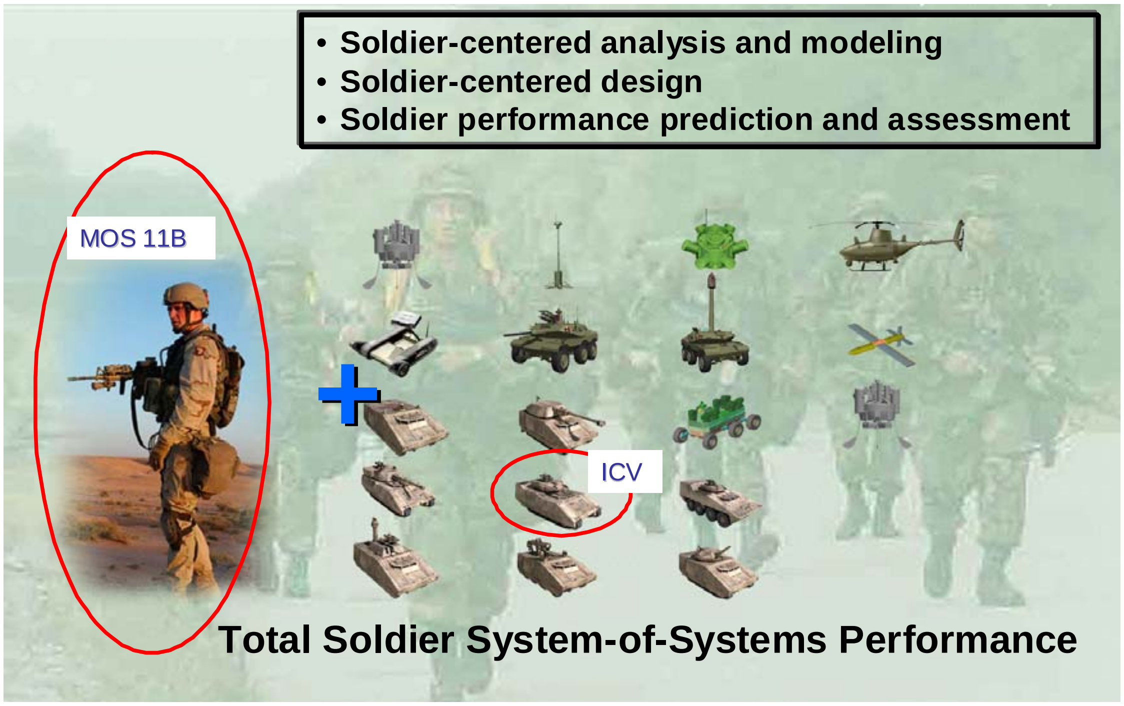


Figure H.1. HV-A Concept: Includes humans into high-level representations of the system

HV-B1: Manpower Projections													
Infantry Platoon													
	VC	PSG/VC	DVR	PL	SL	HC	RBTIC	TL	INF	CCSW	A/GNR	A-TANK	Total
Platoon Leader ICV	1		1	1		1	2						**6**
Platoon Sergeant ICV		1	1		1			2	6				**11**
Rifle Squad ICV	1		1		1			2	6				**11**
Rifle Squad ICV	1		1		1			2	6				**11**
Weapons Squad ICV	1		1		1				2	2	2	2	**11**
Total	**4**	**1**	**5**	**1**	**4**	**1**	**2**	**6**	**20**	**2**	**2**	**2**	**50**

Figure H.2. HV-B Constraints: (HV-B1 Manpower Projections)
Adjusts expected roles, tasks and performance

HV-B5: Health Hazards		
	Limits	*Descriptions*
Noise	<85 dBA	Maximum daily exposure
Heat	68 - 85 degrees F	May drop as low as 41 degrees
MOPP	MOPP Level IV	
Sleep	4 hours of rest every 24 hours	Goal not requirement

Figure H.3. HV-B Constraints: (HV-B5 Health Hazards)
Adjusts expected roles, tasks and performance

	HV-C TASKS		
	Platoon Level	**Squad Level**	**Soldier Level**
	Conduct Tactical Road March		
		Initiate Road March	
		Move Along March Route	
		Report Control Measures	
		Maintain March Security	
		Conduct Scheduled Halts	
		Platoon Arrives at Designated Coordinates	
		Platoon Initiates Screen Operation	
Enemy initiates Ambush			
	React to Ambush Near		
			Driver Reacts to Ambush
			Vehicle Gunner Reacts to Ambush
			Vehicle Commander Reacts to Ambush
			Infantry Squad Reacts to Ambush
			Platoon Leader Reacts to Ambush
		Evacuate Injured Personnel from BFV	
		Disengage From An Enemy Force	
		Treat and Evacuate Casulties	
		Conduct Resupply Operations	
		Conduct Maintenance Operations	
		Conduct Consolidation and Reorganization	
		Destroy Unit Vehicles and Equipment	
		Resume Original Mission	

Figure H.4. HV-C Task: Task Decomposition:
Operational activities are decomposed into human tasks

HV-C2 System Interfaces	
Role	**System**
Platoon Leader	1 LCU Centralized Controller; 2 Centralized Controller, Tactical (UGS-T)
Platoon Sergeant	Multifunction Utility/Logistics and Equipment Transport (MULE-T)
Vehicle Commander	
Squad Leader	3 Centralized Controllers; Small Unmanned Ground Vehicle (SUGV)
Robotic	Armed Rconnaissance Vehicle (ARV-A); Class 1 unmanned Aircraft System (UAS)
Team Leader	6 sets Intelligent Ground Sensors (UGS-U)
Health Care	
Driver	Infantry Carrier Vehicle
Infantry	MK 44 30MM; MK240 7.62MM;

Figure H.5. HV-C Tasks (Relationship): System Interfaces:
Systems that are available to the roles

HV-D Roles		
Abbreviation	**Role Name**	**MOS**
PL 02	*Platoon Leader*	*11A*
PSG/VC E7	*Platoon Sergeant*	*11B40*
VC E6	*Vehicle Commander*	*11B30*
SL E6	*Squad Leader*	*11B30*
VC E5	*Vehicle Commander*	*11B20*
RBTIC E5	*Robotic*	*11B20*
TL E5	*Team Leader*	*11B20*
HC E4	*Health Care*	*68W10*
DVR E4	*Driver*	*11B10*
INF E4	*Infantry*	*11B10*
CCSW E4	Common Close Support Weapon	11B10
A/GNR E4	Gunner	11B10
A-Tank E4	Anti Tank	11B10

Figure H.6. HV-D Roles: Role Definition:
Roles defined for the system with selected attributes

HV- D3 Roles to Task Matrix

Tasks	Platoon Leader	Platoon Sergeant	Vehicle Commander	Squad Leader	Robotic	Team Leader	Health Care	Driver	Common Close Support Weapo	Gunner	Anti Tank	Infantry
Conduct Tactical Road March												
Initiate Road March	P	C										
Move Along March Route			C					P				
Report Control Measures				C		P						
Maintain March Security		P				C						
Conduct Scheduled Halts		C					P					
Platoon Arrives at Designated Coordinates			P					C				
Platton Initiates Screen Operation				P		C						
Enemy initiates Ambush												
React to Ambush Near												
Driver Reacts to Ambush			C					P				
Vehicle Gunner Reacts to Ambush												
Vehicle Commander Reacts to Ambush			P					C				
Infantry Squad Reacts to Ambush				P		C						
Platoon Leader Reacts to Ambush	P	C										
Evacuate Injured Personnel from BFV							P					C
Disengage From An Enemy Force				P		C						
Treat and Evacuate Casulties		C					P					
Conduct Resupply Operations	C	P										
Conduct Maintenance Operations			P					C				
Conduct Consolidation and Reorganization				C		P						
Destroy Unit Vehicles and Equipment			C					P				
Resume Original Mission	P	C										

Figure H.7. HV-D Roles (Relationship): Task Responsibility Matrix:
Tasks assigned to available roles

HV-E Team Composition: Infantry Platoon (ICV PLT)					
Vehicle Team	Platoon Leader (PL) ICV	Platoon Sergeant (PSG) ICV	Rifle Squad ICV	Rifle Squad ICV	Weapons Squad ICV
Members	*VC E5*	*PSG/VC E7*	*VC E6*	*VC E6*	*VC E6*
	DVR E4	*DVR E4*	*DVR E4*	*DVR E4*	*DVR E4*
	PL 02	*SL E6*	*SL E6*	*SL E6*	*SL E6*
	HC E4	*TL E5*	*TL E5*	*TL E5*	*CCSW E4*
	RBTIC E5	*INF E4*	*INF E4*	*INF E4*	*A/GNR E4*
	RBTIC E5	*INF E4*	*INF E4*	*INF E4*	*INF E4*
		INF E4	*INF E4*	*INF E4*	*CCSW E4*
		TL E5	*TL E5*	*TL E5*	*A/GNR E4*
		INF E4	*INF E4*	*INF E4*	*INF E4*
		INF E4	*INF E4*	*INF E4*	*A-Tank E4*
		INF E4	*INF E4*	*INF E4*	*A-Tank E4*

Figure H.8. HV-E Human Network: Role Groupings:
Roles grouped by different functional teams

HV-E2 Interaction Types				
Interaction	Collaboration	Coordination	Multiple Systems	Immediate Response
Example	Able to synchronize with other systems	Able to combine information from multiple sources	Able to communicate with multiple platforms	Able to operate mulitple vehicle types

Figure H.9. HV-E Human Network (Relationship): Interactions
Interaction types between the teams

HV-F Training					
Pay Grade	**Title**	**MOS**	**Training**	**Years of Experience**	
				Min	**Max**
E4	SPC - CPL	11B10	Skill Level 2	3	5
E5	SGT	11B20	Skill Level 3	5	9
E6	SSG	11B30	Skill Level 4	9	16
E7	SFC	11B40	Skill Level 5	16	20

Figure H.10. HV-F Training: Current Training Completed
Required for the defined Knowledge, Skills, and Abilities

HV-F1 System Training Implications
Soldiers to **adapt to many versions of systems**
Soldiers to manage systems generating far **greater volumes of information** at an exponentially faster pace
Soldiers to perform **more cognitively-intensive tasks** with vehicles in motion
Soldiers to isolate, remove, and repair **most field–level failures**
Soldiers to **operate over much greater distances**
Soldiers to **depend on & use embedded training** to acquire new skills
Soldiers to **acquire far greater combined arms skills** at lower echelons
Soldiers to **place much greater trust in networks** to keep them alive
Soldiers to **perform all duties reliably and accurately**

Figure H.11. HV-F Training: Projected Training Requirements
Additional training required by the system

HV-F2 Training Description	
MOS 11B: The infantryman supervises, leads, or serves as a member of an infantry activity that employs individual or crew served weapons in support of offensive and defensive combat opera tions. Duties for MOS 11B at each level of skill are:	
Skill Level 1.	
	Assists in the performance of reconnaissance operations.
	Employs, fires, and recovers anti-personnel and anti-tank mines.
	Locates and neutralizes mines.
	Operates, mounts/dismounts, zeros, and engages targets using night vision sight.
	Operates and maintains communications equipment and operates in a radio net.
	Operates in a NBC contaminated area.
	Constructs field expedient firing aids for infantry weapons.
	Performs as a member of a fire team during a movement to contact, reconnaissance, and security, an attack, defense, situational training exercises and all infantry dismounted battle drills.
	Processes prisoners of war and captured documents.

Figure H.12. HV-F Training: Training Gap
Difference in Current versus Projected Training

HV-G Standards
Task Performance:
•95% Reliability
•95% Accuracy

Figure H.13. HV-G Standards:
Human performance standards defined for tasks

HV-G AUTL Metrics		
ART 2.2.4 CONDUCT COUNTERAMBUSH ACTIONS		
2-19. Execute immediate action against near and far ambushes to minimize casualties, exit the enemy engagement area, inflict casualties on the enemy ambush force, and continue the mission. (FM 7-10) (USAIS)		
No.	Scale	Measure
1	Yes/No	Unit continues its mission after exiting the enemy engagement area.
2	Yes/No	Unit security element detects the ambush.
3	Yes/No	Unit prevents the enemy from gaining intelligence.
4	Yes/No	Unit security element prevents the enemy from engaging the unit main body.
5	Yes/No	Unit bypasses the ambush kill zone and the enemy's associated security positions.
6	Yes/No	Unit attacks and defeats the enemy ambush force before the enemy initiates the ambush.
7	Yes/No	Unit disengages its elements in the kill zone before destroying all elements in the kill zone.
8	Yes/No	Unit engages and fixes the enemy to prevent his withdrawal.
9	Percent	Of enemy casualties.

