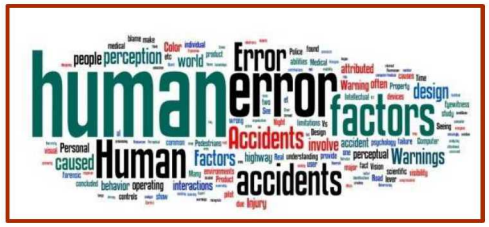
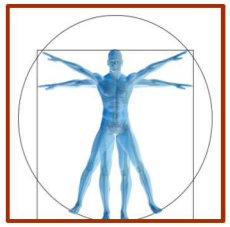
SAND2019-10707PE

History and Current Status of Human Readiness Levels





Joint HRL Working Group Meeting
15-17 October 2019

Chair: Dr. Judi See
Co-Chair: Dr. Holly Handley

PRESENTED BY

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Systems Analysis & Decision Support (2831)
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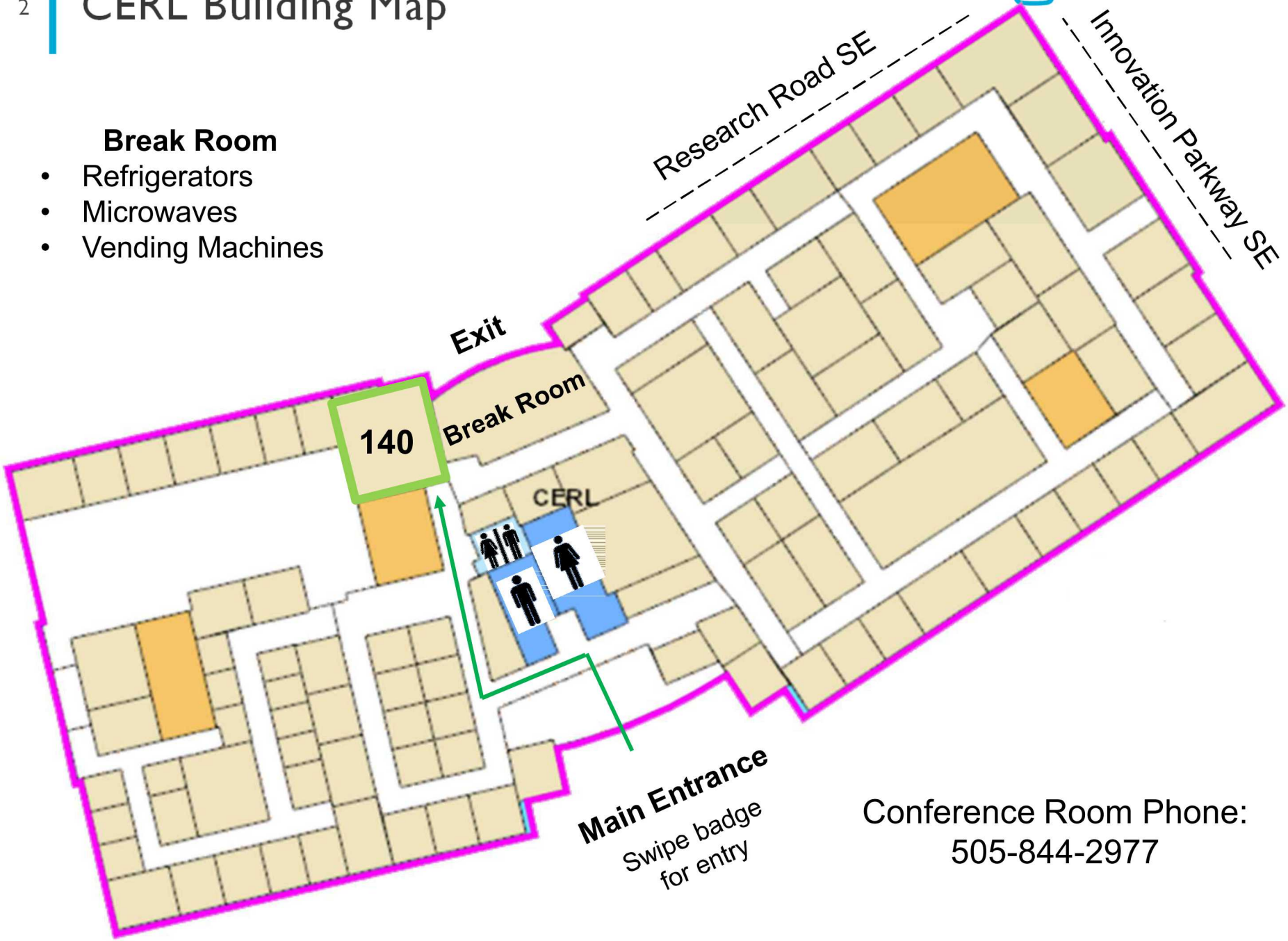
CERL Building Map

