OLD DOMINION UNIVERSITY

Human System Engineering Community Initiatives: *From Human Views to Human Readiness Levels*

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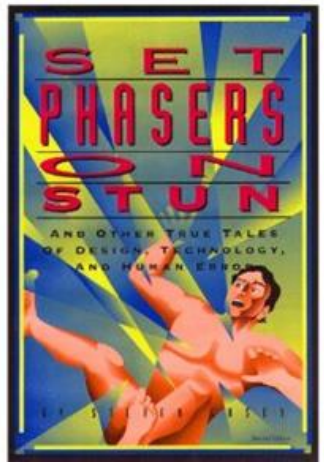
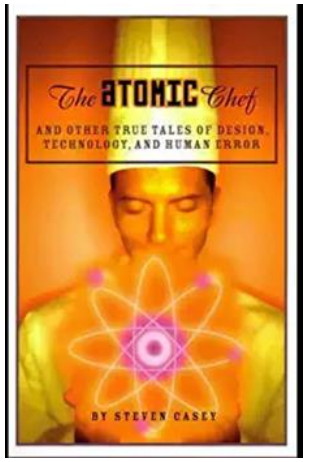
Old Dominion University
Norfolk, VA

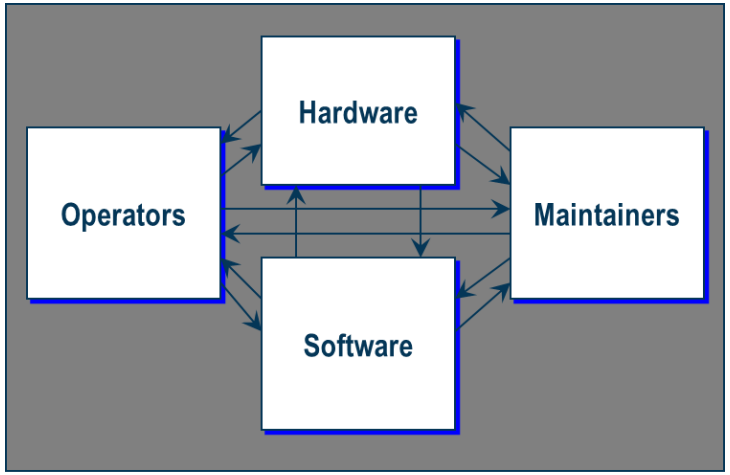
NDIA Human System Engineering Conference
March 3, 2020

Human System Engineering

- "While many systems engineers understand that the human operator and maintainer are part of the system, they often lack the expertise needed to fully specify and incorporate human capabilities into the system design."
  - *System Engineers*: Integration of all **systems** to ensure system success and stakeholder satisfaction.
  - *Human + System Engineers*: Integration of the needs of the **human** into all systems to insure optimal performance and safety.





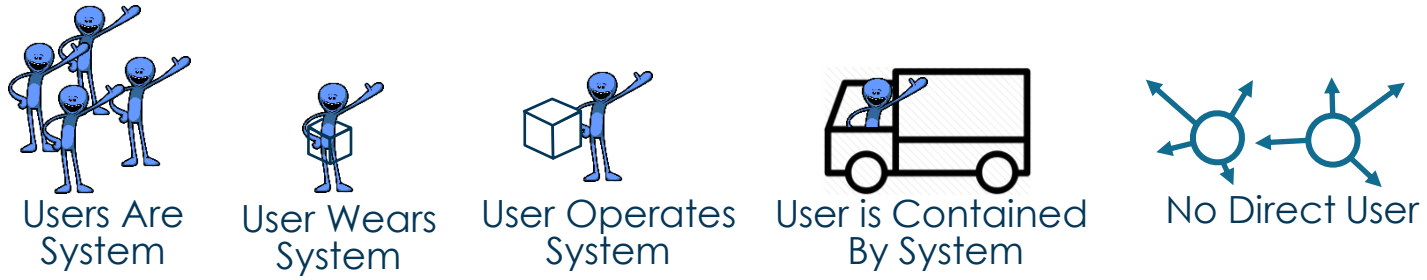


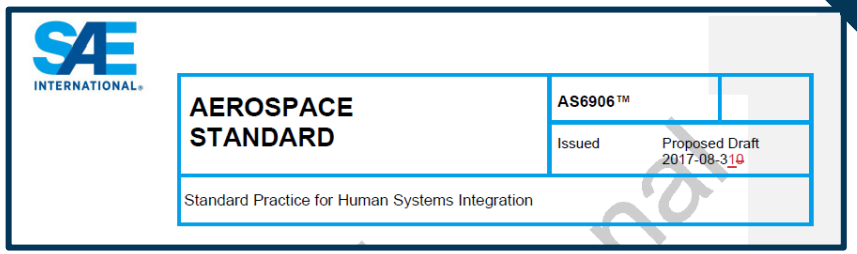
INCOSE, System Engineering Handbook, v3.2.1, 2011

Burns & Gordon, INCOSE Talk, 2005

HSE & HSI for Socio-Technical Systems

- Socio-Technical Systems include both human and technical system aspects and can be defined as “human-technology partnerships.”
- This partnership is supported by both Human System Engineering (HSE) & Human System Integration (HSI):
- **HSE** – Focus on including human considerations into the design of systems.
- **HSI** – Evaluating if the system is ready for human use.