Figure H.14. HV-G Metrics:
Human performance metrics defined for system

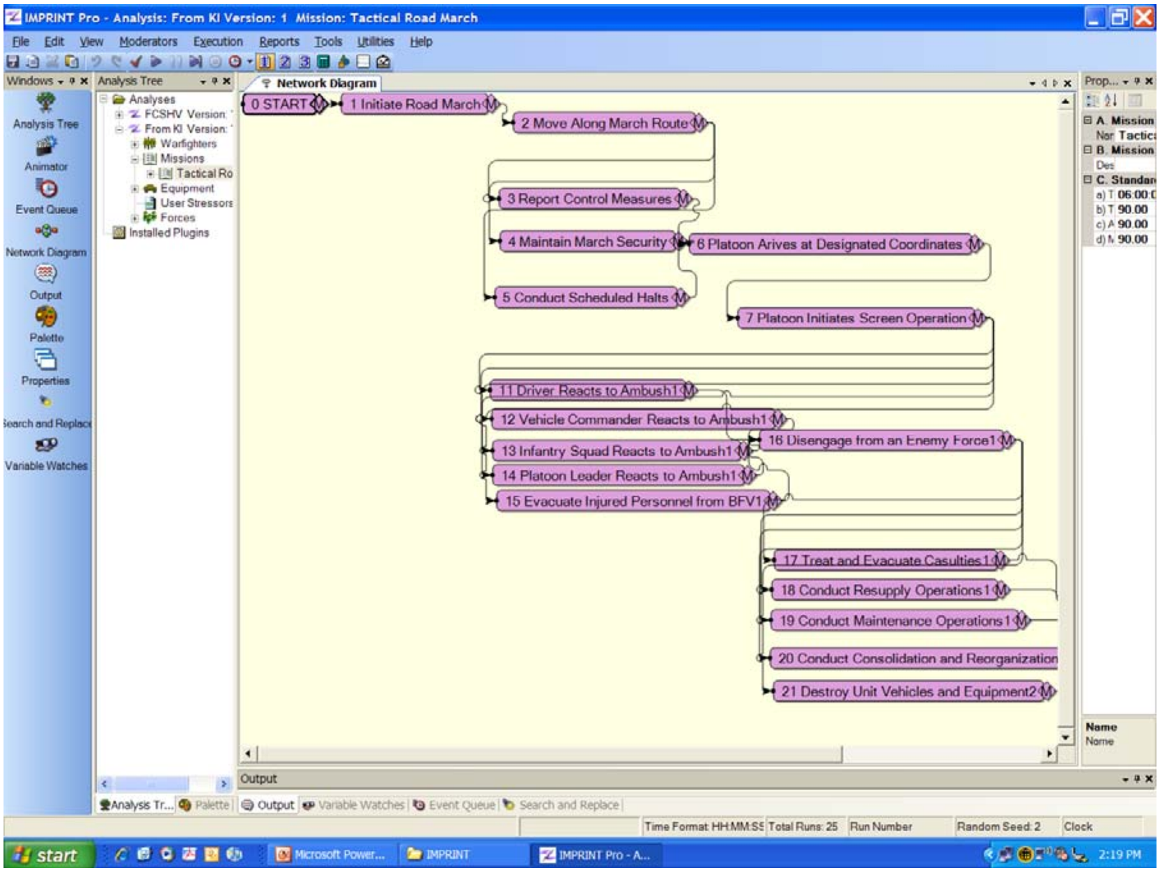


Figure H.15. HV-H Human Dynamics:
IMPRINT Modeling

Abbreviated designation

LIST OF EFFECTIVE PAGES
(LEP)

Effective Pages	Page numbers

CHANGE 3
Ratification Draft #

NATO Research and Technology Organisation

NATO Human View Quick Start Guide

Providing Human Data for System Architectures

North Atlantic Treaty Organization (NATO)
Research Technology Organization (RTO)

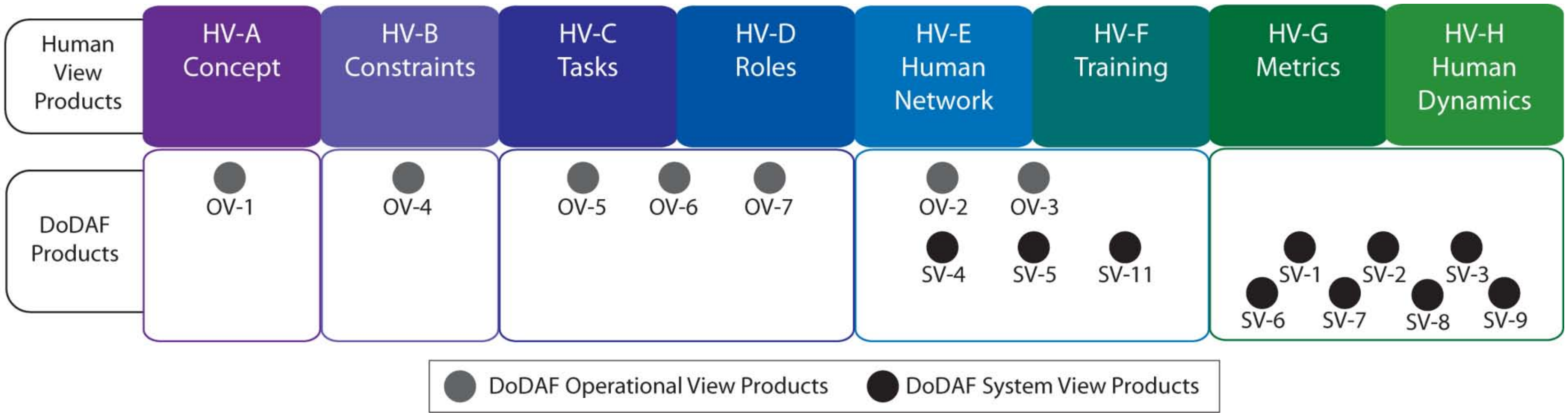
Human Factors and Medicine Panel
Research Technical Group HFM-155
Human Systems Integration for
Network Centric Warfare

Table of Contents

Executive Summary

The purpose of the NATO Human View (HV) is to capture human requirements and to inform on how humans interact within systems. The Human View is a supplementary view to existing architectures, providing an additional set of eight products that augment the DoDAF systems architecture products required of system engineers. The additional parameters are represented in a structured way to document the information needed to specify the human activity. This Quick Start Guide (QSG) provides instructions and templates to create an initial Human View for further development and analysis.

An architecture framework defines a common approach for development, presentation and integration of architecture descriptions. The application of a framework enables architectures to contribute more effectively to building interoperable systems. The framework products capture multiple aspects of a complex system. These products can then be integrated together to evaluate the relationship and impact of the corresponding variables.



Preface

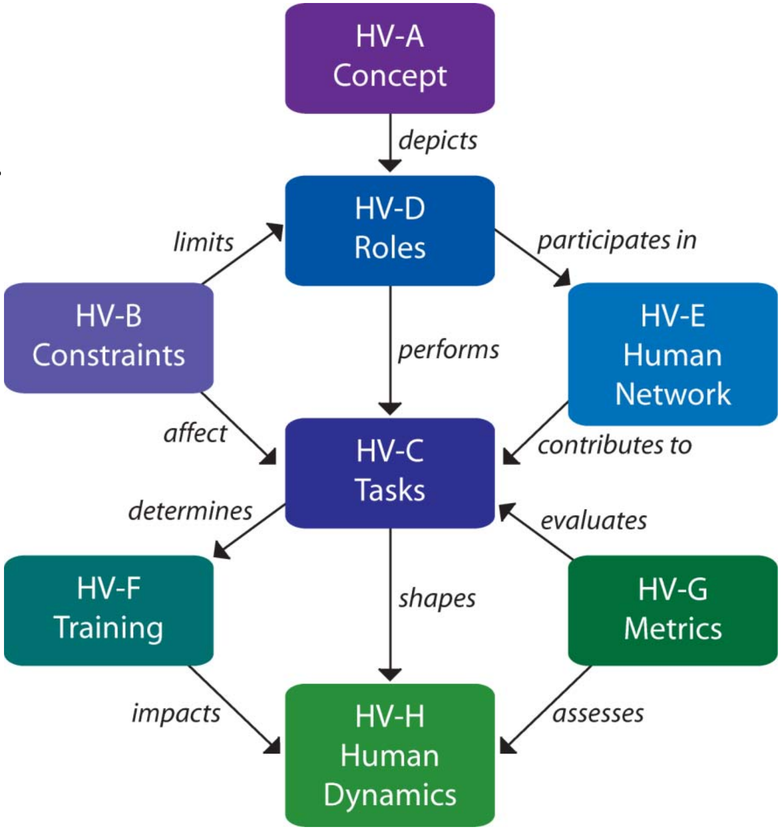
The NATO Human View Quick Start Guide provides a user's guide for implementing the NATO Human View products. It provides descriptions, examples and templates, and relationships to other architecture view points. It is intended specifically for system engineers and human factors practioners who are responsible for completing architecture products. A full description of the development of the NATO Human View can be found in The NATO Human View Handbook.

Each product page in the Quick Start Guide provides a description of the intent of the product, the necessary information requirements, as well as the relationship of the data captured in the product to data in other DoDAF and Human View products. Reusable templates are provided for most products, as well as example products created for two different case studies. Please note that the products were designed to be as broad as possible, therefore the template and the examples may illustrate different aspects of the product data.

Two case studies were completed during the course of the Human View development. The Commander's Update Brief is an operational brief that provides updates regarding the readiness and operational assets throughout the command. The process described and the models produced help evaluate the efficiency of the current process and provide a foundation for determining projected time and staff savings when integrating new technologies. The Human View products have also been used to capture the human elements for a a subset of the US Army's Future Combat System (FCS). The capabilities and limitations of an Infantry Platoon and the resources available in the Infantry Carrier Vehicle were documented using the Human View products. The case study focused on the tasks involved during a tactical road march and the platoon's reaction to an enemy ambush. The products capture the different roles the platoon members assume during these operations, the interactions between the platoon functional teams, and the FCS technology interfaces.

Human View Products Overview

HV-A : Concept - A conceptual, high-level representation of the human component of the enterprise architecture framework.
HV-B : Contraints - Sets of characteristics that are used to adjust the expected roles and tasks based on the capabilities and limitations of the human in the system.
HV-C: Tasks - Descriptions of the human-specific activities in the system.
HV-D: Roles - Descriptions of the roles that have been defined for the humans interacting with the system.
HV-E: Human Network - The human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time.
HV-F: Training - A detailed accounting of how training requirements, strategy, and implementation will impact the human.
HV-G: Metrics - A repository for human-related values, priorities and performance criteria, and maps human factors metrics to any other Human View elements.
HV-H: Human Dynamics - Dynamic aspects of human system components defined in other views.



HV-A | HV-B | HV-C | HV-D | HV-E | HV-F | HV-G | HV-H

Concept

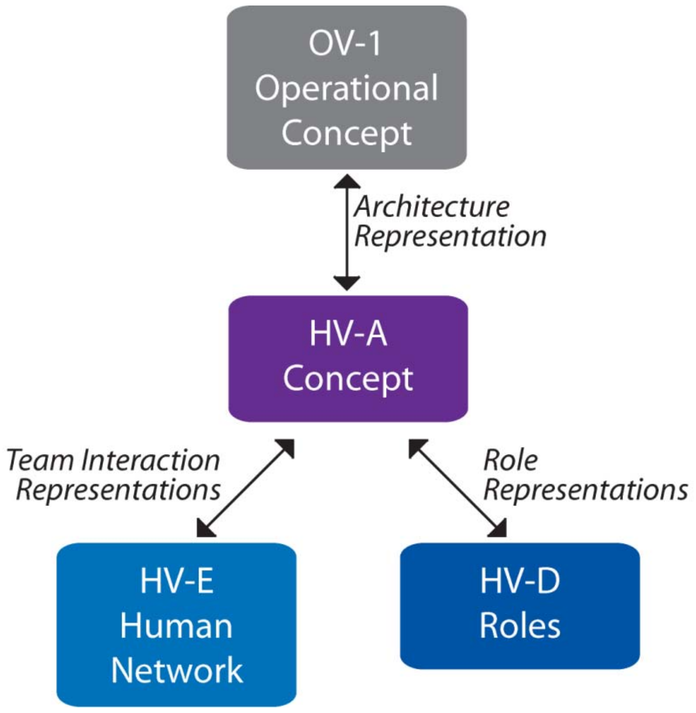
Description

The HV-A is a conceptual, high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components.

Information Requirements

- ❑ Pictorial depictions of the system and its human component.
- ❑ High level indicators of where human system interactions may occur.
- ❑ Textual descriptions of the overall human component of the system.
- ❑ Use cases which describe the human process.

