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Applying the HRL Scale to Human-Machine Teaming

Human-Machine Collaboration For National Security Workshop

Frameworks and Architectures Session

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PRESENTED BY

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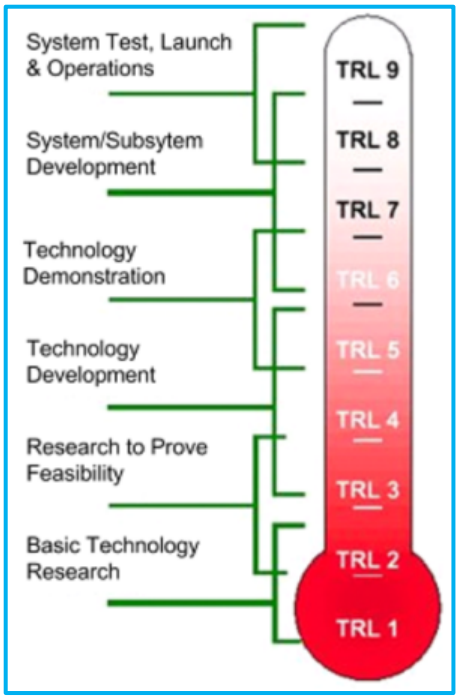
Human Readiness Level (HRL) Scale

- Simple nine-level scale to evaluate, track, and communicate readiness of a system for human use
  - Complements and supplements existing TRL scale during technology development
  - Provides a familiar systematic and consistent approach
  - Focuses on readiness of a technology for human use
  - Fully incorporates human element throughout lifecycle
- TRLs are routinely used throughout DOD, DOE, industry, and academia
- Value of TRLs is widely recognized

HRLs do for humans what TRLs do for technology



Provide Assurance That:	
TRL	Technology will function as intended
HRL	Human is able to use the technology as intended

DOD = Department of Defense; DOE = Department of Energy; TRL = Technology Readiness Level

HRL and TRL Scales

Increasing Maturity

Level		Technology Readiness Level	Human Readiness Level
Production / Deployment	9	Operational use of deliverable	System successfully used in operations across the operational envelope with systematic monitoring of human-system performance
	8	Actual deliverable qualified through test and demonstration	Total human-system performance fully tested, validated, and approved in mission operations, using completed system hardware and software and representative users
	7	Final development version of the deliverable demonstrated in operational environment	Human-system interfaces fully tested and verified in operational environment with system hardware and software and representative users
Technology Demonstration	6	Representative of the deliverable demonstrated in relevant environments	Human-system interfaces fully matured as influenced by human performance analyses, metrics, prototyping, and high-fidelity simulations
	5	Key elements demonstrated in relevant environments	User evaluation of prototypes in mission-relevant simulations completed to inform design
	4	Key elements demonstrated in laboratory environment	Modeling, part-task testing, and trade studies of user interface design concepts completed
Research & Development	3	Concepts demonstrated analytically or experimentally	Requirements for supporting human performance established
	2	Concept and application formulated	Human-focused concept of operations defined and human performance design principles established
		Basic principles observed and	Relevant human capabilities, limitations, and

Understanding HRLs

- Contributions of HRL concept can be understood by examining consequences of neglecting human readiness during development
- U.S. Army Stinger Missile example (Tully, 1986)
  - Fielded at TRL 9
  - Designed for a specific kill probability
  - Actual kill probability was significantly lower by 30% once operators were in the loop
  - Designers assumed human performance would be perfect
  - Soldiers found the missile difficult to use
    - Too complicated
    - 18 separate steps to fire it

If an HRL scale had been used for the Stinger Missile, human performance issues would have been recognized and mitigated earlier in development before fielding.

Tully, A. (1986, September 4). Army finds Stinger too complex. *Reading Eagle.* https://news.google.com/newspapers?nid=1955&dat=19860904&id=Rh0iAAAAIBAJ&sjid=

HRL History

- Concept first proposed in 2010
- Research, maturation, evaluation, and peer review accomplished via diverse organizations and multiple human systems experts
- Early work conducted at Naval Postgraduate School
  - Initial nine-level HRL scale
  - Extension to standardized HSI framework
- Matured through two different working groups
  - 2015 working group led by DOD
  - 2019 working group led by SNL

2019 HRL Working Group Members

Working Group Core Team:

