2012

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Original Publication Citation

Handley, H. A. H., & Tolk, A. (2012). A human view model for socio-technical interactions. *Selected Papers Presented at MODSIM World 2011 Conference and Expo*, October 11-14, Virginia Beach, VA., pp. 268-274.

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A Human View Model for Socio-Technical Interactions

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Abstract. The Human View was developed as an additional architectural viewpoint to focus on the human part of a system. The Human View can be used to collect and organize data in order to understand how human operators interact and impact the other elements of a system. This framework can also be used to develop a model to describe how humans interact with each other in network enabled systems. These socio-technical interactions form the foundation of the emerging area of Human Interoperability. Human Interoperability strives to understand the relationships required between human operators that impact collaboration across networked environments, including the effect of belonging to different organizations. By applying organizational relationship concepts from network theory to the Human View elements, and aligning these relationships with a model developed to identify layers of coalition interoperability, the conditions for different levels for Human Interoperability for network enabled systems can be identified. These requirements can then be captured in the Human View products to improve the overall network enabled system.

1.0 INTRODUCTION

Interoperability is the ability of systems to provide services to and accept services from other systems in order to enable them to operate effectively together [1]. Human Interoperability strives to understand the relationships between human operators that impact collaboration among individuals, teams and organizations across technology environments [2]. Human Interoperability is especially critical under conditions where partnerships and teams may need to be formed rapidly, where technological and organizational compatibilities can present constraints, or closely coupled team interactions have to be achieved across remote locations. By understanding and incorporating Human Interoperability requirements into system design, the resulting networked enabled system can more effectively support timely responses to events. Solutions must include process, organization, and people: “People are included as part of the definition of a system, but their role in that system is generally poorly specified, and the focus of the [system] engineering effort is on the technology components” [3].

The Human View architecture represents a methodology to collect and organize human system data for a network enabled system. It was developed to augment existing architectural frameworks with additional information relevant to the human system requirements in net-centric environments [4]. Additionally, research in the network analysis domain combined knowledge management, operations research and social network techniques to create a "Meta-Matrix." The Meta-Matrix characterizes relationships between the different organizational elements of people, knowledge, resources, tasks, and organizations [5]. By applying these elemental constructs to the Human View, the relationships between the Human View elements can be defined in terms of network organizational analysis. The network definitions from this combined framework can then be mapped to the Layers of Interoperability defined for network enabled systems [6]. This reference model extends traditional technical interoperability models to include organizational aspects important in for coalition interoperability. This methodology is shown in Figure 1.

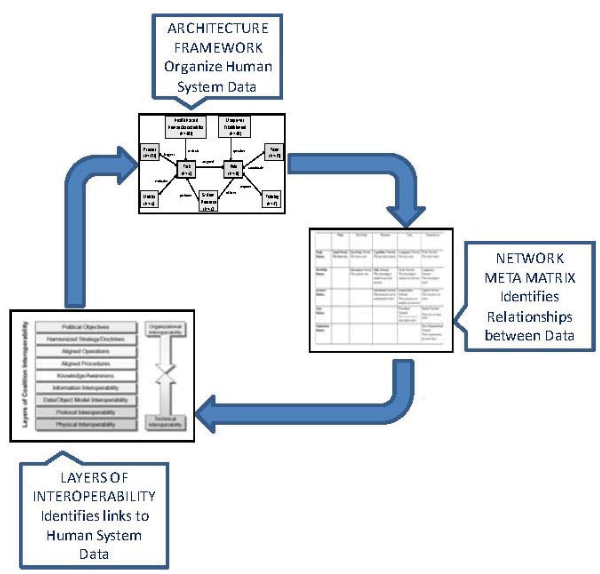

Figure 1. Research Methodology

The composite model resulting from the mapping of the Human View to the Meta-Matrix, and then the Layers of Interoperability can be used to define Human Interoperability goals for a system. The required data that supports these goals can be identified through the model and captured in the Human View products. This information can then be used to inform the system architecture of its strengths and weaknesses with regard to socio-technical design.