Data Relationships



Concept

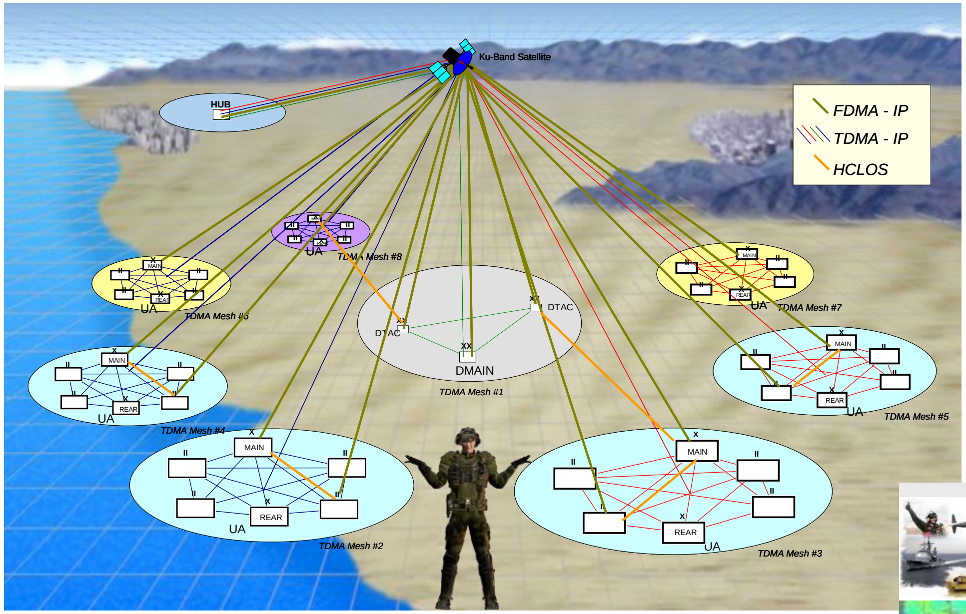
Template

The content of the HV-A depends on the scope and intent of the architecture, but in general it represents the relationship of the human roles to the other architectural components. Because it is a high-level product, no template is shown for this product.

HV-A HV-B HV-C HV-D HV-E HV-F HV-G HV-H

Concept

Examples



Manpower Projections

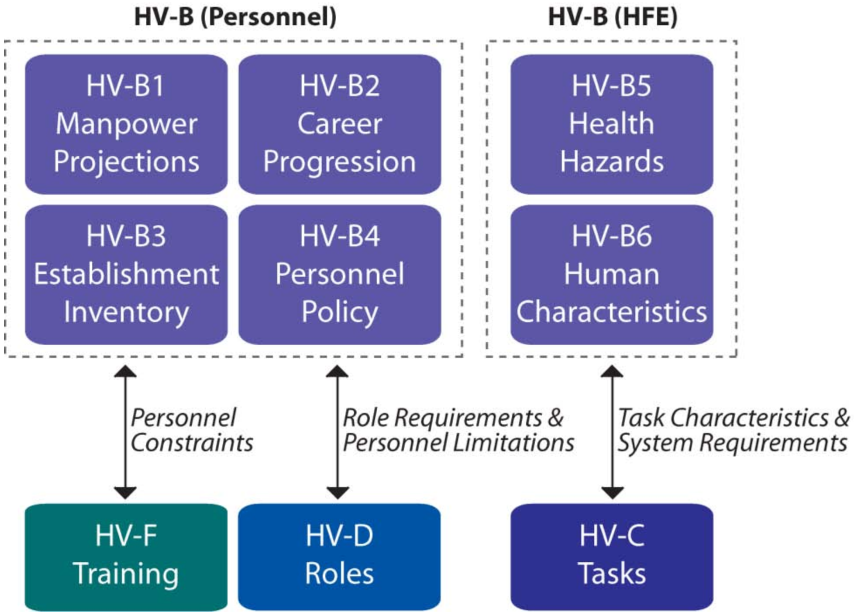
Description

Manpower Projections (HV-B1) illustrates predicted manpower requirements for supporting present and future projects that contribute to larger capabilities.

Information Requirements

- ❑ Manpower forecasting to allow initial adjustments in training, recruiting, professional development, assignment and personnel management.
- ❑ Impacts (and timeframe) related to numbers of personnel, personnel mix, Military Occupational Structure Identification (MOSIDs), Rank/level distribution, and, postings/relocations of personnel.
- ❑ Number of personnel with necessary Knowledge, Skills, and Abilities (KSAs) 'ready and able' to support fielding of future program.

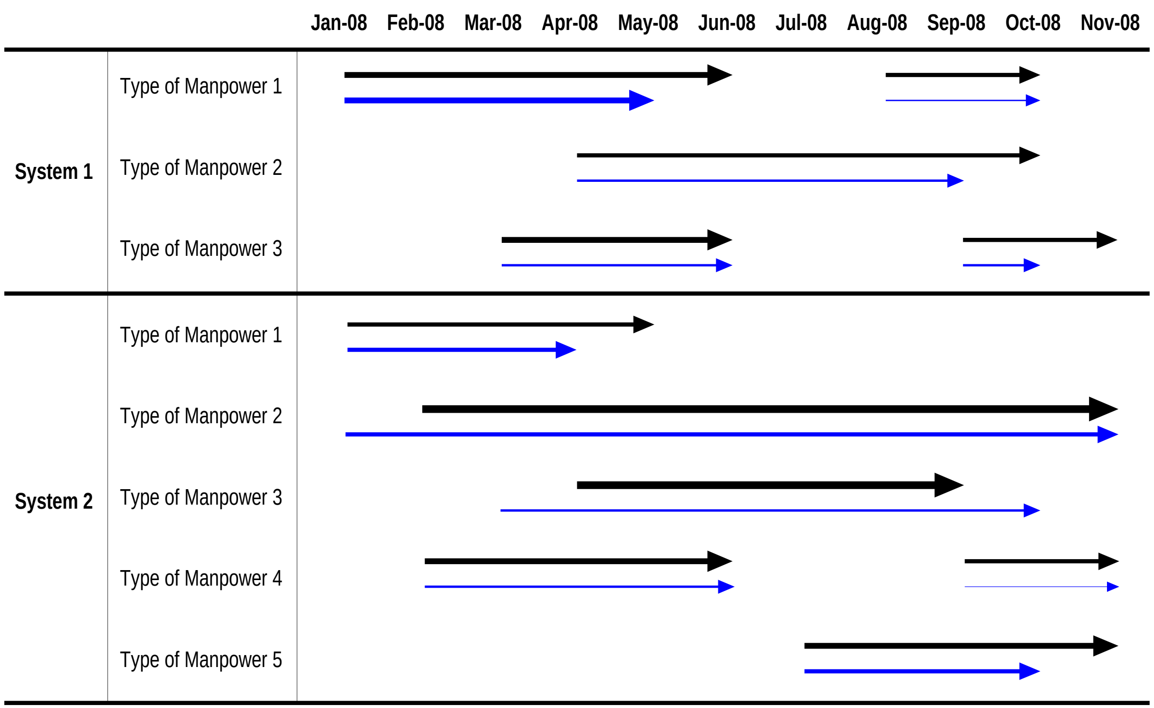
Data Relationships



Manpower Projections

Template

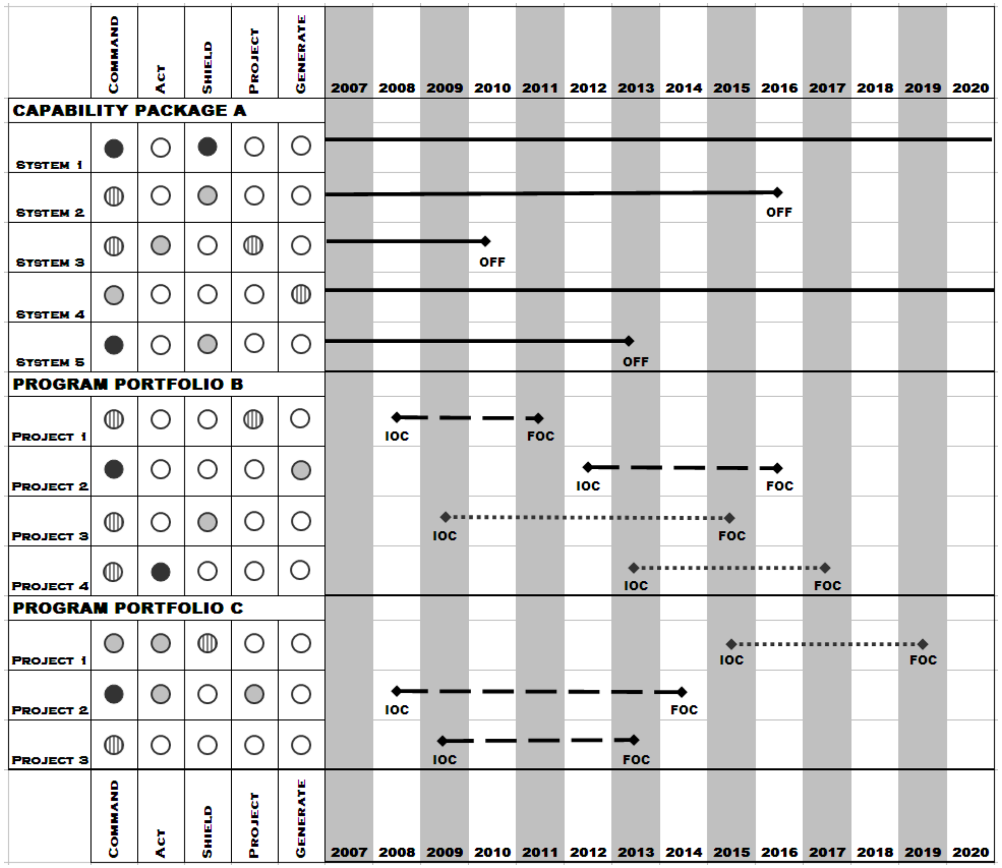
In the sample template, the top line represents the current manpower requirements and the lower line the projected manpower requirements. The thickness of the lines represents the amount of manpower required; thus, thicker lines require more manpower of that type while thinner lines require less manpower. With this type of visualization, the reduction or increase in amount of manpower and the length that manpower is required can be easily identified.



Manpower Projections

Example

This diagram maps current and planned projects to capabilities. For each year, the Initial Operating Capability (IOC) and Final Operating Capability (FOC) are indicated. Manpower requirements for each year can also be indicated by job and rank.



Career Progression

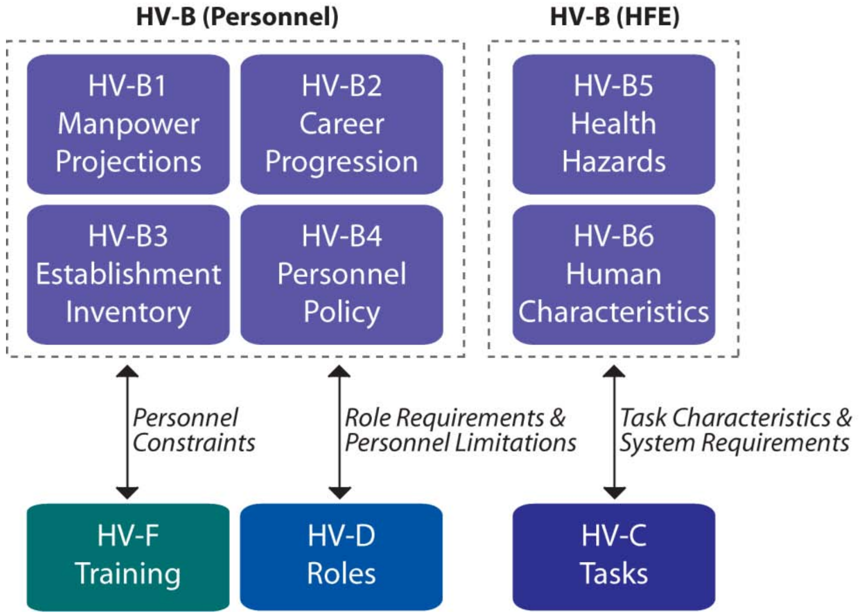
Description

Career Progression (HV-B2) illustrates career progression as well as the essential tasks, skills, and knowledge (and proficiency level) required for a given job.

Information Requirements

- ❑ Impacts of alternative system and capability designs on career progression.
- ❑ Jobs available given an individual's current job and occupation.
- ❑ Competencies required for each individual job.
- ❑ identify availability of individuals with necessary competencies.

