Human-Centered Design in Systems Engineering: Human View Methodology

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Objective and Approach

- Examine dynamic aspects of Human View as an effective methodology for Human Systems Integration (HSI) practitioners coordinating and collaborating with systems engineers.
- Use data from system development effort to build Human Views.
- Use modeling and simulation to analyze dynamic operator elements of the system to augment Human View process.

In Practice

- Design, development, and production of large complex systems requires the HSI practitioner to ensure that HSI results, e.g., the task analysis, are communicated in a language that the systems engineer understands.

- An architecture framework provides that communication medium.

Architecture Frameworks

- Defines common approach for development, presentation, and integration of architecture descriptions.
- Architecture frameworks are used by systems engineers to provide a common set of products and product descriptions for representing systems.
- Current frameworks fail to capture the human-centered design aspects needed to ensure the effectiveness of human operated systems, such as users requirements, capabilities and limitations.

Department of Defense Architecture Framework (DODAF)

- DoDAF defines different views that breakdown a complex system into specific categories:
  - All View - Describes the Scope and Context (Vocabulary) of the Architecture
  - Operational View - Identifies What Needs to be Accomplished
  - Systems and Services View - Relates Systems, Services, and Characteristics to Operational Needs
  - Technical Views - Prescribes Standards and Conventions
- Each of the four views depicts certain architecture attributes -some attributes bridge two views and provide integrity, coherence, and consistency to architecture descriptions.
- However, none of these conventions focus explicitly on the human element - by adding a Human View to the architecture framework, an understanding of the human role in systems/enterprise architectures is included.

Emergence of the Human View

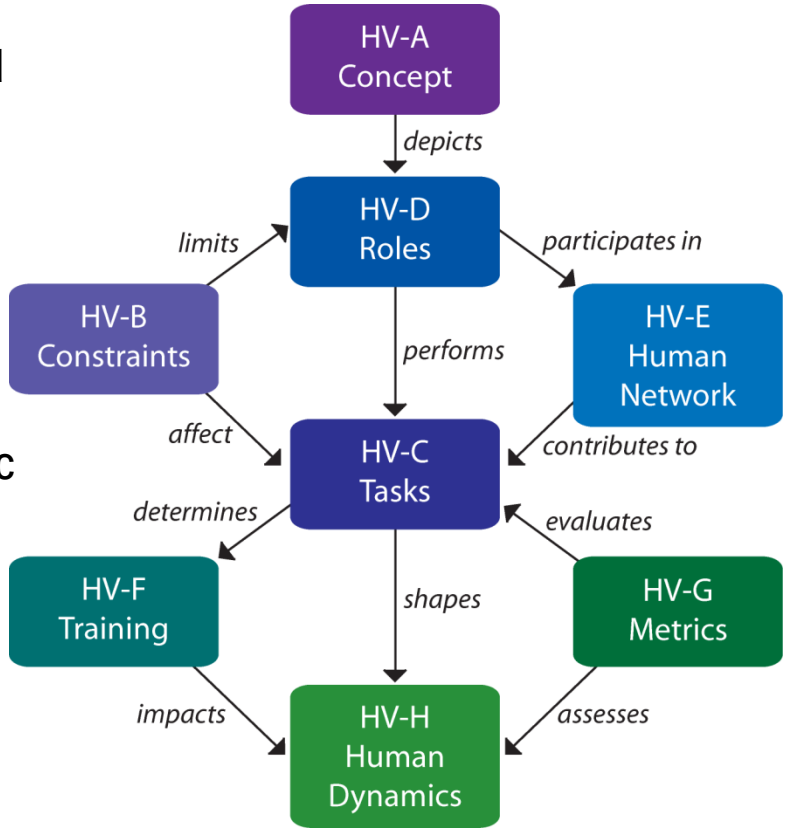
- Early efforts to represent humans in architecture products focused on human role and activities.
  - Hildebrand and Adams, 2002
  - Handley, 2006
- Additional analytical efforts in both Canada (DNDAF) and United Kingdom (MoDAF) have been concerned with how to include human activities in architecture framework.
  - Baker et al, 2006
  - Bruseberg, 2008
- Human View methodology provides HSI practitioner a mechanism to convey an understanding of human role in systems/enterprise architectures to systems engineers.

Human View

- Purpose is to organize information into a framework about how the human functions in the system in order to model the impacts of human performance from tasks, personnel, and system resources.
- Provides a set of products which captures information on *Capabilities, Constraints, Tasks, Roles, Networks, Training, and Metrics*, which are integrated with a dynamic model used to determine human risk.
- By using the Human View
  - It ensures that the human is fully considered in the architecture by structurally incorporating them into engineering planning.
  - It provides human-system parameters that can be used to minimize human risk with the overall system.

Human View Product Descriptions

- *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.



