

Human Readiness Levels and Human Views as Tools for User-Centered Design

Holly A. H. Handley¹ , Judi E. See² , and Pamela A. Savage-Knepshield³ 
¹Old Dominion University, ²Sandia National Laboratories, ³DEVCOM Analysis Center

Correspondence

Holly A. H. Handley, Ph.D., Professor, Engineering Management & Systems Engineering,
Old Dominion University, Norfolk, VA 23529
E-mail: hhandley@odu.edu

Funding Information

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

User research reported by the U.S. Army Combat Capabilities Development Command (DEVCOM) Analysis Center was funded by the Program Executive Office, Control, Communications – Tactical, Project Manager Mission Command, and Product Manager (PdM) Fire Support Command and Control (FSC2).

Acknowledgment

Pamela Savage-Knepshield is now at CACI, INC-FEDERAL. User research was performed by personnel from PdM FSC2; DEVCOM Analysis Center; DEVCOM Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance, and Reconnaissance Center (C5ISR); U.S. Army Communications-Electronics Command (CECOM); and CACI International, Inc. The DEVCOM Army Research Laboratory Human Research Protection Program reviewed all user research, as required by federal regulations. Soldiers provided written consent for participation in software evaluations and for publication of their photographs.

Significance and Practitioner Points

This paper describes an approach that highlights the importance of considering the human component of a system early and often throughout the design and development lifecycle. This approach combines the benefits of applying Human Readiness Levels (HRL) and the Human Views (HV) concurrently in the context of a user-centered design process, reducing system risk by communicating information about the needs and constraints of the human component in the system. The HRL scale provides a metric for human systems integration (HSI) status and maturity that can be easily communicated throughout the system development process. The HVs ensure the human component is seen as part of the overall system architecture and provide an organized repository for HSI data that can be used to support evaluation of HRL levels. This approach has been applied successfully during HSI evaluations for a U.S. Army software modernization program, providing an example that practitioners can leverage in future design and development efforts. Additional research could help elucidate the exact nature of the benefits afforded by this combined approach.

Human Readiness Levels and Human Views as Tools for User-Centered Design

Holly A. H. Handley¹ , Judi E. See² , and Pamela A. Savage-Knepshield³ 
¹Old Dominion University, ²Sandia National Laboratories, ³DEVCOM Analysis Center

Abstract

The Human Readiness Level (HRL) scale is a simple nine-level scale that brings structure and consistency to the real-world application of user-centered design. It enables multidisciplinary consideration of human-focused elements during the system development process. Use of the standardized set of questions comprising the HRL scale results in a single human readiness number that communicates system readiness for human use. The Human Views (HV) are part of an architecture framework that provides a repository for human-focused system information that can be used during system development to support evaluation of HRL levels. This paper illustrates how HRLs and HVs can be used in combination to support user-centered design processes. A real-world example for a U.S. Army software modernization program is described to demonstrate application of HRLs and HVs in the context of user-centered design.

Keywords

human readiness levels, human views, user-centered design, human systems integration

Introduction

Proper attention to human systems design during the development of technological systems is a significant factor in minimizing or preventing human error, which can account for 60% to 90% of accidents and incidents across a wide range of systems.^{1,2,3,4} However, many system development programs have been deficient in applying established and scientifically-based human systems integration (HSI) processes, tools, guidance, and standards, resulting in suboptimal systems that degrade mission performance.⁵

Early and thorough consideration of human issues during system design can reduce subsequent operations and maintenance costs, minimize accidents and incidents that negatively impact safety and costs, and improve the effectiveness of the combined human-system for achieving mission outcomes. Accordingly, various tools such as the Human Readiness Level (HRL) scale and Human Views (HV) have been developed to facilitate accomplishing these objectives and ensure fielded systems are not only technically mature but also ready for human use.

The purpose of this paper is to illustrate the alignment between HRLs and HVs and describe how the two tools were applied in combination to support a real-world user-centered design process. An overview of the HRL scale is provided, followed by a brief review of its developmental history and a general philosophy for its application within existing system engineering processes. Next, the concept of HVs is reviewed, and the relationship between the HRLs and HVs is depicted, using the system engineering V-model. Finally, a real-world user-centered design effort for a U.S. Army software modernization program is presented to demonstrate how the HRLs and HVs were effectively used in concert to facilitate assessment of human, technology, and system readiness. The authors drew upon their extensive history of expertise and experience with HRLs,

HVs, and user-centered design to analyze the relationships among the three tools and posit how leveraging them concurrently can enhance their individual benefits. The U.S. Army software modernization program provides an initial example of the success of this merger.

Human Readiness Level Scale

The HRL scale is a simple nine-level scale designed to evaluate, track, and communicate whether a developing technology or system is ready for human use (Table 1). *Human readiness* refers to the maturity of a technology with respect to use by intended users in the intended operational environment. By addressing human readiness, the HRL scale complements and supplements the existing Technology Readiness Level (TRL) widely used throughout government, industry, and academia to measure the technical maturity of a developing technology.^{6,7,8} The HRL scale emerged from a desire to leverage the success and familiarity of the TRL scale and ensure the human component of a system receives the same level of attention as the technological components early and often throughout the system lifecycle⁹.

The HRL scale is intended to be applied in the context of existing system engineering and HSI processes to ensure elements of human readiness are satisfactorily addressed at the same time that technology readiness is evaluated throughout system design and development. The focus in the HRL scale shifts over time to mirror the technology-to-system progression seen in the TRL scale. Namely, like the TRL scale, elements of the HRL scale at Levels 4 and above are worded to reflect the increased focus on integration of technologies within the intended system application rather than the individual technologies themselves.¹⁰

Table 1. Nine Levels of the HRL Scale

HRL Level	Description
<i>HRL 1:</i> Basic principles for human characteristics, performance, and behavior observed and reported	Broad, high-level exploration of human ramifications for a developing concept or proposed practical application
<i>HRL 2:</i> Human-centered concepts, applications, and guidelines defined	Analysis of implications for human use and application of human-centered design guidelines to inform human use requirements and preliminary designs
<i>HRL 3:</i> Human-centered requirements to support human performance and human-technology interactions established	Mapping of human needs to expected operational and system demands to establish human-centered requirements
<i>HRL 4:</i> Modeling, part-task testing, and trade studies of human systems design concepts and applications completed	Analysis of human systems design concepts via trade studies and evaluation in laboratory environments to identify viable options
<i>HRL 5:</i> Human-centered evaluation of prototypes in mission-relevant part-task simulations completed to inform design	Significant increase in fidelity of key elements, including users participating in testing (independent from design team)

HRL Level	Description
HRL 6: Human systems design fully matured and demonstrated in a relevant high-fidelity, simulated environment or actual environment	Evaluation of human systems design maturity with a functional prototype across the full range of usage scenarios and tasks
HRL 7: Human systems design fully tested and verified in operational environment with system hardware and software and representative users	Evaluation of first development system to determine if recommendations to support human use have been satisfactorily incorporated and resolve identified human performance issues
HRL 8: Human systems design fully tested, verified, and approved in mission operations, using completed system hardware and software and representative users	Verification of human performance with production system in a representative environment before full-rate production and final system fielding
HRL 9: System successfully used in operations across the operational envelope with systematic monitoring of human-system performance	Fielding of qualified system in the operational environment, with operation by intended users

Development of the HRL Scale

Research, maturation, evaluation, and peer review of the HRL scale occurred for more than 10 years, with participation from multiple organizations and experts throughout the HSI community (Table 2). The HRL concept was first proposed in 2010.⁹ Afterwards, nine other HSI management tools were investigated as possible alternatives to the HRL scale that could potentially foster incorporation of human factors and HSI within existing systems engineering processes.¹¹ In that investigation, each tool was characterized with respect to its intended purpose and the features offered to HSI practitioners, systems engineers, and acquisition staff; this comparison also includes the HVs. Although there were some overlaps among the different tools, the primary conclusion was that each tool presents a perspective not addressed in any of the other tools. In particular, the HRL scale is distinguishable from the other tools with respect to its unique ability to serve as an executive-level communication tool.¹¹

