Human System Integration: Challenges and Opportunities

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Surveying the Science & Technology Landscape

HSI in Practice

HSI Science, Methods & Tools

The Grand Canyon of Execution

# *Gap 1: Decision Makers do not perceive there is a problem*

- **Inability to distinguish good vs. poor human interfaces**
- **Effects on human performance are invisible to them or explained away as something else**
- **"Users looked at it"**

<div align="center">

**Human Preference
≠
Human Performance**

</div>

Gap 2: Poor understanding of what supporting the user means

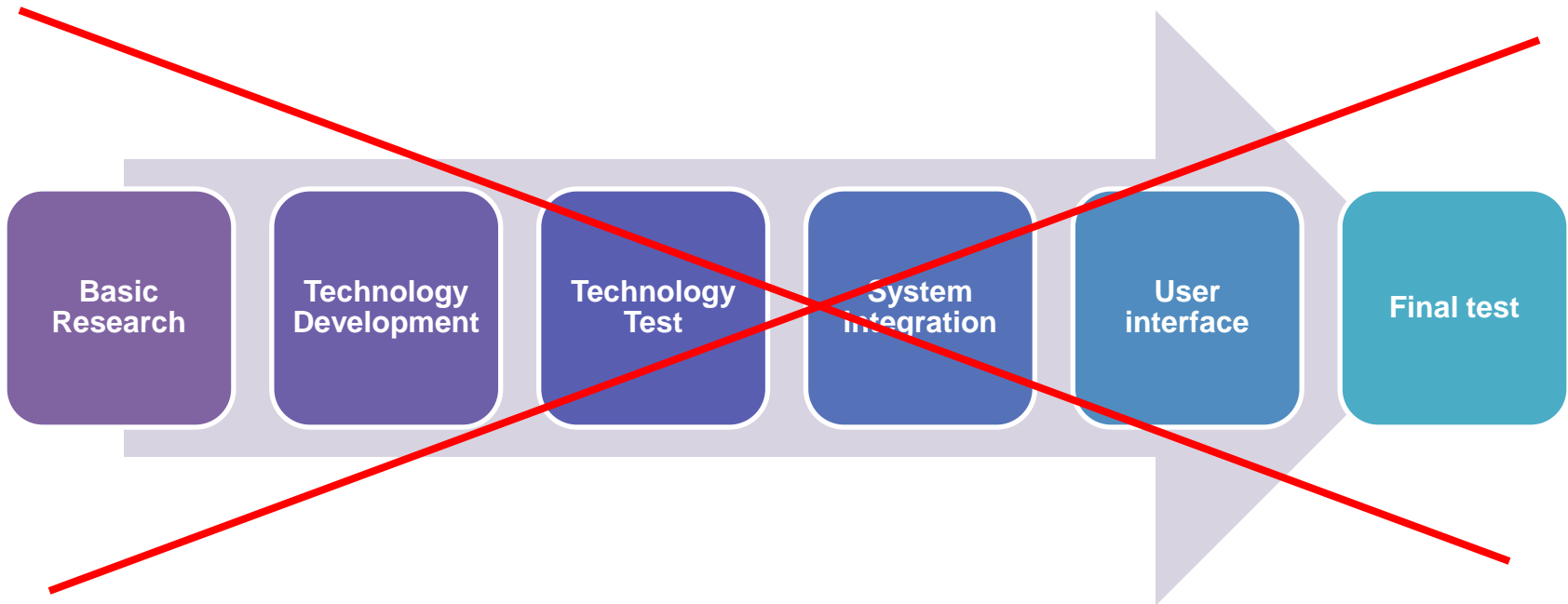- **Focus on "new" UI technologies or concepts, without regard to how it impacts actual user needs or performance**

