Use of IDHEAS to Generalize Human Performance Data for Estimation of Human Error Probabilities

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What's next in human reliability analysis – DATA, DATA, DATA

- Existing human error data – from various fields, in different formats, varying context and levels of details

- Data generalization and use for human reliability analysis - the Integrated Human Event Analysis System (IDHEAS) has an inherent structure for generalizing and integrating human error data

Human error data: The ideal world and reality

$$\text{HEP (failure mode under specific context)} = \frac{\text{\# of errors (failure mode)}}{\text{\# of Occurrence (under the context)}}$$

- Ideal world:

- The same task for a failure mode is repeated thousands of times with the same people under the identical context;
- Do this for all possible contexts

⇩

Failure modes	# Occurrence	Context	Variety
✓ Well-defined failure modes	✓ Known, sufficient number of task occurrences	✓ Context clearly defined and repeated	✓ Sufficient data for all failure modes and contexts

Human error data: The ideal world and reality

$$\text{HEP (failure mode under specific context)} = \frac{\text{\# of errors (failure mode)}}{\text{\# of Occurrence (under the context)}}$$

- Reality:

X Failure modes unknown
X Number of occurrences not reported
X Context undocumented and/or unrepeated
X Lack of variety – limited failure mode / context tested
X Not talking to each other

Type of human error data	Failure modes	# Occurrence	Context	Variety
Statistical	X	X	X	✓
Human error analysis	✓	X	X	✓
Operational database	✓	✓	Unrepeated	Limited
Experimental	✓	✓	✓	X

Examples of statistical data

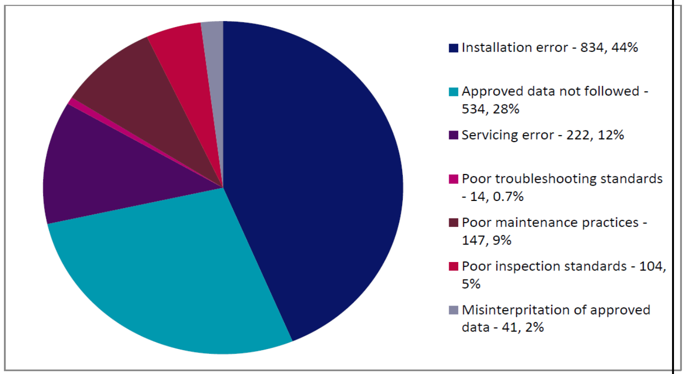
- Statistical study in 2016 - Medical errors are the third leading cause of death in the U.S., after heart disease and cancers, causing at least **250,000** deaths every year (Ref. 1)

- France - Nuclear Power plant replacement of the Dungeness B Data Processing System - The installation team completed 22,000 plant connections to the new system with a less than **2%** error rate. (Ref. 3)

- X Occurrence of the tasks not reported
- X Failure modes unspecified
- X Context undocumented and unrepeated

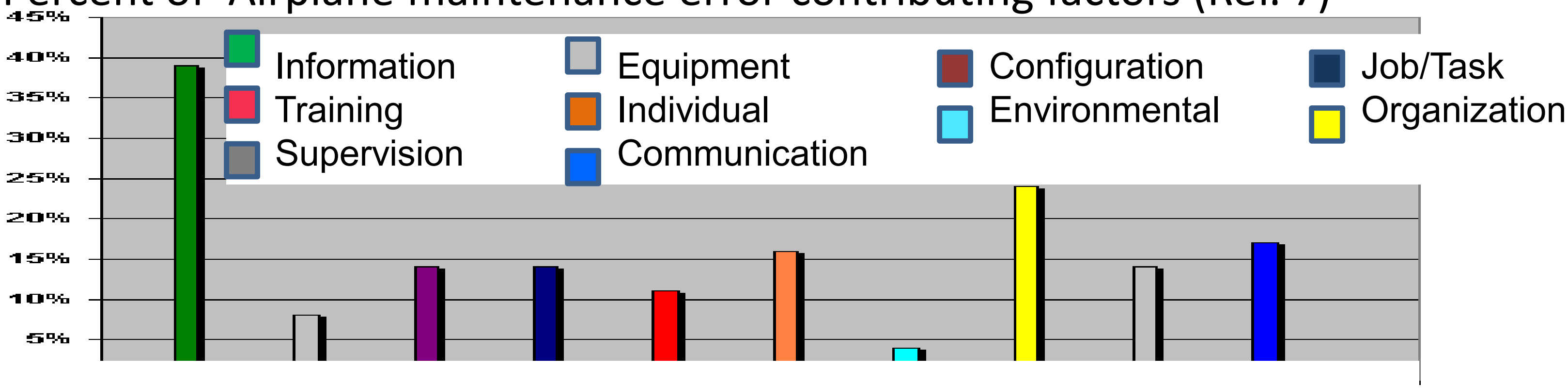
Examples of human error analysis / root causal analysis