Sandia National Laboratories

Break Room

- Refrigerators
- Microwaves
- Vending Machines



Conference Room Phone:
505-844-2977

Participant Biographies

- **Name:** Judi See
- **Organization:** Sandia National Laboratories (SNL), Albuquerque, New Mexico
- **Background:**
  - Doctorate in Experimental Psychology (Human Factors)
  - BCPE certification in human factors/ergonomics
  - 16 years as a DOD contractor, primarily supporting rapid acquisition for the Air Force
  - 10 years at SNL working in human factors and systems analysis
  - Published research in vigilance, visual inspection, workload, and human readiness levels
- **HRL Interest/Experience:**
  - First learned about HRL concept during a 2015 presentation at SNL from NDIA Human Systems chair at that time
  - Led a study to explore utility of an HRL scale for SNL mission
    - Resilience Week Conference, 2016 and 2017
    - *Journal of Human Performance in Extreme Environments*, 2018
    - SNL report, March 2019
  - Currently working to develop a mature and usable HRL scale for SNL
  - Co-chairing HRL joint working group to generalize efforts throughout the broader human systems community
- **Favorite Song or Movie:** *Live Like There's No Tomorrow* by Selena Gomez

Why Human Readiness Levels?

- HRLs have been proposed as an analogue to TRLs to provide similar benefits
- TRLs are routinely used throughout the DOD, DOE, industry, and academia
- Value of TRLs is widely recognized