exciting!
beautiful!
technical!
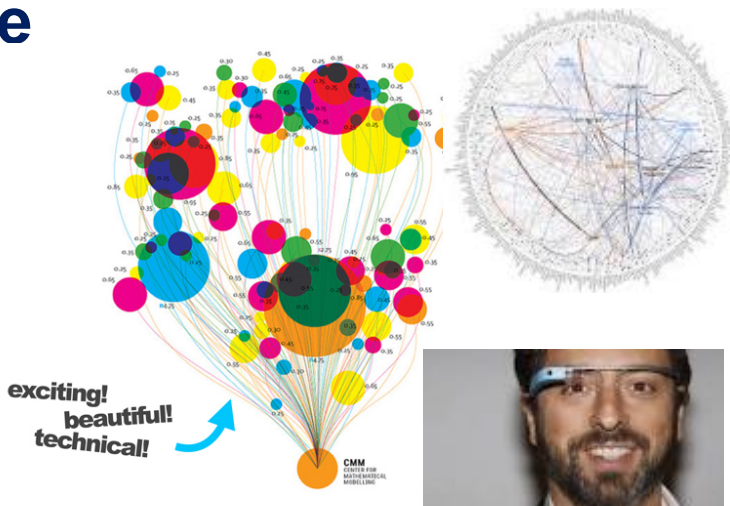
Cool
≠
Effective

Gap 3: HF Too Late in Process

- **Decision makers sincerely believe the human interface <u>can</u> be done at the end and <u>should be</u>**

Basic Research → Technology Development → Technology Test → System Integration → User interface → Final test

- **Removes the ability to effect the fundamental functionality and usability of the interface and usually the ability to make more than surface changes**

Gap 4: The Growth of DYI Systems

- **HSI programs in the DOD largely centered around the procurement process**
  - **Requirements that can be put into contracts and monitored for compliance**
- **Increasing numbers of technologies are being developed in house**
  - **Software**
  - **Additive manufacturing**

Need Easy to Use Human Factors Guides for programs within DoD

Gap 5: HF practitioners do not communicate at the right level

- **Process/detail overload**
  - **What time it is vs how to build the watch**
- **Decision makers want to know**
  - **Will this work?**
  - **Has the needed development work been done?**