Accordingly, subsequent efforts focused on transforming the HRL scale into a comprehensive nine-level scale comparable to the well-known TRL scale. The TRL scale was selected to serve as the foundation for the HRL scale, despite the availability of many other readiness levels scales that could have been used (e.g., integration readiness levels and system readiness levels). Other readiness level scales do not enjoy the same level of familiarity and widespread use as the TRL scale, and they introduce other issues not found in the TRL scale.¹² Additional research to develop the HRL scale is described in a series of papers capturing use of the TRL scale as the foundation for the HRL scale,¹³ description of the HRL scale,¹⁴ and the impact on system integration.¹⁵ The most recent instantiation of the HRL scale is contained in a formal technical standard developed through the American National Standards Institute (ANSI) and the Human Factors and Ergonomics Society (HFES).¹⁰ The ANSI/HFES 400-2021 standard defines the nine

levels of the HRL scale and provides guidance for their application. The standard is available free of charge for download from the HFES online store (see <https://www.hfes.org/Publications/Technical-Standards>).

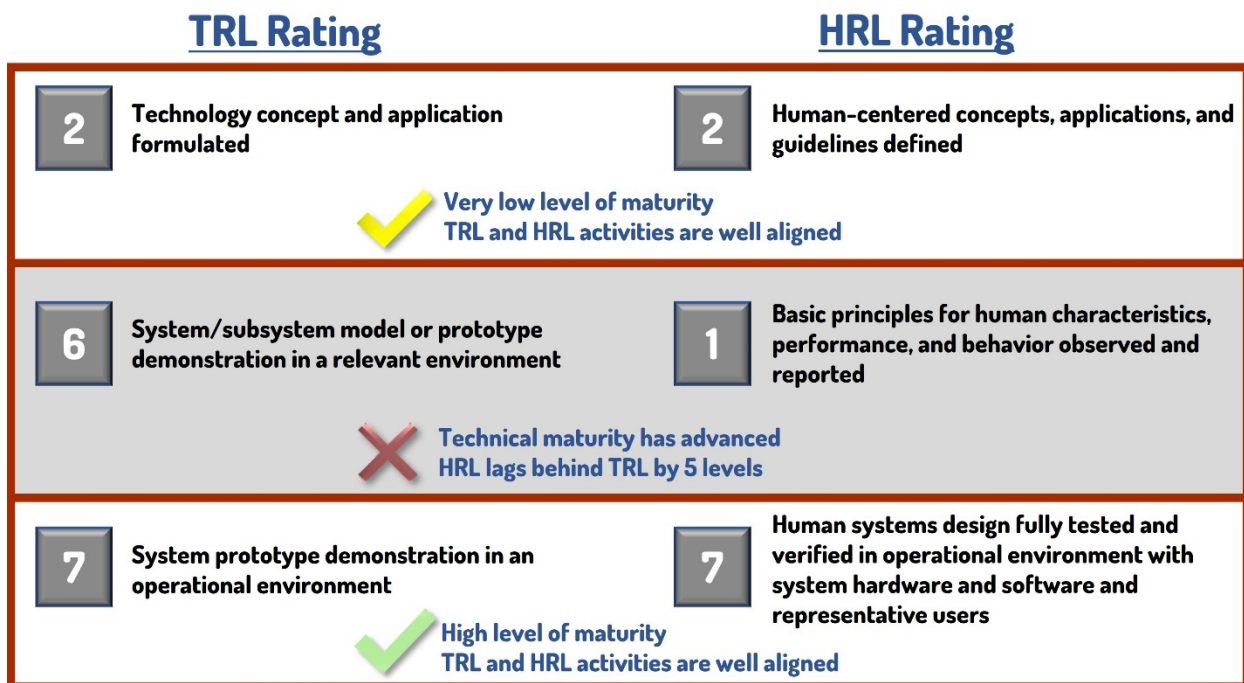
Table 2. Development of the HRL Scale

Year	Milestone
2010	Acosta (2010) proposed HRL concept ⁹
2010	Phillips (2010) instantiated first nine-level HRL scale in a master's thesis ¹⁶
2014	O'Neil (2014) proposed a framework to standardize HSI in a master's thesis ¹⁷
2015	U.S. Air Force Chief Scientist advocated requirements to augment TRL scale ¹⁸
2015	U.S. Department of Defense HSI working group refined HRL scale ¹⁹
2019	Sandia National Laboratories, Old Dominion University, and Naval Postgraduate School chaired working group to mature HRL scale and assess utility ²⁰
2021	ANSI/HFES 400-2021 technical standard published ¹⁰

Application of the HRL Scale

The HRL scale, like the TRL scale, has been intentionally designed to provide a common language applicable across a diverse range of technologies and organizations throughout government, industry, and academia.¹⁰ Successful application of the HRL scale requires one or more qualified human systems experts on the design and development team to evaluate key aspects of HSI by addressing a series of questions, estimate the HRL rating, provide a rationale for that rating, and communicate it at multiple program levels.¹⁰ While HRL and TRL ratings are developed independently, they are provided concurrently at key decision points in the program to support robust and comprehensive assessment of a technology's maturity and facilitate decision making regarding future program directions and resource allocation. In an ideal scenario, the TRL and HRL ratings align directly throughout design and development.¹⁰ However, misalignment may occur for various reasons. For example, human readiness may lag behind technical maturity when an existing technology is applied within a new context of use. Revisiting HRLs allows for the validation of initial assumptions or identifies adjustments needed to bring HRLs and TRLs back into alignment.

Several examples of concurrent application of the TRL and HRL scales to facilitate communication to program decision makers are illustrated in Figure 1. In the first example, TRL and HRL ratings are aligned, but the design and development process is still in its earliest stages of basic research and development. Communications for this example may convey that the TRL/HRL alignment is encouraging, but it is too early in the process to know whether that alignment will persist through fielding. In the second example, the HRL rating lags the TRL rating by five levels, signaling increased risk to the program if additional funding and labor are not applied directly to address human readiness. In the final example, TRL and HRL ratings are again aligned, but the maturity level is much higher. Alignment at this phase of development, just prior to system production, indicates there is a good possibility the fielded system will be both technically mature and usable.

Figure 1. Alignment of TRL and HRL Ratings

The benefit of applying the HRL scale during design and development is facilitation of proactive, comprehensive, and systematic evaluation of the human-related aspects of a system. HRL ratings supplement the TRL ratings that are commonly used to easily communicate program status and ensure that fielded systems are both technically mature and ready for human use. Research has indicated that using high TRL technologies in development programs effectively manages costs and delays, increasing the chances of program success.²¹ Similarly, considerable research has demonstrated that proper attention to the humans in a system during design and development minimizes or prevents human error across a wide range of systems.^{1,2,3,4} Taken together, such findings suggest that equal attention to both the technical and human components of the system can be expected to increase the likelihood of fielding an optimal system that successfully supports the mission, while promoting effective user performance and satisfaction.

Human Views

The foundation for HRL concepts is the Human Viewpoint architecture framework introduced in 2007 to supplement existing architecture frameworks. Architecture frameworks are designed to capture and organize system information consistently across specific areas of interest, without losing sight of the system context. To represent specific areas of interest, architecture frameworks incorporate different perspectives or views of the system such as operational, standards, and systems viewpoints. The Human Views (HV) are the set of models included in this viewpoint.

