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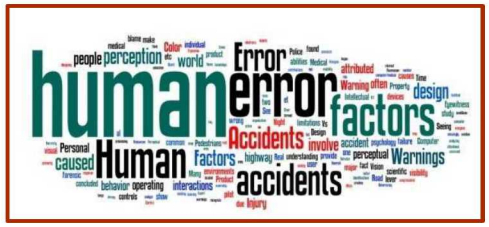
U.S. DEPARTMENT OF ENERGY

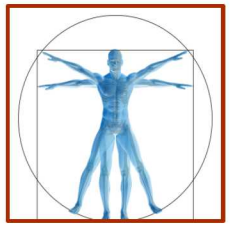
National Nuclear Security Administration

SAND2020-10845C

Maturation of the Human Readiness Level Scale

National Defense Industrial Association
2020 Virtual Systems and Mission Engineering Conference
November 10, 12-13, 2020





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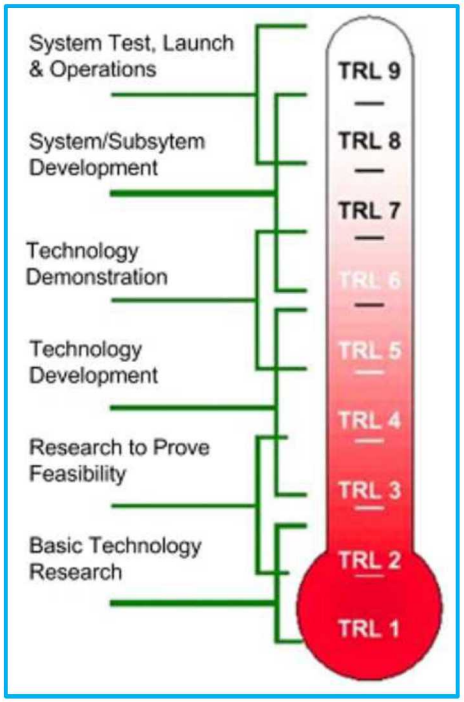
Human Readiness Level (HRL) Scale

- HRL scale is a 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
	1	Basic principles observed and reported	Relevant human capabilities, limitations, and basic human performance issues and risks identified

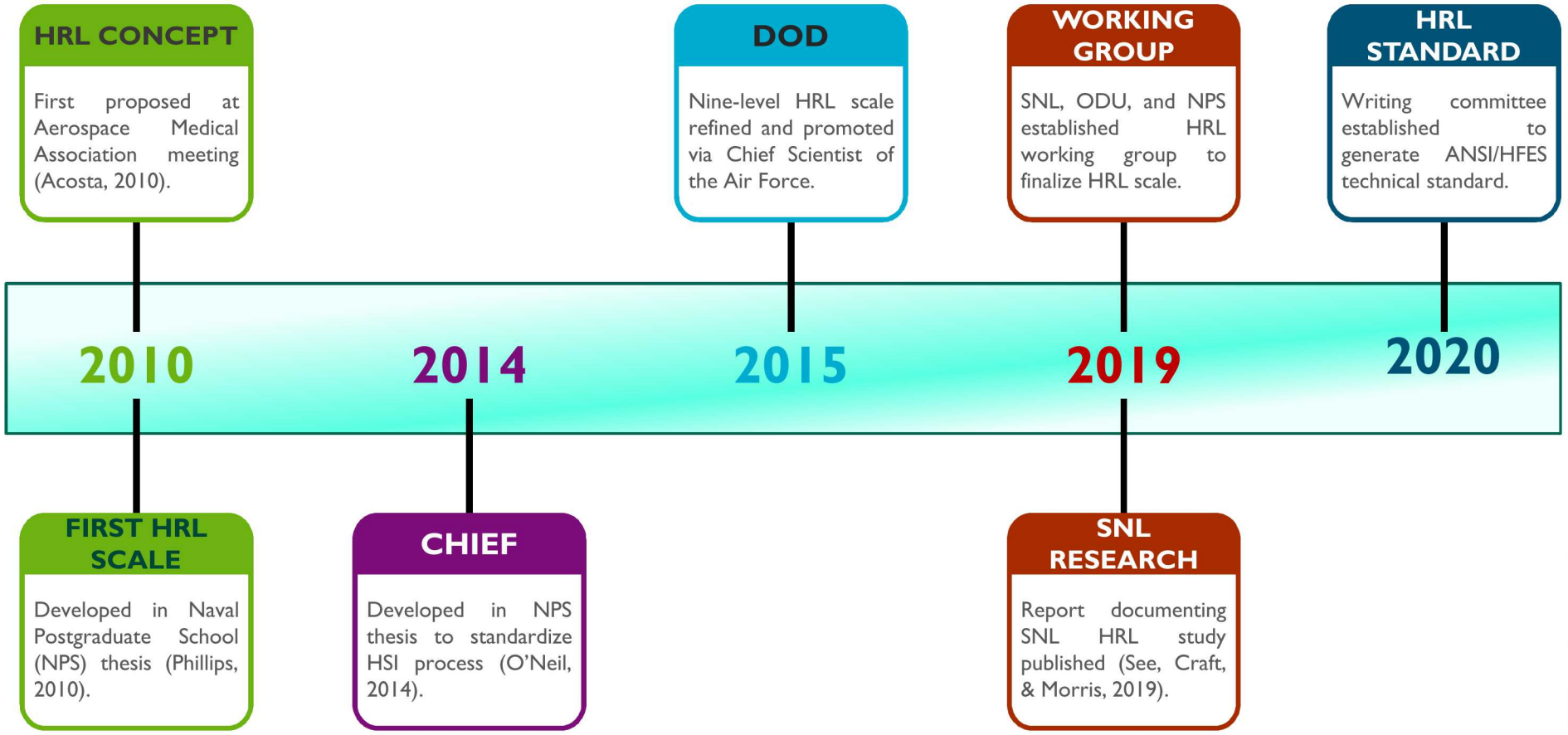
Understanding HRLs

- 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.