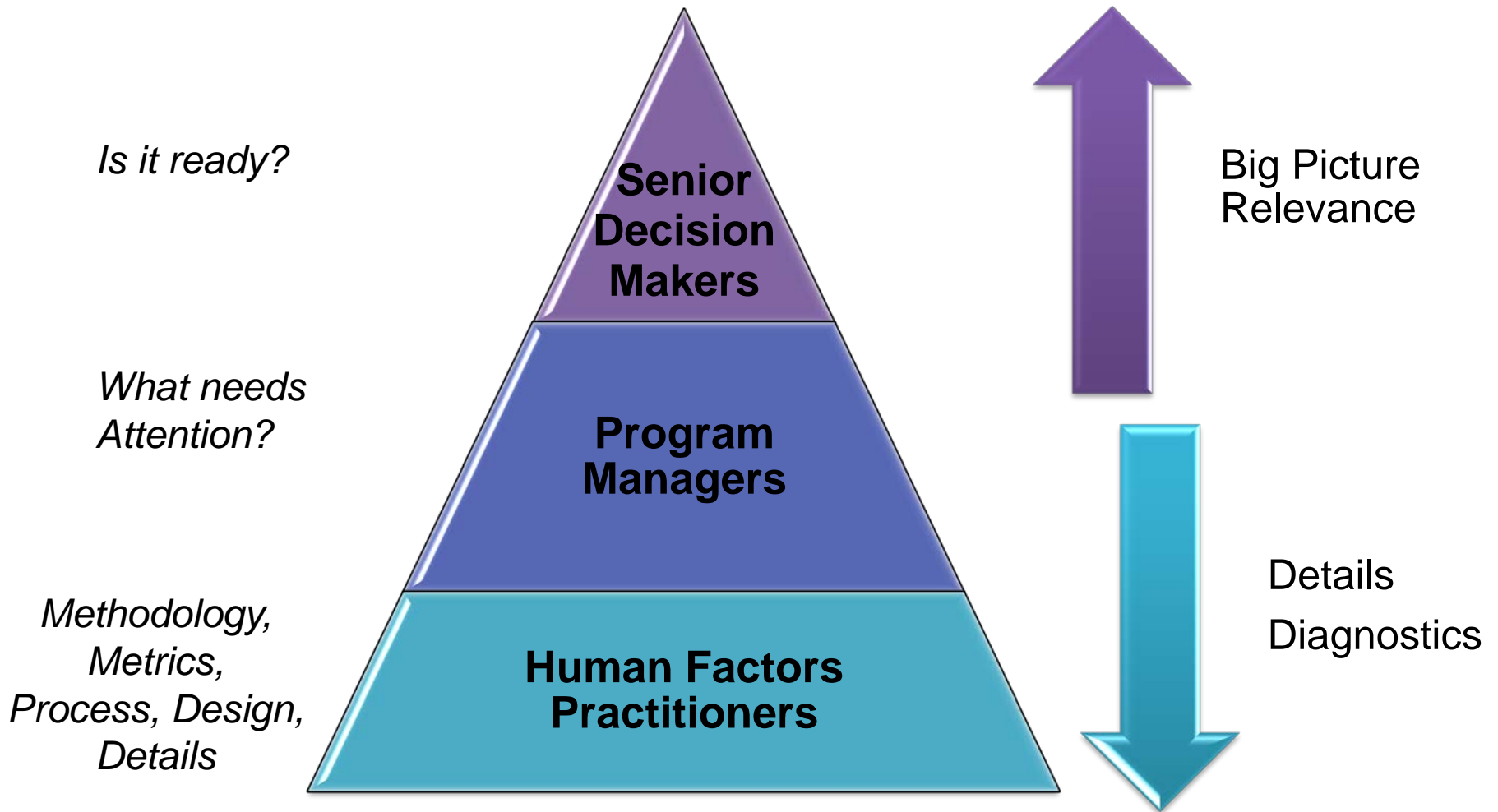**Complex ideas**

⬇

Simple Constructs
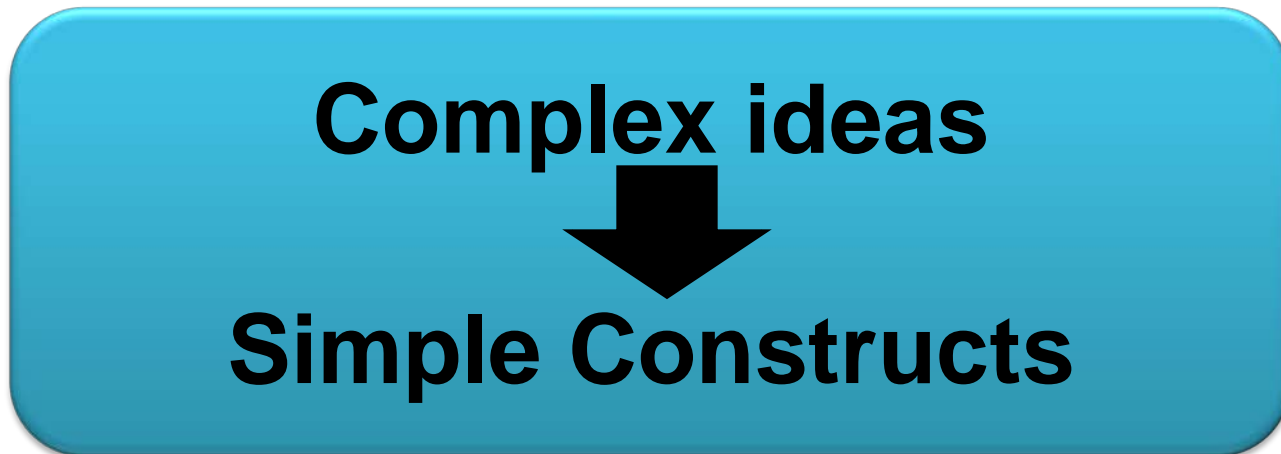
Goal

- **Elevate HSI to provide a high level understanding of its status in a given program**
  - **Should put emphasis on HSI testing/development**
    - **Must be tied to concrete human-system effectiveness measures**
  - **Promote addressing HSI issues early in the development process**
    - **Provide awareness of resources needed earlier in the development process**
  - **Cross HSI disciplines (human factors, training, ….)**

| 6.1 Basic Research | 6.2 Applied Research | 6.3 Advanced Technology Development | 6.4 Demonstration and Validation | 6.5 Engineering and Manufacturing Development |

Gaining Leverage on the Process

Is it ready?

What needs Attention?