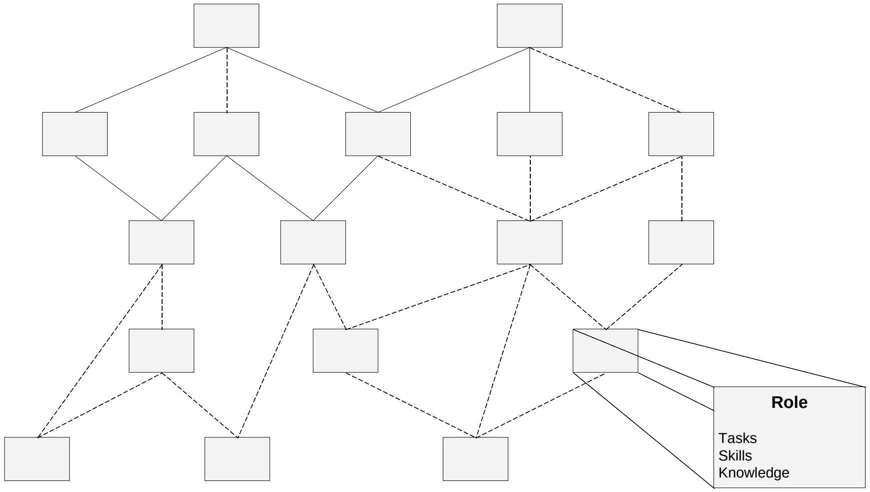
Data Relationships



Career Progression

Template

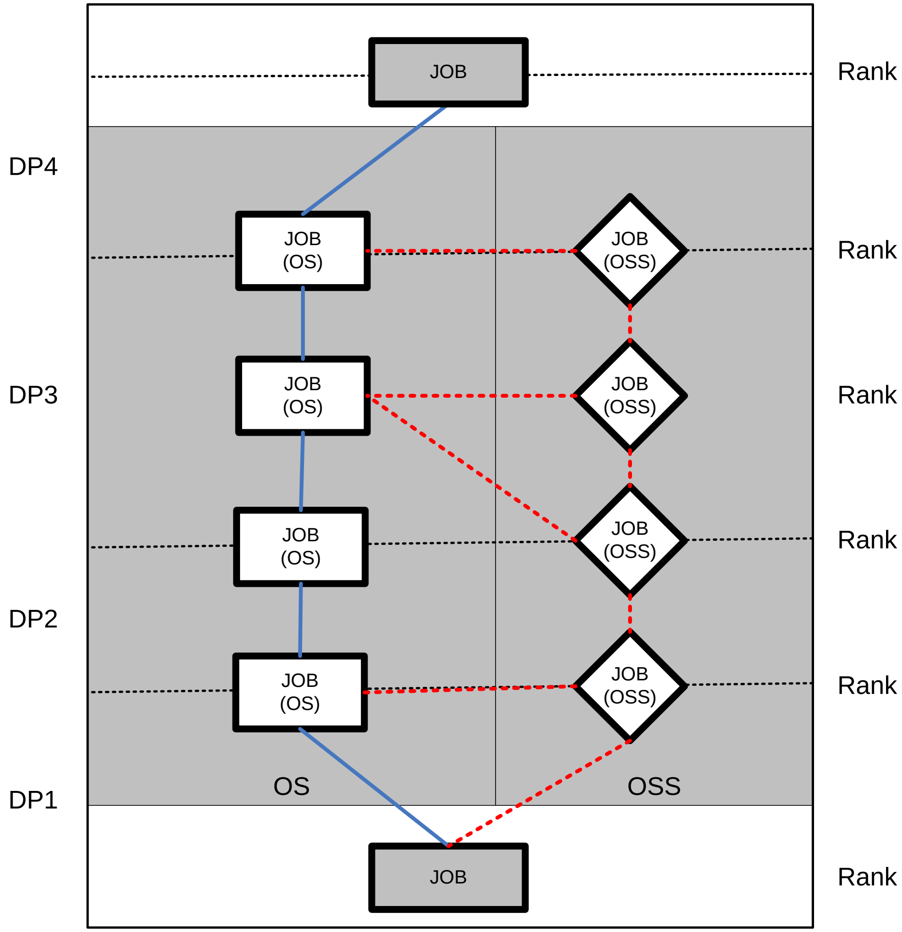
The sample template is represented as a network of roles (rectangles). The roles are connected by lines illustrating how an employee can move from role to role as skills and knowledge are acquired. An example of the possible contents within the rectangle is displayed in the bottom right corner. Under the tasks, skills and knowledge categories, a list of items for that role is provided. For the starting roles (rectangles at the bottom), there are fewer and more general tasks, skills and knowledge. As the individual progresses up the chain, the roles become more specific towards a certain domain or job. This increase in difficulty and specificity are illustrated by the growing list of tasks, skills and knowledge. The items under each tasks, skills and knowledge category should share similar items as the roles below it. Furthermore, the graph can be divided into a left and right side where each side promotes towards different areas (i.e. left side promotes towards management while right side promotes towards technical lead).



Career Progression

Example

This diagram depicts the progression of jobs and accompanying ranks for a particular career field. To advance, individuals move through Development Periods (DP) where training is received to acquire the necessary competencies for the next job. The Operational Specifications (OS) describe the specific requirements for each military occupation and the Occupational Specialty Specifications (OSS) describe unique skills required to perform a specific job.



Establishment Inventory

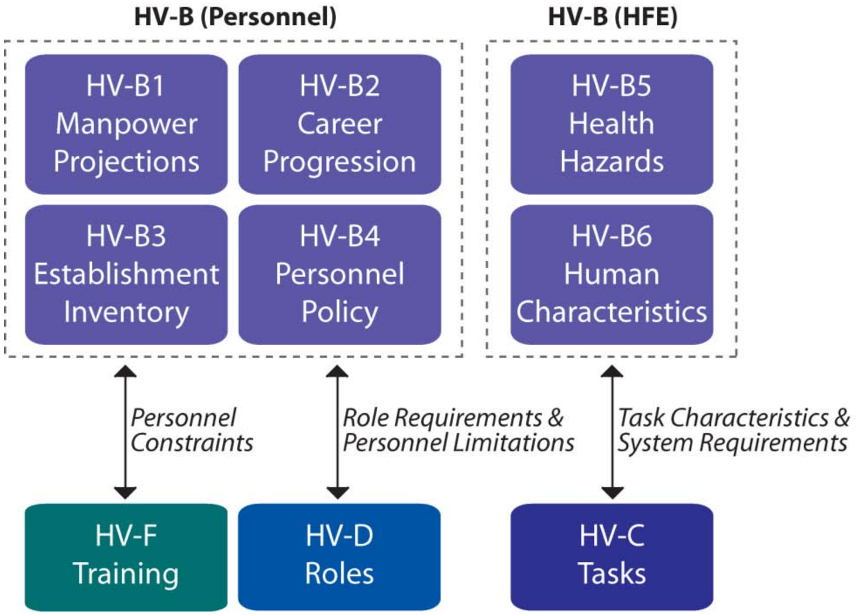
Description

Establishment Inventory (HV-B3) defines current number of personnel by rank and job within each establishment.

Information Requirements

- ❑ Forecasts of trained effective strength.
- ❑ Number of people that must be trained, recruited, etc. to fill gaps required for 'out years'.

Data Relationships



Establishment Inventory

Template

In the sample template the pound sign (#) can represent numbers, percentages, or ranges of people needed in each job category. Additionally, color coding can be used to indicate the scale of additional people needed over the current inventory, for example a red number can indicate many more people are needed and green can indicate no more people are needed. The dash (-) indicates that there is no corresponding inventory for that certain job/rank. Alternatively, instead of the # symbol, letters could be used to represent domain or systems, or any other link between rank and job.

		Rank							
		1	2	3	4	5	6	7	8
Job	Job 1	-	# #	-	#	# #		#	# # #
	Job 2	#	-		-	# # #		-	-
	Job 3	# # # #	-	#	# #		-	# #	
	Job 4	-	# # #		-	# #	# # #	-	#
	Job 5	#	-	# #			# #	#	
	Job 6	# #		# #	-	-		# # #	#
	Job 7	-	# #		# # #	-	# #	-	

Establishment Inventory

Example

This chart describes the current number of personnel by rank and job within each capability.

ESTABLISHMENT																			
				RANK															
				PTE	CPL	MCPL	SGT	WO	MWO	CWO	2LT	LT	CAPT	MAJ	LCOL	COL	REG F	P RES	SPED F
ARMOURED	SOLDIER (00005)		ARMOURED CREWMAN	#															
		RECCE	COYOTE DRIVER	#	#														
		RECCE	COYOTE GUNNER		#														
		RECCE	COYOTE SURV OPS																
		RECCE	ARMED RECCE COMD																
		DF	TANK DRIVER	#	#														
		DF	TANK GUNNER		#														
		DF	TANK LOADER		#	#													
		DF	TANK COMMANDER			#	#	#											
			TROOP WARRANT				#	#											
			SQUADRON SM						#										
			REGIMENT SM							#									
	OFFICER (00178)	RECCE	ARMD RECCE OFFICER								#								
		RECCE	JOB 2								#	#							
		RECCE	JOB 3									#							
		RECCE	JOB 4										#						
		DF	CC/TROOP LEADER										#						
		DF	BATTLE CAPTAIN										#						
		DF	SQN COMMANDER											#					

Personnel Policy

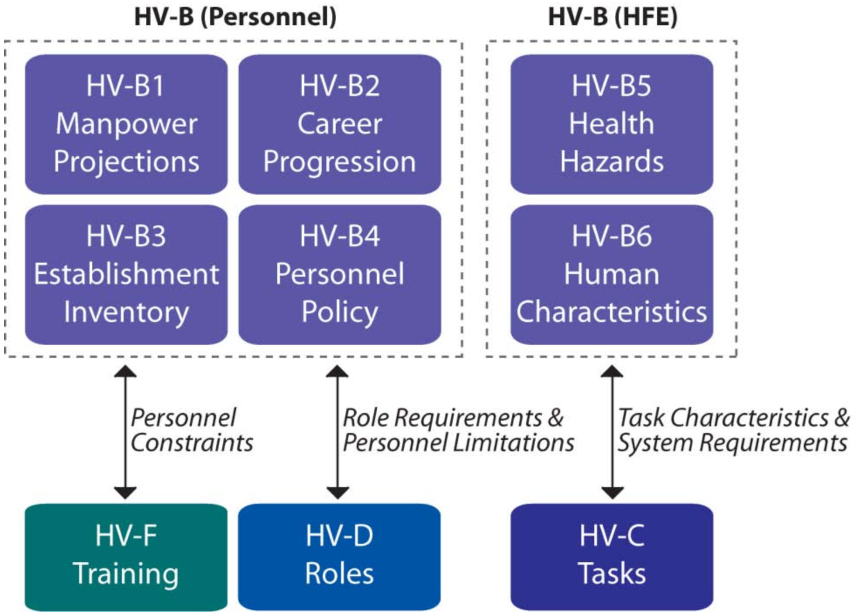
Description

Personnel Policy (HV-B4) ensures that personnel are fairly considered, properly treated, well looked after and supported in a legal, moral and ethical manner.

Information Requirements

- ❑ Department policies dealing with (governing) HR issues.
- ❑ HR documents, such as policies, doctrine, laws, benefits, pay, Standard Operating procedures (SOPs), etc.

Data Relationships



Personnel Policy

Template

In the sample template the check marks (✓) indicate that Human Resources has identified a document relevant for an employee, role or task, while the dash (-) indicates that the document is not relevant for that position. The blank cells can indicate which documents have not yet been reviewed.

	Human Resources Documents									
	1	2	3	4	5	6	7	8	9	10
Employee 1	✓	-	✓	✓	-	✓	-	✓	✓	✓
Employee 2		✓	✓	✓		-		-	-	-
Employee 3	✓	✓	-	✓	-		✓	✓	✓	-
Employee 4	-	✓	✓	✓	-		✓	✓		-
Employee 5	✓	-		✓	✓	✓		-	✓	✓
Employee 6	✓	✓				✓	✓			
Employee 7	-	✓	✓	✓	-		✓	✓		-
Employee 8			✓	✓			-	✓	✓	✓
Employee 9	✓	-		✓	✓	✓		-	✓	-
Employee 10	✓	✓	✓		-		✓	✓	-	-

Personnel Policy

Example

There is no example currently available for this HV product.

Health Hazards

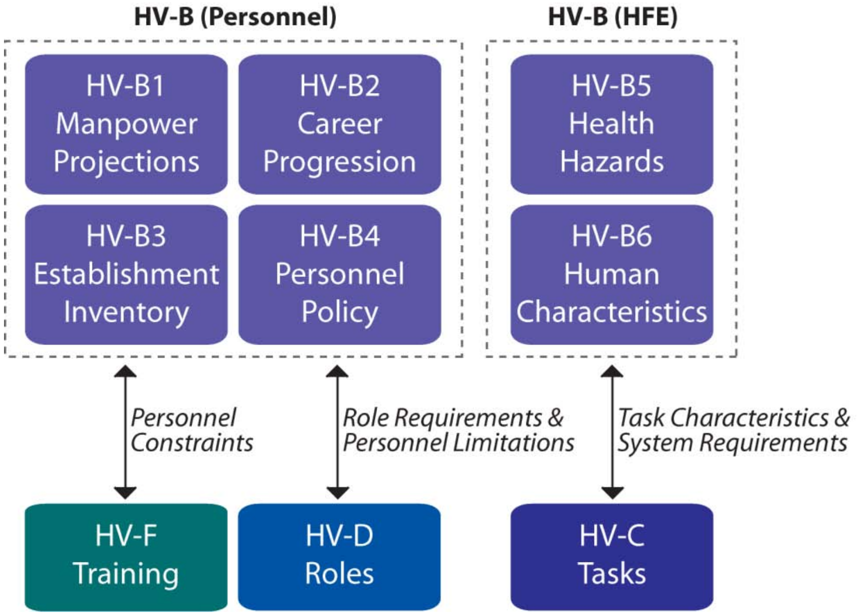
Description

Health Hazards (HV-B5) Considers the design features and operating characteristics of a system that can create significant risks of illness, injury or death.