The next section will describe each of these models individually, and then explain the methodology used to create the composite model. An example of its use to map the goals for an interagency response to a crisis situation is described, as well as the resulting requirements for the Human View products. The conclusion reiterates the need to continue to define Human Interoperability goals for network enabled systems.

2.0 BACKGROUND

One of the goals driving the development of the original Human View was to create an integrated set of products that could be used to inform and influence system design, especially for network enabled systems. The Human View was designed to organize human information in order to provide a comprehensive representation of human capabilities [4]; the "products" that capture the human information are listed in Table 1. In addition, a representation of the relationships between the products was devised in order to provide a model of the data dependencies; see Figure 2. From this representation, a simulation model can be created to evaluate the impact of the human on the system performance, and to compare alternative human-system configurations [7]. The comprehensive Human View and accompanying simulation model provides an understanding of the human role in the system and supplies a basis for stakeholder decisions by linking the engineering community to the manpower, personnel, training, and human factors communities.

Table 1. Human View Architecture Products [4]

Human View Product	Description
HV-A Concept	High-level representation of the human component(s) in the system
HV-B Constraints	Repository for different classes of human limitations
HV-C Tasks	Describes the human-specific activities
HV-D Roles	The job functions defined for the humans interacting with the system
HV-E Human Network	The human-to-human communication patterns that occur in teams
HV-F Training	Accounting of training requirements, strategy, and implementation
HV-G Metrics	Repository for human-related values, priorities, and performance criteria
HV-H Dynamics	The feeder data and scheme for a simulation of humans in the system

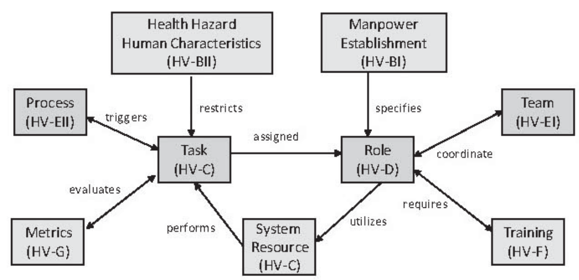

Figure 2. Human View Modeled Dependencies

Network theory has explored the relationships within organizations and had characterized organizational architectures in terms of three domain elements: individuals, tasks, and resources [8]. This was later expanded to include the elements of knowledge and organizations [5]; the resulting extended matrix depicts a set of ten network relationships that connect these elements, as shown in Table 2. This "Meta-Matrix" provides a characterization of the possible networks among the organizational elements using relational primitives and formalizes the dependencies among organizational elements [5]. By applying this matrix to the Human View framework, the Meta-Matrix can provide a way to represent the human system data relationships based on network theory.

Table 2. Extended Meta-Matrix from Network Theory [5]

	People	Knowledge	Resources	Tasks	Organizations
People Relation	Social Network: Who knows who (1)	Knowledge Network: Who knows what (2)	Capabilities Network: Who has what resource (3)	Assignment Network: Who does what (4)	Work Network: Who works where (5)
Knowledge Relation		Information Network: What informs what (6)	Skills Network: What knowledge is needed to use what resource (7)	Needs Network: What knowledge is needed to do what task (8)	Competency Network: What knowledge is where (9)
Resources Relation			Substitution Network: What resources can be substituted for which (10)	Requirements Network: What resources are needed to do what task (11)	Capital Network: What resources are where (12)
Tasks Relation				Precedence Network: Which tasks must be done before which (13)	Market Network: What tasks are done where (14)
Organizations Relation					Inter Organizational Network: Which organizations link with which (15)