Dr. Holly Handley
Old Dominion University

Mr. Michael O'Neil
Naval Postgraduate School

Dr. Judi See
Sandia National Laboratories

Organization	Number
Air Force	2
Army	1
Navy	4
DOE	10
FAA	1
NASA	4
Industry	10
Academia	6
Total	**38**

FAA = Federal Aviation Administration; HSI = Human Systems Integration; NASA = National Aeronautics and Space Administration; NPS = Naval Postgraduate School

Current HRL Work

- HRL scale is being transformed into a formal ANSI/HFES technical standard
  - Lend legitimacy to HRL scale and promote acceptance
  - Provide a reference to support HRL use in formal programs of record
  - Generate awareness outside HSI community
- Writing committee established in September 202
  - Chair: Judi E. See
  - Writing committee: 10 members
- Draft standard will be available 45 days for publi review
- Separate consensus committee will vote whether to approve standard
- Expected completion August 2021

HRL Writing Committee Membership
Federal Aviation Administration
General Motors Company
Human Factors and Ergonomics Society
Johns Hopkins Applied Physics Laboratory
Navy Expeditionary Combat Command
Northrop Grumman
Old Dominion University
SA Technologies
Sandia National Laboratories

ANSI = American National Standards Institute; HFES = Human Factors and Ergonomics Society

Structure of the HRL Scale

- HRL scale is structured to mirror existing TRL calculator tools
  - Each HRL level identifies multiple yes/no "trigger" questions
  - Indicate potentially relevant evaluations to address at that level
- HRL 1: Relevant human capabilities, limitations, and basic human performance issues and risks identified

1. Have potential key user capabilities and limitations been identified?
2. Are usage scenarios for potential users being identified?
3. Have potential key human system issues throughout the lifecycle been identified?
4. Is basic human research relevant to the developing concept or application being conducted?

HRL scale questions serve as triggers to consider applicability of multiple HSI topics throughout design and development.

Application to Human-Machine Teaming

- Like TRLs, HRLs are designed to apply broadly across diverse technologies and organizations
  - Primary question is whether a technology is ready for human use
  - Have suitability and usability for human use been evaluated?
  - Questions are generic in nature
    - E.g., Are usage scenarios for potential users being identified?
    - Questions address whether important human systems activities and evaluations have been performed
- HRL scale supports systematic evaluation in the human-machine teaming domain
  - Comprehensive evaluation of human role in proposed human-machine teaming scenario is critical
  - Multiple questions throughout HRL scale are particularly relevant

HRL scale does not prescribe how to design the human-machine teaming system. It helps human systems experts determine if they have effectively addressed all options to design a system ready for people to use.

Sample HRL Questions

Level		Human Readiness Level	Relevant Questions
Production / Deployment	9	System successfully used in operations across the operational envelope with systematic monitoring of human-system performance	Are human systems performance data and lessons learned being documented?
	8	Total human-system performance fully tested, validated, and approved in mission operations, using completed system hardware and software and representative users	Have human use issues been satisfactorily resolved?
	7	Human-system interfaces fully tested and verified in operational environment with system hardware and software and representative users	Has conformance of final development deliverable to human performance requirements, design principles, standards, and guidance been verified?
Technology Demos	6	Human-system interfaces fully matured as influenced by human performance analyses, metrics, prototyping, and high-fidelity simulations	Has the range of user scenarios and tasks been tested in high-fidelity environments?
	5	User evaluation of prototypes in mission-relevant simulations completed to inform design	Has the suitability of human-machine function allocations been updated?
	4	Modeling, part-task testing, and trade studies of user interface design concepts completed	Have strategies to support human use been identified and recommended?
R & D	3	Requirements for supporting human performance established	Have candidate human-machine function allocations been evaluated?
	2	Human-focused concept of operations defined and human performance design principles established	Have key human performance design principles, standards, and guidance been researched?

Summary and Conclusions

- Application of HRL scale can capture and mitigate human systems issues early in design phase for any type of system
- Shifts attention from lagging indicators to leading indicators
- Supports activities to enhance usability and minimize human error before systems are fielded for human use

- **Lagging Indicators:** human error in fielded systems
- **Leading Indicators:** evidence-based measures of usability readiness

Application of the HRL scale to human-machine teaming designs ensures the human element in the system is considered early and often.

Thank You!

For additional information or questions, contact Judi See at jesee@sandia.gov or 505-844-4567.