Information Requirements

- ❑ Hazards may include system, environmental or task hazard assessment; air quality control assessment; noise/vibration pollution evaluation; impact force, shock protection; Workplace Hazardous Materials Information System (WHIMS) evaluation of tasks; radiation/LASER protection; Chemical and Biological (CB) protection; extremes of temperature, etc.
- ❑ It may include aspects of survivability, i.e. limiting the probability of personal injury, disability or death of personnel in their interactions with the system. This can include providing protection from attack, and reducing detectability, fratricide, system damage, personnel injury and cognitive and physical fatigue.

Data Relationships



Health Hazards

Template

In the sample template the risk level is divided into three categories: Red (R), Yellow (Y), and Green (G) indicating the seriousness of the hazard towards humans. Interpretation of the different categories can be defined relatively to the system, but in general red indicates a serious hazard, yellow a moderate hazards, and green a mild hazard. The hazards can be organized by risk (where the most serious hazards are at the top so they are addressed first), resolution (where the unresolved ones are at the top so they can be addressed first), or length of time it takes for the hazard to come into effect (e.g. mild air pollution may pass air safety standards but may not display any hazard until after five years of being exposed to it).

	Description	**Risk Level** R / Y / G	**Length** Long-term (L) / Short-term (S)	**Solution**	**Resolved** Y / N
Health Hazard 1	Describe hazard	R	L	Describe solution	Y
Health Hazard 2	Describe hazard	R	L	Describe solution	N
Health Hazard 3	Describe hazard	R	S	Describe solution	N
Health Hazard 4	Describe hazard	Y	L	Describe solution	Y
Health Hazard 5	Describe hazard	Y	S	Describe solution	Y
Health Hazard 6	Describe hazard	G	S	Describe solution	N
Health Hazard 7	Describe hazard	G	L	Describe solution	Y

Health Hazards

Example

This table shows the operating limits of FCS infantry personnel to noise and heat, as well as rest requirements.

HV-B5: Health Hazards		
	Limits	*Descriptions*
Noise	<85 dBA	Maximum daily exposure
Heat	68 - 85 degrees F	May drop as low as 41 degrees
MOPP	MOPP Level IV	
Sleep	4 hours of rest every 24 hours	Goal not requirement

Human Characteristics

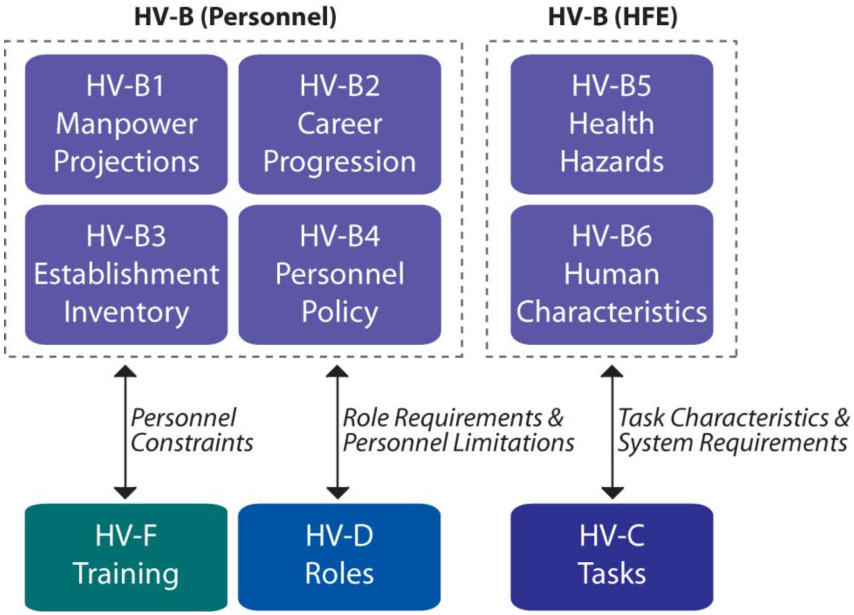
Description

Human Characteristics (HV-B6) considers the physical characteristics of an operator and movement capabilities and limitations of that operator under various operating conditions.

Information Requirements

- ❑ It may include aspects such as anthropometrical/medical data; reach data; range of motion data; physical strength data; visual and auditory assessment; speed or duration of activity data; cognitive workload; working memory capacity; ability to be security cleared; personality, motivation, etc.

Data Relationships



Human Characteristics

Template

The sample template contains categories, such as physical, visual and auditory, cognitive, etc. decomposed into specific characteristics. For example, the characteristics for "physical" could include: strength, length, height, weight of person; characteristics for "visual and auditory" could include: visibility rangers, size of font, intensity of sound; and characteristics of "cognitive" could include: reaction time, situation awareness. The description of the characteristic includes the requirements of the characteristics (e.g. physical design of the system should accommodate 5th – 95th percentile of male and females). The check marks (✓) indicate that the system meets the characteristic requirement while the dash (-) indicates that the system either does not or is not required to meet the characteristic requirement. The blank cells can indicate which systems still need to address certain characteristic requirements.

		Description of Characteristic	System				
			1	2	3	4	5
Category 1	Characteristic 1		✓	-		✓	-
	Characteristic 2		-	✓	-		✓
	Characteristic 3		-		✓	-	✓
	Characteristic 4			✓	✓	-	-
	Characteristic 5		✓	-	-	✓	
Category 2	Characteristic 1		-	✓	-	✓	-
	Characteristic 2		✓	-		-	✓
	Characteristic 3		✓		✓	-	-
	Characteristic 4		-	✓	-	✓	
	Characteristic 5		-		✓	-	✓

Human Characteristics

Example

There is no example currently available for this HV product.

Tasks

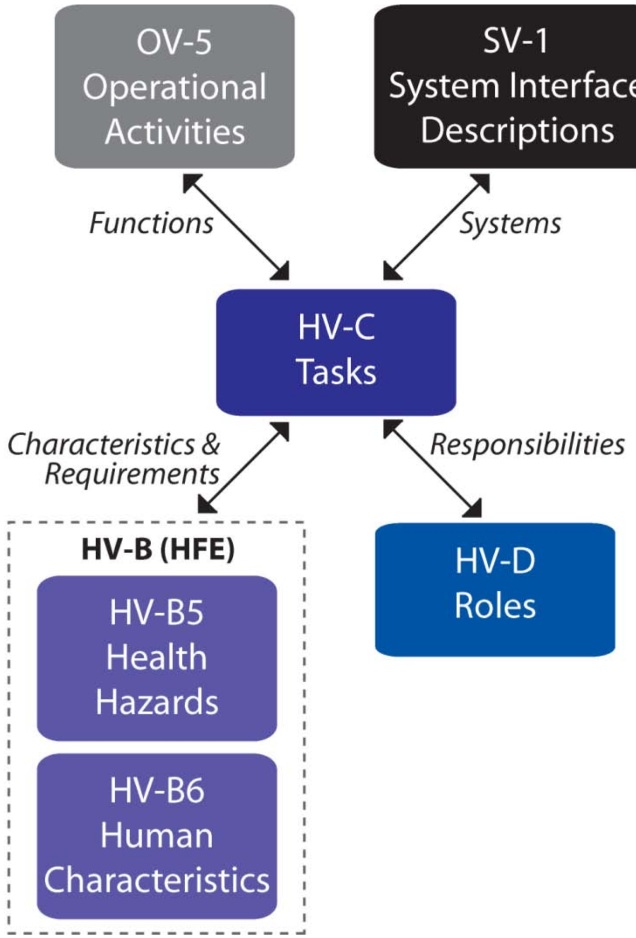
Description

The HV-C describes the human-specific activities, i.e., the tasks that have been assigned to the humans in a system over its entire life cycle. It also considers how the functions are decomposed into tasks and the dependencies between tasks.

Information Requirements

- ❑ Human-related functions in a system
- ❑ Allocation of functions between humans and machines
- ❑ Decomposition of functions into tasks
- ❑ Task descriptions in terms of various criteria and the KSA requirements
- ❑ Depiction of the inter-dependencies between different tasks
- ❑ The tools required to accomplish a task
- ❑ Interface design guideline on the basis of task requirements

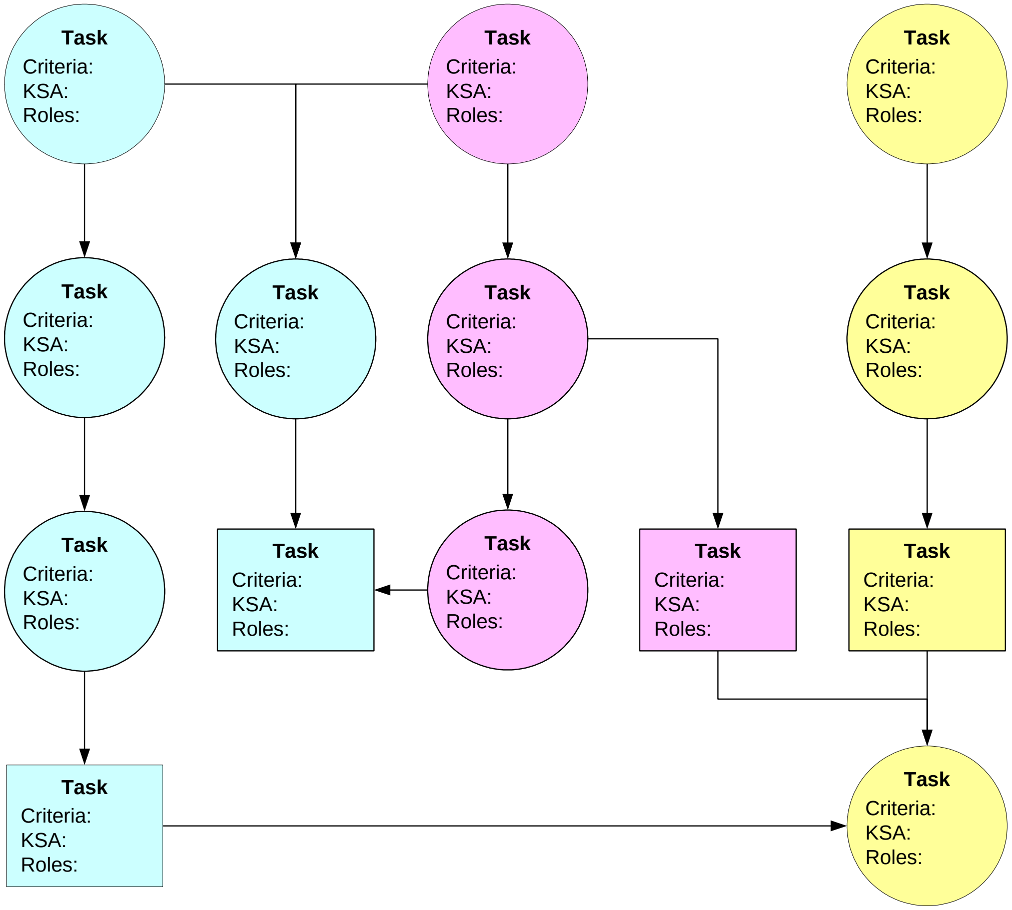
Data Relationships



Tasks

Template

The sample template shows a task decomposition that also includes interdependencies. For each task, the criteria and KSAs required are indicated, along with the role identifier for the task. This visualization groups functions into tasks through color coding. The flow from top to bottom represents the inter-dependencies between tasks where the top tasks need to be completed before starting the bottom ones. Furthermore, the circular tasks are for humans while the rectangular tasks are for machines, depicting the relationship between human and machine interactions.



Tasks

Example

This table decomposes the FCS platoon level tasks of Tactical Road March and Reaction to Ambush to 15 squad level tasks, and 5 individual level tasks.

HV-C TASKS		
Platoon Level	Squad Level	Soldier Level
Conduct Tactical Road March		
	Initiate Road March	
	Move Along March Route	
	Report Control Measures	
	Maintain March Security	
	Conduct Scheduled Halts	
	Platoon Arrives at Designated Coordinates	
	Platoon Initiates Screen Operation	
React to Ambush Near		
		Driver Reacts to Ambush
		Vehicle Gunner Reacts to Ambush
		Vehicle Commander Reacts to Ambush
		Infantry Squad Reacts to Ambush
		Platoon Leader Reacts to Ambush
	Evacuate Injured Personnel from BFV	
	Disengage From An Enemy Force	
	Treat and Evacuate Casulties	
	Conduct Resupply Operations	
	Conduct Maintenance Operations	
	Conduct Consolidation and Reorganization	
	Destroy Unit Vehicles and Equipment	
	Resume Original Mission	

Tasks

Role Relationship Example

This table lists the tasks required by the Commander's Update Brief process and indicates the responsible role for the task.