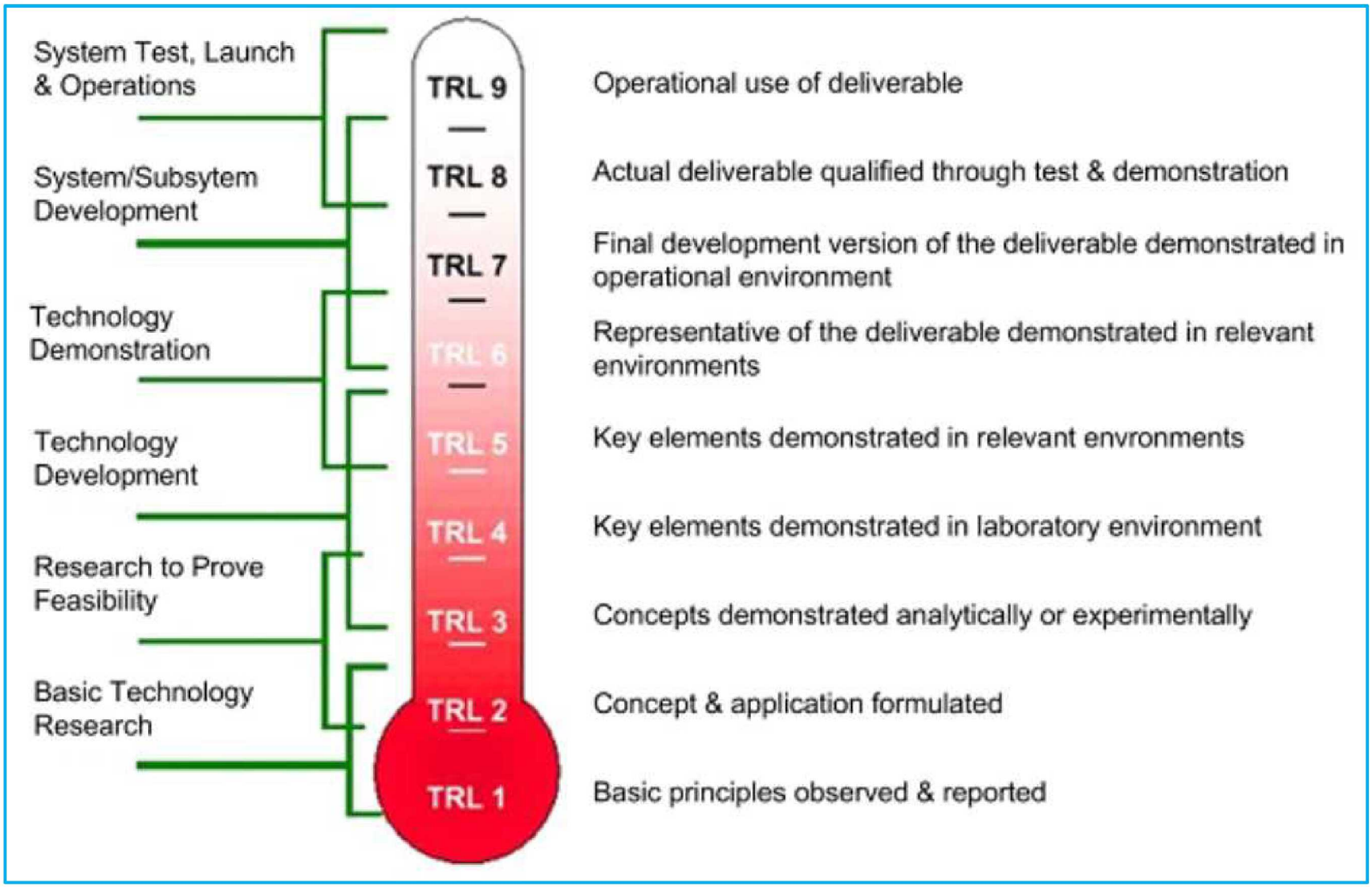
Benefits of TRLs

Demonstrating high maturity for new technologies increases chances of program success.

- Use a common terminology across diverse organizations
- Promote testing and verification to asses maturity
- Gauge progress to plan future level of effort needed to achieve maturity
- Help manage schedule and cost risks
- Provide assurance that technologies will function as intended

- HRLs are designed to complement TRLs during technology development
  - Mirror simple nine-level TRL scale for a familiar systematic and consistent approach
  - BUT, focus on the readiness of a technology for the human element within a system

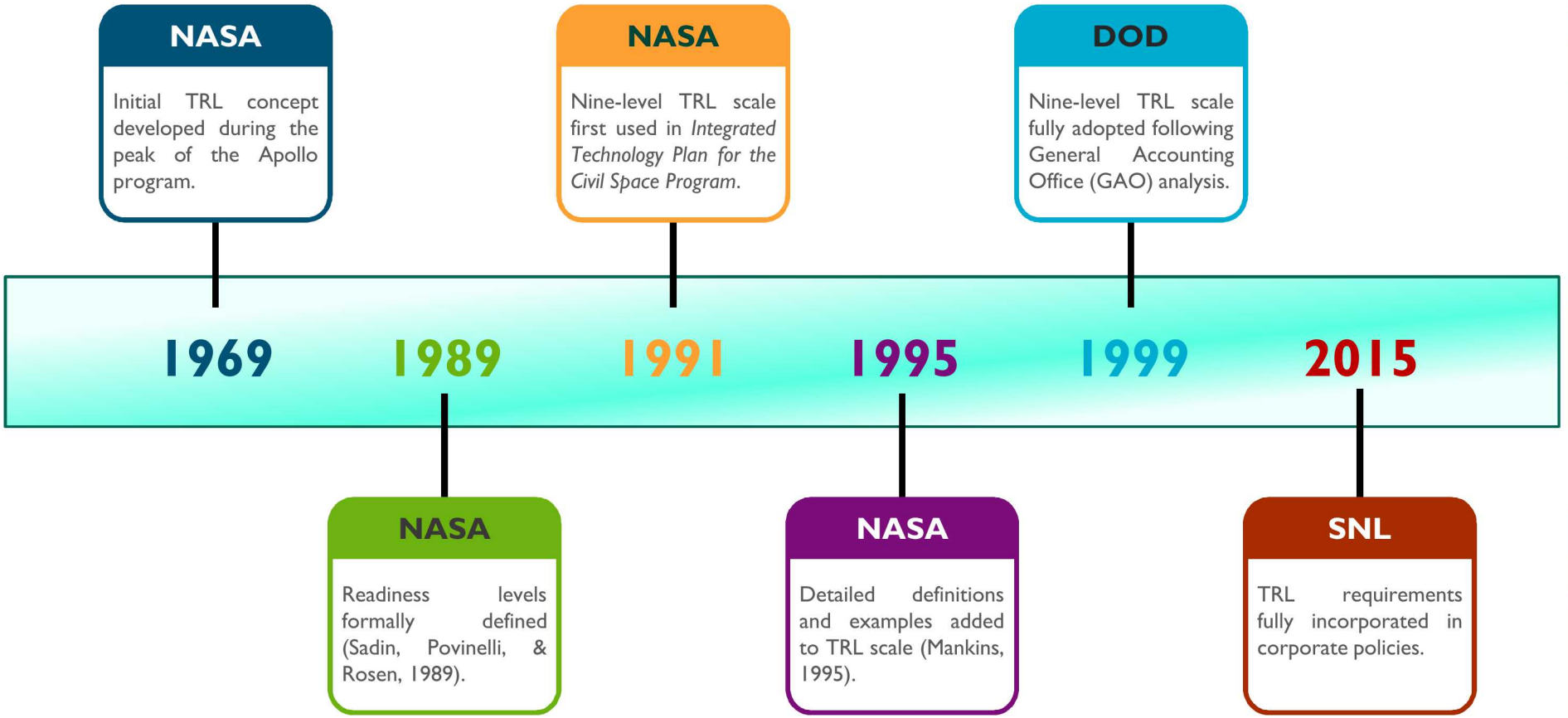
Technology Readiness Levels Scale



TRL scale provides a *systematic metric/measurement system that supports assessments of technology maturity and the consistent comparison of maturity between different types of technology.*