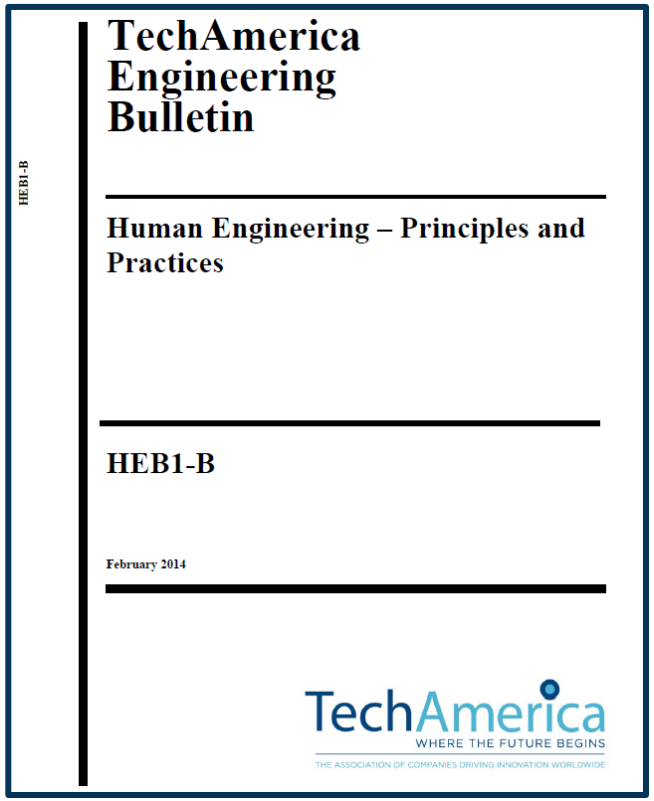

SAE INTERNATIONAL

AEROSPACE STANDARD

AS6906™

Issued Proposed Draft 2017-08-31

Standard Practice for Human Systems Integration


HEB1-B

TechAmerica Engineering Bulletin

Human Engineering – Principles and Practices

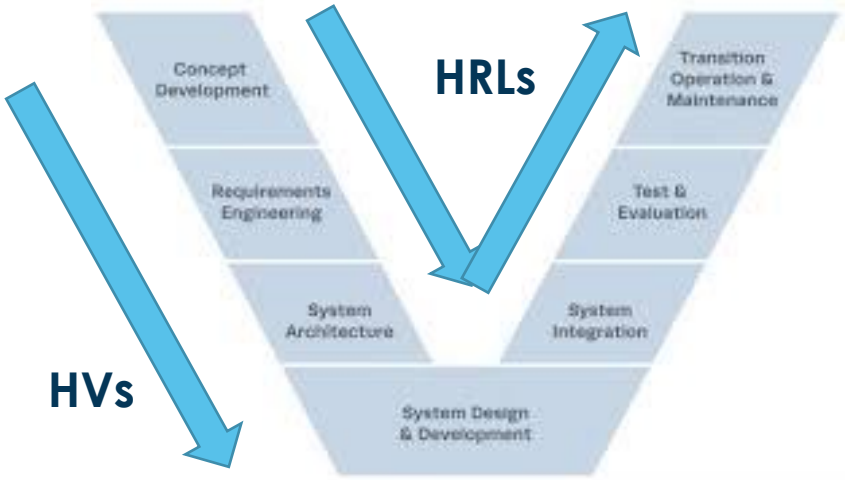
HEB1-B

February 2014

TechAmerica
WHERE THE FUTURE BEGINS
THE ASSOCIATION OF COMPANIES DRIVING INNOVATION WORLDWIDE

Human System Engineering Community

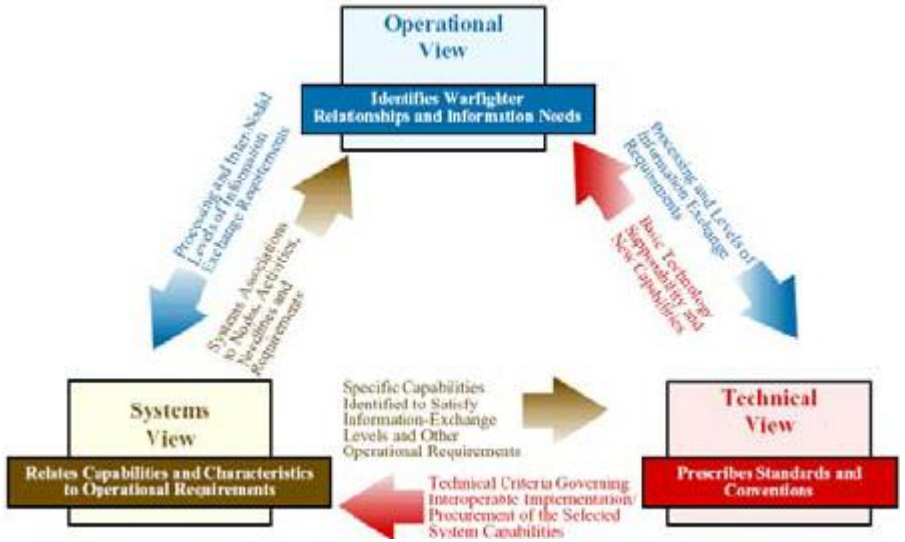
- The HSE community focuses on identifying and improving methods to integrate human concerns into the conceptualization and design of systems.
- We encourage early understanding of human roles and responsibilities, along with limitations and constraints that may impact system design.
- Two Community Initiatives
  - Human Views (HVs) – Circa 2007
  - Human Readiness Levels (HRLs) - Circa 2013



Human Views for System Architectures

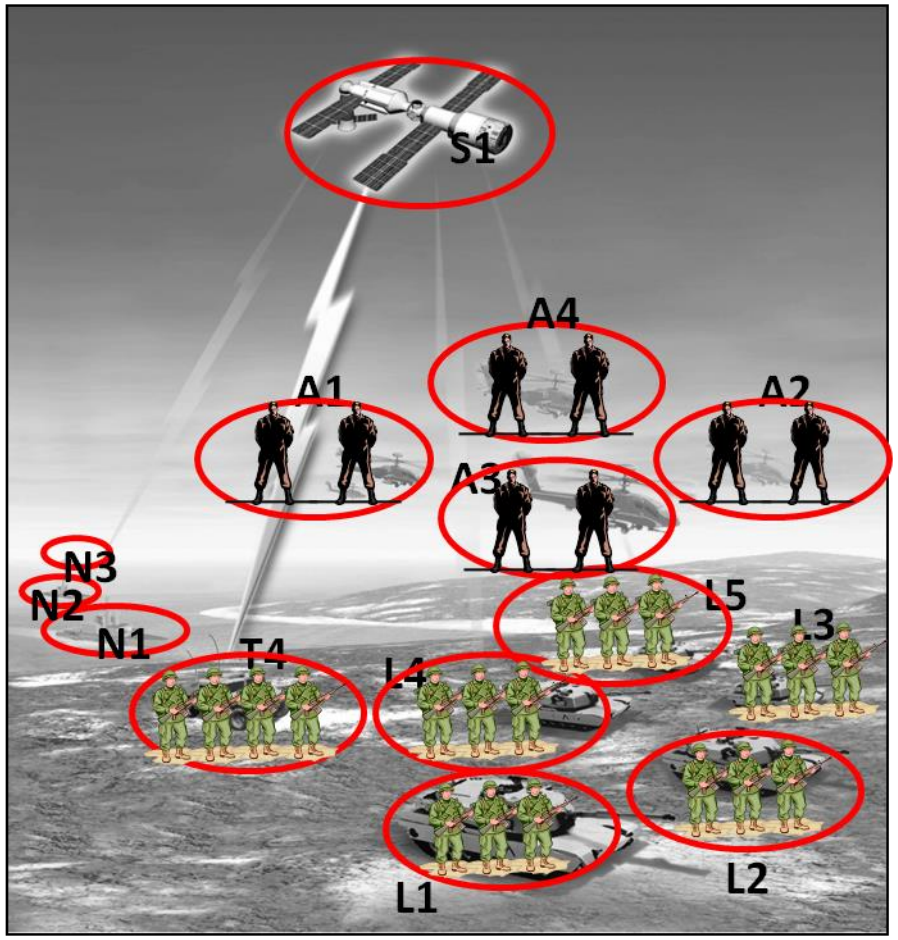
- System Architectures provide a mechanism for managing complexity by applying a set of viewpoints and models for describing systems.
- Architecture Frameworks, such as DoDAF*, fail to explicitly capture human-centric data necessary to ensure the effectiveness of human operated systems.

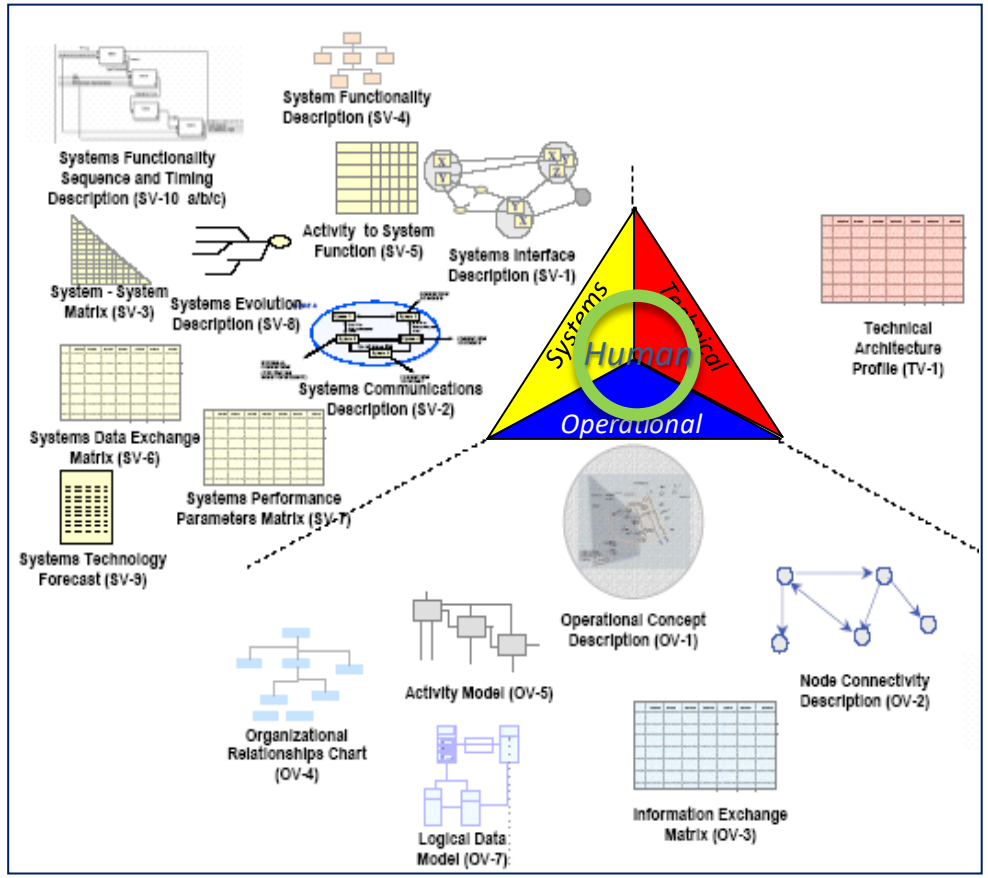
Architecture Frameworks Lack Humans



*Department of Defense Architecture Framework

The Human Viewpoint Goal



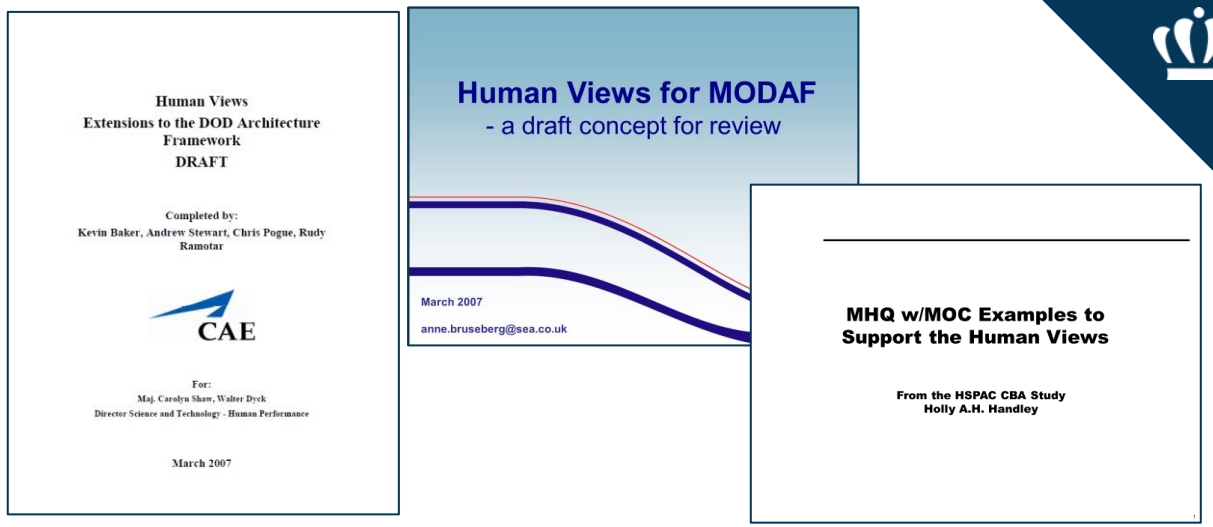


The objective of the Human Viewpoint is to provide a perspective on the human roles, activities and information flows required by a complex system.