Methodology, Metrics, Process, Design, Details

Senior Decision Makers

Program Managers

Human Factors Practitioners

Big Picture Relevance

Details Diagnostics

9

Technology Readiness Level (TRL)

- **TRL 1 – Basic principles observed & reported**
- **TRL 2 – Technology concept and/or application formulated**
- **TRL 3 – Analytical & experimental critical function and/ characteristic proof of concept**

| Initial incorporation of principles and data to form system |

- **TRL 4 – Component and/or breadboard validation in laboratory**
- **TRL 5 – Component and/or breadboard validation in relevant environment**
- **TRL 6 – System/subsystem model or prototype demonstration in relevant environment**

| Subsystem testing of increasing fidelity |

- **TRL 7 – System prototype demonstration in operational environment**
- **TRL 8 – Actual system completed and qualified through test and demonstration**
- **TRL 9 – Actual system proven through successful mission operations**

| Full scale testing |

Manufacturing Readiness Level (MRL)

- **MRL 1 – Basic manufacturing implications identified**
- **MRL 2 – Manufacturing concepts identified**
- **MRL 3 – Manufacturing proof of concept developed**

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Initial incorporation of principles and data to form system

</div>

- **MRL 4 – Capability to produce the concept in a laboratory**
- **MRL 5 – Capability to produce prototype components in a production relevant environment**
- **MRL 6 – Capability to produce a prototype system or subsystem in a production relevant environment.**

<div style="float:right">

Subsystem testing of increasing fidelity

</div>

- **MRL 7 – Capability to produce systems, subsystems or components in a production representative environment.**
- **MRL 8 – Pilot line capability demonstrated. Ready to begin low rate production**
- **MRL 9 – Low Rate Production demonstrated. Capability in place to begin Full Rate Production.**
- **MRL 10 - Full Rate Production demonstrated and lean production practices in place**

<div style="float:right">

Full scale testing

</div>

Human Readiness Level (HRL)

- **Technology Readiness Level**
  - **Accepted measure of technology maturity and readiness**
  - **Includes systematic experimentation, testing and refinement to show the technology as proven**
  - **Well understood in engineering community as requirement for moving system from design into operational use**
  - **Provides tracking throughout development (6.1-6.5)**
- **Human Readiness Level**
  - **Creates a measure of the readiness of the technology for use by human operators/maintainers**
- **Goal is to make HRL as much of a requirement as TRL for moving a new system into operational use.**
- **Develop a Usable HRL Scale**
  - **Map to understood paradigm of TRL**
  - **Include all HSI domains**
  - **9 Point Scale mapped to acquisition milestone and equivalent TRLs**

Background

- **Maj Erik Phillips (2010)**
  - **Human Readiness Levels (HRL)**
  - **9 levels - HSI process based**

- **Hale, Fuchs, Carpenter and Stanney (2011)**
  - **Human Factors Readiness Levels (HFRL)**
  - **6 levels – degree to which 24 human factors study areas addressed**
  - **Uses Design Interactive SHARE tool**

- **Endsley (2013)**
  - **Human Readiness Levels (HRL)**
  - **9 levels – based on testing at increasing levels of fidelity & realism to mirror TRL**

- **O'Neil (2014)**
  - **Comprehensive Human Integration Evaluation Framework (CHIEF) model**
  - **5 level scales - Assesses progress on each HSI Domain - how impacting total system performance (degradation to enhancement)**

DoD HSI TAG Working Group

- **Formed at direction of ASD(R&E) HPTB TAG Proponent**
  - **HFE TAG 68 May 2014**
- **Includes representatives of ASD(R&E), USN/USMC, USA, USAF, USCG, FAA, NASA & DHS**
  - **27 members**
  - **Led by CDR Henry Phillips, Owen Seely, Dr. Larry Shattuck, LCDR Mike O'Neill, and Dr. Jim Pharmer**

- **Goal to create a tool/system that will enable Program Managers to quickly understand:**
  - **Progress made within & across HSI domains**
  - **Degree to which HSI requirements are being considered and implemented in systems engineering decisions**

Working Group Approach for an HSI Metric

- **What standards can be attached to achievement of levels within an HSI metric? The following questions should be considered:**
  - **Was the right work done, and done well?**
  - **Are implications being incorporated into program decisions?**
  - **Are programmatic constraints limiting usability?**
- **How should HSI assessments be conducted?**
  - **Guidelines for how to evaluate achievement of HSI goals are already available in published MILSTDs and service instructions**
  - **Assessment guidelines for an HSI metric should stipulate conditions for score assignment and score veracity evaluation**
- **Want to support Program Managers to understand HSI status through existing processes and guidance**
  - **Systems Engineering Technical Review (SETR) process documents exactly what evidence is required within each HSI domain to advance past a milestone**
  - **Not new requirements – just improved clarity**