Timeline of TRL Scale Development

- 22 years to develop and officially adopt TRL scale at NASA
- 8 years before DOD was on board
- 24 years before SNL was on board



Need for HRLs

- Many systems engineering approaches are technology-centric
  - "Forget" the human in the system until after fielding, when human error occurs
  - Evaluate technical maturity, using the TRL scale
  - TRL scale does not address readiness of a technology for humanware in the sysem
- Most problems in engineered systems are related to people in the system
  - Up to 45% of nuclear power plant accidents
  - 60% of aircraft accidents
  - 80% of NASA mishaps

Makes 3 to 7 errors/hour normally

Up to 15 in unusual situations

(Farris & Richards, 2009)

Fails once per million hours

(Smith, 2005)

- Poor attention to the people in the system increases the likelihood of system failures due to human error – stemming from interfaces poorly suited for people

HRLs shift focus from lagging indicators (human error in fielded systems) to leading indicators (evidence-based measures of usability readiness)

HRL Scale Mirrors TRL Scale

Increasing Maturity

Level		Technology Readiness Level	Human Readiness Level
Production / Deployment	9	Operational use of deliverable	Post-deployment and sustainment of human performance capability
	8	Actual deliverable qualified through test and demonstration	HSI-related requirements qualified and verified through test and demonstration in a representative environment
	7	Final development version of the deliverable demonstrated in operational environment	Human performance using system equipment fully tested, validated, and approved in mission operations
Technology Demonstration	6	Representative of the deliverable demonstrated in relevant environments	System design fully matured as influenced by human performance analyses, metrics, and prototyping
	5	Key elements demonstrated in relevant environments	HSI demonstration and early user evaluation of initial and/or preliminary prototype to inform preliminary design
	4	Key elements demonstrated in laboratory environment	Modeling and analysis of human performance conducted and applied within system concept
Research & Development	3	Concepts demonstrated analytically or experimentally	Mapping of human interactions and application of standards to proof of concept
	2	Concept and application formulated	Human capabilities and limitations and system affordances and constraints applied to preliminary conceptual designs
	1	Basic principles observed and reported	Human-focused concept of operations (human use scenario) defined

Understanding HRLs

- HRLs augment existing TRLs by focusing on the human element of the system
- Contributions of HRL concept can be understood by examining the 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.