Development Timelines

DODAF

- 1990s - C4ISR Architecture Framework v1.0
- 1997 – C4ISR Architecture Framework v2.0
- 2003 - DoDAF v1.0 was released, offering improved guidance, product descriptions, and supplementary information
- 2007 – DoDAF v1.5 was released
- 2009 - DoDAF v2.0 was released
- 2010 – DoDAF v2.02 was released
- 2015 – DoDAF v2.02 Change 1



Human Viewpoint

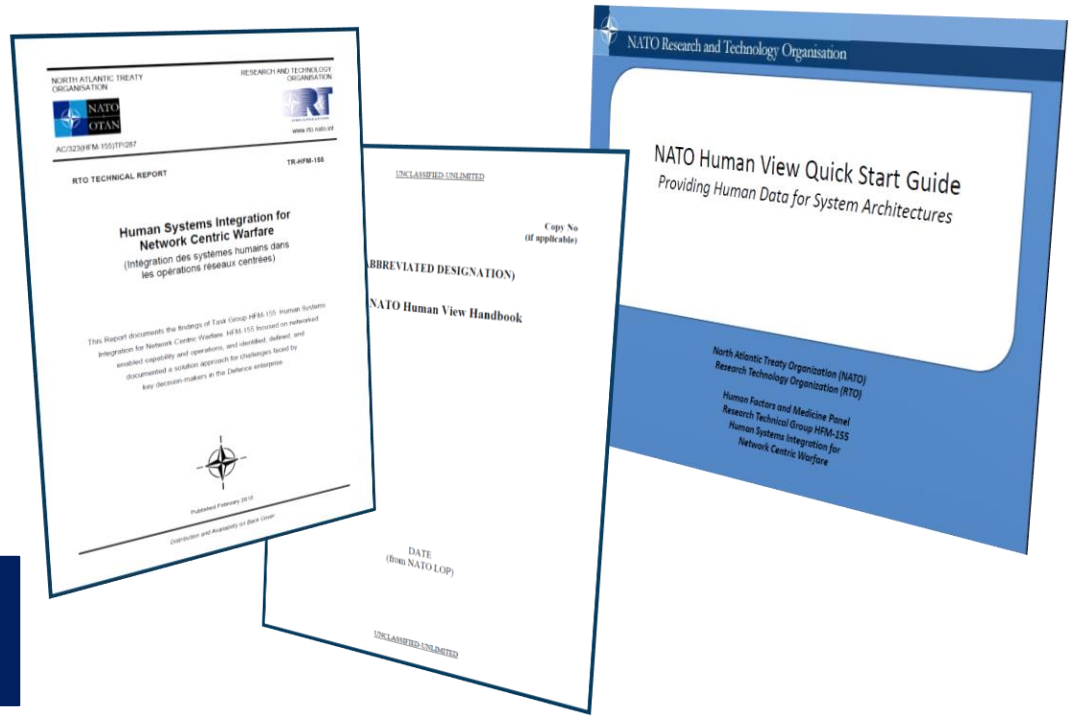
- 2002 - 2006 - Early efforts to represent humans in architecture views
- 2007 - The NATO Research and Technology Organization (RTO) Human Factors & Medicine (HFM) Panel 155 convened a Workshop to design a NATO Human Viewpoint
- 2010 - Human Views Handbook and Guide Released (Aligned with DoDAF v1.0)
- 2011 – HV Briefed to DoDAF Working Group

*Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance

NATO Human Viewpoint

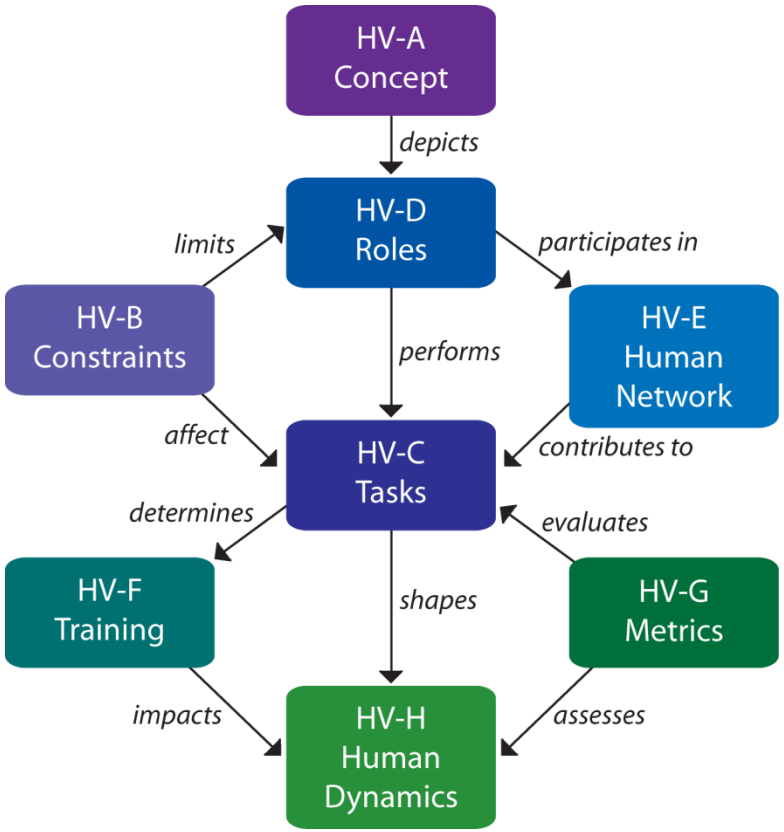
- A NATO Workshop was formed to evaluate emerging Human View concepts and proposed a candidate Human Viewpoint
  - The result was a set of eight Human Views to capture human centric data.
- The NATO Human Viewpoint was designed to be:
  - Independent of any specific architecture framework,
  - Adaptable to different implementation processes,
  - Use data from the overall system development effort to build the models.

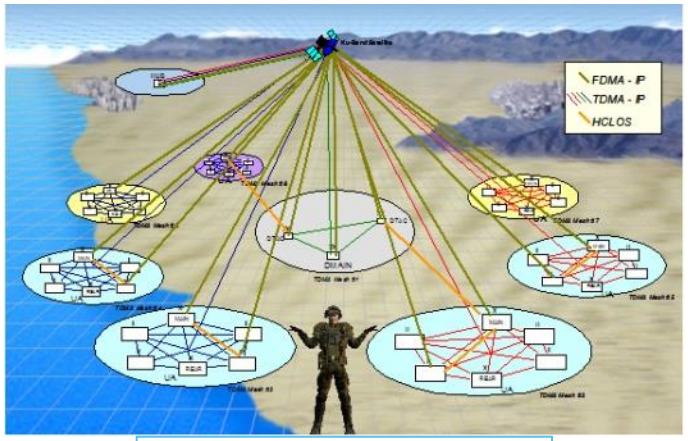
Kevin Baker, Canada
Hans van den Broek, The Netherlands
Anne Bruseberg, United Kingdom
Kar Chan, United States
Walter Dyck, Canada
Holly Handley, United States
Justin Hollands, Canada
Beverly Knapp, United States
Patrick Roche, United States
Robert Smillie, United States
Wenbi Wang, Canada



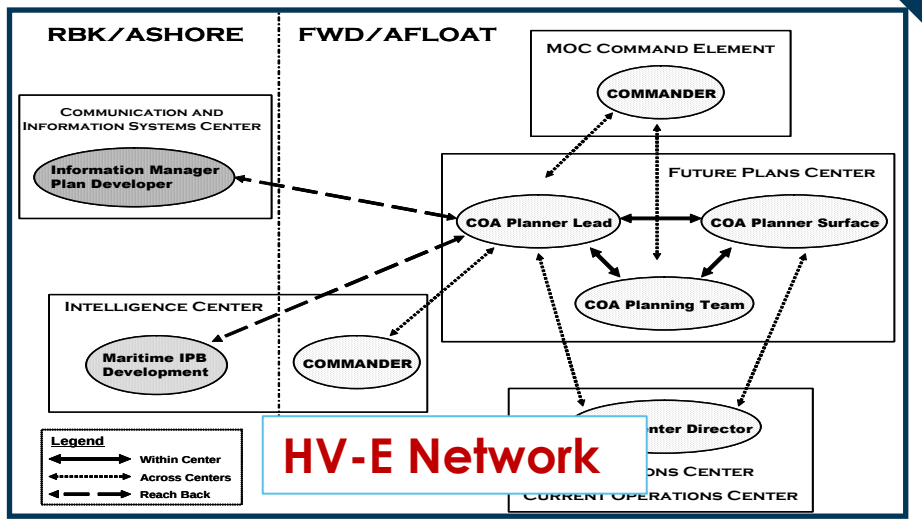
Goal: Ensure the human component has visibility as part of system architecture.