Example: HV-A

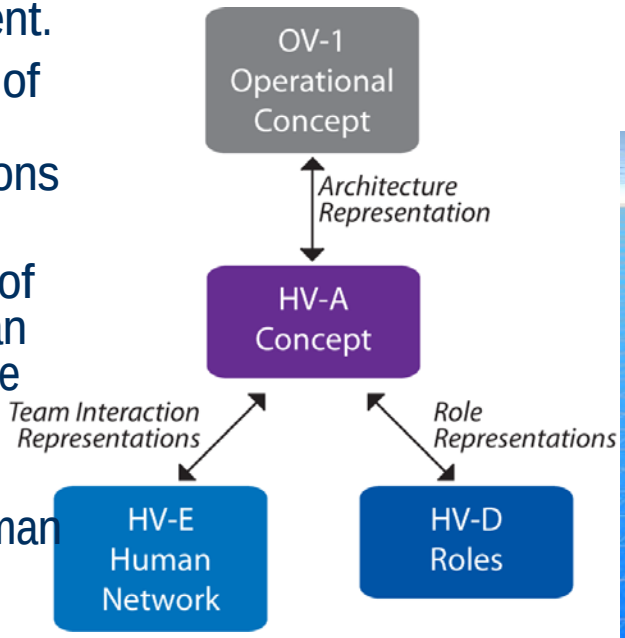
- HV-A is a conceptual, high-level representation of the human component of the enterprise architecture framework. Its purpose is to visualize and facilitate understanding of the human dimension in relation to operational demands and system components.

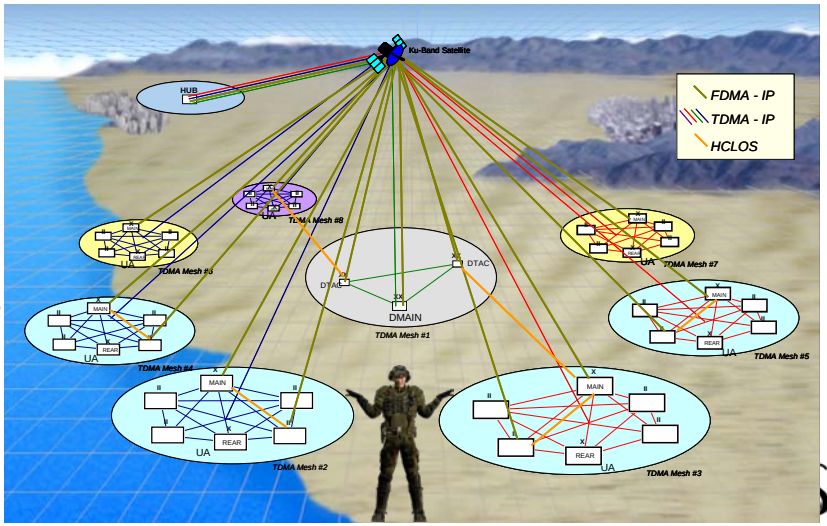
Pictorial depictions of the system and its human component.

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.





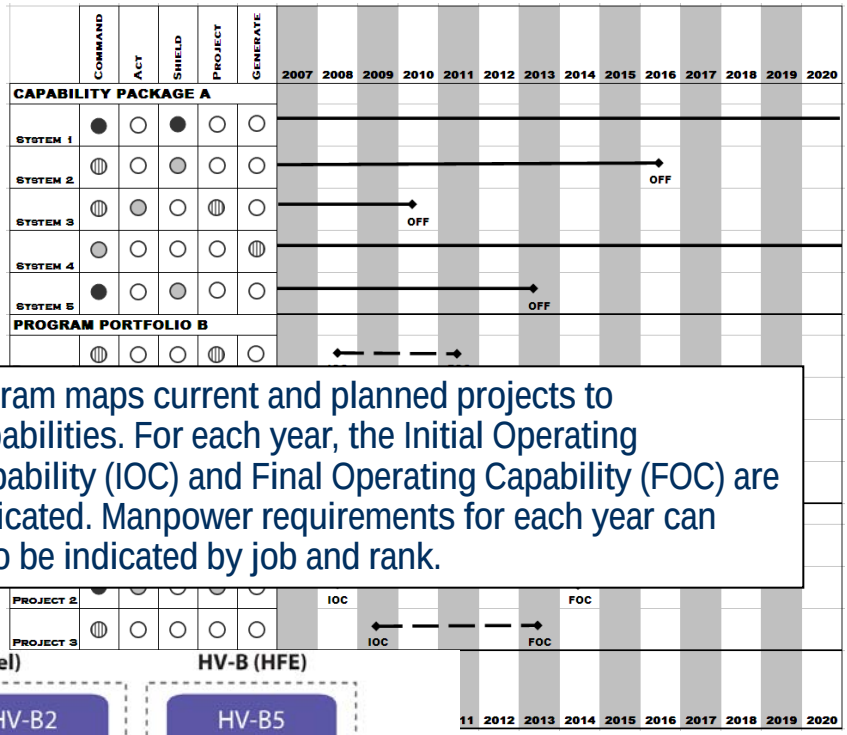
Example: HV-B

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

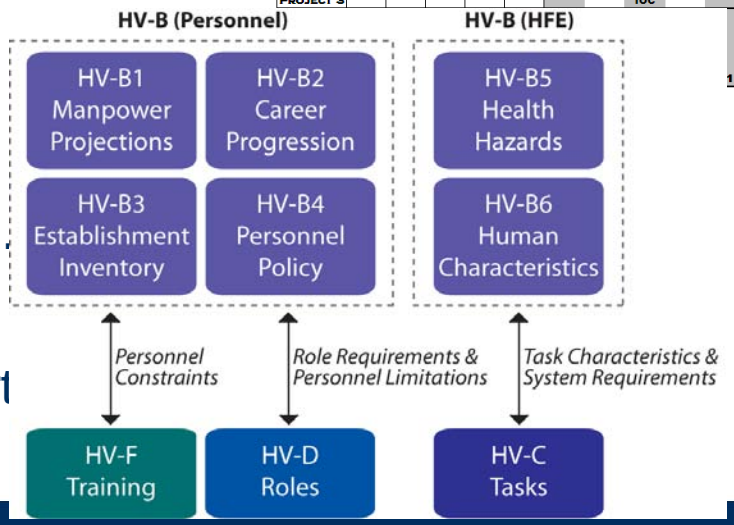
Manpower forecasting to allow initial adjustments in training, recruiting, professional development, assignment and personnel management.