Notably, however, current architecture frameworks do not include a viewpoint to capture the human performance aspects of the system and the human contribution to system effectiveness and cost. The Human Viewpoint was developed as an adjunct to existing system architecture frameworks to address shortcomings that had been noted in existing architecture frameworks by both system engineers and HSI practitioners.²² The Human Viewpoint provides a repository for human-focused data, i.e., elements that are either defined by or impacted by the human operator or user of the system. It also provides necessary relationships to other viewpoints to include the impact of human operators on the system design and resulting performance.²³ The development of a process to integrate humans into model based system engineering (MBSE) compelled systems architects to consider the human in its own architecture framework view instead of arbitrarily adding human considerations into other views.²⁴ Additionally, a retrospective of the Human Viewpoint details its inception and use over the past 10 years.²⁵

The HVs explicitly represent the human in the system and document the unique implications humans bring to system design. As such, they describe the primary areas of human consideration for system design, enabling an understanding of the human role in systems and enterprise architectures. The primary focus of the HVs is to capture human data and information with respect to interactions among humans and between humans and other system elements. The HVs were designed to be independent of any specific architecture framework and adaptable to different implementation processes. Using the complete set of Human Viewpoint models ensures the human component has visibility as part of the system architecture.²² Table 3 describes the eight individual HVs.²⁵

Table 3. Human View Descriptions

Human View (HV)	Name	Description
HV-A	Concept	High-level representation of the human component of the system
HV-B	Constraints	Repository for different sets of limitations
HV-C	Tasks	Descriptions of human-specific activities
HV-D	Roles	Descriptions of job functions defined for humans interacting with the system
HV-E	Human Network	Identification of human-to-human communication patterns, information flows, or work processes
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	Information necessary to complete a simulation of human impact on the system

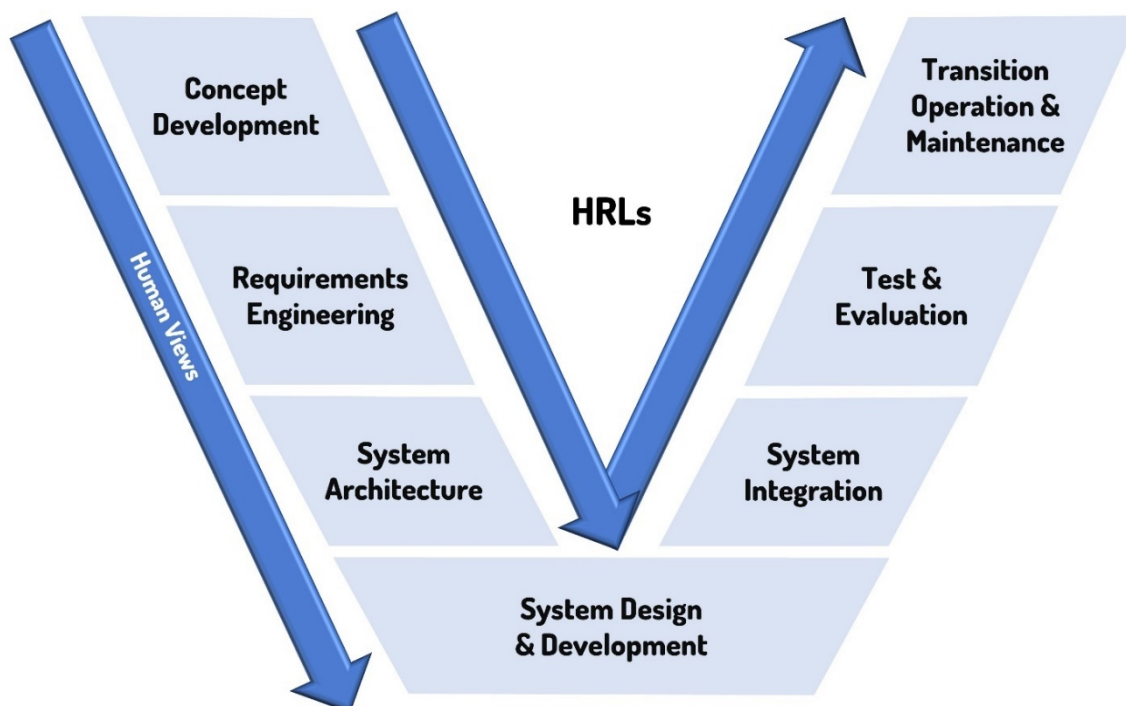
Relationship Between Human Views and Human Readiness Levels

The HVs provide a venue to engage systems engineers in the HRL evaluation process. HRLs emphasize that existing human-focused assessment processes and tools are critical to derive HRL

ratings. Artifacts from these existing processes and tools provide evidence to justify the current HRL rating and to support recommendations for transition to the next level. The HRLs describe consideration of human-focused requirements to support decision making about the developing system and can therefore leverage models developed through the system engineering process.¹⁴ The HVs represent one tool that can be brought to bear to assess the HRL level by providing the data to answer the questions about how human-focused requirements are incorporated into design decisions.

The HVs provide a fully integrated set of models to inform and influence system design, development, and production processes. While the HVs capture and organize data for engineering design and analysis, the HRLs identify the degree to which HSI requirements have been incorporated into design decisions. In this way, the HV data that are part of the architecture development can be referenced in the HRL assessment stages that align with the corresponding stage of system development. Together, the HVs and HRLs can reduce system risk by communicating information about the needs and constraints of the human component. HVs focus on the early stages of system engineering, while HRLs ensure humans are fully and continuously considered as part of the total system throughout the lifecycle. This relationship is illustrated in Figure 2 using the system engineering V-model. Note that while the HVs are initially composed early in the system development stage, they should be continually updated as design decisions are made, and system entities are defined. In this way, they continuously represent the as-is state of the system and can assist in later system engineering activities, such as test and validation.

Figure 2. Relationship Between Human Views and Human Readiness Levels



Mapping Human Views to Human Readiness Levels

As Dr. Mica Endsley pointed out in her plenary address at the National Defense Industrial Association (NDIA) Human Systems conference in 2015, the HVs can be used to support determination of ratings at the first four HRL levels.¹⁸ After HRL 4, HVs are no longer applicable because the system design has progressed beyond the system architecting stage where HVs are employed. Each HRL has a series of supporting questions that practitioners can use to determine if the necessary human-system requirements at that level have been addressed. These questions can be mapped to the individual components of the HVs to illustrate their use in supporting HRL decisions. Tables 4 and 5 depict these mappings for HRL levels 1 and 2 (comparable tables for the HRL 3 and 4 mappings are in Appendix A). As can be seen in the tables, only 4 of the 39 HRL questions in the first four HRL levels do not map directly to an HV description. Further, all HVs are represented at least once across the first four HRL levels. As every system development is different, there may be instances where the HV's collect information that informs the HRLs at an earlier or later level.

Table 4. Mapping Between HRL 1 Questions and Human Views

HRL 1 Question	Human View	Mapping Description
1. Have key human behaviors, capabilities, and limitations been identified?	HV-B	Constraints provide a repository for different limitations, including human limitations.
2. Have preliminary usage scenarios for potential users been identified?	HV-E	Human Network includes role groupings or teams, covering physical proximity of roles and virtual roles for specific task interactions.
3. Have potential key human performance issues and risks been identified and concomitant basic research conducted?	N/A	N/A
4. Has basic human research relevant to a developing concept or application been conducted?	HV-A	Concept is a high-level representation that visualizes and facilitates understanding of the human component of the system in relation to operational demands and system components.