The Human Views

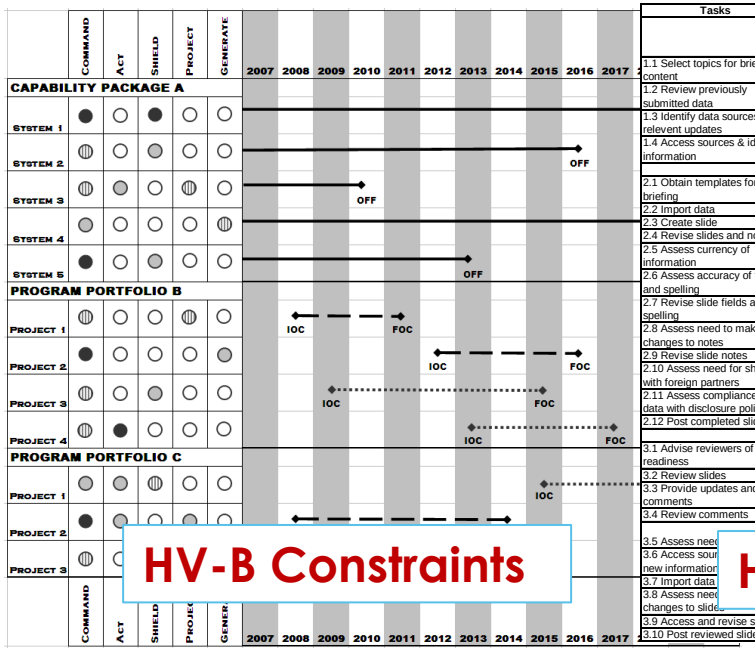




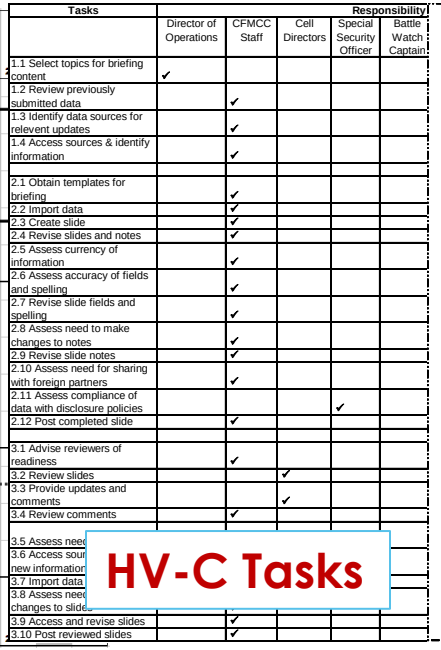
HV-A Concept



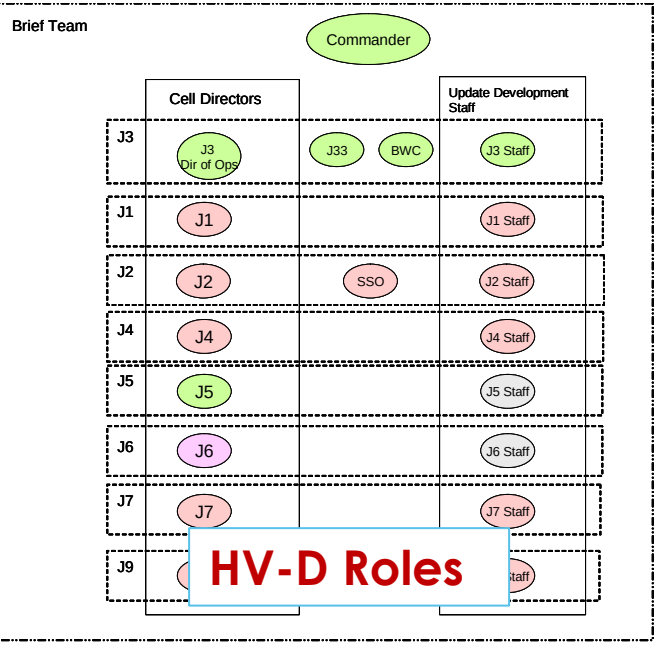
HV-E Network



HV-B Constraints



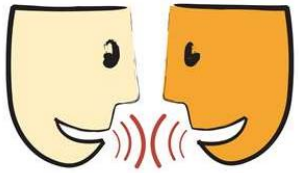
HV-C Tasks

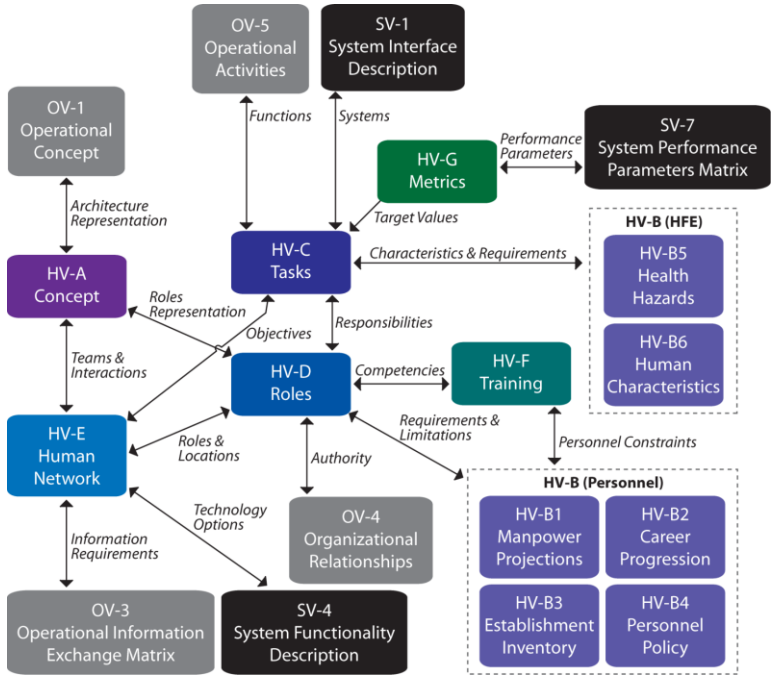


HV-D Roles

Utility of the Human Viewpoint

- Facilitates communicating with other disciplines during system development,
- Organizes information for a comprehensive representation of human capabilities,
- Provides a fully integrated set of products that can be used to inform and influence system design, development, and production process.
- Provides early linkages to the HSI Domains.

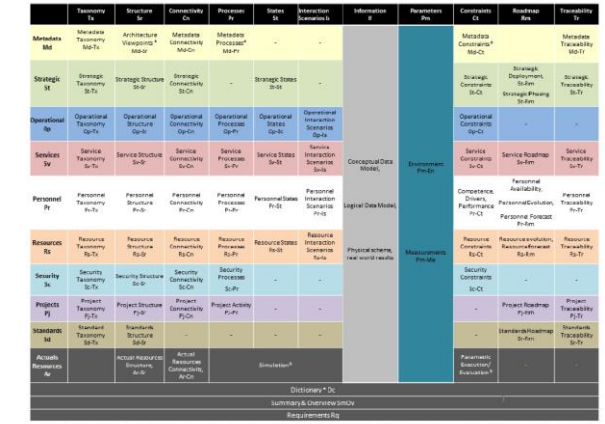




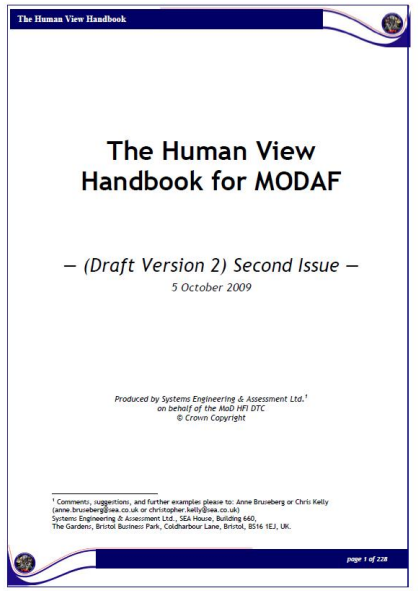
The NATO Human Viewpoint with Relationships to other Views

HSE & SE Community Response

- Never formally integrated into DoDAF:
  - The Human Viewpoint was aligned with DoDAF v1.0,
  - DoDAF v2.0 (released at the same time) which brought more flexibility with customizable "Fit for Purpose" views.
- Approaches to System Architecting changed with Model Based System Engineering (MBSE),
  - System Modeling Language (SysML) used to develop models based on an object-oriented approach,
  - Object Management Group (OMG) Unified Architecture Framework (UAF) with Personnel Views.
- Lack of unity in the HSE community - Two distinct Human Viewpoints emerged:
  - The North Atlantic Treaty Organization (NATO) Human Views
  - The Ministry of Defence Architecture Framework (MoDAF) Human Views.
- Actively used in the Research Community to collect human-focused data for simulation and analysis.