- Percent of error types (failure modes) – Airplane maintenance errors (Ref. 6)



Installation error - 44%
Approved data not followed - 28%
Servicing error - 12%
Poor troubleshooting standards - 0.7%
Poor maintenance practices - 9%
Poor inspection standards - 5%
Misinterpretation of approved data - 2%

- Percent of Airplane maintenance error contributing factors (Ref. 7)



- ✓ Failure modes / contributing factors classified and ranked
- X Occurrence of the tasks not reported
- X Relation between failure modes / contributing factors unspecified

Examples of observed human error rates in operations (human performance databases)

- Error rates for nuclear power plant maintenance tasks (Ref. 4):
  - **1/7** for transporting fuel assemblies with the fuel handling machine
  - **1/48** for removing a ground connection from a switchgear cabinet
  - **1/888** for reassembly of component elements

- Reported error rates in medical pharmacies (Ref. 5):
- **5%** for failure to select ambiguously labeled control/package
- **2%** for failed task related to values/units/scales/indicators
- **0.6%** for procedural omission

- ✓ Human error rates reported for the failure modes
- X ✓ Relation of failure mode / contributing factors (maybe) unspecified

Example: Human error rates in experimental studies

The effect of incomplete information on decision-making in simulated pilot de-icing (Ref.8)

Task: Make decision on de-icing in flight simulation under icing weather

Failure mode: Incorrectly select or use information for decision-making

Context: Incomplete or unreliable information (30%), time pressure

Results: Providing additional accurate information improves handling of icing encounters. Performance drops below the baseline when inaccurate information (high uncertainty) is provided in the decision-aid.

% error

	Accurate and additional information	Accurate and incomplete information	Inaccurate additional information
% Stall	18.1	30	89
% recovery	26.7	63.8	75

- ✓ Failure modes, error rates, and specific context reported
- ✓ Quantitative impact of specific context factors reported
- X Not generalized for more complex context with multiple factors