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.



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.



Example: HV-E

- 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.

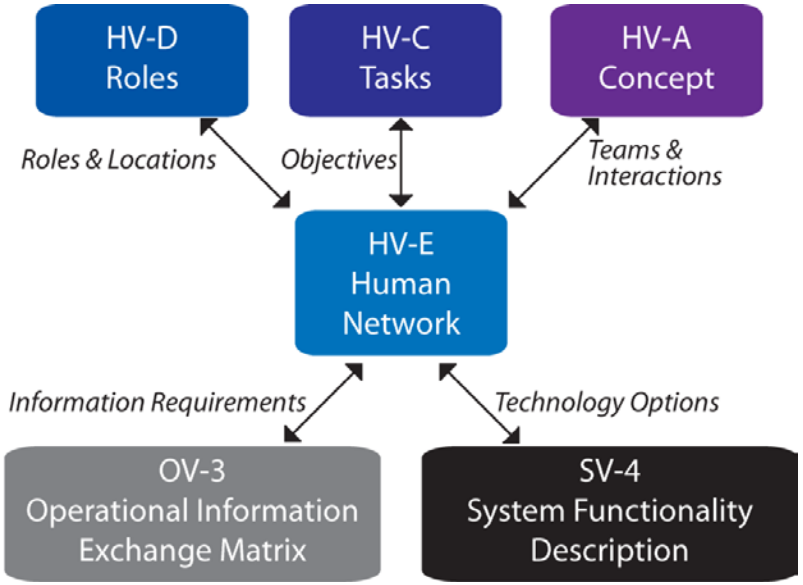
Role groupings or teams formed, including the physical proximity of the roles and virtual roles included for specific team tasks.

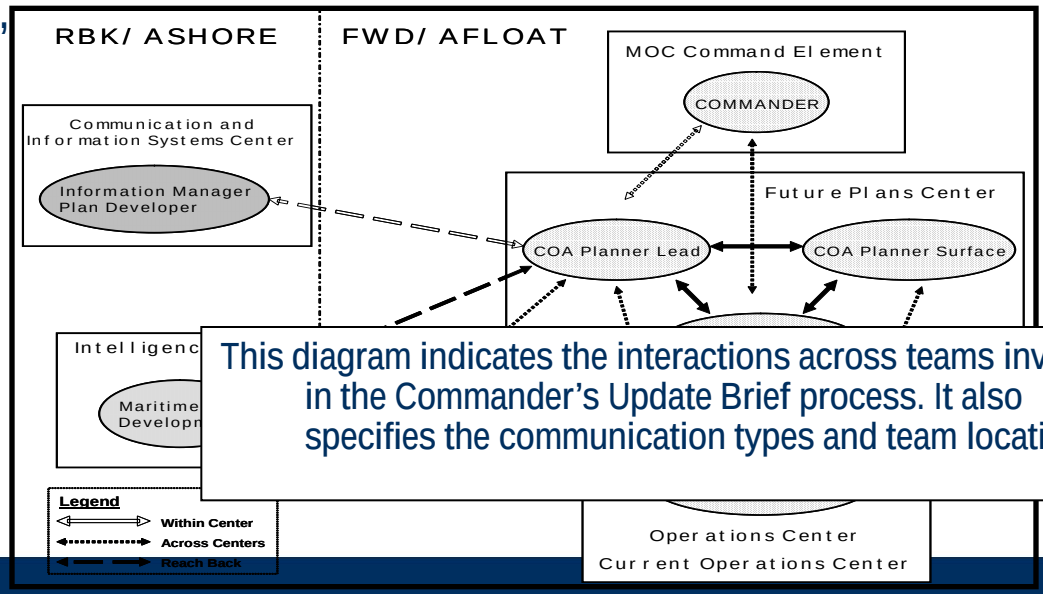
Type of interaction – i.e., collaborate, coordinate, supervise, etc.

Team cohesiveness indicators - i.e., trust, sharing, etc.

Team performance impacts - i.e., synchronization (battle rhythm), level of engagement (command directed).