Table 5. Mapping Between HRL 2 Questions and Human Views

HRL 2 Question	Human View	Mapping Description
1. Has knowledge of relevant human characteristics, capabilities, and limitations been refined?	HV-B	Constraints consider operator physical characteristics, movement capabilities, and limitations in various operating conditions.
2. Have key human-centered design principles, standards, and guidance been established?	HV-A	Concept is a high-level representation of the human component of the system that

HRL 2 Question	Human View	Mapping Description
		includes principles, standards, and guidance for human-use considerations.
3. Have usage scenarios been updated to include basic task descriptions for user roles?	HV-C HV-D	Tasks (HV-C) describe human-specific activities, i.e., functions assigned to humans in a system over its entire lifecycle. These functions are decomposed into a set of tasks that can be mapped to Roles (HV-D) .
4. Has human performance on legacy or comparable systems been analyzed to understand key human technology interactions, human behavior, and human performance issues?	HV-C HV-E	Tasks (HV-C) may create interface design guidelines based on task requirements. Further, elements of the Human Network (HV-E) may include impacts from different required interactions such as collaboration, coordination, and supervision.
5. Have potential sources of human error and misuse been identified?	HV-A	Concept is a high-level representation of the human component of the system, which includes identifying the types of human errors that may occur and ways in which humans may misuse system elements.
6. Are appropriate metrics for successful human performance being identified?	HV-G	Metrics provide a repository for human-related values, priorities, and performance criteria, mapping human factors metrics to other Human View elements.

All systems include a human-technology partnership of varying degrees that defines the extent to which systems depend on user interactions. The HVs facilitate the inclusion of human considerations during system design and development. While system engineers focus on the integration of all subsystems to ensure system success and stakeholder satisfaction, applying the HVs in the architecting stage can ensure integration of human considerations as well for optimal performance, usability, and safety. The data captured in the HVs can be used to provide a more complete description of the system for analysis and performance evaluation and provide the basis for HRL determinations at the early stages of system design.

Linking HRLs and Human Views to User-Centered Design

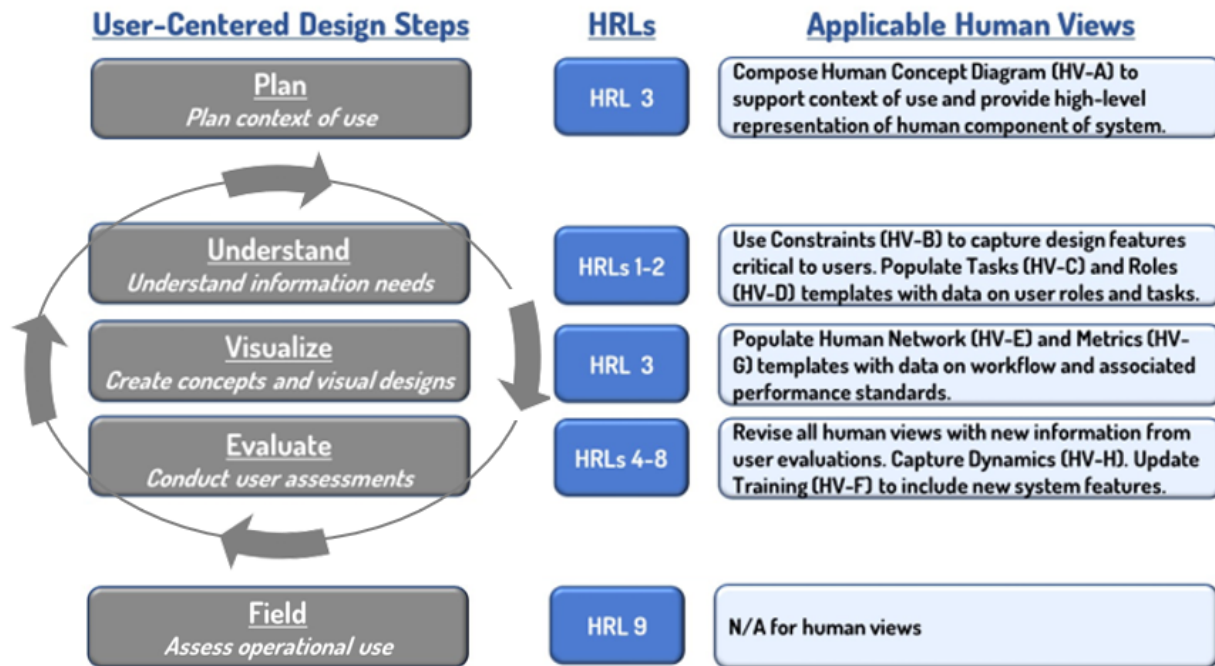
Overview

User-centered design is an approach that capitalizes on information about the people who will use the system during system development. The international standard for user-centered design defines a general process for including human-centered activities throughout the development lifecycle but does not specify exact methods.²⁶ User-centered design involves early and sustained focus on users, tasks, and environments and an appropriate allocation of functions among the users and the system components. User-centered design describes role interactions with the

envisioned system based on the different user types completing their required tasks. From these usage scenarios, a high-level system description can be determined, and system requirements can be defined.

The user-centered approach starts by identifying the different users who interact with the system and their roles, as defined by user responsibilities and needs.^{27,28,29,30} The tasks to be accomplished are listed and grouped by user types. Since tasks may cross user boundaries, they are often depicted in the form of a matrix mapping user roles to tasks. Usage scenarios describe how users will interact with the system to achieve their goals and can help derive requirements for the solution system. Scenario content will vary but typically includes the user's motivation, context, and goals. Creation of usage scenarios covering the different combinations of scenarios across roles, tasks, and technologies exemplifies how the system will be employed. A key element of user-centered design is collecting feedback from users throughout the design process to assess design assumptions and ensure the final system is ready and suitable for human use. Within user-centered design, readiness and suitability for human use are captured under the overarching term *usability*, which is defined as the extent to which a product can be used by specified users to achieve specified goals in a specified context of use.³¹

The user-centered design process generally progresses through five phases, from planning to fielding (Figure 3). As shown in Figure 3, all of the HRLs are applicable to the user-centered design process. However, since the phases comprising the user-centered design process can be revisited as necessary using an iterative approach, the process does not necessarily begin with HRL 1 or follow a strict linear progression from HRL 1 to HRL 9. Likewise, all of the HVs are applicable to the user-centered design process. In fact, they align quite naturally, given the focus of the user-centered design process on user tasks (HV-C), roles (HV-D), and usage scenarios (HV-E). While the data collected in a single view can be examined for completeness or content, the data across sets of HVs can be evaluated to identify appropriate types and range of data, inconsistencies among the data, and other project-specific concerns. The user-centered design approach provides an iterative development of the HVs as information is collected via user evaluations; the HVs provides a repository for the human-focused data elicited during the user-centered design process. The alignment among the user-centered design process, HRLs, and HVs shown in Figure 3 is illustrated in the next section with a real-world user-centered design example.

Figure 3. User-Centered Design Process Aligned with HRLs and Human Views

Real-World User-Centered Design Example

A user-centered design process is being applied to a current U.S. Army software modernization program, using the HRL scale to evaluate, track, and communicate the human readiness of the software. This process combining user-centered design with application of the HRL scale was used for various elements of another program that has been previously reported.^{32,33} The example described here highlights a different modernization program that is upgrading existing Precision Fires-Dismounted (PF-D) software. The PF-D system is a field artillery command and control software application used by forward-deployed dismounted Soldiers to transmit and receive fire support messages over standard military radios in a handheld device (Figure 4 Panel A). The HRL scale was applied in its entirety to PF-D, which is currently being used successfully in operations across the operational envelope by intended users. Although fielding is still in progress (HRL 9), the HSI team has begun conducting post-fielding user satisfaction assessments with units who have used the system more than six months. At the same time, the Army is seeking to field a new version of the software, called Precision Fires-Dismounted/Mounted (PF-D/M), that broadens the capabilities to include forward observer Soldiers operating the software mounted in tactical fire support vehicles (Figure 4 Panel B). While the dismounted user role is well-documented and understood, the mounted role is not.

