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IDHEAS - An Integrated Human Event Analysis System

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Presented by Jing Xing to the public meeting on IDHEAS
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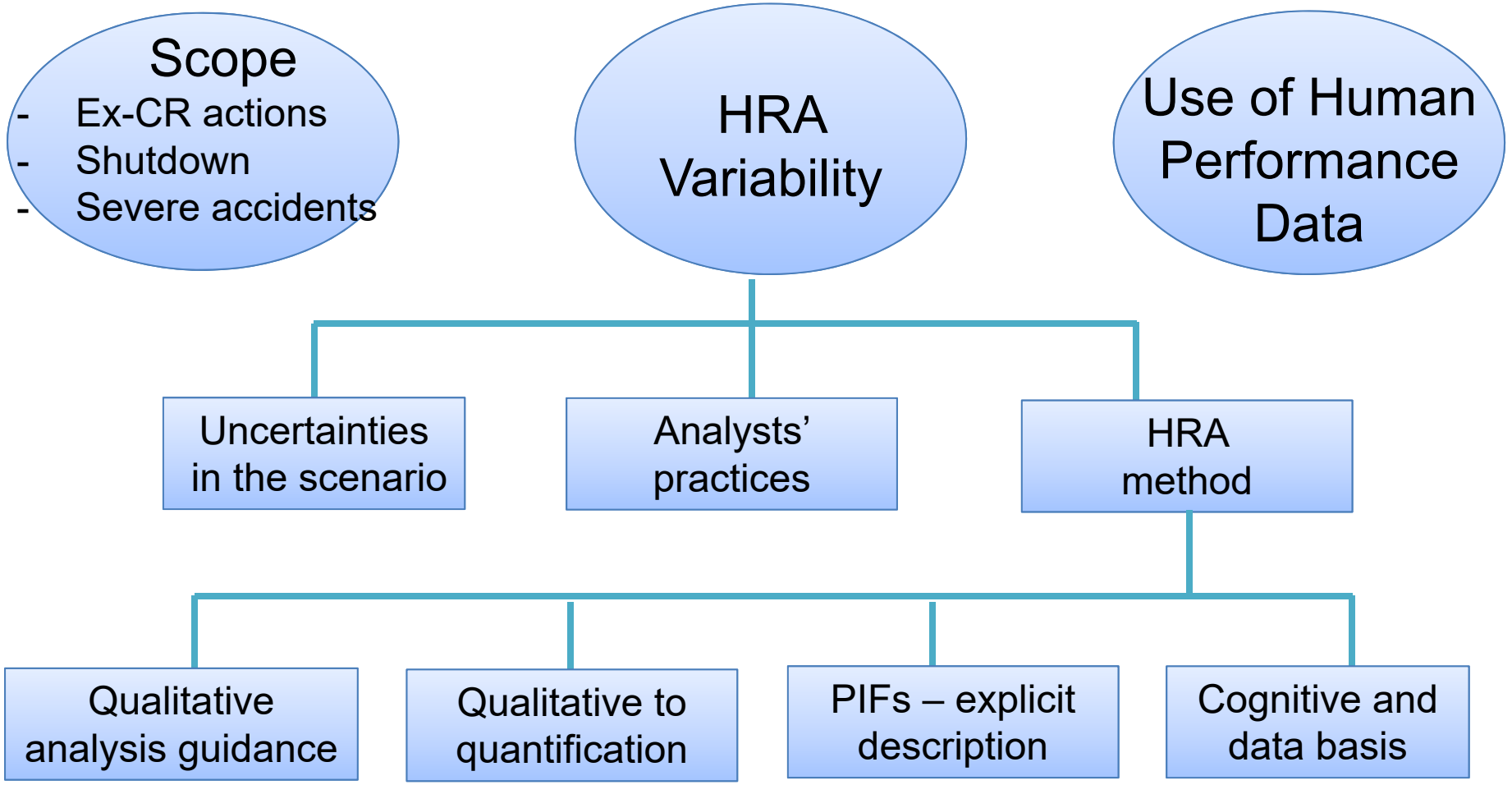
Outline

I. Overview of IDHEAS

II. IDHEAS General Methodology (IDHEAS-G)

III. Generalization of Human Error Data - IDHEAS-DATA

Where we started …



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What we have achieved

- Expanded scope – IDHEAS is an HRA method suite for all nuclear HRA applications