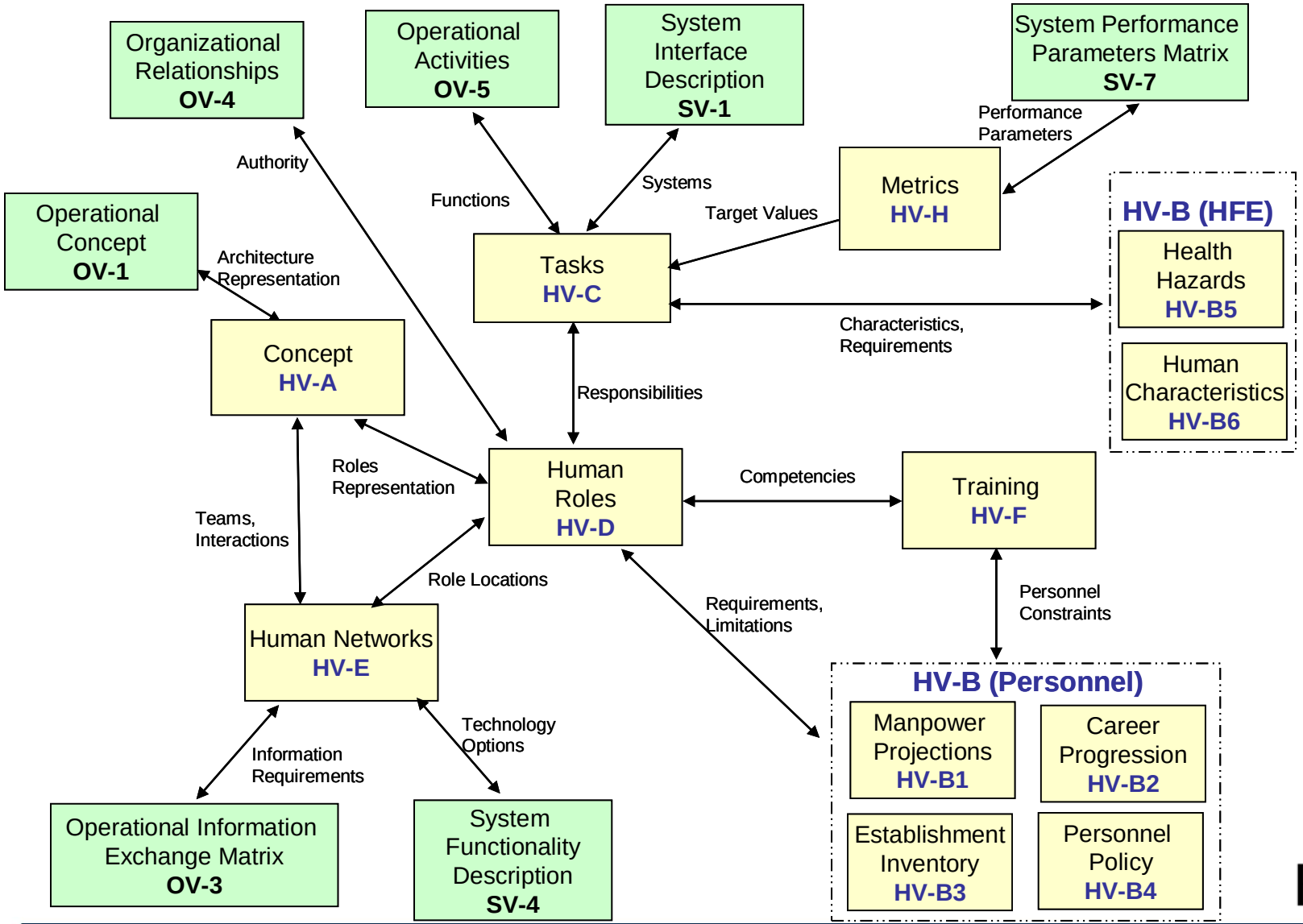
Team dependencies - i.e., frequency/degree of interaction between roles.





This diagram indicates the interactions across teams involved in the Commander's Update Brief process. It also specifies the communication types and team locations.

Human View Interaction with DoDAF



Human View Case Study

- Used Improved Performance Research Integration Tool (IMPRINT).
  - Stochastic task-network modelling tool to help assess interaction of people and system performance from concept and design through field-testing and system upgrades. (Mitchell et al, 2008)
  - Helps researchers and designers evaluate operator mental workload while testing alternate system-operator function allocations. (Wickens, 1991)
- Purpose of the dynamic Human View is to capture the interaction of the human system components.
  - An effective modeling and simulation tool can assess the static Human View data under dynamic situations and provide the system engineer designers with a robust set of HSI criteria.