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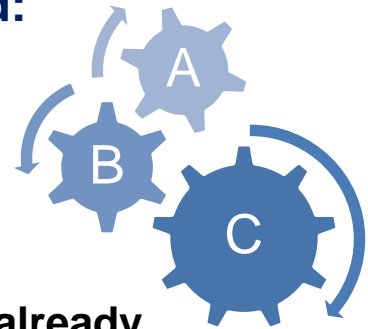
Potential Labels

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

Human Readiness Level (TAG Working Group DRAFT)

- **HRL 1 – Human focused concept of operations defined**
- **HRL 2 – Human capabilities & limitations and system affordances & constraints applied to preliminary designs**
- **HRL 3 – Mapping of human interactions and application of standards to proof of concept**

> **Initial incorporation of principles and data to form system**

- **HRL 4 – Modeling and analysis of human performance conducted and applied within system concept**
- **HRL 5 – HSI demonstration and early user evaluation of initial prototypes to inform design**
- **HRL 6 – System design fully matured by human performance analyses, metrics and prototyping**

> **Subsystem testing of increasing fidelity**

- **HRL 7 – HSI requirements verified through development test and evaluation in representative environment**
- **HRL 8 – Human performance using system fully tested, validated and approved in mission operations**
- **HRL 9 – Post deployment and sustainment of human performance capability**

> **Full scale testing**

Human Readiness Level (Draft)

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

What is HRL Showing?

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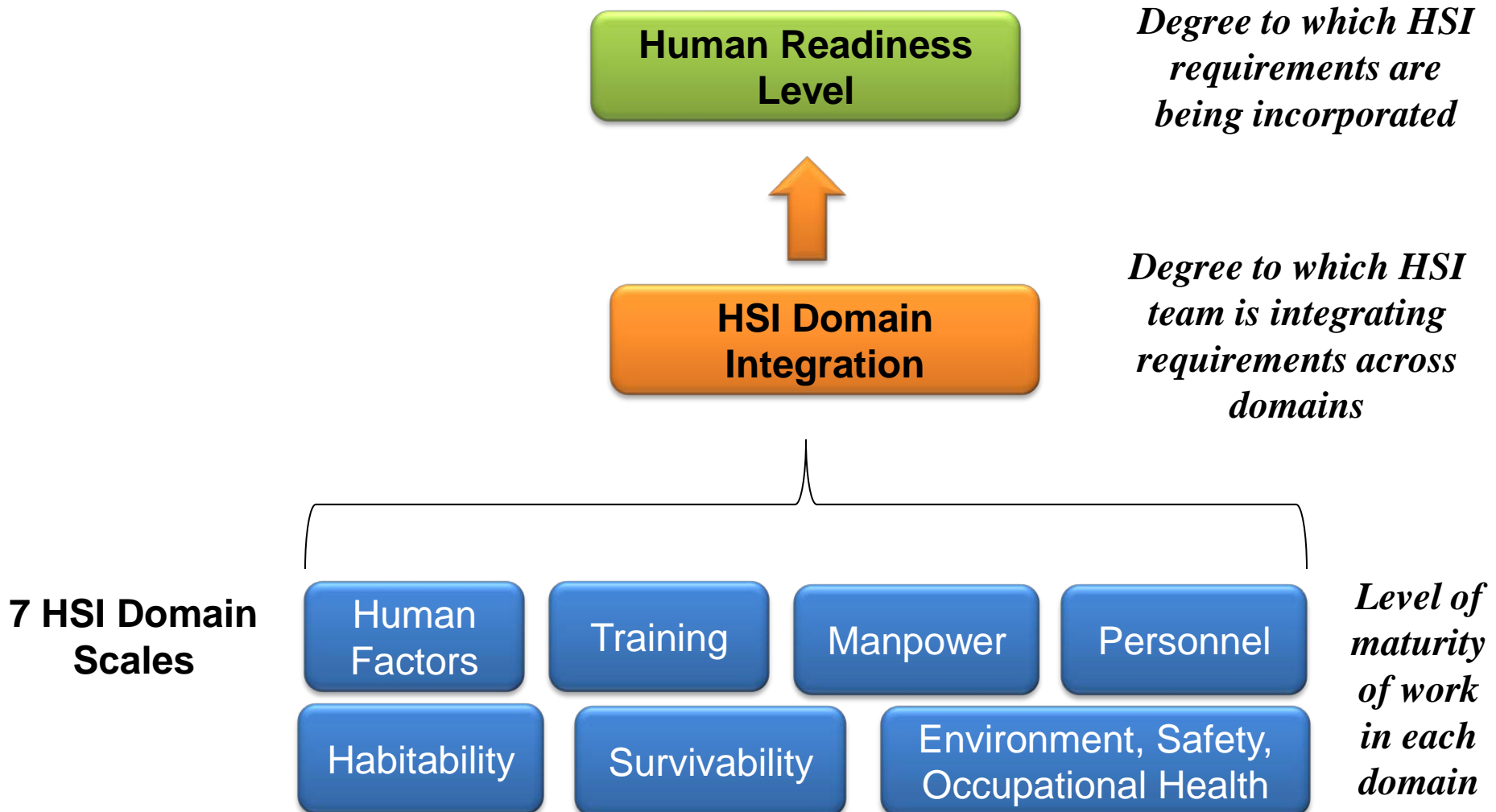
HSI IL	Definition	Description	Supporting Information
1	Human-focused concept of operations (human use scenario) defined	The scenario for human use (human focused CONOPS) of the conceptualized system has been defined and developed for all end user categories. Scenario was used as basis for defining the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