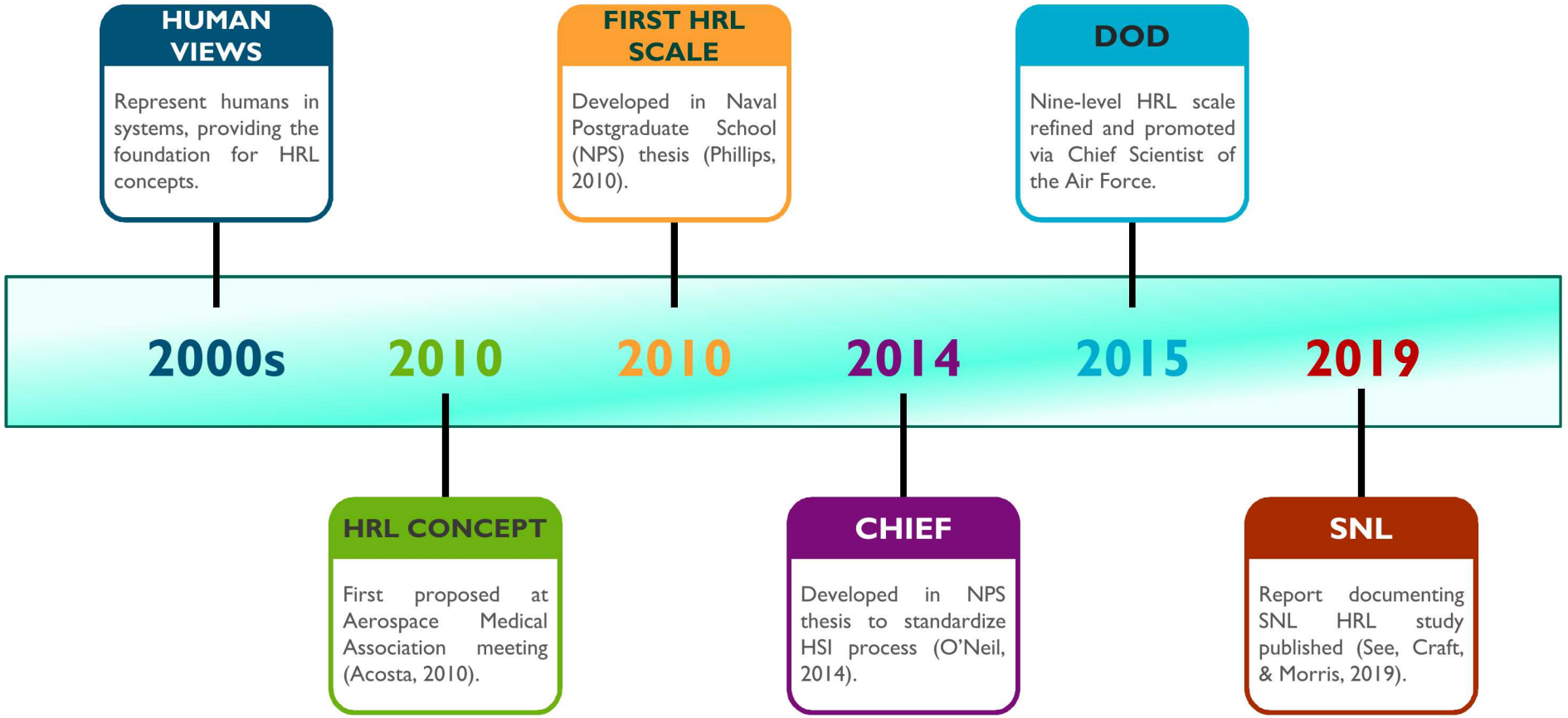
Benefits of HRL Scale

- Many benefits mirror those frequently cited for TRLs
  - Provides a common language for addressing human readiness across diverse programs
  - Promotes testing and verification to assess human readiness
  - Helps gauge progress to plan future level of effort needed to achieve human readiness
  - Manages schedule and cost risks
  - Provides a proactive cradle-to-grave planning framework
- Current HRL scale emphasizes both **progress** and **performance**
  - Human systems considerations and evaluations progress from basic conceptual design phases through prototype demonstrations and final qualification and fielding
  - Advancement to next HRL level cannot occur until human performance observations or measurements are deemed satisfactory by human systems experts

Demonstrating human readiness for new technologies increases chances of program success – planning for the human element in the system now means fewer problems later during operations and maintenance.

Timeline of HRL Scale Development

Is the technology ready for human use?

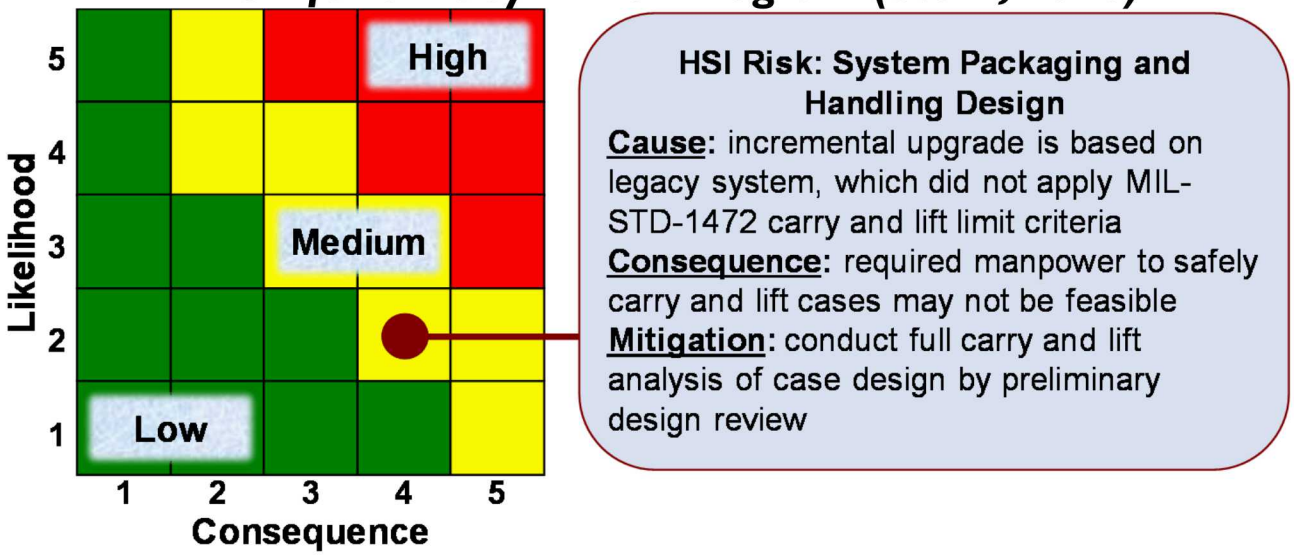


CHIEF = Comprehensive Human Integration Evaluation Framework; DOD = Department of Defense; HSI = Human Systems Integration