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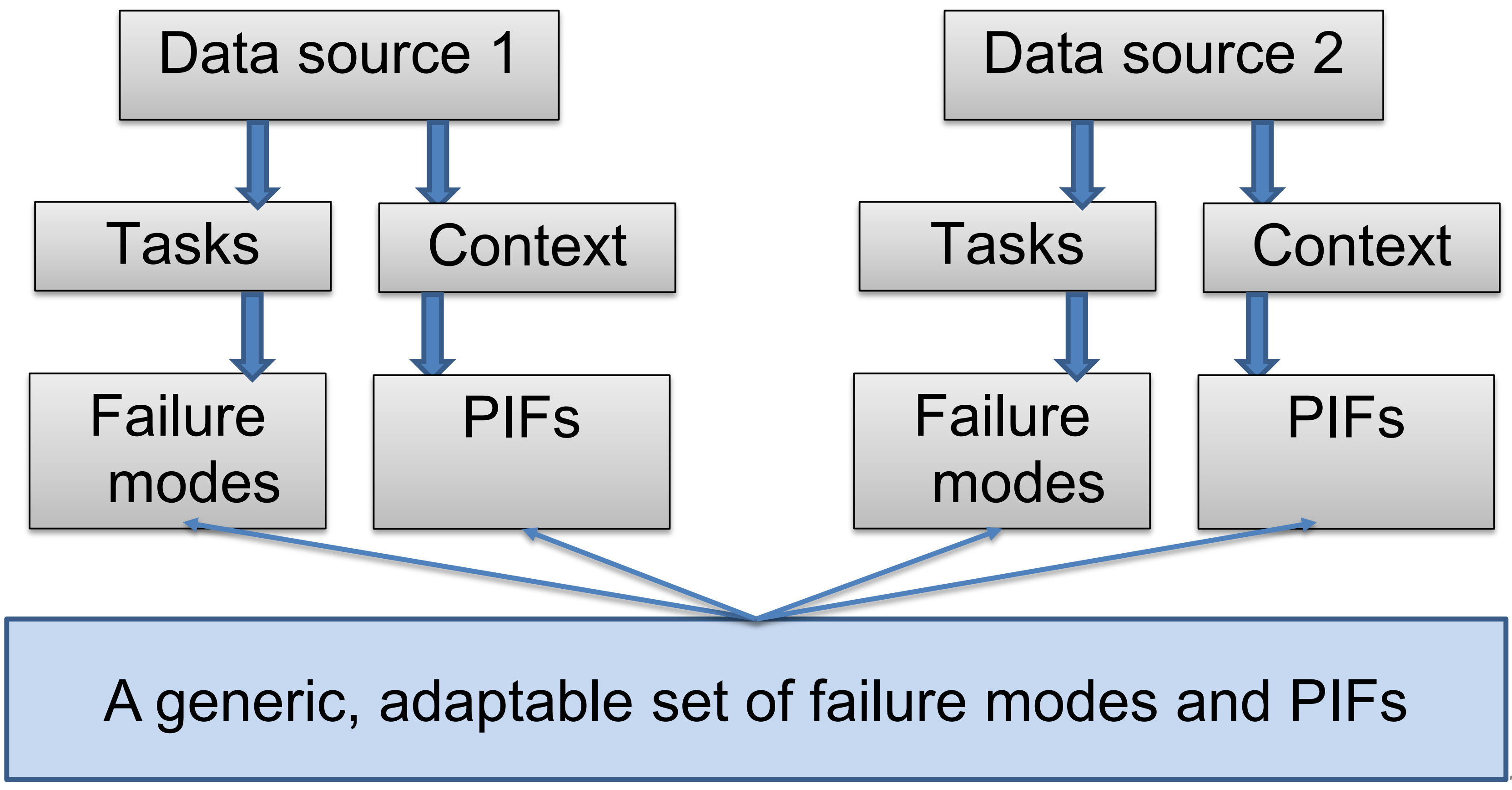
Generalizing human error data to inform human error probability estimation

HEP = *f*(states of performance influencing factors)



Demonstration of IDHEAS-G cognitive failure modes

Failure of macrocognitive function

- Failure of Detection
- Failure of Understanding
- Failure of Decisionmaking
- Failure of Action Execution
- Failure of Teamwork

Failures of cognitive process

- D1- Fail to establish acceptance-criteria
- D2 – Fail to attend to sources of information
- D-3 – Fail to perceive the information
- D4- Fail to verify and modify detection
- D5- Fail to retain or communicate Information

Behaviorally observable failure modes

- D3-1 Primary information is not available
- D3-2 Key alarm or alert not attended to
- D3-3 Key information not perceived
- D3-4 Information misperceived (e.g., failing to discriminate signals, reading errors)
- D3-5 Parameters incorrectly monitored

Demonstration of IDHEAS-G PIF structure

Context

PIF

PIF attributes

Systems and environment

- Environmental factors
- System opacity
- Information
- Tools and parts
- HSI
    - Alarm not salient
    - Mode confusion
    - Key Information masking
    - Ambiguity of Indicators

