

Improving System Design by Mapping a Human-Factors Integration (HFI) Ontology to a Model-Based Enterprise Architecture (MBEA) Metamodel

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Abstract

This paper builds on the author's previous work regarding domain-specific ontologies (DSO) and its importance in the human-factors integration (HFI) space. Explicit term definitions captured by a DSO allow the HFI vocabulary to be mapped into a model-based enterprise architecture (MBEA). Integrating this terminology into the overall MBEA provides insight into the role that individuals play by considering personnel as a critical system component. Often considered external actors, human resources are typically not accounted for in the original solution design. However, MBEA promises to reverse this trend by implementing the Unified Architecture Framework (UAF). The UAF is composed of various domains and their aspects and is meant to graphically illustrate enterprise concepts such as strategy, operations, resources, personnel, and services in a digital environment. Capturing HFI information in a model improves the traceability of person(s) and organizational concerns, responsibilities, and competencies to highlight gaps that must be addressed. The incorporation of the HFI DSO into an MBEA enhances communication between disciplines and provides transparency for stakeholders. This research demonstrates the feasibility of constructing a DSO based on an HFI body of knowledge; leveraging the Web Ontology Language (OWL), the subject-predicate-object (SPO) approach, and the Protégé ontology editor. It also shows that by importing the OWL file into a concept model, understanding HFI terms facilitates MBEA while maintaining personnel as a critical part of a successful organization. This research identifies areas for improvement of the UAF domain-specific modeling language (DSML) to ensure that it adequately addresses HFI concerns by mapping like-terms.

Keywords: Human-factors integration, Human-systems integration, Systems engineering, Ontology, Enterprise architecture, Metamodel

INTRODUCTION

Although systems engineering (SE) and human-factors integration (HFI) depend on each other, their respective approaches are not immediately compatible (Bruseberg, 2008). The main focus of the enterprise architecture (EA) Human View (HV) is to capture human data and information about the interactions both between humans and with other system elements. The Unified Architecture Framework (UAF) *Personnel* viewpoint replaces select U.S Department of Defense (DoD) Architecture Framework (DoDAF)

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Operational Views (OV) and System Views (SV) intending to identify characteristics of human resources (e.g., organizations, persons, posts) that are necessary to participate in the operational architecture (Martin & O’Neil, 2021).

Research Background

The SE discipline utilizes frameworks to provide insights into the current and future states of systems which incorporate human-factors integration (HFI) aspects (Bruseberg, 2008)¹. Model-based systems engineering (MBSE) introduces the value of model-based enterprise architecture (MBEA) and its contribution to the state-of-the-art techniques for ensuring traceability between organizational domains. The UAF v1.3, published by the Object Management Group (OMG), is the exemplar methodology examined in this paper. The purported UAF “grid” represents a common set of stakeholder viewpoints (rows) and relevant aspects (columns) as shown in Figure 1.

	Motivation Mv	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Sequences Sq	Information If	Traceability Tr
Strategic St	St-Mv	St-Tx	St-Sr	St-Cn	St-Pr	St-St	-	St-If	St-Tr
Operational Op	Rq-Mv	Op-Tx	Op-Sr	Op-Cn	Op-Pr	Op-St	Op-Sq	Op-If	Op-Tr
Services Sv		Sv-Tx	Sv-Sr	Sv-Cn	Sv-Pr	Sv-St	Sv-Sq	Rs-If	Sv-Tr
Personnel Ps		Ps-Tx	Ps-Sr	Ps-Cn	Ps-Pr	Ps-St	Ps-Sq		Ps-Tr
Resources Rs		Rs-Tx	Rs-Sr	Rs-Cn	Rs-Pr	Rs-St	Rs-Sq		Rs-Tr
Security Sc	Sc-Mv	Sc-Tx	Sc-Sr	Sc-Cn	Sc-Pr	-			Pj-Tr
Projects Pj	Pj-Mv	Pj-Tx	Pj-Sr	Pj-Cn	Pj-Pr	-			Pj-Tr
Standards Sd	-	Sd-Tx	Sd-Sr	-					Sd-Tr

Figure 1: Rendering of the UAF grid (Object Management Group, 2025).

The UAF Personnel (Ps) viewpoint is derived from the U.K Ministry of Defense (MoD) Architecture Framework (MoDAF) with influence from the DoDAF and North Atlantic Treaty Organization (NATO) Architecture Framework (NAF) (Object Management Group, 2025). The MoDAF HVs are meant to enable communication in the acquisition process (Bruseberg, 2008). Similarly, the focus of the NAF HVs is to capture human data and information about the interactions amongst humans and their exchanges with other system elements (Handley & Houston, 2010). Table 1 shows prominent deliverables associated with traditional MBEA HVs.

¹Human-factors integration (HFI) is the U.K equivalent to the U.S term human-systems integration (HSI).

Table 1: Enterprise architecture HVs.