Figure 4. Precision Fires-Dismounted (Panel A) and -Mounted (Panel B) Versions

The evaluation for this new mounted software version has progressed to HRL 5 at the time this paper was published, illustrating implementation of the HRLs in two different phases of the system development process—the “basic research and development” phase (Levels 1 – 3) and the “technology demonstration” phase (Levels 4 – 5). The approach for implementing the HRLs is the same, regardless of which phase is involved. Namely, application of HRL Levels 1 through 5 to the user-centered design process for the software involved determining whether each of the supporting questions at each level could be answered affirmatively. The last HRL for which all questions could be answered with a “yes” response identified the system’s HRL rating (Level 5 in this case). Although all HRL levels were completely addressed for the previous version of the software, it was necessary to begin again with HRL 1 for the new software version because it involves use of a different hardware interface as well as different user roles and tasks. The HSI team’s evaluations of select questions at each level for HRLs 1 through 5 are described in the following sections to illustrate how HRLs and HVs can be applied in the context of a real-world user-centered design process. Given that HSI is considered a system engineering discipline within the Department of Defense, all HSI evaluations were performed in close collaboration with the lead system engineer for the effort.

Human Readiness Level 1. HRL 1 represents a broad, high-level exploration of the nature of the human users in the system and the concomitant implications for design of the developing concept or the proposed practical application (i.e., the PF-D/M software). The intent is to begin addressing human involvement in the system at a very high level to start identifying the characteristics of the people who might use the concept or application and how they might use it. One key question at HRL 1 is Question 4, which relates to conducting human research relevant to the developing concept or application to promote improved understanding of human capabilities, limitations, performance, and behavior. This question maps specifically to HV-A (Concept) to support a high-level representation of the human component of the system. The HV-A graphic or description captures the general tasking and interactions among roles that the system will facilitate and compels an understanding about who the users are.

To learn more about the capabilities and limitations of the intended PF-D/M users for HRL 1 Question 4, the HSI team reviewed the literature on Army entrance exams and requirements for military occupational specialty (MOS) 13F, which is the MOS for Soldiers performing the duties of a joint fire support specialist. To qualify for MOS 13F, candidates must obtain a score of 96 percent or greater on the Armed Services Vocational Aptitude Battery (ASVAB) as well as passing scores on subtests for arithmetic reasoning, mathematics knowledge, coding speed, and mechanical comprehension. MOS 13F candidates undergo 10 weeks of basic training and 11 weeks of advanced individual training to gain proficiency in setting up and operating communications systems, encoding and decoding messages, preparing fire support plans, operating laser range finders and targeting devices, and determining target locations. Understanding the knowledge, skills, and abilities required of system users enabled the design team to identify specific system features for which design and evaluation attention was applied during later HRLs. For example, knowing users would operate laser range finders and targeting devices led designers to seek automated solutions for their connectivity to PF-D/M. Without the HRL scale, these solutions would not have been considered early in design or may not have been considered at all.

Human Readiness Level 2. At HRL 2, the human research begun at HRL 1 is transformed into applied research concepts. These concepts are more fully explored as additional information about proposed technologies and their application becomes available, supporting further analysis of the implications for human involvement and preliminary determinations of the technology characteristics that will support effective human use. HRL 2 Question 3 involves updating the preliminary usage scenarios identified in HRL 1 to include basic task descriptions for user roles. For the PF-D/M software, usage scenarios describe the basic course of events that transpire when Soldiers use the system to perform duties such as preparing fire support plans. This particular HRL question maps specifically to HV-C (Tasks) to describe human-specific activities and HV-D (Roles) to describe the job functions for humans interacting with the system. These HVs provide the templates for the practitioner to capture the data as they are collected.

To support evaluation of HRL 2 Question 3, the HSI team reviewed usage scenarios from the previous version of the software to gauge applicability to the new version of the software and the implications for its design. The same graphical user interface from the PF-D version of the software is being used for the mounted version but is being iteratively refined as needed. Therefore, the HSI team re-examined all previous scenarios to identify which elements might transfer directly to the PF-D/M interface and which elements would require additional modification and refinement for usability. For example, handheld laser range finders may be used by PF-D users whereas PF-M users in specific tactical ground vehicles will use a vehicle-integrated laser system. Initial usage scenarios were updated to reflect what was currently known about the digital systems used in fire support vehicles and annotations made to revisit the scenarios and fill knowledge gaps when further hardware details become available. A sample scenario is shown in Table 6. The HSI team also verified user roles and tasks for each scenario against information in the mission essential task list documented in TC 3-09.8 *Fire Support and Field Artillery Certification and Qualification*³⁴ and ATP 3-09.30 *Observed Fires*.³⁵

Table 6. Sample Usage Scenario to Address HRL 2 Question 3 for PF-D

Create a Target and Send it for Fire Mission Processing
Trigger: Battlefield threat fires on friendly troops Course of Events: 1. Actor navigates to Target Center 2. Actor selects “New” button 3. System displays new “Target Data” screen 4. Actor completes all required fields indicated by mandatory field indicators 5. System validates data according to data entry rules 6. Actor selects “Send” button when satisfied with accuracy of entered data 7. System validates data set is complete 8. System stores target and sends to selected recipient if validation is successful

Human Readiness Level 3. HRL 3 focuses on establishing requirements to support human performance and human-technology interactions, based on laboratory experiments and relevant analyses such as function, task, cognitive task, operational use, training needs, safety, and HSI domain analyses. Along these lines, HRL 3 Question 6 directly involves completing initial safety analyses for human users. The HSI domain for safety and occupational health is particularly important for new technologies and system upgrades to minimize introduction of human safety and occupational health hazards. Accordingly, preliminary safety requirements, risks, and implications are captured during evaluation of HRL 3 to support development of appropriate prevention and mitigation strategies in subsequent levels. This question maps specifically to HV-B (Constraints) to identify different sets of limitations. In this case, system design may be constrained by the need to mitigate or prevent identified safety issues. Constraints can include considerations of design features and operating characteristics of a system that may create significant risks of acute or chronic illness, injury, or death. The HV-B helps map the identified constraints to the relevant aspects of the system design.

To address HRL 3 Question 6, the HSI team leveraged work on the earlier PF-D version of the software. For that version, the HSI team worked directly with the Army’s Communications-Electronics Command Software Safety Engineer. The Software Safety Engineer provides subject matter expertise in system and software safety to minimize hazards for systems procured by the Army early in the acquisition process, in accordance with Army Regulation 385-10.³⁶ The Software Safety Engineer is responsible for executing the system safety program and was involved early in the acquisition process, beginning with the previous PF-D version of the software. The engineer developed a System Safety Management Plan, defined system-specific methods for determining the severity and probability of identified hazards, established a hazard tracking system, provided safety and occupational health domain content for inclusion in HSI assessments, documented a process to formally document acceptable risks specified in the System Safety Management Plan, and chartered the System Safety Working Group comprised of representatives from the user group, developers, testers, HSI personnel, and other stakeholders. All of this work was considered when performing safety analyses for the PF-D/M version of the software during HRL 3.

Human Readiness Level 4. HRL 4 marks the transition from basic research and development to technology demonstrations at increasing levels of fidelity. During HRL 4, modeling, part-task testing, and trade studies of human systems design concepts and applications are completed. HRL 4 Question 6 involves identifying and recommending strategies to accommodate manpower, personnel, and training concerns. The intent is to reduce lifecycle costs and provide systems that will be operable with known manpower, personnel, and training constraints to the extent possible. Tradeoffs between manpower, personnel, and training are considered during HRL 4. For example, design features that simplify operations may be recommended to minimize future cost and schedule resources required for manpower and training. Strategizing at this stage fosters appropriate technology use and reduces the likelihood of disuse and misuse. This question maps specifically to HV-B (Constraints) to identify different sets of manpower and personnel limitations and to HV-F (Training) to provide a detailed accounting of training requirements, strategy, and implementation.