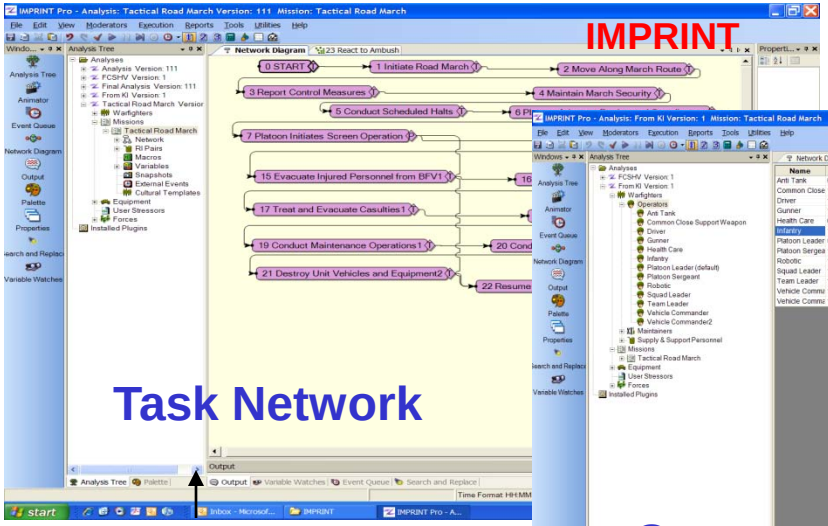
Dynamic Model Elements

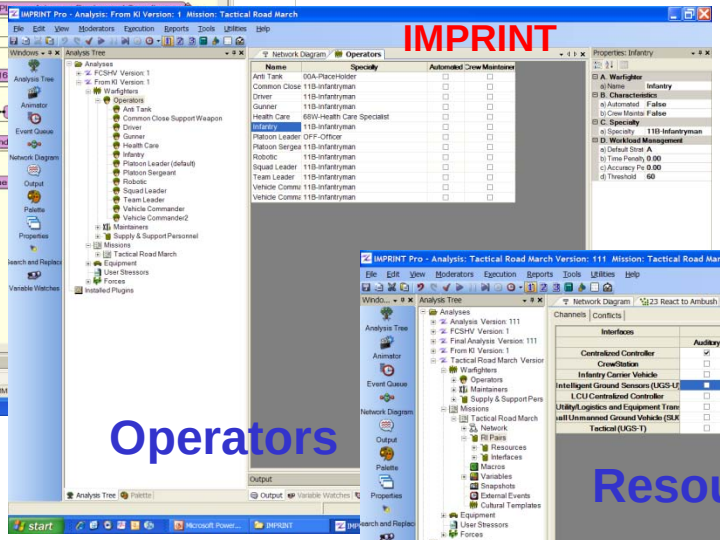
Human View Product	Data Required by Simulation Model
HV-A Concept	Hypothesis to be tested by the model.
HV-B Constraints	Selection of the Moderator settings of Personnel and Stressors.
HV-C Tasks	Generation of the Network Diagram composed of Tasks and Subtasks; Assignment of System Interfaces to Tasks.
HV-D Roles	Creation of Operator list; Assignment of Operators to Tasks.
HV-E Human Network	Identification of Team Functions and Operator Teams.
HV-F Training	Selection of the Moderator setting of Training.
HV-G Metrics	Identification of Mission Level Time & Accuracy criterion and selection of Task Level Time & Accuracy standards.

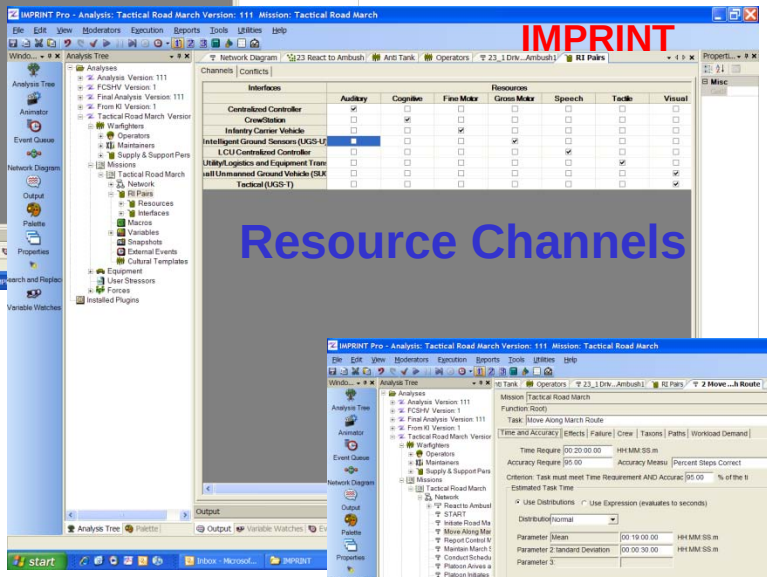
Method

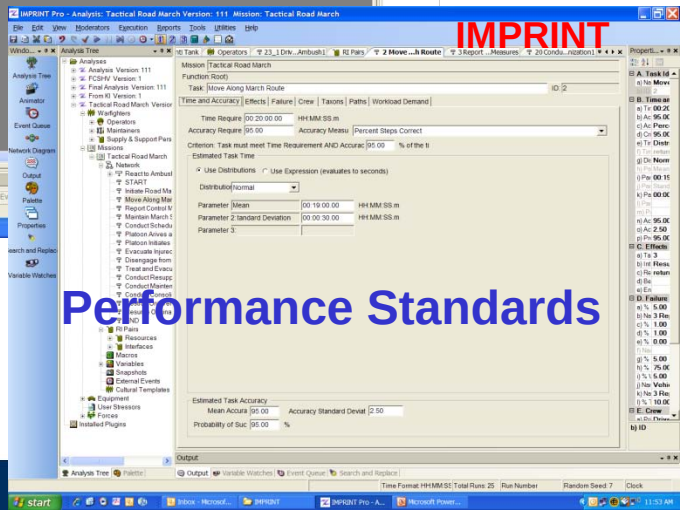
- Used U.S. Army's Future Combat System.
- Created experimental model in IMPRINT.
  - Operators were defined by the Human View roles.
  - Task descriptions were used to create a network diagram for a specified mission.
  - Task-role combination provided the operator assignments.
  - Performance standards/measures were used to define the expected task times, accuracy, and outcomes.
  - Constraints determine moderators that impact performance (e.g., heat, etc.).
  - IMPRINT outputs provide data that describe overall success/failure of the mission, task performance completion and potential errors, and operator workload.
- Results used to support systems engineering process to ensure human/operator requirements are met.