View	Focus	Description
HV-A	Concept	A high-level representation of the human component in the enterprise architecture
HV-B	Constraint	Characteristics that are used to adjust the expected roles and tasks based on human capabilities
HV-C	Task	Descriptions of the human-specific activities in the system
HV-D	Role	Defines human interaction with other elements of the system
HV-E	Human Network	Communication patterns that occur as a result of ad hoc or deliberate team formation
HV-F	Training	Accounts for how training requirements, strategy, and implementation will impact the human
HV-G	Metric	A repository for human-related values, priorities and performance criteria
HV-H	Human Dynamics	Dynamic aspects of human system components defined in other views

When evaluating respective elements that are provided by the UAF Modeling Language (UAFML), the genesis of terms is not immediately clear. Table 2 describes the five (5) concrete classes within the UAF Ps domain.

Table 2: UAF Personnel classes.

UAF Term	Description
Competence	A specific set of abilities defined by knowledge, skills and aptitude
Organization	A group of Persons, Posts, Organizations and/or Responsibilities that are associated for a particular purpose
Person	A type of a human being used to define characteristics (e.g., properties such as address, telephone number, nationality, etc.)
Post	A type of job title or position that a person can fill (e.g., Lawyer, Solution Architect, Machine Operator or Chief Executive Officer)
Responsibility	The type of duty required of a Person or Organization

Further investigation into the origin of UAF concepts regarding human resources and their importance within an MBEA is warranted to properly bridge the gap between the SE and HFI domains.

Research Objective

This research aims to improve current MBEA frameworks with respect to HFI aspects by aligning a DSO to the UAF metamodel. By constructing an HFI ontology based on established HVs and mapping the classes to the UAF metamodel elements, potential gaps are identified in the implementation of the UAF Ps viewpoint.

Metamodeling

Metamodeling is a widely applied technique in the construction of domain-specific modeling languages (DSML) to constrain the semantics of all instantiations (Sprinkle et al., 2007). They are models that consist of statements about models (Jeusfeld et al., 2009). that are used to describe the concepts of a DSML, the relationships between abstractions, and the rules that constrain model elements (Bertoa & Vallecillo, 2010). Figure 2 represents the relationship between metamodels, models, and occurrences.

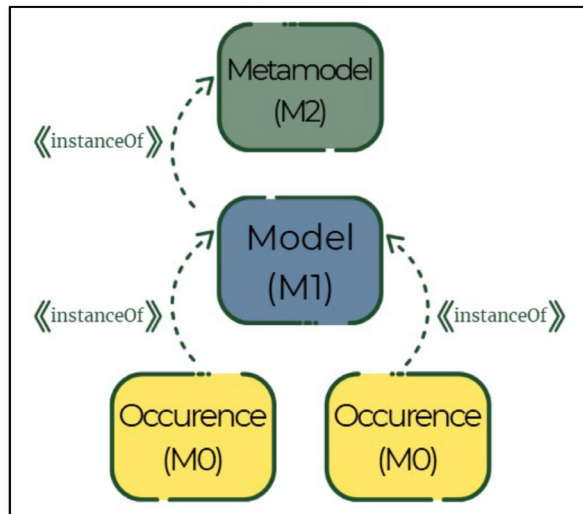


Figure 2: Model layers of abstraction.

Research Approach

An ontology of the HFI HVs in Table 1 is constructed within the open-source ontology editor, Protégé, to highlight equivalencies and relationships of the fundamental terminology. Figure 3 shows the basic metrics of the HFI DSO within Protégé where classes are the nouns, object properties represent the relationships between them, and axioms are predicate triples.

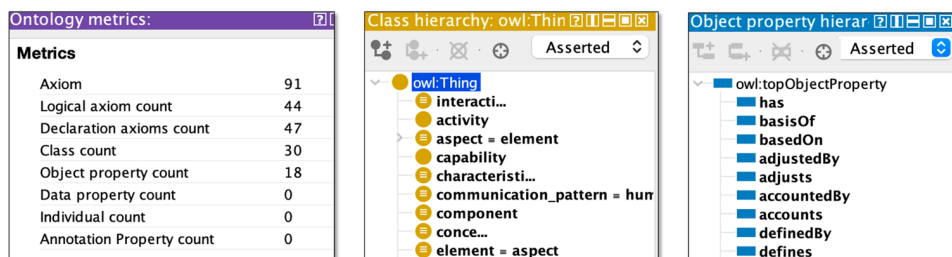


Figure 3: HFI DSO basic metrics.

The “Ontology metrics” show simple counts of core ontological elements; the “Class hierarchy” shows a subset of subjects and objects; and the “Object property hierarchy” shows a select few predicates within the Protégé OWL file. After the thirty (30) classes are imported into a CCM, refinement of the taxonomy is conducted. Figure 4 shows the HFI DSO class taxonomy results.

#	△ NAF HV Class	Superclass
1	activity	
2	aspect	⊗ characteristic
3	characteristic	
4	communication_pattern	
5	component	⊗ system_element
6	concept	⊗ representation
7	constraint	⊗ characteristic
8	description	
9	enterprise_architecture	
10	human	
11	human_capability	
12	human_dynamics	⊗ aspect
13	human_network	⊗ team_formation
14	implementation	
15	interaction	
16	metrics	⊗ repository
17	performance_criteria	⊗ metrics
18	priority	⊗ characteristic
19	repository	
20	representation	⊗ view
21	requirement	
22	role	
23	strategy	
24	system	
25	system_element	⊗ system
26	task	⊗ activity
27	team_formation	
28	training	⊗ strategy
29	value	
30	view	

Figure 4: Representation of HFI DSO class taxonomy within a CCM.