The grid genericizes the framework making it more appealing for use by industry while still supporting the needs of the DoD, MOD and NATO.



The Human View Handbook

The Human View Handbook for MODAF

— (Draft Version 2) Second Issue —

5 October 2009

Produced by Systems Engineering & Assessment Ltd.[1] on behalf of the MoD HFI DTC

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[1] Comments, suggestions, and further examples: please to: Anne Brueseberg or Chris Kelly (anne.brueseberg@sea.co.uk or christopher.kelly@sea.co.uk)
Systems Engineering & Assessment Ltd., SEA House, Building 640, The Gardens, Bristol Business Park, Coldharbour Lane, Bristol, BS16 1EJ, UK.

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Human Views to Human Readiness Levels

- Mica Endsley, the Chief Scientist of the Air Force, presented Human Readiness Levels (HRLs) in 2015 as an adjunct to Technology Readiness levels (TRLs).
  - The Human Views were included in the descriptions of the levels.
- Human Readiness Level (HRL)
  - A measure of the readiness of the technology for use by human operators and maintainers.

HRL HV

HRL	Definition	Description	Supporting Info
1	Human-focused concept of operations (human use scenario) defined	The scenario for human use (human focused CONOPS) of the conceptualized system has been defined and developed for all end user categories. Scenario was used as basis for defining the system.	Human View (HV)-A Concept, HV-C Tasks, Task List Repository, Scenarios/CONOPS
2	Human capabilities & limitations and system affordances & constraints applied to preliminary conceptual designs	Human capabilities and limitations (for all users) and system affordances/constraints have been defined and applied to the refinement of the system concept.	HV-B Human Constraints; Published research and paper studies that identify the human capabilities and limitations; Initial set of HSI-related functional requirements
3	Mapping of human interactions and application of standards to proof of concept	Prior to engineering design, Human to human and human to system network has been defined/refined and proven to map to technology/system architecture and functional expectations. HSI design criteria and standards have been levied to drive the system concept and pre-design.	HV-E Human Network, decomposed standards mapped to HSI-related requirements and specifications,
4	Modeling and analysis of human performance conducted and applied within system concept	Lab HSI tools and resources have been used to analyze and validate human performance within the system concept.	Workload models, anthropometric models, discrete event simulations, analysis of performance shaping factors
5	HSI demonstration and Early User Evaluation of initial and/or preliminary prototype to inform preliminary design	Initial and/or preliminary prototypes have been iteratively evaluated and demonstrated with end users. Human Performance data was collected and used to refine the system, the requirements, and drive improvements of the prototypes.	Static screen shots, CADs, working prototypes, HSI issue tracker, human performance data, Focus group data (wants vs needs), revised human task list, modeled workload (physical and cognitive) validated and/or refined, HSI Issue Tracking, HSI Trade Studies (domain goal tradeoffs)
6	System design fully matured as influenced by human perf analyses, metrics, and prototyping	System design fidelity increases and use of the system is demonstrated. Design has been modified to incorporate lessons learned to optimize human performance, workload, SA, usability, ergonomics, trainability, and safety.	Evolved and improved prototypes; objective and subjective HSI metrics, Survey data, SAGAT/SART, SUS, NASA TLX, Field User Evaluation reports
7	HSI-related requirements qualified and verified through developmental test and evaluation in a representative env	Full system capability with all levels of human users have verified human performance expectations under DT conditions.	DT reports, RTM, human performance validation data, Log/Maintenance Demo data, Survey data, SAGAT/SART, SUS, NASA TLX, Lessons Learned tracking
8	Human Performance using system equipment fully tested, validated, and approved in mission ops	Full system capability with all levels of human users (fully trained and invested) have validated human performance expectations are valid and met in under mission conditions, such as those in OT&E.	OT&E reports, Survey data, SAGAT/SART, SUS, NASA TLX
9	Post-deployment and sustainment of human performance capability	Extensive and iterative review and verification of fielded system begins, as well as post-product improvement evaluations for the next incremental builds. Activity examples include post-fielding training eval analysis and sustaining a hazard analysis for fielded system.	Post-deployment surveys, Training effectiveness evaluations, HSI as signoff to ECPs, Sustainment of HSI design concepts, end user workload stabilization (vice increase),

Human Readiness Scale (Circa 2013)

2015 Human Systems Conference

"Human Systems: Maintaining Our Physical Edge, Enabling Our Cognitive Edge"

10 - 11 February 2015

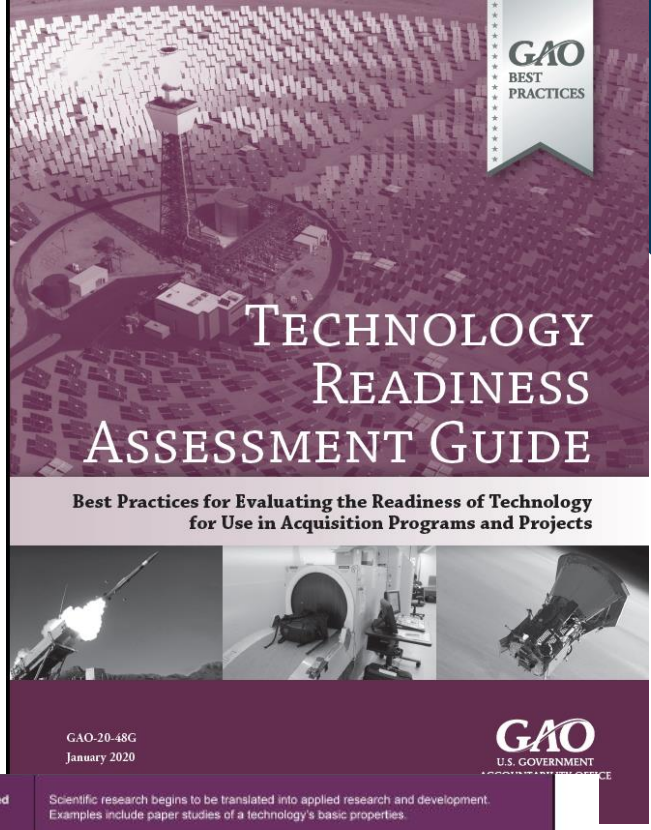
Alexandria, VA

Plenary Address: Human Readiness Levels: Linking S&T to Acquisition

- Ms. Mica Endsley, PhD, Chief Scientist, U.S. Air Force

Technology Readiness Levels (TRLs)

- TRLs provide a common understanding of a technology's status in order to make decisions regarding funding and transition to major programs.
- The TRL indicates how mature a technology is on a nine-point scale:
  - 1 - Basic Principles Observed
  - 9 - System in Operational Environment
- While the TRL scale has been widely effective across major government agencies and industry, it does not address issues of human-system integration (HSI).