Tasks	Responsibility							
	Director of Operations	CFMCC Staff	Cell Directors	Special Security Officer	Battle Watch Captain	J33	Remote Staff	Commander
4.1 Access slides posted by assigned cells					✓			
4.2 Assess if all slides have been posted					✓			
4.3 Notify appropriate cell staff that slides are due					✓			
4.4 Access status of requested slides		✓						
4.5 Notify BWC to proceed without slides		✓						
4.6 Arrange posted slides in order for briefing					✓			
5.1 Advise reviewers of readiness					✓			
5.2 Review slides			✓					
5.3 Provide updates and comments			✓					
5.4 Review comments		✓						
5.5 Access & revise slides		✓						
5.6 Post reviewed slides		✓						
5.7 Ensure order and content of posted slides					✓			
6.1 Send Link for collaborative session						✓		
6.2 Access Session	✓		✓		✓		✓	✓
6.3 Initiate Collaborative session						✓		
6.4 Take roll call					✓			
6.5 Present the brief	✓							
6.6 Discuss issues and implications								✓
6.7 Determine action items								✓
6.8 Distribute action items					✓			

Tasks

System Relationship Example

This table lists the tasks required by the Commander's Update Brief process and indicates the systems that are required for completion of the task.

Tasks	Systems	C2F CaS Crisis Action Page	Digital ROE	SIPRNET	Electronic Bookmarks	IIDBT	Cells Shared Folder	Email or other direct comms	SameTime or IWS
1.1 Select topics for briefing content		✓	✓						
1.2 Review previously submitted data		✓							
1.3 Identify data sources for relevent updates				✓					
1.4 Access sources & identify information				✓	✓				
2.1 Obtain templates for briefing						✓			
2.2 Import data				✓					
2.3 Create slide						✓			
2.4 Revise slides and notes						✓			
2.5 Assess currency of information									
2.6 Assess accuracy of fields and spelling									
2.7 Revise slide fields and spelling						✓			
2.8 Assess need to make changes to notes									
2.9 Revise slide notes						✓			
2.10 Assess need for sharing with foreign partners									
2.11 Assess compliance of data with disclosure policies								✓	
2.12 Post completed slide							✓		
3.1 Advise reviewers of readiness								✓	
3.2 Review slides							✓		
3.3 Provide updates and comments								✓	
3.4 Review comments								✓	

Roles

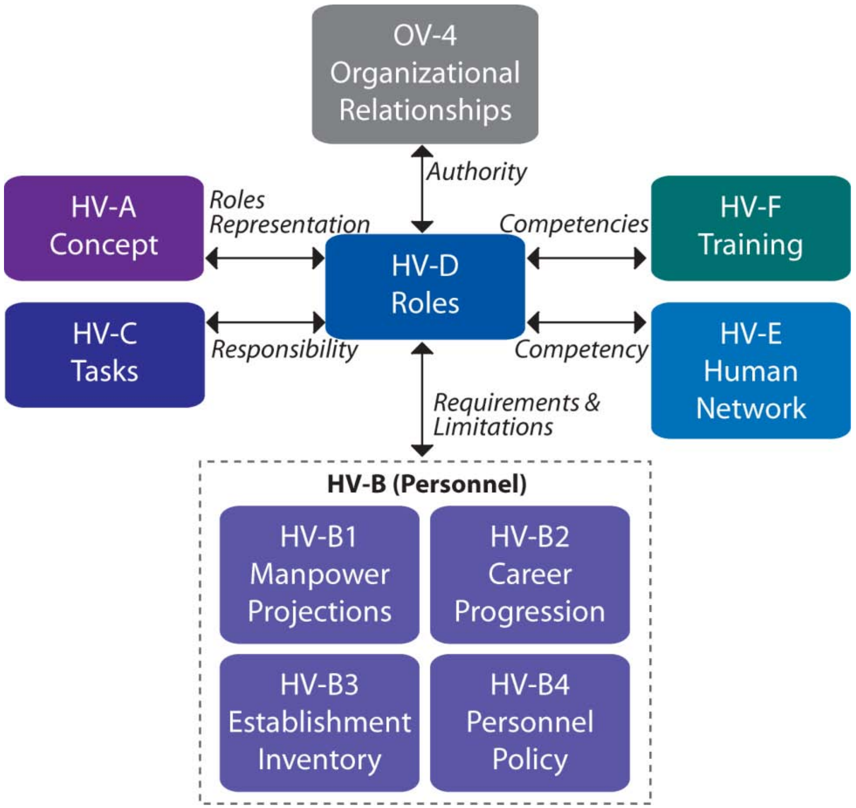
Description

The HV-D describes the roles that have been defined for the humans interacting with the system. A role represents a job function defining specific behavior within the context of an organization, with some associated semantics regarding the authority and responsibility conferred to the person in the role, and *competencies* required to do the job.

Information Requirements

- ❑ Responsibility - accountability and commitment
- ❑ Authority - the access ability of an individual to perform a specific task
- ❑ Competencies - the quality of being able to perform; a combination of knowledge, skills and attributes
- ❑ Multiplicity - a role may be performed by a human or by multiple humans at the same time.

Data Relationships



Roles

Template

The sample template shows a task decomposition that also includes interdependencies. For each task, the criteria and KSAs required are indicated, along with the role identifier for the task. This visualization groups functions into tasks through color coding. The flow from top to bottom represents the inter-dependencies between tasks where the top tasks need to be completed before starting the bottom ones. Furthermore, the circular tasks are for humans while the rectangular tasks are for machines, depicting the relationship between human and machine interactions.

Human Tasks	**Job Area**				
	1	**2**	**3**	**4**	**5**
Task 1	**Role Title** R: xxx A: xxx C: xxx			**Role Title** R: xxx A: xxx C: xxx	
Task 2		**Role Title** R: xxx A: xxx C: xxx			
Task 3			**Role Title** R: xxx A: xxx C: xxx		**Role Title** R: xxx A: xxx C: xxx
Task 4	**Role Title** R: xxx A: xxx C: xxx **Role Title** R: xxx A: xxx C: xxx		**Role Title** R: xxx A: xxx C: xxx		

Roles

Example

This table lists the 12 roles defined for the FCS Infantry Platoon and their required Military Occupational Specialty (MOS).

HV-D Roles		
Abbreviation	**Role Name**	**MOS**
PL 02	*Platoon Leader*	*11A*
PSG/VC E7	*Platoon Sergeant*	*11B40*
VC E6	*Vehicle Commander*	*11B30*
SL E6	*Squad Leader*	*11B30*
VC E5	*Vehicle Commander*	*11B20*
RBTIC E5	*Robotic*	*11B20*
TL E5	*Team Leader*	*11B20*
HC E4	*Health Care*	*68W10*
DVR E4	*Driver*	*11B10*
INF E4	*Infantry*	*11B10*
CCSW E4	Common Close Support Weapon	11B10
A/GNR E4	Gunner	11B10
A-Tank E4	Anti Tank	11B10

Roles

Task Relationship Example

This table indicates the assignment of FCS roles to the previously defined tasks.

P = Primary Responsibility
C = Contingent Responsibility

HV- D3 Roles to Task Matrix

Tasks	Platoon Leader	Platoon Sergeant	Vehicle Commander	Squad Leader	Robotic	Team Leader	Health Care	Driver	Common Close Support Weapo	Gunner	Anti Tank	Infantry
Conduct Tactical Road March												
Initiate Road March	P	C										
Move Along March Route			C					P				
Report Control Measures				C		P						
Maintain March Security		P				C						
Conduct Scheduled Halts		C					P					
Platoon Arrives at Designated Coordinates			P					C				
Platton Initiates Screen Operation				P		C						
Enemy initiates Ambush												
React to Ambush Near												
Driver Reacts to Ambush			C					P				
Vehicle Gunner Reacts to Ambush												
Vehicle Commander Reacts to Ambush			P					C				
Infantry Squad Reacts to Ambush				P		C						
Platoon Leader Reacts to Ambush	P	C										
Evacuate Injured Personnel from BFV							P					C
Disengage From An Enemy Force				P		C						
Treat and Evacuate Casulties		C					P					
Conduct Resupply Operations	C	P										
Conduct Maintenance Operations			P					C				
Conduct Consolidation and Reorganization				C		P						
Destroy Unit Vehicles and Equipment			C					P				
Resume Original Mission	P	C										

Roles

System Relationship Example

A this table indicates the FCS controllers and system interfaces available to each role.

HV-C2 System Interfaces	
Role	**System**
Platoon Leader	1 LCU Centralized Controller; 2 Centralized Controller, Tactical (UGS-T)
Platoon Sergeant	Multifunction Utility/Logistics and Equipment Transport (MULE-T)
Vehicle Commander	
Squad Leader	3 Centralized Controllers; Small Unmanned Ground Vehicle (SUGV)
Robotic	Armed Rconnaissance Vehicle (ARV-A); Class 1 unmanned Aircraft System (UAS)
Team Leader	6 sets Intelligent Ground Sensors (UGS-U)
Health Care	
Driver	Infantry Carrier Vehicle
Infantry	MK 44 30MM; MK240 7.62MM;

Human Network

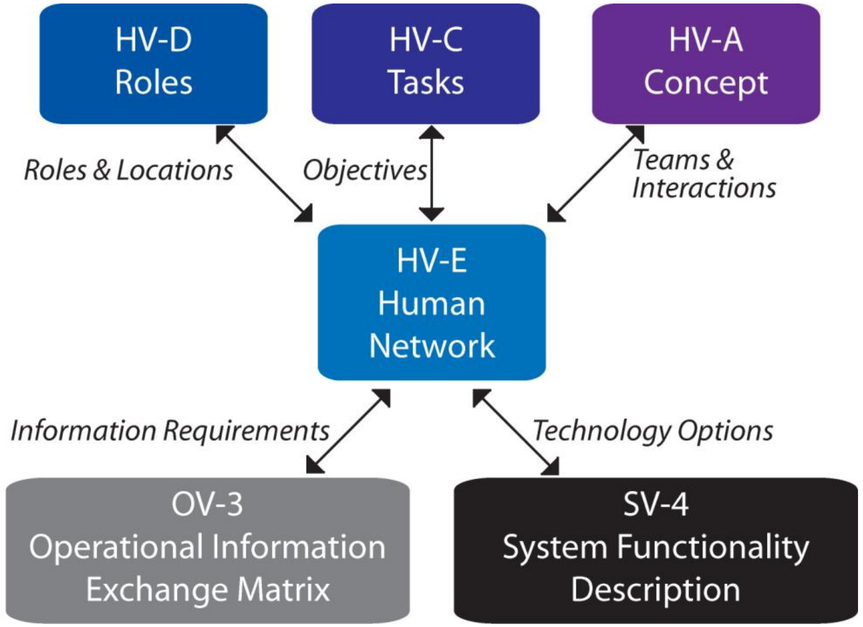
Description

The HV-E captures the human to human communication patterns that occur as a result of ad hoc or deliberate team formation, especially teams distributed across space and time.

Information Requirements

- ❑ Role groupings or teams formed, including the physical proximity of the roles and virtual roles included for specific team tasks.
- ❑ Type of interaction – i.e., collaborate, coordinate, supervise, etc.
- ❑ Team cohesiveness indicators - i.e., trust, sharing, etc.
- ❑ Team performance impacts - i.e., synchronization (battle rhythm), level of engagement (command directed)
- ❑ Team dependencies - i.e., frequency/degree of interaction between roles