This representation adheres to the ontological concept of “is a” relationships. For example, an “HV Class” “representation” is a type of “view”. The UAFML metamodel is constructed within a Cameo Concept Model (CCM) using Dassault Systemés CATIA Magic software. CCMs enable the mapping between ontologies and the metamodels of DSMLs. Metamodel principles are founded on OWL, but are focused on the semantics and syntax of a specific modeling language instead of a comprehensive body of knowledge. Figure 5 shows a concept modeling diagram that exemplifies the “Equivalent Classes” between the imported HFI ontology and the five (5) UAFML metamodel Ps classes identified in Table 2.

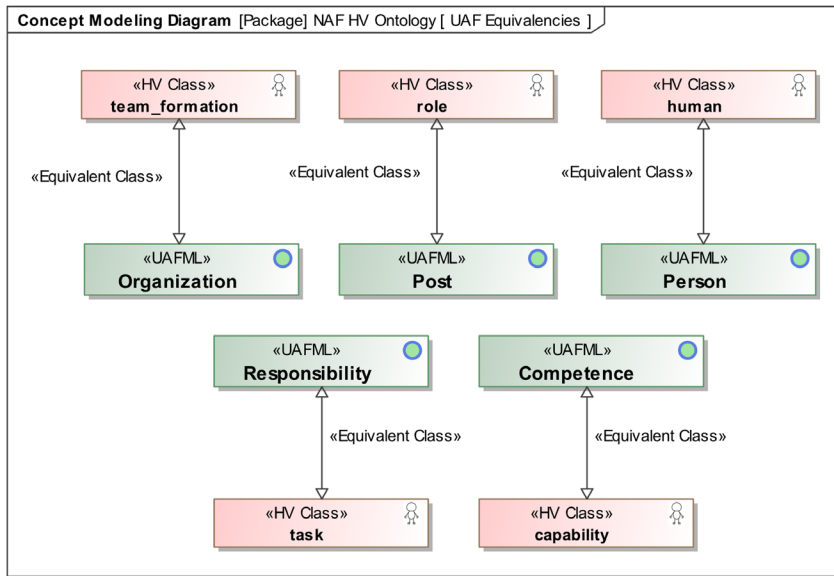


Figure 5: UAFML equivalent classes to HV concepts.

As an example, the viewer understands that the “HV Class” “human” is an “Equivalent Class” of the “UAFML” term “Person”.

Research Results

Figure 6 shows the HFI classes taxonomy and equivalent UAF terms as defined within a concept model.

#	△ NAF HV Class	Superclass	UAF Equivalent
1	activity		FunctionAction
2	aspect	characteristic	
3	characteristic		Information
4	communication_pattern		Command
5	component	system_element	
6	concept	representation	HighLevelOperationalC oncept
7	constraint	characteristic	ResourceConstraint
8	description		Definition
9	enterprise_architecture		ArchitecturalDescription
10	human		Person
11	human_capability		Competence
12	human_dynamics	aspect	
13	human_network	team_formation	
14	implementation		WholeLifeConfiguration
15	interaction		ResourceExchange
16	metrics	repository	Measurement
17	performance_criteria	metrics	
18	priority	characteristic	
19	repository		
20	representation	view	
21	requirement		Capability
22	role		Post
23	strategy		EnterpriseVision
24	system		System
25	system_element	system	
26	task	activity	Responsibility
27	team_formation		Organization
28	training	strategy	
29	value		ValueItem
30	view		View

Figure 6: Recommended HFI and UAFML mappings.

Discussion of Results

The integration of HVs into the UAF exemplifies the importance of a cross-domain approach to enterprise architecture. Almost all classes within the HV metamodel are equivalent to a MBEA DSML term; however, they span several viewpoints as shown in Table 3.

Table 3: Domains of equivalent UAF terms.

UAF Term	UAF Domain
ArchitecturalDescription	Summary & Overview
Capability	Strategic
Command	Personnel
Competence	Personnel
Definition	Architecture Management
EnterpriseVision	Strategic
FunctionAction	Resources
HighLevelOperationalConcept	Operational
Measurement	Architecture Management
Organization	Personnel
Person	Personnel
Post	Personnel
ResourceConstraint	Resources
ResourceExchange	Resources
Responsibility	Personnel
System	Resources
ValueItem	Strategic
View	Summary & Overview
WholeLifeConfiguration	Strategic

CONCLUSION

Constructing an initial HFI DSO iteration was completed by extracting key terms from traditional deliverables to leverage a SPO approach. Like-terms are then mapped to the UAF metamodel to highlight gaps and areas for improvement within the modernized MBEA method. Based on the results, the sole “repository” class is not captured by the UAF DSML. This research demonstrates the feasibility of HFI integration with the SE discipline using the UAF as a case study. Future work will include additional DSO iterations and subsequent mappings between DSMLs that intend to capture HFI information.

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