Interoperability is often viewed as a problem to be solved through technological solutions. However, true interoperability is achieved through a combination of non-material solutions (organization, process, and people), as well as through technology (data, information, and systems). A model was developed to address the interoperability issues raised with the transition of coalitions to networked enabled systems [6]. Networked enabled systems must focus not only on technology concerns, but also people and process components as well, especially systems that cross organizational boundaries. The reference model of Layers of Interoperability, shown in Figure 3, depicts the interplay of technical and organizational interoperability within a networked enabled environment. The lower levels of the model address layers of technical interoperability, such as the ability to collect and distribute data and information, while the top levels focus more on the non-material requirements, i.e., the organizational interoperability layers dealing with the harmonization and coordination of related operations [6]. This representation of the Layers of Interoperability can be mapped to the Meta-Matrix through the network definitions. This mapping can then be used to identify the Human Interoperability goals of the network enabled system.

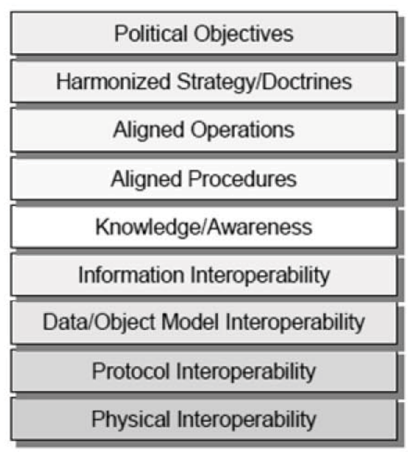

Figure 3. Layers of Interoperability [6]

3.0 METHODLOGY

The Meta-Matrix relationships are numbered one through fifteen as shown in Table 2; these numbers were used to identify the people, knowledge, resource, tools, and organization relationships in the Human View, depicted in Figure 2. The first step was to align the Human View entities with the Meta Matrix entities. This was based on the definition of the Human View products, and the result is shown in Table 3. Through the mapping process, several of the Human View entities shown in Figure 2 were "pruned", as these were not relevant to the current mapping; this included the HV-B Constraints and HV-G Metrics elements. The second step was to align the Meta-Matrix relationships with the Human View dependencies; this resulted in the Human View network as shown in Figure 4. In this figure the Human View entity names have been replaced with the Meta Matrix entities, and the dependencies labeled with the network numbers. Additionally, the HV-EI Process has been folded back into the HV-C Task; and indicated with a "self loop" on the Task entity (#13). While this figure validates the mapping of the Human View to Meta-Matrix, the table form of the mapping, similar to Table 2, will be used for the aggregate model.

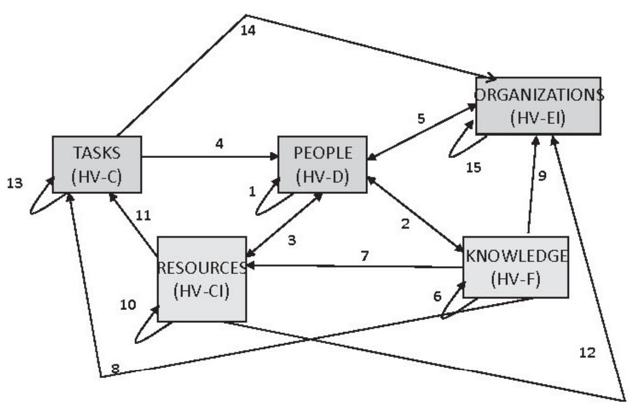

Figure 4. Mapping of Meta Network to Human View Relationships

The next step was to map the five network entities to the Layers of Interoperability model shown in Figure 3. This was done by evaluating the description of each interoperability layer and performing a best match to the entity, as shown in Table 4. This match was then used to identify each of the Layers of Interoperability within the Meta-Matrix. The mapping was limited to the top five layers of the model, which represent the non-materiel interoperability solution.