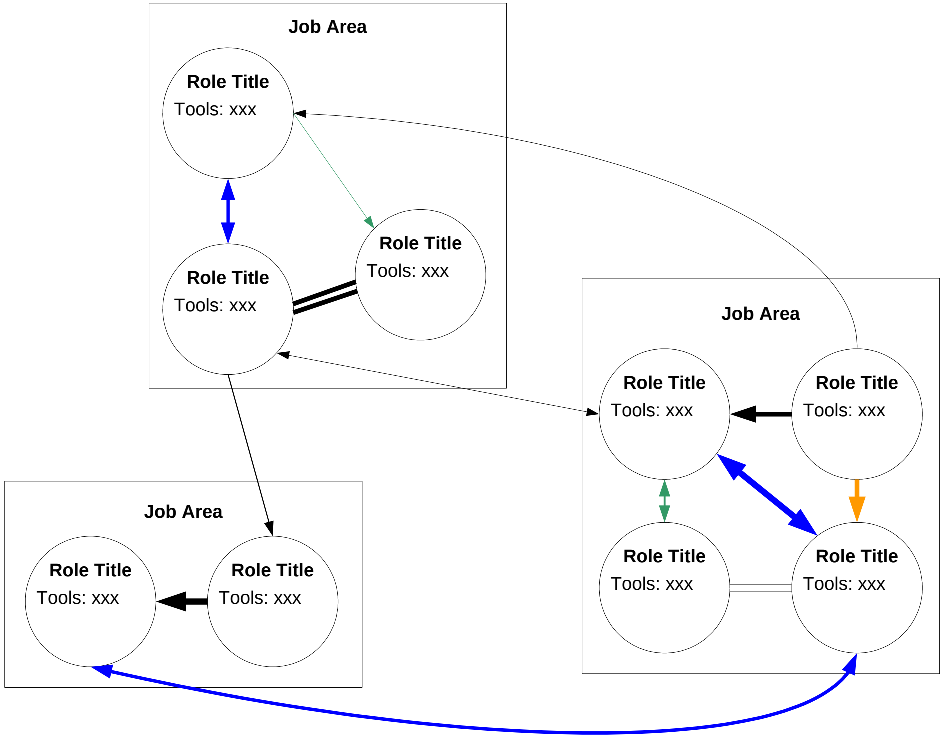
Data Relationships



Human Network

Template

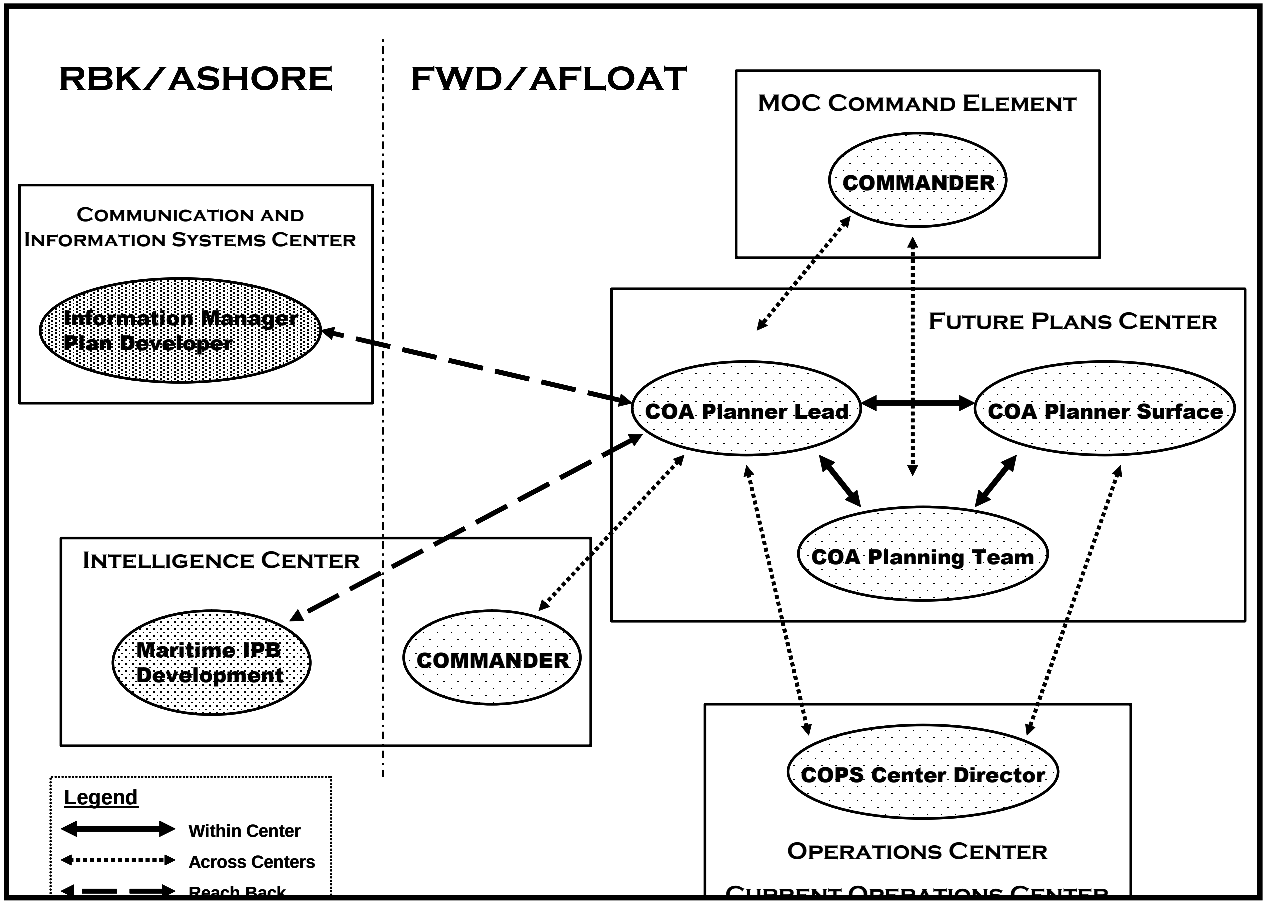
In the sample template each individual circle represents a role. The dashed circle represents a virtual role used for specific team functions. Job areas show role groups / teams formed. The role title distinguishes the individual roles while details for that role, such as tools used, can also be indicated. The type of interaction between the roles is indicated by connecting symbols where the thickness of the symbols indicate the frequency of the interactions (thicker lines = more frequent, thinner lines = less frequent). Color of the connecting symbols can also be used to indicate additional attributes, such as the cohesiveness of the roles.



Human Network

Example

This diagram indicates the interactions across teams involved in the Commander’s Update Brief process. It also specifies the communication types and team locations.



Training

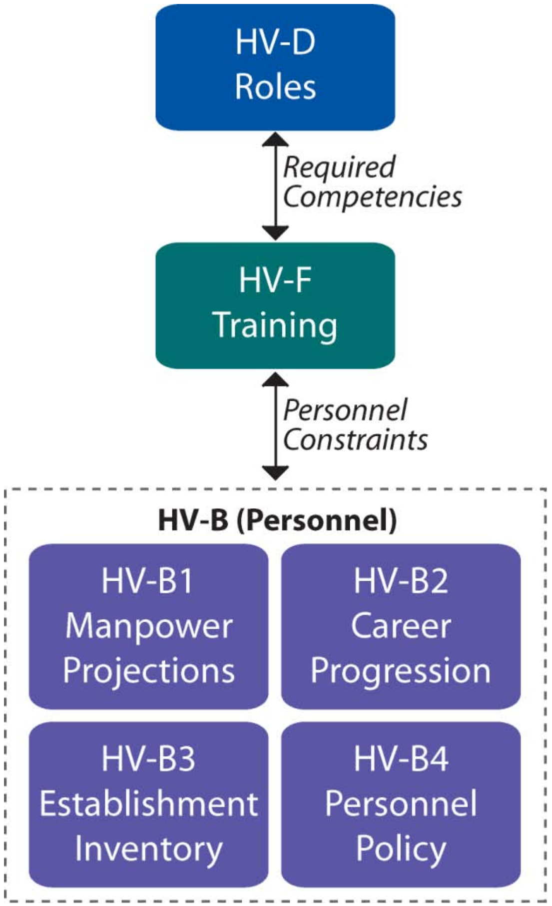
Description

HV-F is a detailed accounting of how training requirements, strategy, and implementation will impact the human. It illustrates the instruction or education and on-the-job or unit training required to provide personnel their essential tasks, skills, and knowledge to meet the job requirements.

Information Requirements

- ❑ As-is training resources, availability, and suitability
- ❑ Risk imposed by to-be operational and system demands
- ❑ Cost and maturity of training options for tradeoff analysis
- ❑ Determine training required to obtain necessary knowledge, skills, and ability to support career progression
- ❑ Differentiation of basic, intermediate, or advance job training; operational vs. system specific training; and individual vs. team training

Data Relationships



Training

Templates

Two sample templates are provided as an example of a series of training products capturing different features. In the first, training requirements and the corresponding skills gained are indicated via a check mark (✓), or not, indicated via a dash (-). In the second, a table that connects skills to a job or employee is shown. The skills are grouped by categories to easily analyze the completeness of the skill set.

	Skills Gained									
Requirement	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	✓	-	✓	✓	-	✓	-	✓	✓	✓
2	-	✓	✓	✓	-	-	-	-	-	-
3	✓	✓	-	✓	-	-	✓	✓	✓	-
4	-	✓	✓	✓	-	-	✓	✓	-	-
5	✓	-	-	✓	✓	✓	-	-	✓	✓
6	✓	✓	-	-	-	✓	✓	-	-	-
7	-	✓	✓	✓	-	-	✓	✓	-	-
8	-	-	✓	✓	-	-	-	✓	✓	✓
9	✓	-	-	✓	✓	✓	-	-	✓	-
10	✓	✓	✓	-	-	-	✓	✓	-	-

Sample Template for Training Requirements

		Job or Employee				
	Skills	**1**	**2**	**3**	**4**	**5**
Category 1	**1**	-	✓	✓	✓	-
	2	✓	✓	✓	-	-
	3	✓	-	✓	✓	✓
	4	-	-	-	-	✓
	5	✓	✓	✓	✓	-
Category 2	**1**	✓	✓	✓	✓	✓
	2	-	-	✓	-	✓
	3	-	✓	✓	-	-
	4	-	-	✓	✓	-
	5	✓	-	-	-	✓

Sample Template for Existing Skill Inventory

Training

Examples

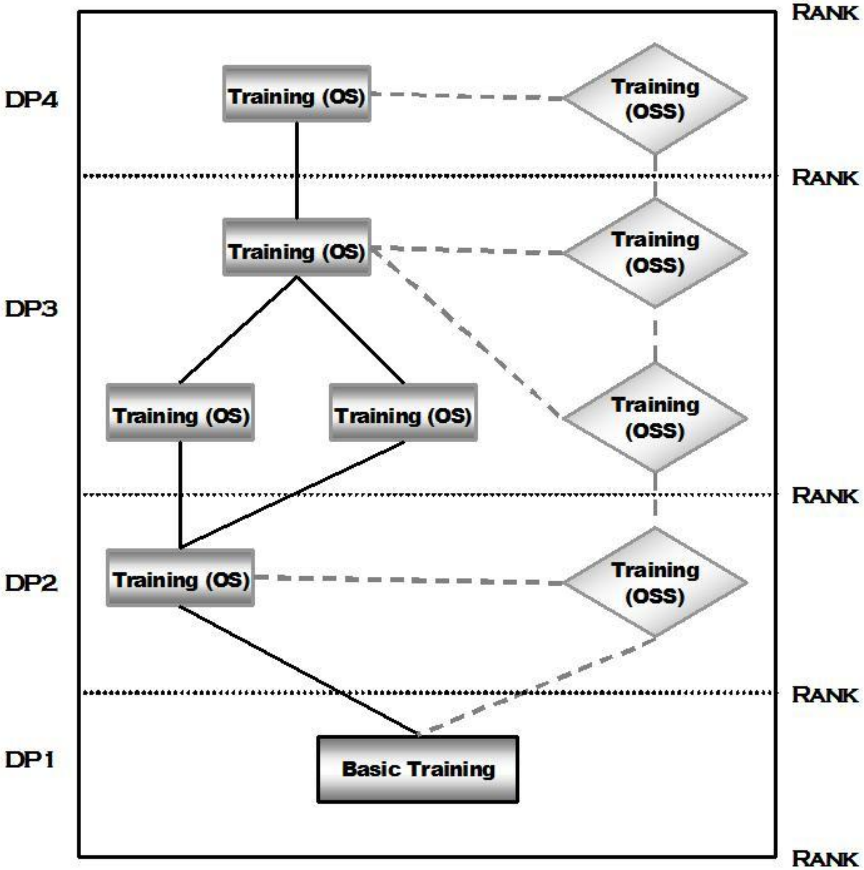
This table calls out the current personnel in the Commander's Update Brief process by code, title, and name. Additionally, the rank, designator, billet and clearance are listed, which can be referenced to training requirements.

Code	Title	Name	Rank	Designator	Billet Ref		Clearance	Location
J00	*Commander*	FITZGERALD	O-9	1310	JTF-001	JFMCC-001	TS	IWO
J1	Director of Manpower and Personnel	LANE	O-5	1315	JTF-2201	JFMCC-1901	S	W-5
J2	Director of Intelligence	HOPPA	O-6	1630	JTF-1501	JFMCC-1101	TS/SCI	W-5
SSO	*Special Security Officer*	SMITH	E-6	CTA	JTF-1504	JFMCC-1201	TS/SCI	W-5
J3	*Director of Operations*	GOULDING	O-6	1110	JFMCC-020	JTF-501	TS/SCI	IWO
J33	*Current Operations (COPS)*	GRAY	O-5	1147	JFMCC-301	JTF-801	TS	IWO
BWC	*Battle Watch Captain*	MAYO	O-4	1320	JFMC-403	JTF-903	TS	IWO
J4	Director of Logistics	FALLON	O-6	3100	JFMCC-1501	JTF-2401	S	W-5
J5	Director of Planning	PETIT	O-5	1310	JFMCC-771	JTF-603	TS	IWO
J6	Director of C4I	BURKE	O-6	1120	JFMCC-2001	JTF-2501	TS	W-5
J7	Director of Training	VACANT						
J9	Director of Experimentation	VACANT						

Training

Examples

This diagram depicts the progression of training required to provide personnel their essential tasks, skills, and knowledge to meet job requirements for a particular career field. Training is received during Development Periods (DP) to support career advancement and ensures that the individual has the necessary competencies to meet the requirement of a job. The Operational Specifications (OS) describe the specific requirements for each military occupation and the Occupational Specialty Specifications (OSS) describe unique skills required to perform a specific job.