Timeline of HRL Scale Maturation

From Initial Concept to HRL Standard



The concept of human views developed in the early 2000s provided a foundation for HRL scale.

ANSI = American National Standards Institute; CHIEF = Comprehensive Human Integration Evaluation Framework; HFES = Human Factors and Ergonomics Society; HSI = Human Systems Integration; ODU = Old Dominion University

HRL Concept Proposed

HRL CONCEPT

First proposed at Aerospace Medical Association meeting (Acosta, 2010).

- Year 2010
- Aerospace Medical Association Meeting
- Phoenix, Arizona
- Discussion panel
- Dr. Hector Acosta

The goal in postulating the HRL concept was to reduce technology risks related to the human element by ensuring comprehensive HSI coverage during technology maturity assessments.

First HRL Scale

FIRST HRL SCALE

Developed in Naval Postgraduate School (NPS) thesis (Phillips, 2010).

- Year 2010
- NPS Master's Thesis: *The Development and Initial Evaluation of the Human Readiness Level Framework*
- Student: Eric L. Phillips
- Thesis Advisor: Dr. Hector Acosta

- Initial nine-level HRL scale developed
- 15 HSI and defense acquisition experts provided feedback
  - Saw value in HRL concept to support HSI planning and program risk management
  - Requested more detailed descriptions at each level
- Follow-on case study
  - HSI practitioner applied scale to developmental Air Force acquisition program
  - Recommended expanding list of HSI activities at each HRL level to cover broader range of program needs

CHIEF Framework

CHIEF

Developed in NPS thesis to standardize HSI process (O'Neil, 2014).

- Year 2014
- NPS Master's Thesis: *Development of a Human Systems Integration Framework for Coast Guard Acquisition*
- Student: Michael P. O'Neil
- Thesis Advisor: Dr. Lawrence G. Shattuck

- Comprehensive Human Integration Evaluation Framework (CHIEF) to standardize HSI throughout design and development
- Rates the state of HSI throughout development in a process akin to TRL ratings
- Each HSI domain receives two ratings
  - Impact on total system performance: rated 1 (*severe degradation*) to 5 (*optimizing*) to convey impact on total system performance
  - Progress relative to current phase of acquisition: rated on a three-point scale
    - Behind (-)
    - Concurrent (1)
    - Ahead (+)

DOD HSI Working Group

DOD

Nine-level HRL scale refined and promoted via Chief Scientist of the Air Force.

- Year 2015
- Chief Scientist of the Air Force advocated nine-level HRL scale
- DOD HSI working group established

- Dr. Mica Endsley, Chief Scientist of the Air Force, 2013 to 2015
  - Briefed implementation of a nine-level HRL scale mirroring TRL scale
  - Advocated requiring HRL scale along with TRL scale
- DOD HSI working group established
  - 20 representatives from U.S. armed services and multiple federal agencies
  - Tasked to create a tool to quickly convey HSI progress for program managers
  - Refined previous versions of HRL scale
  - Added more detailed definitions and descriptions

SNL Research

SNL RESEARCH

Report documenting SNL HRL study published (See, Craft, & Morris, 2019).

- Year 2019
- SNL Report: *Human Readiness Levels in the Systems Engineering Process at Sandia National Laboratories* (SAND2019-3123)
- Authors: Judi E. See, Richard Craft, and Jason D. Morris

- Evaluated utility of HRL concepts for SNL mission work
- Interviewed diverse sample of 26 designers and developers
- HRL concept perceived as having value to manage human element in system proactively, systematically, and comprehensively
- Interviewees recommended incorporating HRL concept into existing readiness level tools and systems engineering processes

Modeling HRL scale after existing TRL frameworks minimizes the burden on overloaded systems engineering processes.

Joint HRL Working Group

WORKING GROUP

SNL, ODU, and NPS established HRL working group to finalize HRL scale.

- Year 2019
- Second HRL working group established
- Core Team: SNL, ODU, NPS
- Working Group: 38 HSI experts representing 25 organizations in DOD, DOE, other federal agencies, industry, and academia

- Capitalized on previous successes to finalize HRL scale
- Leveraged inputs from diverse team of HSI experts
- Demonstrated utility of HRL scale for three diverse real-world scenarios
- Used feedback to further improve HRL scale

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; NASA = National Aeronautics and Space Administration

HRL Standard

HRL STANDARD

Writing committee established to generate ANSI/HFES technical standard.

- Year 2020
- ANSI/HFES HRL technical standard begun
- Chair: Judi E. See
- Writing Committee: 10 members

- Writing committee established in September 2020
  - 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
- Separate consensus committee will provide review and approval
- Expected completion August 2021

HRL Writing Committee Membership
Federal Aviation Administration
General Motors Company
HFES
Johns Hopkins Applied Physics Laboratory
Navy Expeditionary Combat Command
Northrop Grumman
SA Technologies
Sandia National Laboratories

Summary

- HRL scale has been under development for 10 years
- Diverse organizations and numerous human systems experts have been involved in research, maturation, evaluation, and peer review
- Two different working groups transformed initial HRL concept into progressively more robust versions of a nine-level HRL scale
- Working group outcomes were leveraged to mature HRL scale and begin preparation of formal technical standard

HRL Scale Practical Applications

- Captures and mitigates human systems issues early in design phase
- Shifts attention from lagging indicators (human error in fielded systems) to leading indicators (evidence-based measures of usability readiness)
- Supports activities to enhance usability and minimize human error before systems are fielded for human use

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Thank You!

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