Table 3. Entity Mapping from Human View to Meta Network

Human View Entity	Meta Matrix Entity
Role (HV-D)	People
Training (HV-F)	Knowledge
System Resource (HV-CI)	Resource
Task (HV-C)	Task
Team (HV-EI)	Organization

Table 4. Layers of Interoperability Description and Entity Assignment

Layer of Interoperability	Description	Meta Matrix Entities
Political Objectives	Do the partners share the same political values?	Organization
Harmonized Strategy	Are the social and cultural backgrounds of the partners aligned?	People
Aligned Operations	Are the decision makers aware of the processes of the partners?	Tasks
Aligned Procedures	Are the tactical requirements supported by knowledge systems?	Resources
Knowledge/ Awareness	Are various views on the operation supported?	Knowledge

The result of the composite mapping of the Human View to the Meta Matrix to the Layers of interoperability is shown in Figure 5. The rows represent the organizational elements of the Meta-Matrix with the network relationships labeled in each cell. The columns represent the Human View product that will capture the data to support the relationships identified in each column. The Layers of Interoperability are labeled within the cells, in addition to the network relationships, that support that layer. While there is a one-to-one mapping of the Layer of Interoperability to the organizational entities in the cells along the diagonal, adjacent cells also contribute information to that layer as shown. This composite model will be used in the next section to illustrate how it can drive the Human View requirements in order to meet Human Interoperability goals.

	Role (HV-C)	Training (HV-F)	System (HV-CI)	Tasks (HV-C)	Team (HV-EI)
People Networks	1 (Social Network) HARMONIZED STRATEGY (HS)	2 (Knowledge Network) KA & HS	3 (Capabilities Network) AP & HS	4 (Assignment Network) AO & HS	5 (Work Network) PO & HS
Knowledge Networks		6 (Information Network) KNOWLEDGE AWARENESS (KA)	7 (Skills Network) AP & KA	8 (Needs Network) AO & KA	9 (Competency Network) PO & KA
Resources Networks			10 (Substitution Network) ALIGNED PROCEDURES (AP)	11 (Requirements Network) AO & AP	12 (Capital Network) PO & AP
Tasks Networks				13 (Precedence Network) ALIGNED OPERATIONS (AO)	14 (Market Network) PO & AO
Organization Networks					15 (Inter-Organizational Network) POLITICAL OBJECTIVES (PO)

Figure 5. Composite Mapping of the Models

4.0 INTERAGENCY EXAMPLE

An interagency response to a crisis situation is an example where increased levels of Human Interoperability, as indicated by the top five Layers of Interoperability shown on Figure 3, can increase the effectiveness of the interagency response. Emergency situations, such as a natural disaster or other crisis situation beyond the scope of local emergency resources, activate the use of an Incident Center (IC) that mobilizes to provide assistance during the event. "Incidents typically include two or more organizations or sub-organizations, each with its own command structure, that respond to the crisis as one unified IC center" [9]. In some cases the interagency response enacted is defined as a Defense Support to Civil Authority (DSCA), indicating military commands are available to provide key support and resources to civilian authorities [10]. The main response phases are described in [9]; however the goals of each phase have been summarized in Table 5. Based on the goal description, it can be mapped to represent a Meta-Matrix relationship, and therefore support one or several interoperability layers, as shown in the second and third columns of the table.

Table 5. Interagency Response Goals aligned with Meta Network and Interoperability

Interagency Response Goals	Meta Matrix	Interoperability Layer
Pre event Planning & Monitoring	*Organization & Knowledge Entities*	*Understand the willingness and abilities of different organizations.*
A. Set up a partnership between organizations	Which organizations link with which? (15)	Political Objectives
B. Agree on tasking for situational contingencies	What tasks are done where? (14)	Political Objectives; Aligned Operations
C. Agree on business practices for information sharing	What knowledge is needed to do what task? (8)	Aligned Operations
D. Train staff on procedures from different organizational personnel	Who works where? (5)	Political Objectives Harmonized Strategy
E. Share and synthesize information to identify triggering event	What knowledge is where? (9)	Political Objectives;
Trigger and Progress on Crisis Tasks	*Resource & People Entities*	*Guidance regarding roles, pooling resources, and sharing information.*
F. Broaden communication network	What resources are where? (12)	Aligned Operations
G. Establish two-way correspondence between field respondents	Who knows who? (1)	Harmonized Strategy
H. Ability to share field reports and data	Who knows what? (2)	Harmonized Strategy
I. Alert other agencies of the situation progress	Who does what? (4)	Aligned Operations; Harmonized Strategy
J. Re-task resources as necessary	Who has what Resource? (3)	Harmonized Strategy
Conclusion of Crisis Tasking	*Task Entity*	*Complete tasking with depleted resources.*
K. Conclude tasking associated with resolving the situation	Which tasks must be done before which? (13)	Aligned Operations