Dynamic Model Inputs









Interfaces (HV-E)

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;

Tasks (HV-C)

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	

Roles (HV-D)

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

Metrics (HV-G)

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

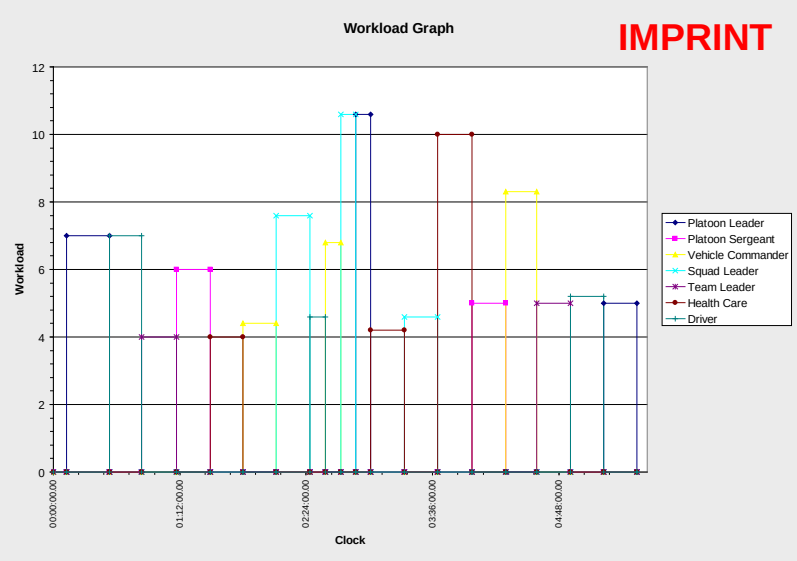
Approach

- Baseline simulation was executed to provide expected levels of mission performance parameters of time and accuracy.
  - IMPRINT provides for the overall development of a network task model that accounts for the tasks and the types and numbers of operators performing those tasks.
  - It also provides the opportunity to examine the effects of unexpected outcomes.

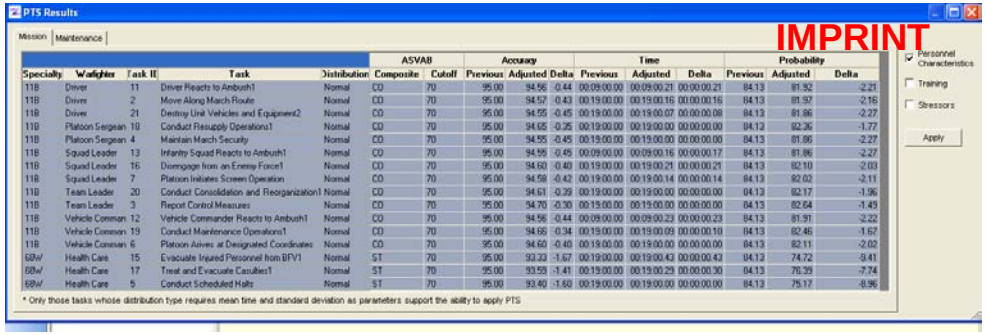
- Simulation was run multiple times, the outcome measures were analyzed in terms of performance and workload.

Dynamic Model Outputs

Operator Workload



Impact of Constraints



Mission Success Rates

Run	Mission Performance Time	RNS	Accuracy Result
1	05:38:13.78	2	No failure
2	05:38:11.31	3	No failure
3	05:36:48.93	4	No failure
4	05:39:56.18	5	No failure
5	05:40:36.60	6	No failure
6	05:41:00.88	7	No failure
7	05:39:12.05	8	No failure
8	05:36:08.66	9	No failure
9	05:40:42.82	10	No failure
10	05:39:38.28	11	No failure
11	05:39:10.11	12	No failure
12	05:34:43.11	13	No failure
13	05:38:48.06	14	No failure
14	05:39:44.32	15	No failure
15	05:35:47.95	16	No failure
16	05:55:01.82	17	No failure
17	05:37:18.57	18	No failure
18	05:38:39.54	19	No failure
19	05:40:10.08	20	No failure
20	05:38:52.16	21	No failure
21	05:35:53.98	22	No failure
22	06:00:09.75	23	No failure
23	05:36:05.52	24	No failure
24	05:38:45.16	25	No failure
25	05:37:21.77	26	No failure