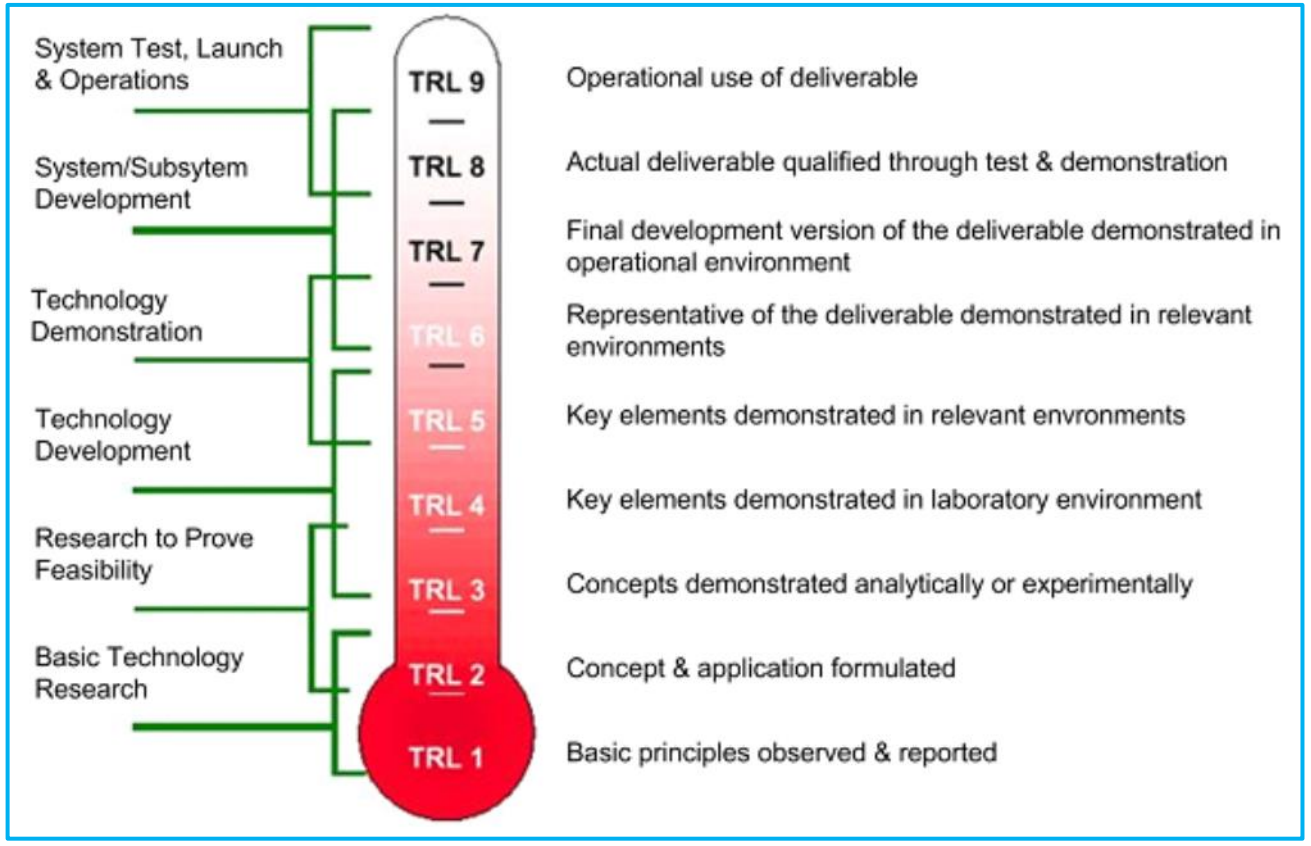


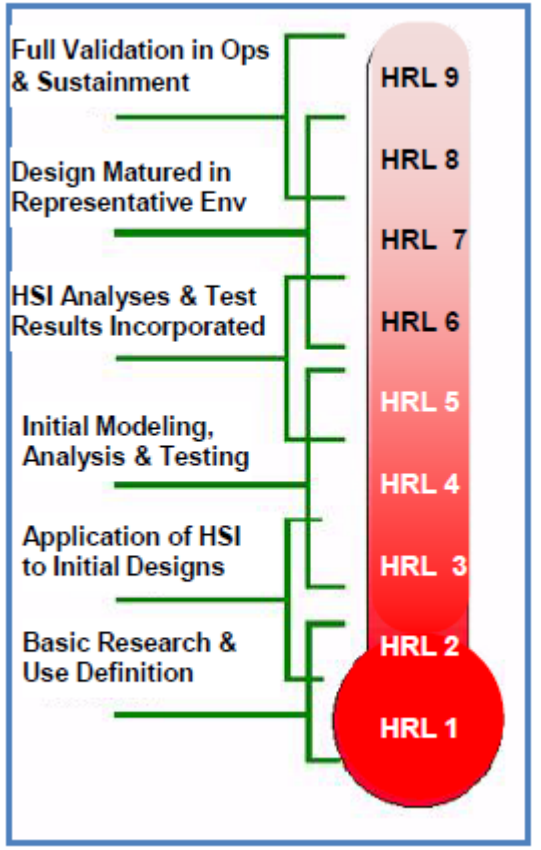
1	Basic principles observed and reported	Scientific research begins to be translated into applied research and development. Examples include paper studies of a technology's basic properties.
2	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that they will work together. This is relatively low fidelity compared with the eventual system. Examples include integration of ad hoc hardware in the laboratory.
5	Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include high fidelity laboratory integration of components.
6	System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in its relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7	System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requirement demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, a vehicle, or space).
8	Actual system completed and qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9	Actual system proven through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Source: GAO analysis of agency documents. | GAO-20-48G

Human Readiness Levels Goal

- Enable Project Managers to quickly assess:
  - Work accomplished within/across Human System Integration (HSI) domains,
  - Degree to which HSI requirements are incorporated into design decisions,
  - Mirror the TRL scale for easy comprehension.





HRLs are designed to complement TRLs during technology development
BUT, focus on the readiness of a technology for the human element within a system.

Déjà vu??

Headquarters U.S. Air Force

U.S. AIR FORCE

Human System Integration: Challenges and Opportunities

Dr. Mica Endsley
USAF Chief Scientist

Human Readiness Level (DRAFT)

- HRL 1 – Basic HF/E principles observed & reported
- HRL 2 – Basic HF/E principles & standards applied to system design
- HRL 3 – Prototype of user interface developed

Initial incorporation of principles and data to form system

- HRL 4 – User interface prototype validated in part-task simulation
- HRL 5 – User interface prototype validated in mission relevant simulation
- HRL 6 – User interface prototype modified to incorporate lessons learned to provide optimal human performance, workload, situation awareness, usability, reach, fit, trainability and safety

Subsystem testing of increasing fidelity

- HRL 7 – User interface prototype validated in operational environment
- HRL 8 – User interface of actual system complete and qualified across the operational envelope through operational testing
- HRL 9 – User interface successfully used in operations across the operational envelope

Full scale testing

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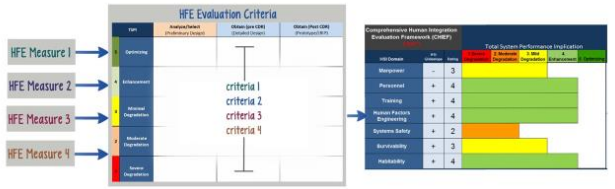
Toward an HSI Assessment Methodology for U.S. Coast Guard Systems

18th NDIA Systems Engineering Conference
Springfield, VA



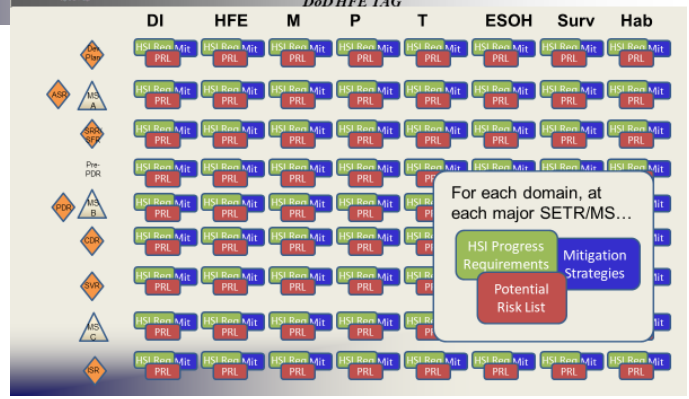
DoD HFE TAG

HSI PROGRESS & RISK SPECIFICATION TOOL (HPRST)

Development Team:
CDR Henry Phillips, Eric Stohr, Dr. Jim Pharmer & Owen Seely
30 Sep 2015

HPRST Contents

DoD HFE TAG



18TH ANNUAL SYSTEMS ENGINERING CONFERENCE

OCTOBER 26-29, 2015 ▶ SPRINGFIELD, VA

Track 5	Sellier	Human Systems Integration 4B5	17881 (Panel) Human Readiness Levels in DoD Acquisition? ▶ Mr. Jon Coleman, *711 HPW/HP* ▶ Dr. Christopher Nemeth, CHFP, *Applied Research Associates* ▶ Dr. Michael Miller, *Air Force Institute of Technology* ▶ CDR Hank Phillips, USN, *NAWCTSD* ▶ LCDR Michael O'Neil, USCG, *U.S. Coast Guard, Human Systems Integration Division*

HRL Timeline

- Phillips (2010)
  - Human Readiness Levels (HRL) - 9 levels - HSI process based
- Endsley (2013)
  - Human Readiness Levels (HRL) - 9 levels – based on testing at increasing levels of fidelity & realism to mirror TRL
- O'Neil (2014)
  - Comprehensive Human Integration Evaluation Framework (CHIEF)
  - 5 level scales - Assesses progress on each HSI Domain
- DoD HFE Tag (2015)
  - HSI Progress & Risk Specification tool (HPRST).
  - Recognize human systems risks and consequences and communicate these risks to Program Managers.
- Sandia National Labs (2019)
  - Report documenting SNL HRL study published
  - See, Craft, & Morris, 2019.
- HRL Working Group (2019)
  - HFES Science Policy Fellowship

TRL Development:

- 22 Years to develop and officially adopt the TRL scale at NASA (1969 – 1991)
- 8 more years until DoD adopted the scale (1999)

HRL Re-Boot!
SNL + Working Group

- Unity
- Socialization
- Champion

HRL Working Group

- An industry wide working group was established to mature the HRL scale developed at Sandia National Laboratories
  - Thirty-Five Members from DoD, DoE, Academia & Industry
  - Supported by the HFES Government Relations Committee & Science Policy Fellows
- Our objectives include:
  - Gather input from a diverse set of HSI experts
  - Develop a usable and verified HRL scale
  - Generate awareness of HRL scale utility
  - Coordinate high-level sponsorship
  - Begin applying the scale in real-world missions

1	Relevant human capabilities, limitations, and basic human performance issues and risks identified
2	Human-focused concept of operations defined, and human performance design principles established
3	Analyses of human operational, environmental, functional, cognitive, and physical needs completed, based on proof of concept
4	Modeling, part-task testing, and trade studies of user interface design concepts completed
5	User evaluation of prototypes in mission-relevant simulations completed to inform design
6	Human-system interfaces fully matured as influenced by human performance analyses, metrics, prototyping, and high-fidelity simulations
7	Human-system interfaces fully tested and verified in operational environment with system hardware and software and representative users
8	Total human-system performance fully tested, validated, and approved in mission operations, using completed system hardware and software and representative users
9	System successfully used in operations across the operational envelope with systematic monitoring of human-system performance

1st Workshop – Definitions and Supporting Questions

- Identified the questions that must be satisfactorily addressed at each HRL level before advancing to the next level.
- Eighty questions spanning the nine levels from initial concept development to fielding along with the exit criteria and supporting evidence required at each HRL.