Table 6. Human View Product Requirements base on Interoperability Goals

Human View Product	*Role (HV-D):* **Harmonized Strategy (HS)**	*Training (HV-F):* **Knowledge Awareness (KA)**	*System (HV-CI):* **Aligned Procedures (AP)**	*Tasks (HV-C):* **Aligned Operations (AO)**	*Team (HV-EI):* **Political Objectives (PO)**
People Networks	G. Establish Two-way Comms (1) **HS**	H. Ability to Share Field Data (2) **KA & HS**	J. Re-task Resources (3) **AP & HS**	I. Alert other Agencies (4) **AO & HS**	D. Train Different Staff (5) **PO & HS**
Knowledge Networks		*Information Network (6)* ***KA***	*Skills Network (7)* ***AP & KA***	C. Agree on Practices (8) **AO & KA**	E. Share Information (9) **PO & KA**
Resources Networks			*Substitution Network (10)* ***AP***	*Requirements Network (11)* **AO & AP**	F. Broaden Communications (12) **PO & AP**
Tasks Networks				K. Conclude Tasking (13) **AO**	B. Agree on Tasking (14) **PO & AO**
Organization Networks					A. Set up Partnership (15) **PO**
Product Completed	**HV-D: "Human Roles Matrix for DSCA Events"**.	**HV-F: "Information Flow for DSCA Events"**	*No Product Completed*	**HV-C: "Task to Role Assignment Matrix for DSCA Events"**	**HV-E: "Team Interaction Matrix for DSCA Events"**
Product Description	*Identification of people, roles, and contact information to facilitate communication* .	*Information on access and flow of information to facilitate situation awareness.*	*N/A*	*Assignment of tasks, and descriptions of processes to facilitate understanding of procedures.*	*Command and control structure of contributing organizations to facilitate team interactions.*

These goals can then be mapped to the composite model to determine the requirements of the Human View products. The Human View products can be either created, or evaluated if they already exist, to determine the necessary data that should be captured in each product to support the Human Interoperability conditions. As shown in Table 6, the mapping of the interagency response goals to the composite model helped define the requirements for each of the Human View products created. The Human View products completed for the DSCA response, as indicated in the row labeled "Product Completed" can be viewed in [9]; the content of each product is described in the "Product Description" row of Table 6.

5.0 CONCLUSION

The Human View was developed as an additional architectural viewpoint to focus on the human part of a system. The Human View can be used to collect and organize social parameters in order to understand the way that humans interact with other elements of the system. The framework can also be used to develop a model of socio-technical interactions and applied to the emerging area of Human Interoperability. Human interoperability strives to improve collaboration among diverse people and teams. Understanding and incorporating human interoperability into system design can assist in the integration and interaction among human operators, improving congruent behaviors for collaborative tasks.

By mapping a matrix of network relationships to the Human View elements and aligning these with a model of coalition interoperability layers, the conditions for different levels for Human Interoperability for network enabled systems can be assessed. An example has shown how, from this mapping, the design variables affecting Human Interoperability can be identified and captured in the Human View products and used to improve network enabled system design. By including Human Interoperability requirements, systems can be designed that facilitate sharing and collaboration through technological environments across teams and organizations.

ACKNOWLEDGEMENTS

The authors would like to thank Nancy Heacox and Chiesha Stevens for sharing information about the DSCA Human View products completed for the Trident Warrior 2006 experiment.

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