MS A

MS B

MS C

- **Captures whether HSI requirements have been taken into consideration in system design**

- **Captures whether HSI capabilities have been demonstrated under test conditions of closer approximation to operational use**

- **Provides progress ties to Acquisition Life Cycle gates & milestone reviews**

- **Structured to approximate the TRL scale's Definition, Description & Supporting Info**

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Assessing HRL on a Program

Human Readiness Level

Degree to which HSI requirements are being incorporated

HSI Domain Integration

Degree to which HSI team is integrating requirements across domains

7 HSI Domain Scales

Human Factors

Training

Manpower

Personnel

Habitability

Survivability

Environment, Safety, Occupational Health

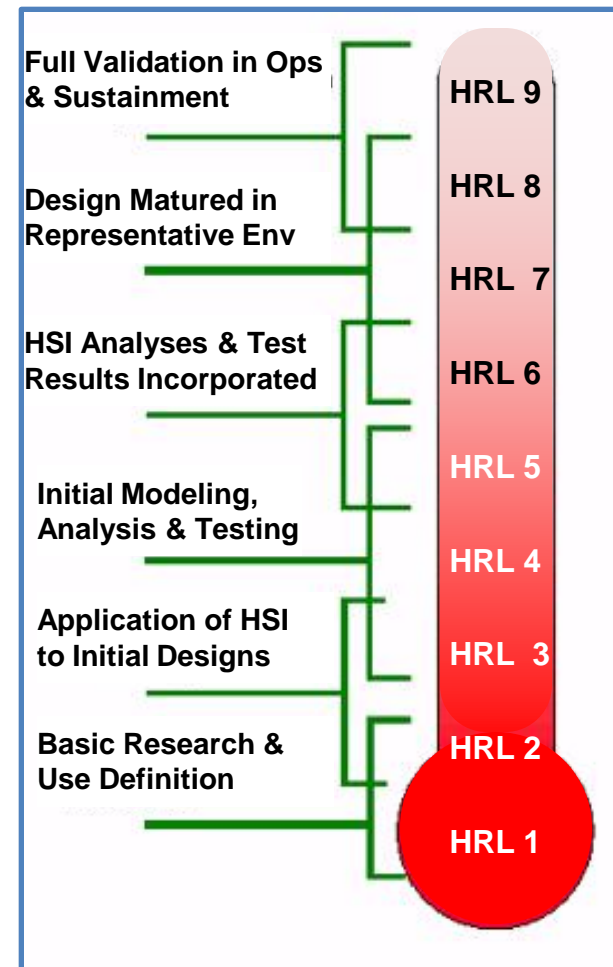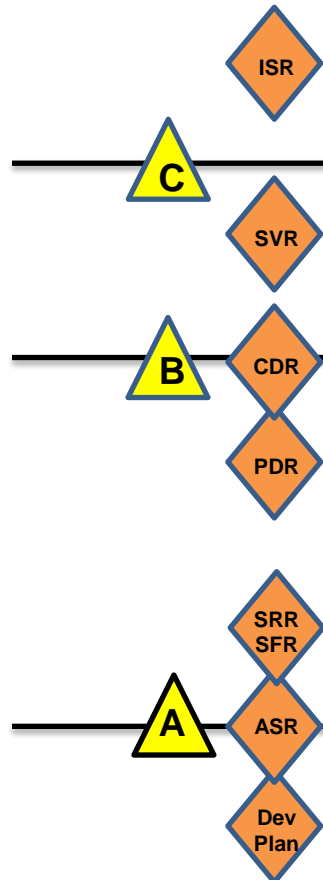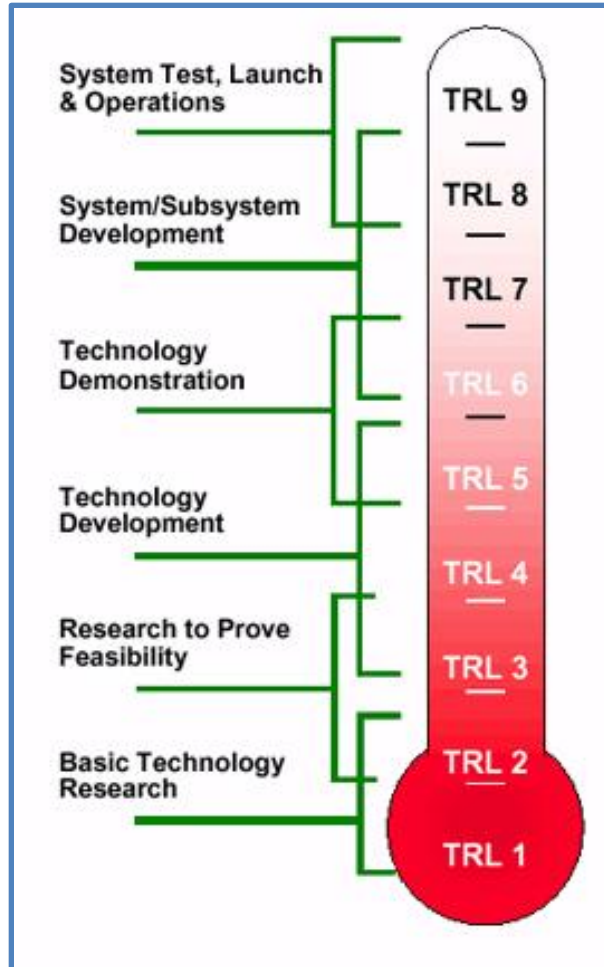*Level of maturity of work in each domain*