To address the manpower aspect of HRL 4 Question 6, the HSI team explored the number of military and civilian personnel required, authorized, and potentially available to train, operate, maintain, and support the PF-D/M software system. Workload balancing is not a major concern since this system is for only a single user. Nevertheless, the HSI team continually monitors workload during demonstrations and tests to ensure a single user can operate the software, regardless of operational environment conditions and constraints. With respect to personnel, Developmental Operations exercises and usability testing were used to assess the extent to which operation of the software system would require new skills. For example, during evaluation of the previous PF-D version of the software, ability to establish, maintain, and troubleshoot digital communications was identified as a high severity issue. The design and development team collaborated on a solution to sustain communications when systems have mismatched technical connectivity information and through effective design facilitate users' ability to update incorrect information with the press of a single button. Stringent usability measures and metrics (e.g., 85% of users will accomplish tasks on the first attempt with no training) and adherence to tasks with doctrinal time standards help ensure success of the system when it reaches the battlefield.

With respect to training, the HSI team placed early focus on streamlining workflows, enhancing help text in the software, and embedding help within the application. Of note for training, the HSI team identified a gap in training coverage during evaluation of HRL 4 for the previous PF-D version of the software. During the Developmental Operations exercise, it was discovered that Soldiers were unable to set up the routing lists required in the scenario. This training gap also represented a void in the usage scenario itself. The scenario was subsequently updated to include this functionality. These modifications were transferred to the PF-D/M training evaluation during HRL 4, as applicable.

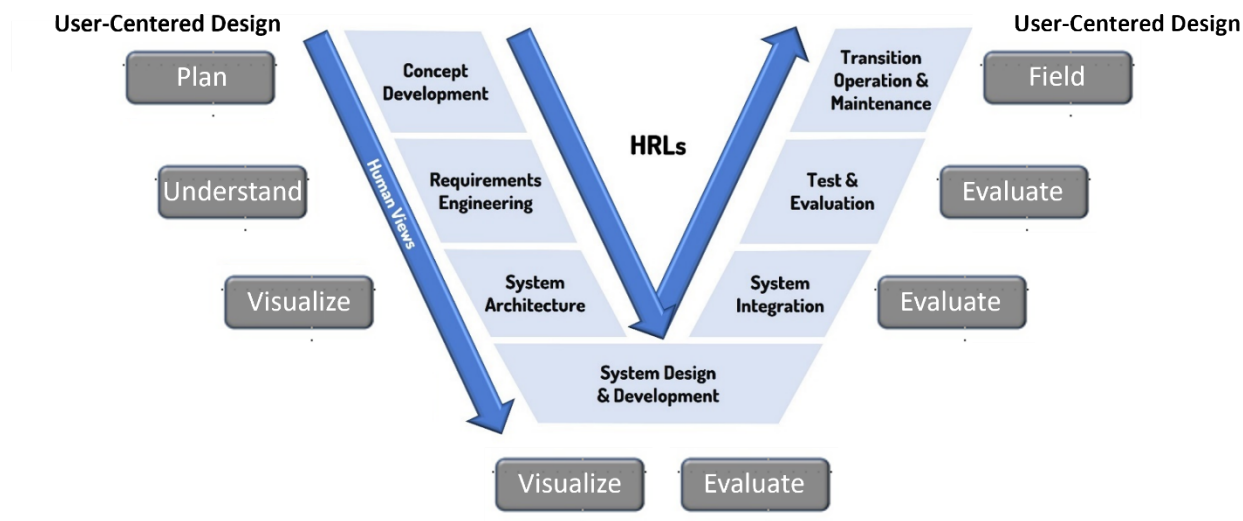
Human Readiness Level 5. HRL 5 involves evaluation of human performance via prototypes in mission-relevant part-task simulations or actual environments. HRL 5 represents the latest level to begin engaging representative users during testing; however, the HSI team for

the PF-D/M software was able to engage representative users throughout the entire user-centered design process to ensure external validity of test results. Although the HVs are applicable only through HRL 4, the PF-D/M software has progressed to HRL 5 to date. Therefore, for completeness, the activities conducted at HRL 5 are briefly described here. To address HRL 5, human performance data were collected via a number of usability tests in which Soldiers were asked to perform relevant tasks with the software, as they would in the field. For all usability tests, an 85% metric was used to determine whether results are considered acceptable. This 85% metric is based on the expectation that Soldiers who have completed MOS training should be able to use a system to complete mission-critical tasks on their first attempt 85% of the time. The most recent usability test for the PF-D/M software identified 13 issues that failed to meet the 85% usability target (i.e., less than 85% of Soldiers rated ease of use as 3 or 4 on a four-point scale). For example, Soldiers experienced difficulties when performing a task to save frequently used messages to favorites. Some users could not find the option to add a message as a favorite and did not know where to look. They provided suggestions to the HSI team to improve this task before fielding (e.g., place a star next to a message so it can quickly be added to the “favorites” list).

Conclusions and Practitioner Guidance

Human systems experts have often struggled to quantify the progress of their efforts, as there is no single performance measure for HSI. The HRL scale fills this gap by providing a metric for HSI status and maturity that can be easily communicated to program managers and leaders throughout the system development process. The HVs provide a customizable architecture framework that collects human-focused data required to support system development.²³ The HVs were designed to be integrated with an architecture framework to support tradeoff analyses across both technology and humans and as a bridge between the system engineering and HSI communities.³⁷ User-centered design involves conducting user research early in the system design process to facilitate the conceptualization of a user interface, identify areas for design emphasis, and inform design trades. As shown in Figure 5, this paper highlights the relationship among these three different aspects of a human-focused design.

Figure 5. Relationship Between Human Views, Human Readiness Levels, and User-Centered Design



Application of the HRL scale to the U.S. Army software modernization program in the context of user-centered design demonstrated that the HRL scale is flexible and tailorable to program needs. For example, at times, the HSI team discovered that a particular HRL supporting question had already been answered sufficiently when an earlier question in the HRL scale was addressed. Further, the HSI team found that results from previous user-centered design activities for a similar system could be leveraged to expedite completion of the present effort. In accordance with the guidance in the ANSI/HFES 400-2021 standard, the HSI team also exercised the flexibility to skip HRL questions that were not applicable to the software modernization program. Specifically, the question regarding maintenance and sustainment in HRLs 4 through 8 was deemed not applicable for this program because software updates are handled by the host platform. The team determined that the HRL framework suitably addressed HSI considerations throughout the Army acquisition process and effectively adhered to the key Army HSI program tenet to *focus on the Soldier*. An HRL rating can be calculated at any point in the acquisition process to provide an indication of performance risks and support course corrections. With each increase in the program's TRL rating, its HRL rating was calculated. Each time, the two ratings were in alignment, demonstrating human systems design and evaluation activities can keep pace with the rest of the technological system when the ANSI/HFES 400-2021 standard is used to guide a user-centered design process.

It should be noted that all of these observations are based on the current application within a software modernization program. Application of the HRL scale to hardware and integrated hardware/software development efforts has not yet been specifically demonstrated. However, the outcomes reported in this paper are expected to be generalizable, given that the strategy to apply the HRL scale applies generically across multiple types of systems and technologies.