DOD HFE TAG HRL Working Group

- Formed at direction of ASD (R&E) HPTB, with 27 members
  - Revised wording for each of the nine HRL levels (Slide 6) (Phillips, 2015)
  - Developed HSI Progress & Risk Specification Tool (HPRST) (Stohr, 2016)
- HPRST supports performance- and risk-based assessments of human readiness
  - Addresses both the likelihood and the consequences of identified risks
  - Suggests mitigation strategies to address human readiness risks
  - Facilitates communications regarding program risks due to poor human readiness
- HSI-RMT interactive software application uses a similar risk management approach (Kosnik, et al., 2018)

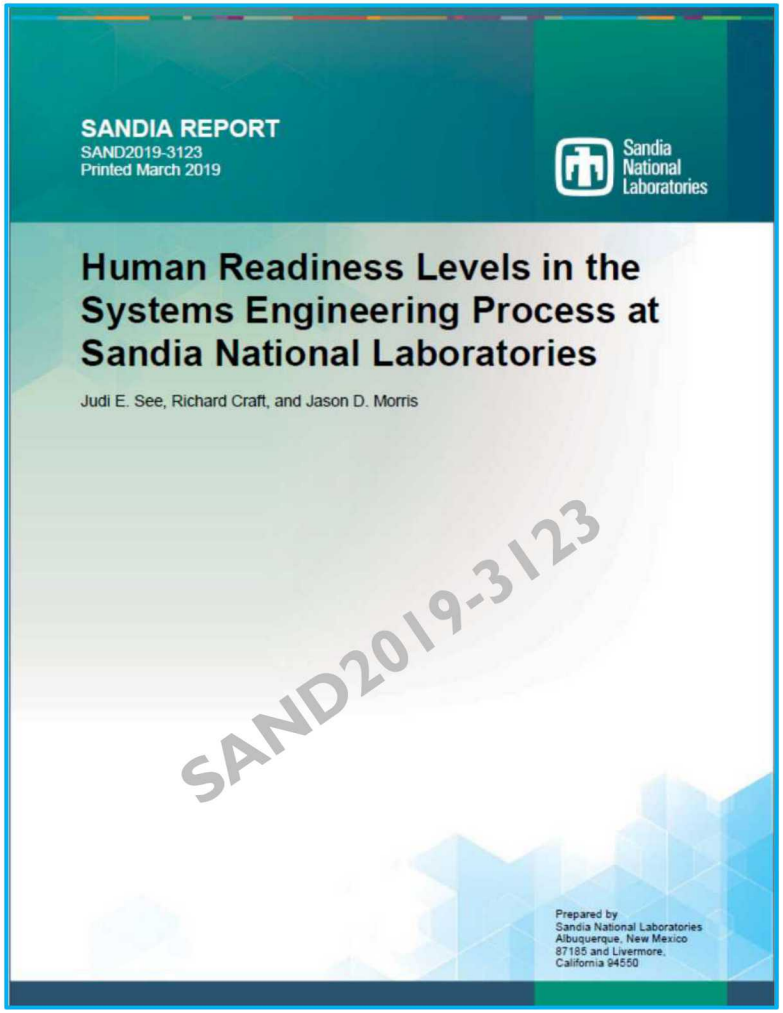
HPRST for a Body Armor Program (Stohr, 2016)



ASD (R&E) = Assistant Secretary of Defense for Research and Engineering; HFE TAG = Human Factors Engineering Technical Advisory Group; HPTB = Human Performance Training and Biosystems Directorate; HSI-RMT – Human Systems Integration Risk Management Tool

SNL Study Phase 1: Established Baseline

- Evaluated utility of HRL concept for types of work conducted to support SNL's primary nuclear weapons mission
- Observations of current baseline approaches and perceptions of HRL concept were based on interviews with a diverse sample of 26 designers and developers
  - Human element in the system is not managed proactively, systematically, or comprehensively within or across programs
  - HRL concept was perceived as having value to fill this gap
  - Interviewees recommended incorporating the concept into existing readiness level tools and systems engineering processes to minimize burden on an overloaded process



SNL Study Phase 2: Refining and Maturing HRL Scale

- Specifying the questions that must be answered at each level (plus exit criteria and supporting evidence) in order to advance to the next level
  - Modeled after current NNSA readiness calculator for TRLs, MRLs, and PRLs
  - Conducting peer reviews with SNL human systems experts
- Established technical basis by mapping HRLs to existing standards and guides
  - U.S. NUREG-0711 *Human Factors Engineering Program Review Model*
  - UK Joint Service Publication (JSP) 912 *Human Factors Integration for Defence Systems*
- JSP 912 has two major elements that address the concept of human readiness
  - System readiness levels (SRL) for human factors integration assess maturity at each of nine steps progressing from user requirements (SRL 1) to a proven system (SRL 9)
  - Successful implementation of the human factors integration process occurs in six stages