Determining HSI Maturity at the Domain Level

- **Glideslope shows incremental achievements in HSI maturity for each domain**

- **Reflects the information requirements of existing SETR processes**

- **Progress up the glideslope is justified if:**
  - **the right work is conducted & up to professional standards**
  - **acknowledged/incorporated by decision-makers (LSE) and**
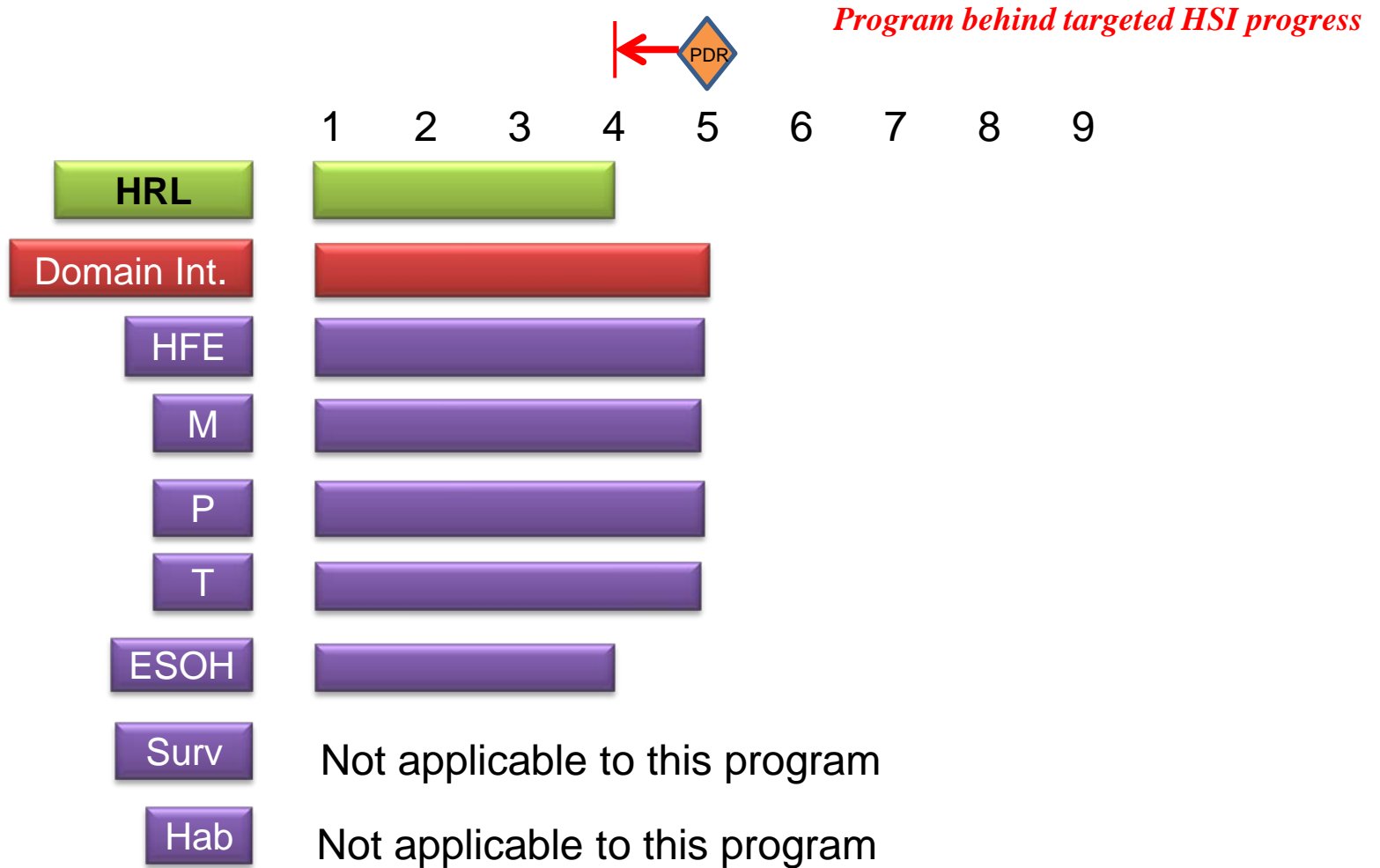 - **(at 8/9) whether measurable improvements in usability & human system performance result**

1 Minimal skillsets defined

2 Skillset deltas defined - what currently exists v what is needed

3 Skillset inclusions when mapping the human network

4 Manpower modeling with skillsets included

5 Skillset capability & limitations refined

6 Skillsets reqs & limitations stabilize & assist in finalizing the design

7 Skillset verification

8 Human perf factors including cognitive, physical, and sensory capabilities, knowledge, skills, abilities, and experience levels are identified to match system tasks and workload; criteria are developed to effectively recruit, select and train personnel for safe, efficient and effective system operation.

9 Skillsets required not increased after post-deployment

Example: Personnel Domain

HRL Progress Needed at Each Program Milestone

Use Case I: Maintainer Exoskeleton

Program behind targeted HSI progress

PDR

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

HRL

Domain Int.

HFE

M

P

T

ESOH

Surv — Not applicable to this program

Hab — Not applicable to this program

Path Forward

- **Distribute Draft HRL Scales & Documentation for Review by HSI Community**
  - **Revise where needed**

- **Distribute Draft HRL Scales to Acquisition Community for comment and input**
  - **Revise where needed**

- **Work with ASD (R&E) to incorporate HRL into acquisition guidance**

- **Develop supporting documentation**
  - **Guidance for HSI practitioners**

- **Socialize HRLs with Acquisition Professionals**
  - **Program Managers, PEOs, Key Decision Makers**

Summary

- **HSI needs to overcome significant challenges in its degree of instantiation in programs**
  - **Bridge the Grand Canyon of Execution**
- **Support DYI systems development**
- **Key Leverage Points**
  - **Requirements**
    - **HSI must be in system requirements (operability, maintainability, trainability**
  - **Human Readiness Levels –**
    - **Raise the visibility and understandability of HSI to Program Managers and Decision Makers**

> *"If you keep doing what you have been doing, you will keep getting what you have been getting"*

Human Readiness Level (DRAFT)

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

Initial incorporation of principles and data to form system

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

Subsystem testing of increasing fidelity

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

Full scale testing