Metrics

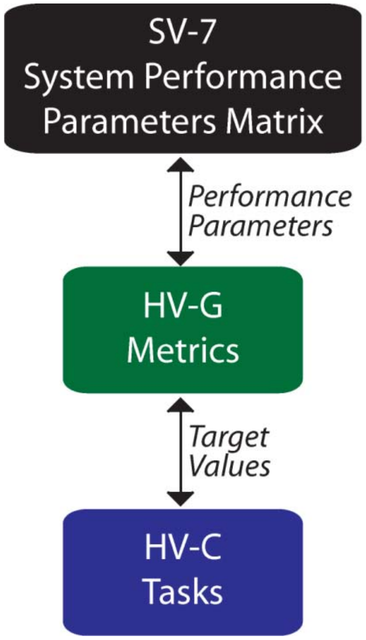
Description

The HV-G provides a repository for human-related values, priorities and performance criteria, and maps human factors metrics to any other Human View elements. It may map high-level (qualitative) values to quantifiable performance metrics and assessment targets or it may map measurable metrics to human functions, i.e., human performance specifications.

Information Requirements

- ❑ Human Factors Value definitions level 1…n
- ❑ Human Performance Metrics (what is to be measured)
- ❑ Target Values (what quantifiable value is acceptable)
- ❑ Human Task to Metrics mapping
- ❑ Value definition links
- ❑ Value to design element mapping
- ❑ Methods of compliance

Data Relationships



Metrics

Template

The sample template lists objectives, risks, and standards for each task. The objectives indicate the requirements for evaluating the performance. Risks are the dangers associated with low performance of the task; risks can be color coded as well for easier interpretation. Standards or guidelines used may or may not be applicable to every task. The tasks can be analyzed to evaluate the performance of humans using the system and can also be grouped by categories.

Tasks	**Objective**	**Risks**	**Standards / Guidelines Used**	**Status** (P)ass / (F)ail
Task 1				F
Task 2				F
Task 3				F
Task 4				P
Task 5				P

Metrics

Example

This table provides a listing of the objective, indicators, and risks associated with each of the tasks identified for the Commander's Update Brief process.

Tasks	Objectives	Indicators	Risks
1.0 Identify new information for assigned topics	1. Relevant new information is identified; 2. Requests for breifing, both standard and special are acted upon		
1.1 Select topics for briefing content		Brief development is started within time targets	Missed trigger to begin process
1.2 Review previously submitted data			
1.3 Identify data sources for relevent updates		Information identified is the most up-to-date available	Topical requirements are misunderstood
1.4 Access sources & identify information		Information identified is relevant to the situation	Data sources are not accessible
2.0 Create assigned slides	1. All available information required to respond to situation is included; 2. Preparation is within time limits		
2.1 Obtain templates for briefing			
2.2 Import data			There is a lack of connectivity to sources
2.3 Create slide		Information on the slide is relevant to the situation	Data updates are not imported
2.4 Revise slides and notes			
2.5 Assess currency of information		Information on the slide is the most up-to-date available	
2.6 Assess accuracy of fields and spelling			The request for a special format is missed
2.7 Revise slide fields and spelling			
2.8 Assess need to make changes to notes			
2.9 Revise slide notes			
2.10 Assess need for sharing with foreign partners			
2.11 Assess compliance of data with disclosure policies			
2.12 Post completed slide		Slide preparation is within time limits	Development schedule is not followed

Human Dynamics

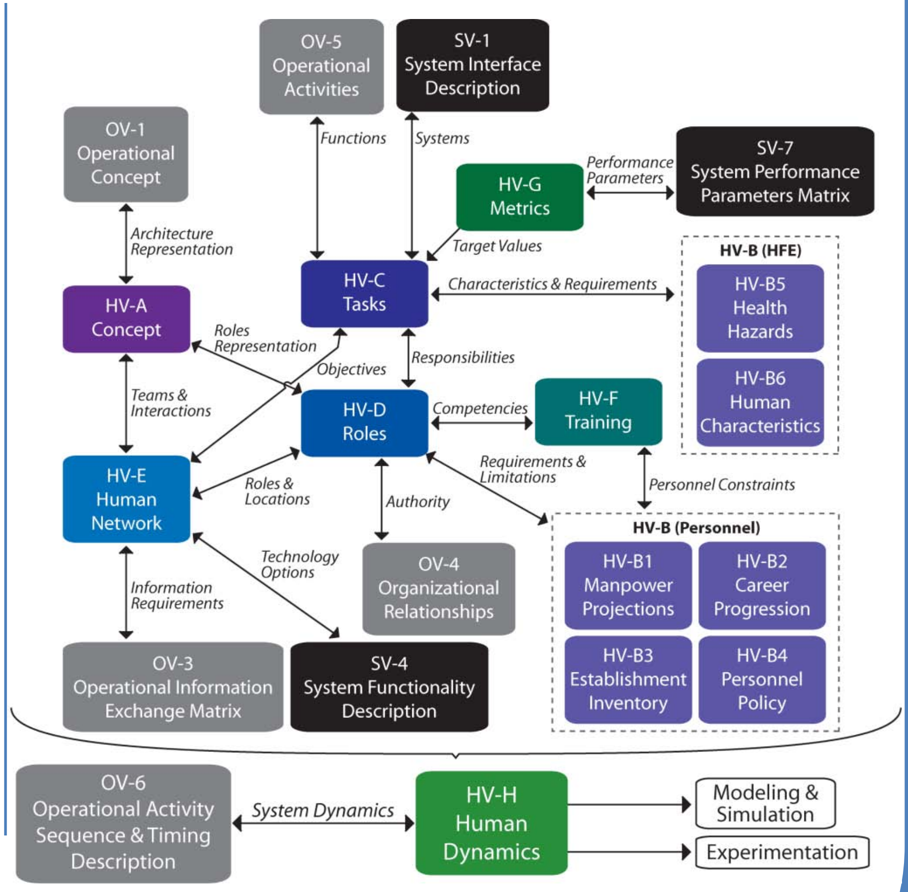
Description

The HV-H captures dynamic aspects of human system components defined in other views. It pulls together definitions from across the Human View to be able to communicate enterprise behaviour. It provides inputs to human behaviour and executable models that may be supported by simulation tools.

Information Requirements

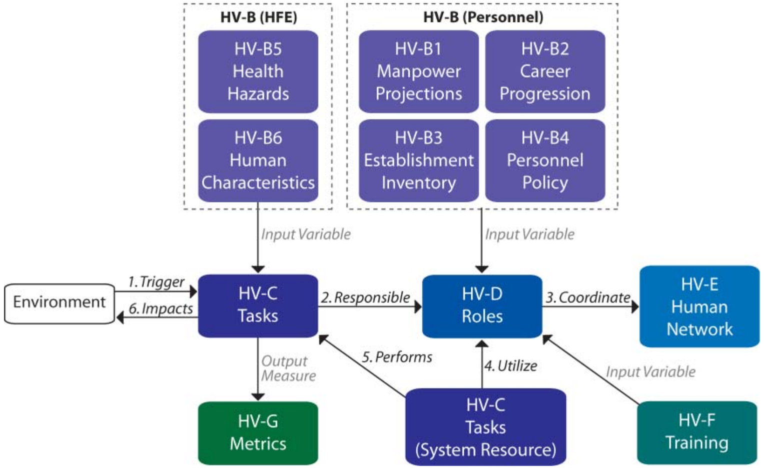
- Organisational/team structure
- Task/Role assignments to people
- Team interaction modes
- Demands on collaboration load (e.g. need to spend effort in building shared awareness, consensus-finding, communicating)
- Task switches/interruptions
- Critical / frequent / representative / typical scenarios
- Operational constraints (e.g. extensive heat stress)
- Time conditions: sequence, duration, concurrency
- Workload
- Decision speed
- Team interaction/collaboration style
- Trust in commanders intent

Data Relationships



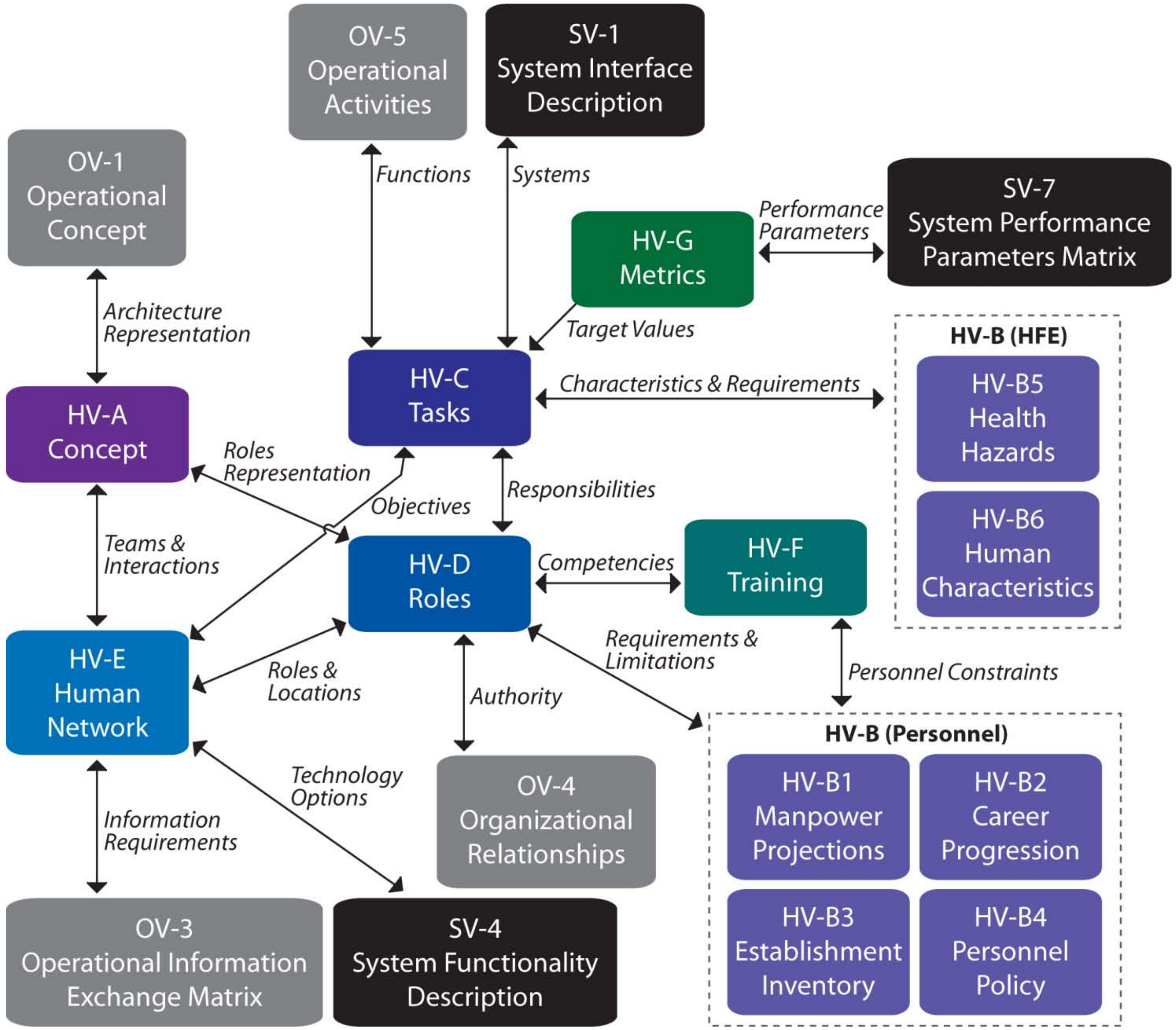
Human Dynamics

Process Model



Information Captured in Human View		Data Required by Simulation Model
HV-A Concept	A high-level representation of the human component of the system.	Hypothesis to be tested by the model.
HV-B Human Factors Constraints	Operator capabilities and limitations under various conditions.	Selection of the Moderator settings of Personnel and Stressors.
HV-C Tasks	Task decomposition and interdependencies; systems available for task completion.	Generation of the Network Diagram composed of Tasks and Subtasks; Assignment of System Interfaces to Tasks.
HV-D Roles	List of roles and assigned task responsibilities.	Creation of Operator list; Assignment of Operators to Tasks.
HV-E Human Network	Role groupings or teams formed; interaction types between roles and teams.	Identification of Team Functions and Operator Teams.
HV-F Training	Training required to obtain necessary knowledge, skills, and abilities to perform assigned tasks.	Selection of the Moderator setting of Training.
HV-G Metrics	Performance parameters and standards.	Identification of Mission Level Time & Accuracy criterion and selection of Task Level Time & Accuracy standards.

Summary of DoDAF Product Relationships



Acronym List

CB	Chemical and Biological
DoDAF	Department of Defense Architectural Framework
HFE	Human Factors and Ergonomics
HV	Human View
KSAs	Knowledge, Skills, and Abilities
MODIS	Military Occupational Structure Identification
NATO	North Atlantic Treaty Organization
OV	Operational View
QSG	Quick Start Guide
RTO	Research & Technology Organization
SOPs	Standard Operating Procedures
SV	System View
WHIMS	Workplace Hazardous Materials Information System

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14. Abstract

This report describes and documents the Human View (HV) as a viable method for Human Systems Integration to identify and assess the human specific aspects of a total systems engineering approach (architecture framework) for system design and development. Modeling and simulation extends the HV to illustrate and capture the dynamic nature of human performance in a variable environment. Experimentation provides the data to populate HVs and the resultant models and, to validate the modeled simulation.

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