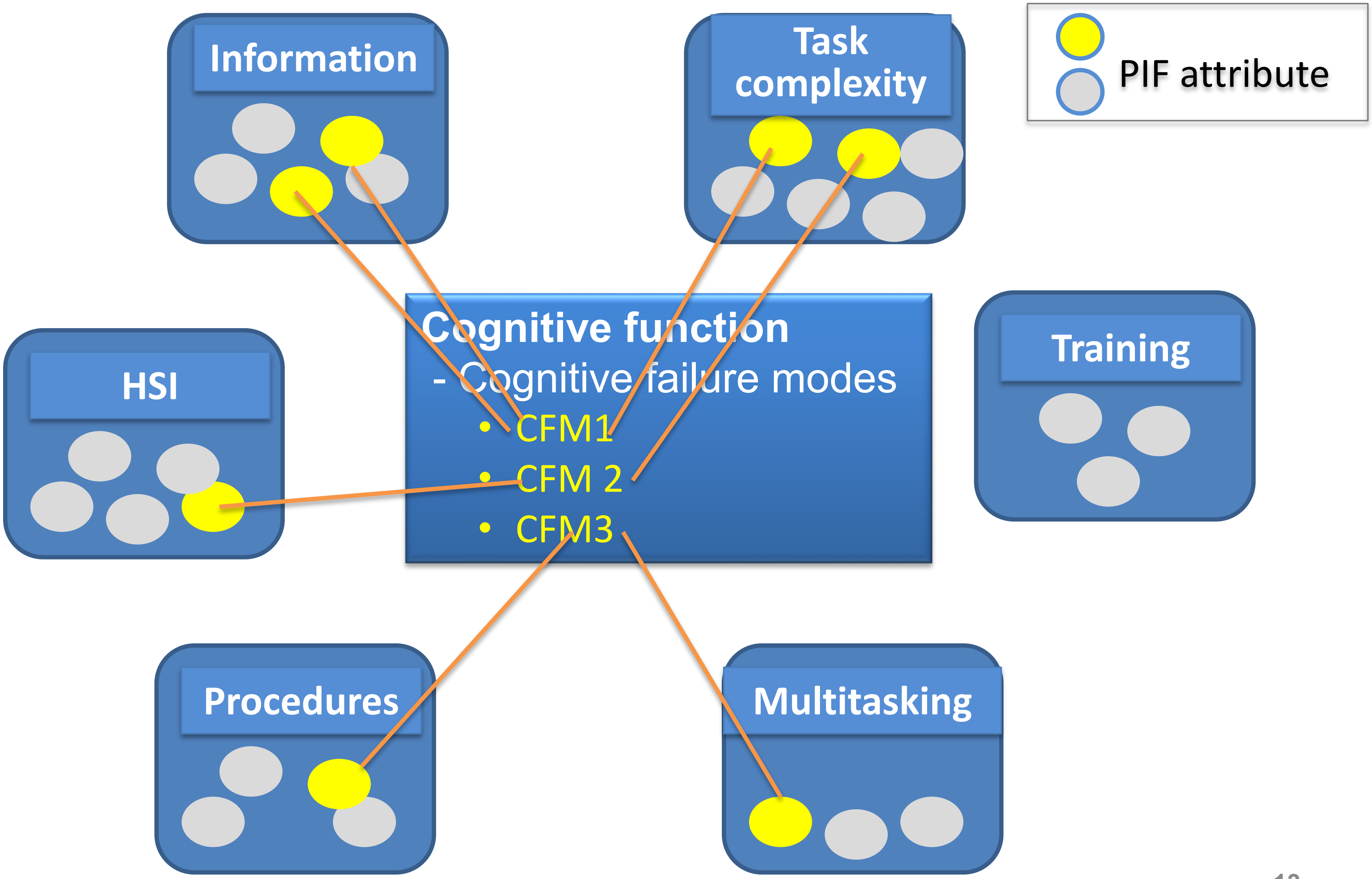
Personnel / team / organization

- Procedures
- Training
- Work process
- Organization factors
- Teamwork factors
    - Teamwork infrastructure
    - Distributed teams
    - Communication equipment
    - Communication protocol

Task / situation

- Unfamiliar scenario
- Multitasking, Interruption, and distraction
- Cognitive complexity
- Mental fatigue and stress
- Physical demands

Generalizing human error data to IDHEAS-G cognitive failure modes (CFMs) and PIFs