Phase	HRL	Name	Description	Core Question		Question
Technology Demonstration	5	User evaluation of prototypes in mission-relevant simulations completed to inform design	Human performance is evaluated via prototypes in mission-relevant simulations The fidelity of key elements has increased significantly, and users participating in testing are independent from the design team.	Have design recommendations based on user evaluation of prototypes in mission-relevant simulations been provided?	32	Have strategies to mitigate safety implications for human users been updated, based on prototype testing in mission-relevant simulations?
					33	Have strategies to accommodate manpower, personnel, and training concerns been updated, based on prototype testing in mission-relevant simulations?
					34	Have strategies to address environmental implications been updated, based on prototype testing in mission-relevant simulations?
					35	Have strategies to address implications for other relevant HSI domains been updated, based on prototype testing in mission-relevant simulations?
					36	Has the suitability of human-machine function allocations been determined, based on prototype testing in mission-relevant simulations?
					37	Is prototype testing in mission-relevant simulations being used to update procedures for human user roles throughout the lifecycle?
					38	Have task analyses to optimize task flow and sequencing been updated, based on prototype testing in mission-relevant simulations?
					39	Have relevant human performance data been evaluated to determine whether metrics for successful human performance can be met, based on prototype testing in mission-relevant simulations?
					40	Have strategies to support human usability been identified and recommended, based on prototype testing in mission-relevant simulations?

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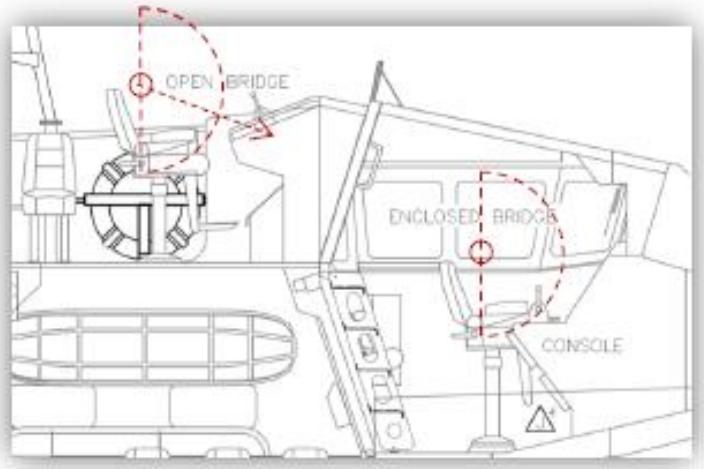
- Apply the HRL scale and accompanying questions to different system examples in order to address its utility and internal consistency.

MANPRINT (HSI) Assessment

Assessment Concern	Supporting Question
Manpower, Personnel, and Training (MPT) - AMBER	
The Manpower Estimate Report (MER) lacks detailed task analysis information to justify the estimates;	Q15 – HRL 3 Have human user tasks critical to system goals been identified?
The acquisition strategy of maximizing the use of commercial software may result in excessive training burdens and personnel skill demands that will increase life cycle costs;	Q 24- HRL 4 Have strategies to accommodate manpower, personnel, and training concerns been identified and recommended?

Co-Rater Reliability to Ensure Consistent Ratings

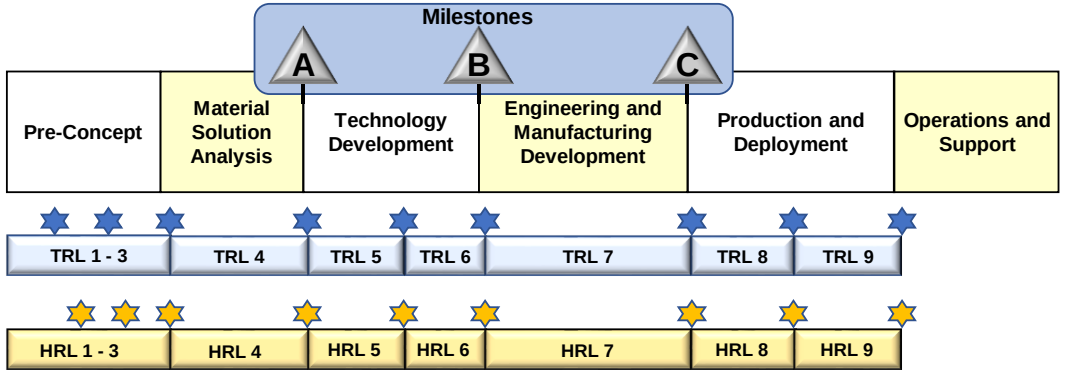
47 ft Motor Lifeboat



Display and Control Placement: Deficiencies in placement, orientation, labeling, lighting and illumination lead to inefficient operation, errors, frustration, and inadvertent operation. Operators must develop and employ a host of workarounds to utilize bridge workstations effectively.

HSE Community Benefits of HRLs

- Communicate & Collaborate
- Identify Actionable Items
- Influence Decisions
- Impact Allocation of Resources



DOD Acquisition Process and TRLs/HRLs

Talking Points:

- Provides a *common language* and a *consistent framework* for addressing human readiness across diverse programs.
- HRL scale shifts the focus from *lagging indicators* of human readiness (human error in fielded systems) to *leading indicators* (evidence-based measures of usability readiness).

HSE Community Challenges for HRLs

- Multiple Acronyms
  - **HRL** has been used consistently since its inception in 2010.
  - Existing readiness levels are three-letter acronyms
- Proliferation of "RLs"
  - IRL, MRL, PRL, SRL, TRL.
- Confusion on what they are not:
  - *NOT an assessment of an individual's readiness or fitness for duty.*
- Lack of Unity in the Community
  - HPRST, CHIEF, etc.

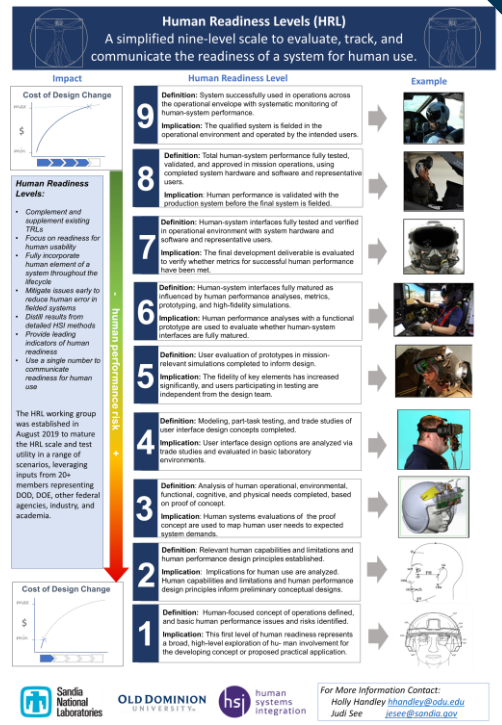
Human Readiness Level (HRL)
Human Factors Readiness Level (HFRL)
HSI Readiness Level (HSIRL)
Human Use Readiness Level (HURL)
Personnel Use Readiness Level (PURL)
HSI Integration Readiness Level (HSIIRL)

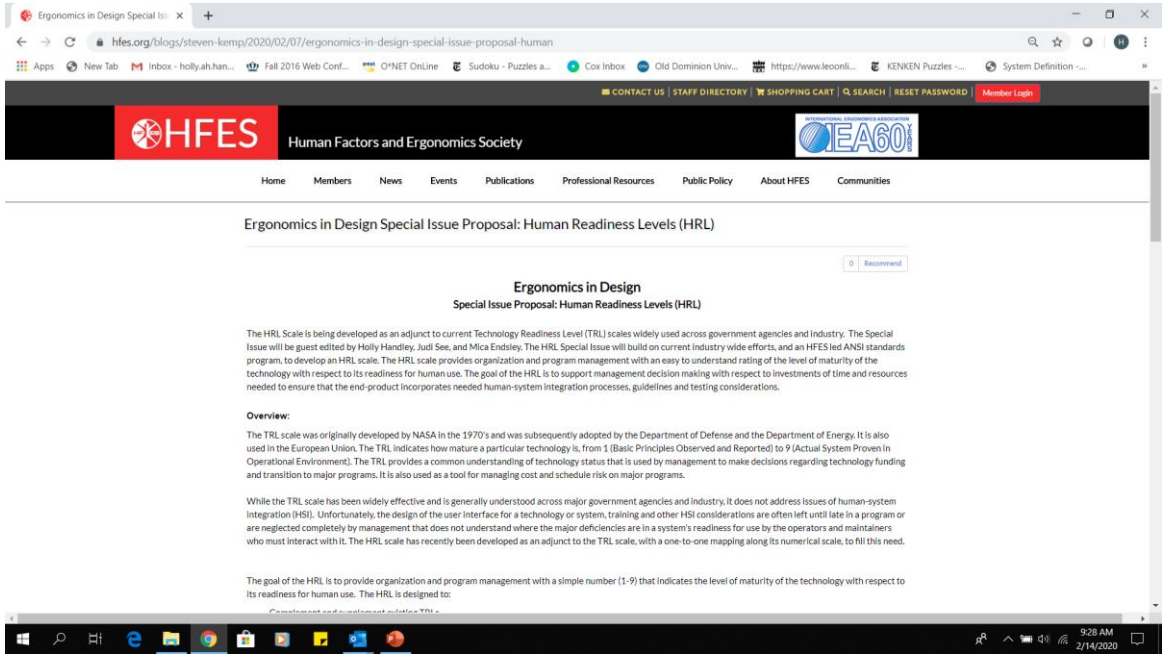
The **Human Readiness Levels** scale is a simple nine-level scale to evaluate, track, and communicate the readiness of a system for human use.