Stage 1:	User need definition	***Stage 4:***	System design
Stage 2:	System requirements definition	***Stage 5:***	Test and acceptance
Stage 3:	Assess tenders	***Stage 6:***	In-service feedback

- These JSP 912 elements map very well to the proposed HRL Scale

NNSA = National Nuclear Security Administration; MRL = Manufacturing Readiness Level; PRL = Programmatic Readiness Level

Mapping HRLs to JSP 912

UK JSP 912			U.S. Proposed HRL Scale	
Human Factors Integration SRL		Human Factors Integration Process		
9	Human factors issues monitored and managed	Stage 6: In-service feedback	Post-deployment and sustainment of human performance capability	9
8	Human-related aspects of design and function achieved and accepted	Stage 5: Test and acceptance	HSI-related requirements qualified and verified	8
7	System prototype demonstrated in integration environment		Human performance fully tested and validated	7
6	Sub-systems verified in representative environment	Stage 4: Detailed system design	Design fully matured through human performance prototyping	6
			Preliminary design informed by early user evaluation	5
5	Initial human factors tests conducted		Modeling and analysis of human performance conducted	4
4	Human factors input provided to develop system requirements and align with other project disciplines	Stage 3: Assess tenders Stage 2: System requirements definition	Mapping of human interactions and application of standards	3
3	Human component requirements defined		Human capabilities and limitations and system affordances and constraints applied to concept	2
2	Human roles defined	Stage 1: User need definition	Human-focused concept of operations defined	1
1	Human factors issues understood			

Similarities Between HRL Level 1 and JSP 912

Topics and Activities

HRL Level 1	○ Engage human systems professionals	○ Identify user roles in the lifecycle	○ Explore potential key human systems issues	○ Analyze human system pros and cons in legacy systems
JSP 912	○ Identify human factors lead	○ Specify human roles in system	○ Ensure human considerations are included ○ Conduct initial analysis of human issues ○ Explore major human issues (performance and workload)	○ Assess risks and requirements ○ Analyze legacy and comparable systems

SNL Study Phase 2: Sample Questions

1. Has fundamental concept, innovation, or scientific principle/methodology or approach been developed?
2. Do rough or envelope calculations support the assumed concept?
3. Do basic principles (physical, chemical, or mathematical) support the concept?
4. Do paper studies confirm basic scientific principles of new technology/material?
5. Are basic scientific principles observed and understood
6. Does basic characterization data of the proposed technology/material exists?
7. Does it appear the concept can be supported by software?
8. Have mathematical formulations of concepts that might be realizable in software been developed?
9. Has an initial or tentative plan and schedule been developed?

TRL Level 1

1. Have human systems professionals with requisite expertise been engaged to support this effort?
2. Is an overarching human systems program plan being developed and integrated within the system plan?
3. Have the activities required to implement the human systems program plan been budgeted?
4. Have user roles throughout the lifecycle been identified?
5. Have usage scenarios for each user role been developed?
6. Have basic task descriptions for each user role been developed?
7. Have human user tasks critical to system goals been identified?
8. Have potential key human systems issues throughout the lifecycle been identified?
9. Have human systems pros and cons from legacy or comparable systems been documented and analyzed?
10. Have critical human systems principles been identified?
11. Have key human systems standards and guidance been identified?

HRL Level 1

SNL Study Phase 2: Initial Peer Review

- Conducted internal SNL peer reviews of initial question set
- Four human systems experts with diverse backgrounds independently reviewed questions
- Group met in person to discuss feedback and recommendations
- Study team updated HRL scale accordingly

The "question" approach provides a standard process that is easy to follow.

Add a column to the HRL spreadsheet to identify "consequences" if the human systems activities are not performed.

HRL scale may need to be tailorable. Small programs may not be able to fund use of the full HRL scale in its entirety.

Who actually "owns" or manages the HRL rating when work spans multiple sites?

Products get built all the time without human factors input. How do you convince people the HRL scale is necessary?

Non-human systems experts who will receive the HRL scale rating need overview guidance or training on the scale.