Evaluate data - PIF effects on human errors

Error factor (EF) = Error rate at a poor state of the PIF / error rate at the nominal state

PIF - *Multitasking, Distraction and interruption*

Ref	Context and task	Error rates and impact factor (EF)
Ref .8	Experiment on dual task: Airplane pilots detecting de-icing cue and responding to air traffic control information	Error rate in detecting icing cue alone vs. dual-task: 2.8% vs 21% missing cue EF= **7.2** 5% vs 20% missing changes EF= **4** 1% vs 37% wrong diagnosis EF= **37**
Ref. 9	Effect of interruption on target detection	Accuracy for no interruption vs interruption Simple Spatial .726 (.21) .803 (.11) Complex Spatial . 549 (.254) .441 (.273) EF(weak interruption on detection) =**1.1** for simple task EF(weak interruption on detection) =**0.9** for complex task
Ref. 10	Driving simulation with cell phone conversation	Missing dangerous targets: 2.5% without cell phone distraction 7% with cell phone distraction EF(persistent distraction) = **2.8**
Ref. 11	Experiment on performing sequences of action steps	error rate =0.15 for no interruption, 0.3 for 2.8s interruption, EF(interruption) = **2** 0.45 for 4.4s interruption, , EF(longer interruption) = **3**
Ref. 12	The effect of interruption on driving and fighting in military weapon system	4% for no interruption and 8% with interruption EF(interruption) =**2**

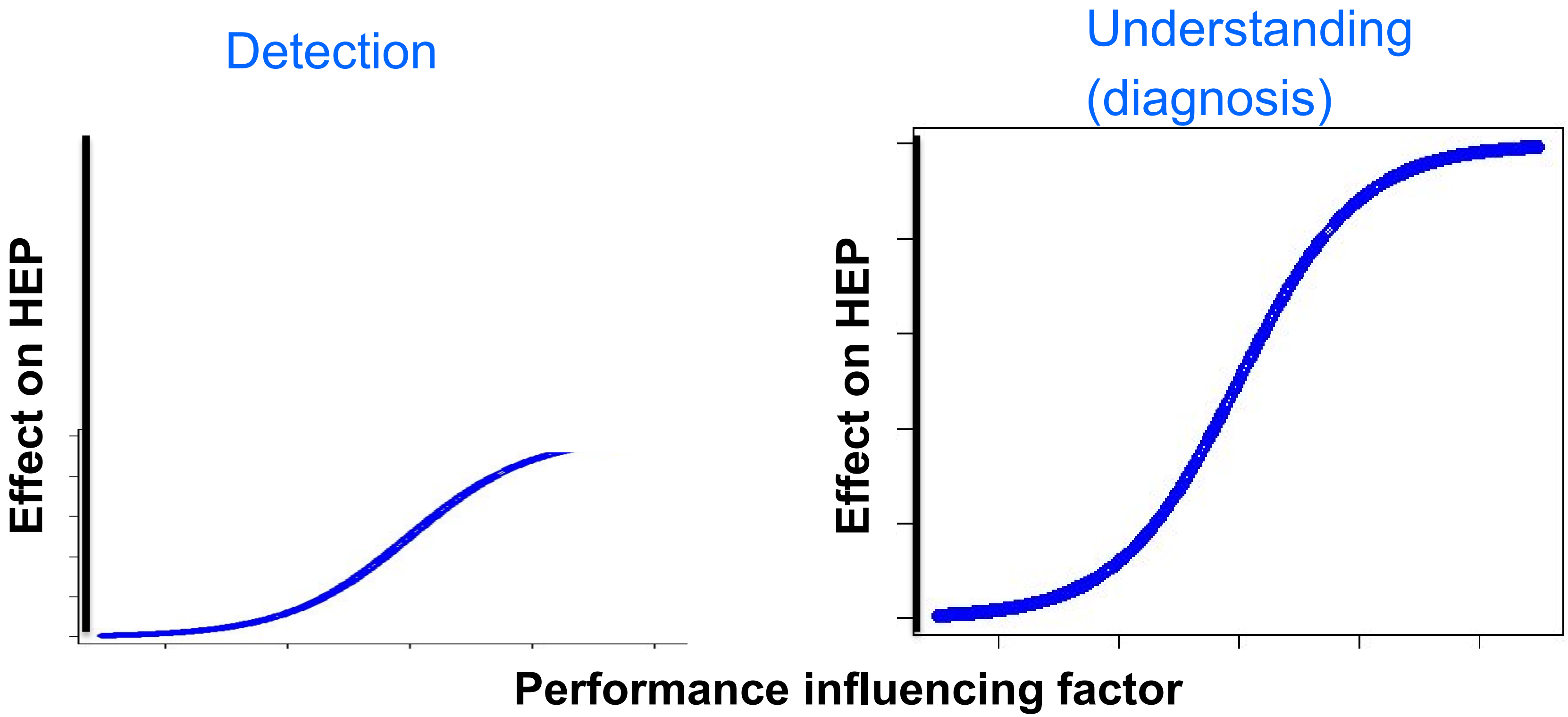
Interpret and represent human error data