The HRL and HV tools described in this paper could be used in isolation to effectively address the human component of a system at any time throughout the lifecycle. However, using the tools

in combination may multiply the beneficial impacts because it incorporates the human element from multiple fronts and angles concurrently. Use of HVs ensures the human component is seen as a part of the system architecture and is just as critical as the technological components. The HVs also provides an organized repository for collected data. HRLs offer a mechanism for consistent evaluation and communication of human readiness across diverse technologies, organizations, and practitioners. User-centered design is an existing iterative evaluation and refinement process that provides a context in which to apply HRLs and HVs to support an effective, suitable, and survivable design. While one tool is better than none, human systems practitioners should consider applying both tools in the context of user-centered design during system design and development and educating other system engineers on their unique and combined advantages.

ORCID

Holly A. H. Handley  <https://orcid.org/0000-0002-4798-003X>

Judi E. See  <https://orcid.org/0000-0002-4089-5609>

Pamela A. Savage-Knepshield  <https://orcid.org/0000-0001-7887-7011>

References

1. Chen S-T, Wall A, Davies P, Yang Z, Wang J, Chou Y-H. A human and organisational factors (HOF) analysis method for marine casualties using HFACS-maritime accidents (HFACS-MA). *Safety Sci.* 2013; 60: 105–114. doi:10.1016/j.ssci.2013.06.009
2. Ghasemi M, Nasleseraji J, Hoseinabadi S, Zare M. Application of SHERPA to identify and prevent human errors in control units of petrochemical industry. *Int J Safety Ergon.* 2013; 19(2): 203–209. doi:10.1080/10803548.2013.11076979
3. Shappell S, Detwiler C, Holcomb, K, Hackworth, C, Boquet A, Wiegmann, D. Office of Aerospace Medicine. *Human error and commercial aviation accidents: A comprehensive, fine-grained analysis using HFACS*. Report No. DOT/FAA/AM-06/18. July, 2006. Accessed September 11, 2023. <https://commons.erau.edu/publication/1218>
4. Vaurio JK. Human factors, human reliability and risk assessment in license renewal of a nuclear power plant. *Reliab Eng Sys Saf.* 2009; 94(11): 1818–1826. doi:10.1016/j.ress.2009.05.014
5. Pew RW, Mavor AS. *Human-System Integration in the System Development Process: A New Look*. National Academies Press; 2007.
6. US Government Accountability Office. Technology readiness assessment guide: Best practices for evaluating the readiness of technology for use in acquisition programs and projects. Report No. GAO-20-48G. January 2020. Accessed September 11, 2023. <https://www.gao.gov/assets/gao-20-48g.pdf>
7. Mankins JC. Technology readiness levels: A white paper. National Aeronautics and Space Administration. 1995. Accessed September 11, 2023. http://www.artemisinnovation.com/images/TRL_White_Paper_2004-Edited.pdf

8. National Aeronautics and Space Administration. Integrated technology plan for the civil space program. Report No. NASA-TM-107988. Office of Aeronautics and Space Technology. 1991. Accessed September 11, 2023. https://www.lpi.usra.edu/lunar/strategies/NASALunarArchitecture/exp_tech_plan.pdf
9. Acosta H. Human readiness levels: Implementing HSI—Connecting some dots. Panel discussion: 81st Annual Scientific Meeting of the Aerospace Medical Association; May 9–13, 2010; Phoenix, AZ.
10. American National Standards Institute/Human Factors and Ergonomics Society. Human readiness level scale in the system development process. 2021. my.hfes.org/online-store/publications
11. Craft, R. A comparison of ten human systems integration management tools. Report Number SAND2021-14553 O. 2021. Sandia National Laboratories.
12. See, JE, Craft, R, & Morris, JD. Human readiness levels in the systems engineering process at Sandia National Laboratories. Report Number SAND2019-3123. March 2019. Sandia National Laboratories. Accessed March 11, 2024. <https://www.osti.gov/servlets/purl/1761924>
13. Salazar G, Russi-Vigoya MN. Technology Readiness Level as the Foundation of Human Readiness Level. *Ergonomics in Design*, 2021; 29(4), 25-29. <https://doi.org/10.1177/10648046211020527>
14. See, J. Human readiness levels explained. *Ergonomics in Design: The Quarterly of Human Factors Applications*, 2021; 29(4), 5–10. <https://doi.org/10.1177/10648046211017410>
15. Schwartz, B, Dodson, J. Human readiness levels promote effective system integration. *Ergonomics in Design: The Quarterly of Human Factors Applications*, 2021; 29(4), 11–15. <https://doi.org/10.1177/10648046211021250>
16. Phillips EL. The development and initial evaluation of the human readiness level framework [Unpublished master's thesis]. Naval Postgraduate School. 2010. <https://apps.dtic.mil/sti/pdfs/ADA525365.pdf>
17. O'Neil MP. Development of a human systems integration framework for Coast Guard acquisition [Unpublished master's thesis]. Naval Postgraduate School. 2014. <https://apps.dtic.mil/dtic/tr/fulltext/u2/a608012.pdf>
18. Endsley M. Human readiness levels: Linking S&T to acquisition ...and beyond. Plenary address presented at: 2015 National Defense Industrial Association Human Systems Conference, February 10–11, 2015; Alexandria, VA. https://ndiastorage.blob.core.usgovcloudapi.net/ndia/2015/human/WedHumanReadinessLevels_NDIA_HSC_021115.pdf
19. Phillips H. DOD HFE TAG: Human readiness level (HRL) working group. Paper presented at: DOD HFE TAG 69th Meeting; May 4–8, 2015; Orlando, FL.
20. Salazar G, See JE, Handley HAH, Craft R. Understanding human readiness levels. *Proc Hum Factors Ergon Soc Annu Meet*; 2021; 64(1): 1765–1769. doi:10.1177/1071181320641427
21. US Government Accountability Office. Best practices: Better management of technology development can improve weapon system outcomes. Report No. GAO/NSIAD-99-162. July 1999. Accessed March 11, 2024. <http://www.gao.gov/assets/160/156673.pdf>

22. North Atlantic Treaty Organisation. Human systems integration for network centric warfare. Report No. TR-HFM-155. February, 2010. Accessed September 11, 2023. <https://apps.dtic.mil/sti/tr/pdf/ADA524077.pdf>
23. Handley HAH, Smillie RJ. Architecture framework human view: The NATO approach. *Sys Eng*. 2008; 11(2): 156–164. doi:10.1002/sys.20093
24. Watson M, Rusnock C, Colombi J, & Miller M. (2017). Human-centered design using system modeling language. *J Cogn Eng Decis Making*. 11(3): 252-269.
25. Handley HAH. A retrospective of the human viewpoint and its applicability to future systems. *Sys Eng*. 2021; 25(1): 91–103. doi:10.1002/sys.21603
26. International Organization for Standardization. Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems. ISO 9241-210:2019. July, 2019. Accessed September 11, 2023. <https://www.iso.org/standard/77520.html>
27. Holtzblatt, K., Wendell, J.B., Wood, S. (2005). *Rapid contextual design: a how-to guide to key techniques for user-centered design*. Morgan Kaufmann. DOI: 10.1145/1066348.1066325.
28. Holtzblatt, K. & Beyer, H. (2016). Contextual design: design for life (interactive technologies). Morgan Kaufmann. ISBN: 978-0-12-800894-2.
29. Savage-Knepshild, P. (2012). Soldier-centered design and evaluation techniques. In P. Savage-Knepshild, J. Martin, J. Lockett III, & L. Allender, L. (Eds.), *Designing soldier systems* (pp. 275-307). CRC Press. ISBN: 978-1-4094-0777-5.
30. Vredenburg, K., Mao, J.-Y., Smith, P. W. & Carey, T. (2002). A survey of user-centered design practice. In D. R. Wixon (Ed.), *CHI* (pp. 471-478), ACM. ISBN: 1-58113-453-3
31. Savage-Knepshild P. *Real-world application & exercise: Use of the HRL Scale in an Army acquisition program*. Presented at: Hum Factors Ergon Soc 66th Intl Annu Meet; August 10–14, 2022; Atlanta, GA.
32. Savage-Knepshild PA, Hernandez CL, Sines S. Exploring the synergy between human systems integration and human readiness levels: A retrospective analysis. *Ergon Des*; 2021; 29(4): 16–24. doi:/10.1177/10648046211009718
33. ISO 9241—11:2018. Ergonomics of human-system interaction – Part 11: Usability: Definitions and concepts.
34. Department of the Army. Fire support and field artillery certification and qualification. TC 3-09.8. March 30, 2020. Accessed September 11, 2023. https://armypubs.army.mil/epubs/DR_pubs/DR_a/ARN30053-TC_3-09.8-001-WEB-1.pdf
35. Department of the Army. Observed fires. ATP 3-09.30. September 28, 2017. Accessed September 11, 2023. https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/ARN5011_ATP%203-09x30%20FINAL%20WEB.pdf
36. Department of the Army. The Army safety and occupational health program. Army Regulation 385-10. July 24, 2023. Accessed September 11, 2023. https://armypubs.army.mil/epubs/DR_pubs/DR_a/ARN34981-AR_385-10-000-WEB-1.pdf
37. Bruseberg A. Human views for MODAF as a bridge between human factors integration and systems engineering. *J Cogn Eng Decis Mak*. 2008; 2(3): 220–248. doi:10.1518/155534308X377090