- It distills results obtained from, but does not replace, detailed HSI methods and tools.
- The HRL scale is designed to complement and supplement the existing TRL scale.
- Whereas the TRL scale focuses on technical maturity, the HRL scale focuses on readiness for human usability.
- The purpose of the HRL scale is to fully incorporate the human element of the system throughout the lifecycle.
- Human systems issues can be captured and mitigated early in the design phase in order to reduce human error in the fielded system.

Human Readiness Levels - Way Ahead

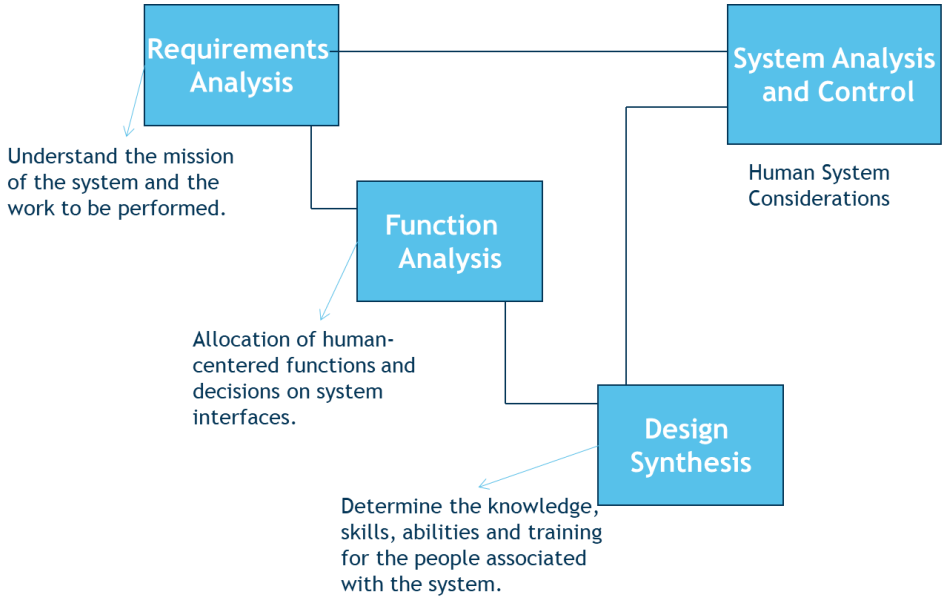
- Socialization:
  - NDIA
  - HFETAG
  - HFES
- HFES/ANSI Standard for HRLs
  - Similar Process as the recent "Standard Practice for HSI"
- Ergonomics in Design Journal, *Special Issue*:
  - Mica Endsley, Judi See & Holly Handley, Editors
  - Posted on HFES Website





HSE: Engineering for the Total System

Human Views – Capture Data For Engineering Design and Analysis



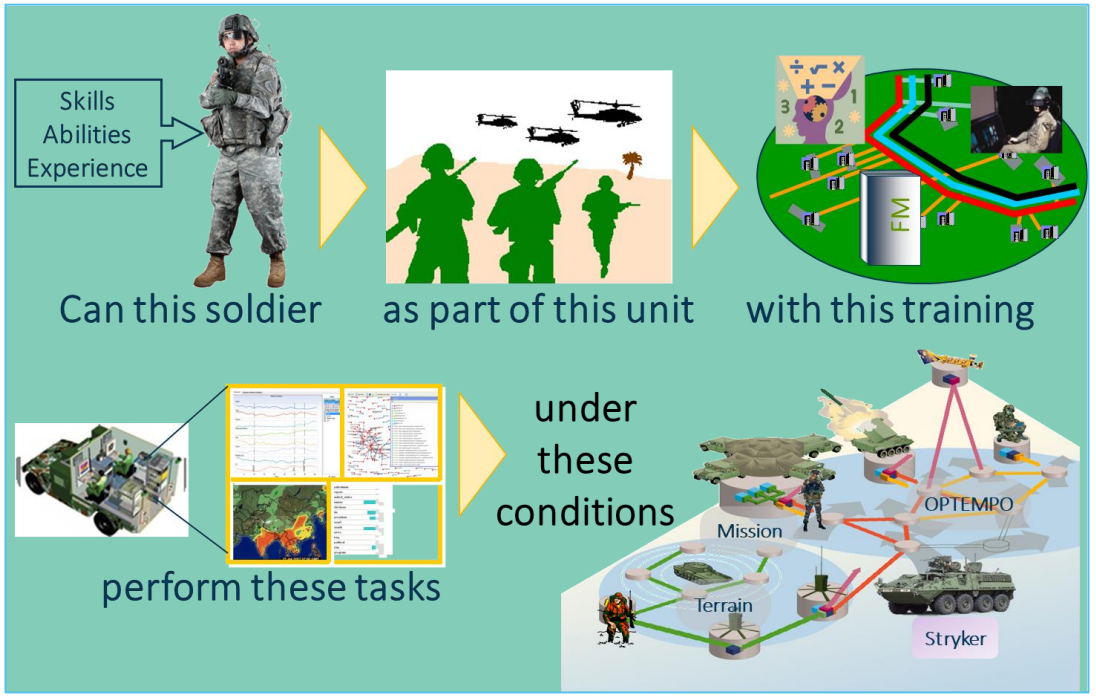
HV-A Concept	a high-level representation of the human component of the system
HV-B Constraints	a repository for different sets of limitations
HV-C Tasks	describes the human-specific activities
HV-D Roles	describes the job functions that have been defined for the humans interacting with the system
HV-E Human Network	captures the human to human communication patterns that occur as a result of team formation
HV-F Training	accounting of training requirements, strategy, and implementation
HV-G Metrics	a repository for human-related values, priorities and performance criteria
HV-H Dynamics	the information necessary to complete a simulation of the human impact on the system

Human Readiness Levels – Assess the Degree to which HSI Requirements Have Been Addressed

Evaluation Activity	HRL 3	HRL 4	HRL 5	HRL 6	HRL 7	HRL 8
Usage scenarios	✓			✓	✓	✓
Human performance metrics	✓	✓	✓	✓	✓	✓
Human-machine allocations	✓	✓	✓			
Safety	✓	✓	✓	✓	✓	✓
Manpower, personnel, training	✓	✓	✓	✓	✓	✓
Environment	✓	✓	✓	✓	✓	✓
Other relevant HSI domains	✓	✓	✓	✓	✓	✓
Strategies for human usability	✓	✓	✓	✓	✓	✓
User procedures		✓	✓	✓	✓	✓
Issue tracking system				✓	✓	✓

Human System Engineering Benefits

- Human System Engineering can reduce system risk by:
  - Communicating information about the needs and limitations of the human component,
  - Ensuring that systems will not require expensive “train-arounds” or late-stage fixes to address issues of ineffective usability.



Beverly Knapp, Acting Director Army HSI

The aim is not to train an operator to work a machine
that is designed to achieve some goal;
Rather the aim is to design the machine to support the operator
who is responsible for achieving the goal.

Conclusion

- Comprehensive integration of the human component into the systems engineering effort is critical to the design, development, and operation of successful systems.
- Supporting Human + System Engineering can reduce total ownership cost and improve the overall system performance.
  - Both the Human Views and the Human Readiness Levels enable successful HSE efforts.

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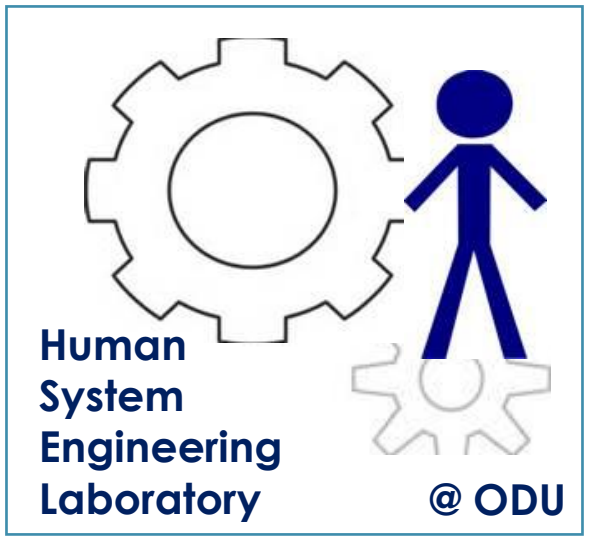

Acknowledgements
Judi See: HRL Lead Architect
HRL Working Group Members