PIF - *Multitasking, Distraction and interruption*

PIF state / Macrocognitive function	Low impact - Distraction - Interruption	Moderate impact - Secondary task - Prolonged interruption	High impact - Intermingled multitasking - Concurrently multitasking
Detection	EF(weak interruption) = **[0.9, 1.1]**	EF(persistent distraction)=**2.8**	EF(dual-task) = [**5, 7.5**]
Understanding			EF(intermingled)=**37**
Decisionmaking	EF(interruption on simple decision) = **1.6** EF(interruption on complex decision) = **1.7**		
Action Execution	EF(2.8s) = **2** EF(4.4s)=**3** EF(interruption)=**2**	HEP (interruption) = **2**	
Teamwork			
Undetermined	EF(interruption)=**2**		

Integrating the data to inform PIF quantification

Example PIF – Multitasking, interruption, and distraction



Evaluate data - PIF effects on human errors

PIF – *Teamwork factors*

ID	Context and task	Error rate
	Nuclear waste handling facility maintenance and operation Supervisor verification error	Check-off sheet, low dependence 1E-1 Check-off sheet, medium dependence 3E-1 Check-off sheet, high dependence and stress 5E-1 EF(independent checking) = **5** for high dependence EF(independent checking) = **3** for medium dependence
	Failure to restore from testing	Two persons, operator check 5E-3 Single person, operator check 1E-2 Single person, no check 3E-2 EF(no team verification) = **2**
	Failure to restore following maintenance	Two persons, operator check 3E-3 Single person, operator check 5E-3 Single person, no check 5E-2 EF(no team verification) = **1.7**
	Experiment of vigilance dual task – detecting targets (responding to visual alarms) and completing jigsaw puzzle.	Paired team, low target presentation speed 19% Single person, low target presentation speed 29% Paired team, high target presentation speed 28% Single person, high target presentation speed 38% EF(team detection) = **1.5, 1.3** for low and high complexity

Evaluate Data - PIF effects on human errors

PIF – *Information completeness and Correctness*

ID	Context and task	Error rate
04	Expert judgment of HEPs for NPP internal at-power event Information misleading	HEP (information obviously incorrect) = 3E-2 IHEP (information not obviously incorrect) =8E-2E-1 HEP(No information misleading) = 1E-3 EF = **30** for Information obviously incorrect EF=**80** for Information not obviously incorrect
40	Experimental study on supporting decision making and action selection under time pressure and information uncertainty in pilots de-icing simulation	Error rate - Percentage of early buffet: Accurate information 7.87% Accurate information but not timely) 20.56% 30% inaccurate information 73.63.% Error rate - Percentage of stall: Accurate information 18% Accurate information not timey 30% (30%) inaccurate information 89% EF = **1.5, 2.5** for accurate but not-timely or not-organized information EF= **5, 9** for 30% inaccurate information

Conclusions

- Human error data are available, not perfect, but can be used to inform quantification of human error reliabilities
- IDHEAS provides a framework to generalize human error data for HRA
- We preliminarily generalized the data to inform the quantification of performance influencing factors on human error probabilities

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Thank you!

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