SNL Study Phase 2: Path Forward

- Conduct tabletop reviews of HRL scale utility for realistic scenarios
  - Include a broad range of experts—human factors engineers, product realization team leads, systems designers, component designers, and design review panel members
  - Use scenarios derived from historical systems, components, and re-use technologies as well as historical human systems issues
- Test utility of approach for current weapon programs
- Revise HRL scale accordingly
- Develop tailored implementation guidance for multiple levels of HRL scale users
  - ***Human systems experts*** – practitioners who apply the scale and report/document observations and results used to justify progression for each level
  - ***Program leads*** – program managers, system leads, and component leads who must understand HRL inputs and take appropriate action during design and development before the system can advance to the next HRL level
  - ***Other*** – individuals who may use or reference HRL verification and validation documentation (e.g., quality engineers, assessment teams, and anomaly investigation teams)

SNL Study Phase 2: Path Forward

- Implement approach internally at SNL through Human Factors Department
- Incorporate HRL scale and question set into existing National Nuclear Security Administration (NNSA) readiness level calculator tool

#	HW / SW	T/M/P	TRL	Technology Readiness Survey Questions (Terms in italics are defined in Defintions tab.)	SCORE %
1	B	T	1	Has fundamental concept, innovation or scientific principle/methodology or approach been developed?	
2	B	T	1	Do rough or envelope calculations support the assumed concept?	
3	B	T	1	Do basic principles (physical, chemical, mathematical) support the concept?	
4	B	T	1	Do paper studies confirm basic scientific principles of new technology/material?	
5	B	T	1	Are basic scientific principles observed and understood?	
6	H	T	1	Does basic characterization data of the proposed technology/material exists?	
7	S	T	1	Does it appear the concept can be supported by software?	
8	S	T	1	Have mathematical formulations of concepts that might be realizable in software been developed?	
9	B	P/T	1	Has an initial or tentative plan and schedule been developed?	
10	B	P/T	2	Is it known who will perform the research or project?	
11	B	T	2	Is the research approach documented?	
12	B		2	Has potential system or component applications been identified?	
13	B	T	2	Has an apparent design solution been identified?	
14	B	T	2	Has the technology been decomposed into to its basic sub-elements or functions?	
15	B	T	2	Has a functional requirements generation process been initiated?	
16	B	T	2	Has the user interface been defined?	
17	B	T	2	Have paper studies confirmed system or component application feasibility?	

Instructions | Start | TRL | MRL | PRL | Comments | Definitions | Results

B = Both Hardware and Software
H = Hardware
M = Manufacturing
P = Programmatic
S = Software
T = Technology

https://dpbps.sandia.gov/Pages/ReadinessCalculator.aspx

Path Forward: Joint Working Group

- Use a diverse set of HSI experts to further mature and test the HRL scale
- Develop a usable and verified HRL scale that can be applied in any domain
- Generate awareness of HRL scale utility and benefits
- Coordinate high-level sponsorship
- Begin applying the scale in real-world missions

More on the HRL working group purpose and charter from Holly later this morning.

References

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Sandia National Laboratories

Meeting Agenda

Day	Time	Activity
Mon 14 Oct	--	Travel to Albuquerque
Tues 15 Oct	7:30	Badging
	8:30	Introductions
	9:00	Presentation: HRL History and Status (Judi See)
	10:00	Presentation: HRL Implementation Roadmap (Victoria Newton)
	10:45	Break
	11:00	Presentation: HRL Joint Working Group Purpose and Charter (Holly Handley)
	11:45	HRL Scale Review – Afternoon Plan (Judi See)
	12:00	Lunch
	1:15	Working groups (HRLs 1-3), ~1 hour per level
	4:00	Day 1 review (Judi See and Holly Handley)
	5:00	Adjourn
	6:00	Group dinner
Wednes 16 Oct	8:00	Working groups (HRLs 4-6), ~1 hour per level
	11:00	Day 2 morning review
	12:00	Lunch
	1:15	Working groups (HRLs 7-9), ~1 hour per level
	4:00	Day 2 afternoon review
	5:00	Adjourn
Thurs 17 Oct	9:00	Summary, path forward, schedule, action items (Judi See and Holly Handley)
	11:00	Adjourn and travel home

Afternoon Plan – Review HRLs 1-3

- Divide into smaller groups
- Focus on HRLs 1-3 this afternoon
- Think about a system/technology you have worked on
  - Evaluate whether the scale would have been useful for that effort
  - If not, what more is needed?
- Review HRLs 1-3 by Level
  - Is the description for each level clear?
  - Do the questions within each level cover all activities that should/must be completed for a human systems evaluation?
  - Should any questions be deleted?
  - Do the "Considerations" fields help clarify what the human systems expert should do at each level?
  - Are the exit criteria clear?
  - Are exit criteria sufficient to ensure that the system/technology advances to the next HRL level only IF and WHEN the current level has been satisfactorily addressed?
  - Is the required supporting evidence sufficient?

Overall HRL Scale Review

- Think about the scale in its entirety
- Review overall structure and progression of HRL levels
- Does the "question" approach work, or is there a better alternative?
- Do the questions have the right level of detail?
- Are there any gaps in the set of questions currently used?
- Could you, as a human systems expert, use the scale to evaluate a system/technology under development?
- Do you think you could successfully communicate the HRL scale to design teams?
- What issues do you see with using an HRL scale during design and development?