IMPRINT

Individual Task Performance

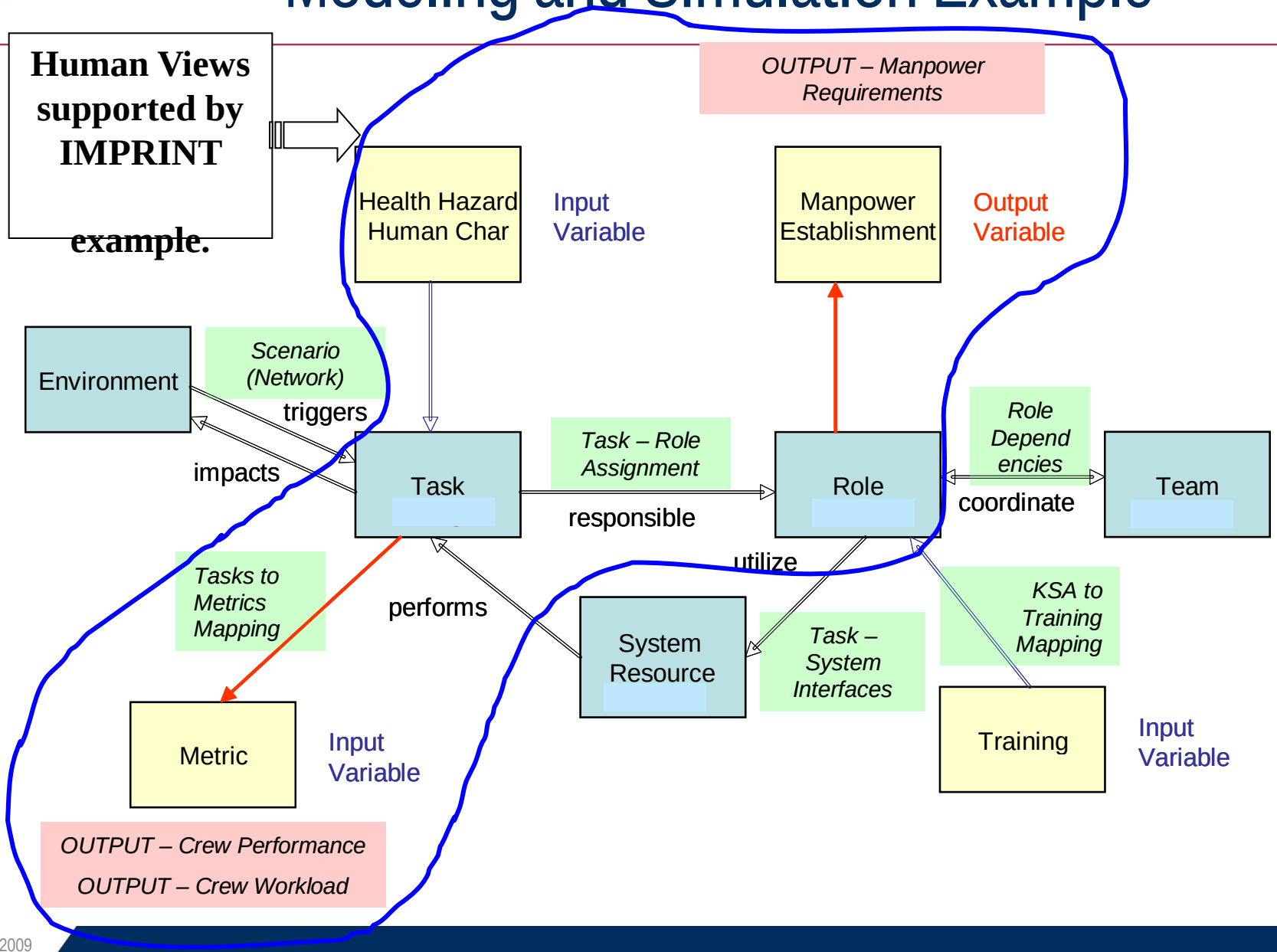
	Time						Accuracy				Overall
Task	Standard	Minimum	Maximum	Mean	Std. Dev.	% Met	Accuracy Standard	Accuracy Measure	% Met	Mission Aborts	% Met Both Time AND Accuracy
START	00:08:00.00	00:05:57.80	00:07:29.40	00:06:52.21	00:00:25.76	100.00	90.00	Percent Steps Correct	100.00	0	100.00 This DOES meet the performance criterion of 90%
Initiate Road March	00:25:00.00	00:23:01.37	00:25:13.73	00:24:08.51	00:00:31.39	96.00	90.00	Percent Steps Correct	92.00	0	88.00 This does NOT meet the performance criterion of 90%
Move Along March Route	00:20:00.00	00:17:30.67	00:20:07.57	00:19:02.03	00:00:33.38	96.00	90.00	Percent Steps Correct	100.00	0	96.00 This DOES meet the performance criterion of 90%
Report Control Measures	00:20:00.00	00:18:11.83	00:20:22.81	00:18:55.64	00:00:34.64	96.00	90.00	Percent Steps Correct	92.00	0	88.00 This does NOT meet the performance criterion of 90%
Maintain March Security	00:20:00.00	00:17:40.71	00:19:59.11	00:18:47.98	00:00:34.83	100.00	90.00	Percent Steps Correct	100.00	0	100.00 This DOES meet the performance criterion of 90%
Conduct Scheduled Halts	00:20:00.00	00:18:00.54	00:19:32.56	00:18:56.32	00:00:21.07	100.00	90.00	Percent Steps Correct	100.00	0	100.00 This DOES meet the performance criterion of 90%
Platoon Arives at Designated Coordinates	00:20:00.00	00:18:16.84	00:19:34.86	00:18:58.48	00:00:20.44	100.00	90.00	Percent Steps Correct	96.00	0	96.00 This DOES meet the performance criterion of 90%
Platoon Initiates Screen Operation	00:20:00.00	00:17:56.41	00:20:14.44	00:19:04.15	00:00:31.37	92.00	90.00	Percent Steps Correct	96.00	0	88.00 This does NOT meet the performance criterion of 90%
Driver Reacts to Ambush1	00:10:00.00	00:08:19.06	00:10:09.37	00:09:11.21	00:00:30.59	96.00	90.00	Percent Steps Correct	92.00	0	88.00 This does NOT meet the performance criterion of 90%
Vehicle Commander Reacts to Ambush1	00:10:00.00	00:07:56.72	00:09:52.43	00:09:00.04	00:00:24.85	100.00	90.00	Percent Steps Correct	96.00	0	96.00 This DOES meet the performance criterion of 90%
Infantry Squad Reacts to Ambush1	00:10:00.00	00:08:17.82	00:09:47.78	00:08:50.08	00:00:25.59	100.00	90.00	Percent Steps Correct	92.00	0	92.00 This DOES meet the performance criterion of 90%
Platoon Leader Reacts to Ambush1	00:10:00.00	00:08:02.94	00:09:32.83	00:08:52.93	00:00:24.06	100.00	90.00	Percent Steps Correct	100.00	0	100.00 This DOES meet the performance criterion of 90%
Evacuate Injured Personnel from BFV1	00:20:00.00	00:17:34.35	00:19:54.06	00:18:50.51	00:00:31.65	100.00	90.00	Percent Steps Correct	92.00	0	92.00 This DOES meet the performance criterion of 90%
Disengage from an Enemy Force1	00:20:00.00	00:17:57.22	00:20:03.71	00:19:00.60	00:00:36.99	92.00	90.00	Percent Steps Correct	76.00	0	68.00 This does NOT meet the performance criterion of 90%
Treat and Evacuate Casulties1	00:20:00.00	00:17:36.50	00:19:50.97	00:19:05.12	00:00:33.61	100.00	90.00	Percent Steps Correct	92.00	0	92.00 This DOES meet the performance criterion of 90%
Conduct Resupply Operations1	00:20:00.00	00:18:23.12	00:19:57.86	00:19:03.19	00:00:28.29	100.00	90.00	Percent Steps Correct	92.00	0	92.00 This DOES meet the performance criterion of 90%
Conduct Maintenance Operations1	00:20:00.00	00:17:37.41	00:19:45.42	00:18:54.63	00:00:27.62	100.00	90.00	Percent Steps Correct	96.00	0	96.00 This DOES meet the performance criterion of 90%
Conduct Consolidation and Reorganization1	00:20:00.00	00:17:47.45	00:20:06.05	00:19:01.20	00:00:32.18	92.59	90.00	Percent Steps Correct	92.59	0	85.19 This does NOT meet the performance criterion of 90%
Destroy Unit Vehicles and Equipment2	00:20:00.00	00:17:55.55	00:19:38.60	00:18:52.68	00:00:24.30	100.00	90.00	Percent Steps Correct	96.00	0	96.00 This DOES meet the performance criterion of 90%
Resume Original Mission2	00:20:00.00	00:18:10.37	00:20:05.01	00:18:59.88	00:00:30.03	96.00	90.00	Percent Steps Correct	100.00	0	96.00 This DOES meet the performance criterion of 90%
END	00:07:00.00	00:04:51.16	00:06:36.74	00:05:54.19	00:00:26.88	100.00	90.00	Percent Steps Correct	96.00	0	96.00 This DOES meet the performance criterion of 90%