Appendix A

Table A-1. Mapping Between HRL 3 Questions and Human Views

HRL 3 Question	Human View	Mapping Description
1. Have human systems experts with requisite expertise been engaged and funded to support the design and development effort?	N/A	N/A
2. Have usage scenarios been updated, based on human needs analyses for the proof of concept?	HV-E	Human Network captures human-to-human communication patterns that occur as a result of team formation or work processes.
3. Have cognitive task analyses and function and task analyses for each user role been completed?	HV-D	Roles describe roles for humans interacting with the system. A role represents a job function defining specific behavior within an organization and related semantics regarding user authority and responsibility in that role and job competencies.
4. Have candidate human-machine function allocations been evaluated, based on the human needs analyses for the proof of concept?	HV-C	Tasks clarify human-related functions in a system and can provide justification for allocation of functions between humans and machines.
5. Have situation awareness information flow and sharing requirements across teams of human or automated system components been identified?	HV-E	Human Network includes communication patterns and technology impact, i.e., distributed cognition, shared awareness, common operational picture, etc.
6. Have initial safety analyses for human users been completed?	HV-B	Constraints can include considerations of design features and system operating characteristics that create significant risks of illness, injury, or death.
7. Have initial manpower, personnel, and training analyses been completed?	HV-B HV-F	Constraints (HV-B) can include manpower requirements for supporting present and future capabilities as well as supporting personnel types by rank and job within each category. Training (HV-F) provides a detailed accounting of training requirements, strategy, and implementation.

HRL 3 Question	Human View	Mapping Description
8. Have initial environmental conditions, constraints, and impacts been analyzed?	HV-B	Constraints provide a repository for different limitations, including those imposed by the environment.
9. Have initial analyses for other relevant HSI domains been completed?	N/A	N/A
10. Have initial analyses to address human interactions during maintenance and sustainment been completed?	HV-D	Roles may define other attributes of a role such as responsibilities for different system usages.
11. Have characteristics of the target population been specified?	HV-B	Constraints consider operator physical characteristics, movement capabilities, and limitations under various operating conditions.
12. Are human capabilities, limitations, and needs being mapped to expected operational and system demands to identify human performance issues and system requirements?	HV-G	Metrics may map high-level (qualitative) values to quantifiable performance metrics and assessment targets, or they may map measurable metrics to human functions. Metrics provide the basis for human factors assessments, requirements tracking, and certification.
13. Have relevant human performance data been collected and evaluated to determine the feasibility of appropriate metrics for successful human performance, based on the proof of concept?	HV-G	Metrics may include human performance metrics (what is to be measured), target values (what quantifiable value is acceptable), and human function-to-metrics mapping.
14. Have preliminary design features to accommodate human capabilities, limitations, and needs been investigated and recommended, based on the proof of concept?	HV-A	Concept depicts how the human will impact performance (mission success, survivability, supportability, and cost) and how the human will be impacted by system design and operational context (personnel availability, skill demands, training requirements, workload, and wellbeing).
15. Have requirements to support human performance been identified and included in system level requirements?	HV-G	Metrics may include metrics specified as human performance requirements needed to support system level requirements.

Table A-2. Mapping Between HRL 4 Questions and Human Views

HRL 4 Question	Human View	Mapping Description
1. Have analytical tools, models, and prototypes for human systems design concepts or applications been developed for each class of user to support assessment of critical human performance issues?	HV-H	Dynamics capture changes in states, configurations, and performance parameters over time or due to varying conditions or triggering events. Dynamics can inform other design aspects (when capturing behavior aspects) and can be used to assess design decisions (by modeling future behavior).
2. Have usage scenarios been updated, based on modeling and part-task testing?	HV-H	Dynamics include timelines and defined mission phases as well as critical, frequent, and typical scenarios;
3. Have task analyses been updated based on the developing prototype and optimized for human performance, using modeling and part-task testing?	HV-C	Tasks are descriptions of human-specific activities that can be captured in task analyses.
4. Have human-machine teaming and function allocations been updated, based on modeling and part task testing?	HV-C	Tasks clarify human-related functions in a system and can provide justification for allocation of functions between humans and machines.
5. Have strategies to mitigate safety implications for human users been identified and recommended?	HV-B	Constraints can include considerations of design features and system operating characteristics that create significant risks of illness, injury, or death.
6. Have strategies to accommodate manpower, personnel, and training concerns been identified and recommended?	HV-B HV-F	Constraints (HV-B) can include manpower requirements for supporting present and future capabilities as well as supporting personnel types by rank and job within each category. Training (HV-F) provides a detailed accounting of training requirements, strategy, and implementation.
7. Have strategies to address environmental constraints and impacts been identified and recommended?	HV-B	Constraints provide a repository for different limitations, including those imposed by the environment.
8. Have strategies to address other relevant HSI domains been identified and recommended?	N/A	N/A

HRL 4 Question	Human View	Mapping Description
9. Have strategies to address human interactions during maintenance and sustainment been identified and recommended?	HV-D	Roles may define additional attributes of a role such as responsibilities for different system usages.
10. Is modeling and part-task testing being used to design procedures for human user roles throughout the lifecycle?	HV-C	Tasks may be described in terms of criteria such as requirements for knowledge, skills, and abilities. Tasks may create interface design guidelines and task completion methods based on task requirements.
11. Have analyses been completed to support systemwide trade studies for features affecting human performance?	HV-H	Dynamics may include states and state changes, e.g., organizational/team structure, function/role assignments to people, team interaction modes, demands on collaboration load, task switches/interruptions, and conditions (e.g., triggering events and scenarios).
12. Have relevant human performance data been collected and evaluated to determine whether human performance metrics are successfully met, based on modeling and part-task testing?	HV-H	Dynamics may include a sequence of consecutive tasks and performance measures (observed or predicted), e.g., workload; decision speed; team interaction/collaboration style; trust in commander's intent; quality of shared awareness, coordination, or implicit communication.
13. Have strategies to support human use been identified and recommended, based on modeling, part task testing, and trade studies?	HV-C	Tasks provide descriptions of human-specific activities that may be observed via modeling and part-task testing.
14. Has conformance of preliminary designs to human performance requirements, design principles, standards, and guidance been verified?	HV-B HV-G	Constraints (HV-B) include human resource policies as well as essential tasks, skills, and knowledge (proficiency level) required for a given job. Metrics (HV-G) may include quantifiable performance metrics and assessment targets and may map measurable metrics to human tasks.