IMPRINT

Simulation Results

- Simulation output identified tasks that did not meet the Future Combat System accuracy standard.
- IMPRINT outputs of operator workload and resource conflicts were further investigated to determine if an overloaded condition or a resource shortage contributed to the accuracy detriment of the tasks.
- Analysis verified that the Human View static products can be used to structure the input data to a simulation tool, such as IMPRINT, to provide the simulation environment for the dynamic Human View.
- The dynamic Human View is critical in the architecture framework approach because it captures the dynamic aspects of the human system components defined in other views.

Human View Products Supported by Modeling and Simulation Example



Comments – 1

- Several efforts in various countries are underway to define and structure Human View as viable methodology for HSI practitioners to coordinate and collaborate with the system engineers.

  [Example: UK MODAF Human View]

- While the ergonomists always had a set of tools and processes to support system development (e.g., task analysis, function allocation, etc.), the Human View products facilitate a more structured language for communicating with the other engineering disciplines during system development.

Comments – 2

- The Human View products are derived using an ergonomic approach, namely, a top down method analyzing human gaps in existing architecture frameworks, or based on specific needs that evolved during the course of the architecture development to capture specific human view data.

- HSI practitioners can use Human View methodology to provide a fully integrated set of products that ensure an effective and efficient design, development, and production process.

Conclusions

- Human View products facilitate a more structured language for communicating with other disciplines during system development.
- HSI practitioners can use Human View methodology to provide a fully integrated set of products that ensure an effective and efficient design, development, and production process.
- Analysis results demonstrated that Human View data for a complex system, such as the Future Combat System, can be used to assess design impacts when combined with a simulation tool, such as, IMPRINT.
- Dynamic Human View is critical in the architecture framework because it captures the dynamic aspects of the human system components defined in other views.