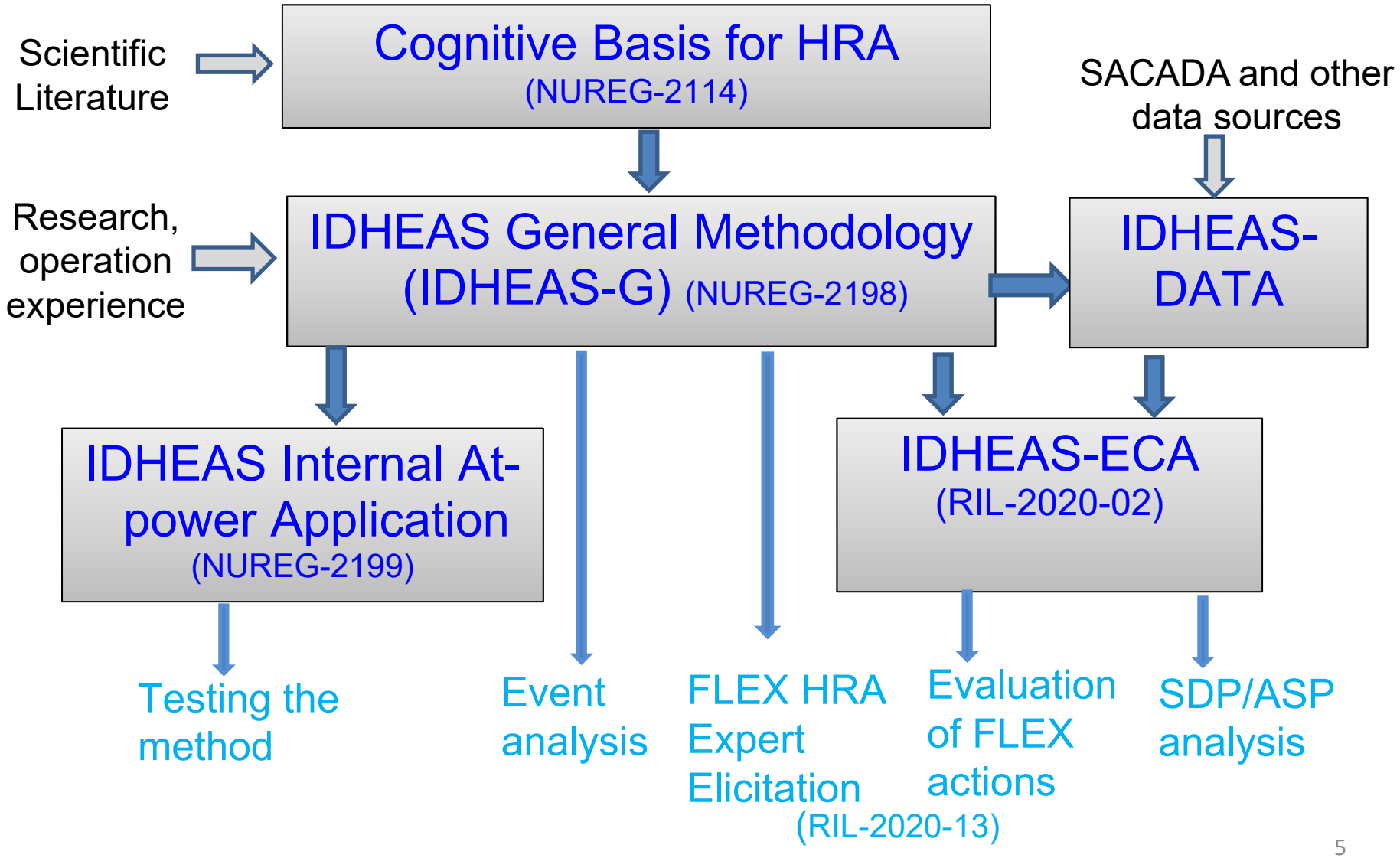
- Use of human performance data – Human error data were explicitly used in IDHEAS

  - The method and data structure are based on the same cognitive basis model such that data can be generalized and used by the method.

- HRA variability – IDHEAS improves HRA method variability by enhancing the four areas (identified in HRA benchmarking studies)

  - Systematic qualitative analysis guidance
  - Links between qualitative analysis outcomes and quantification of human error probabilities (HEPs)
  - Explicit attributes for every performance influencing factor (PIF)
  - Cognitive and data basis that links PIF attributes to cognitive failure modes (CFMs)

Development of IDHEAS
- An Integrated Human Event Analysis System



Development of IDHEAS
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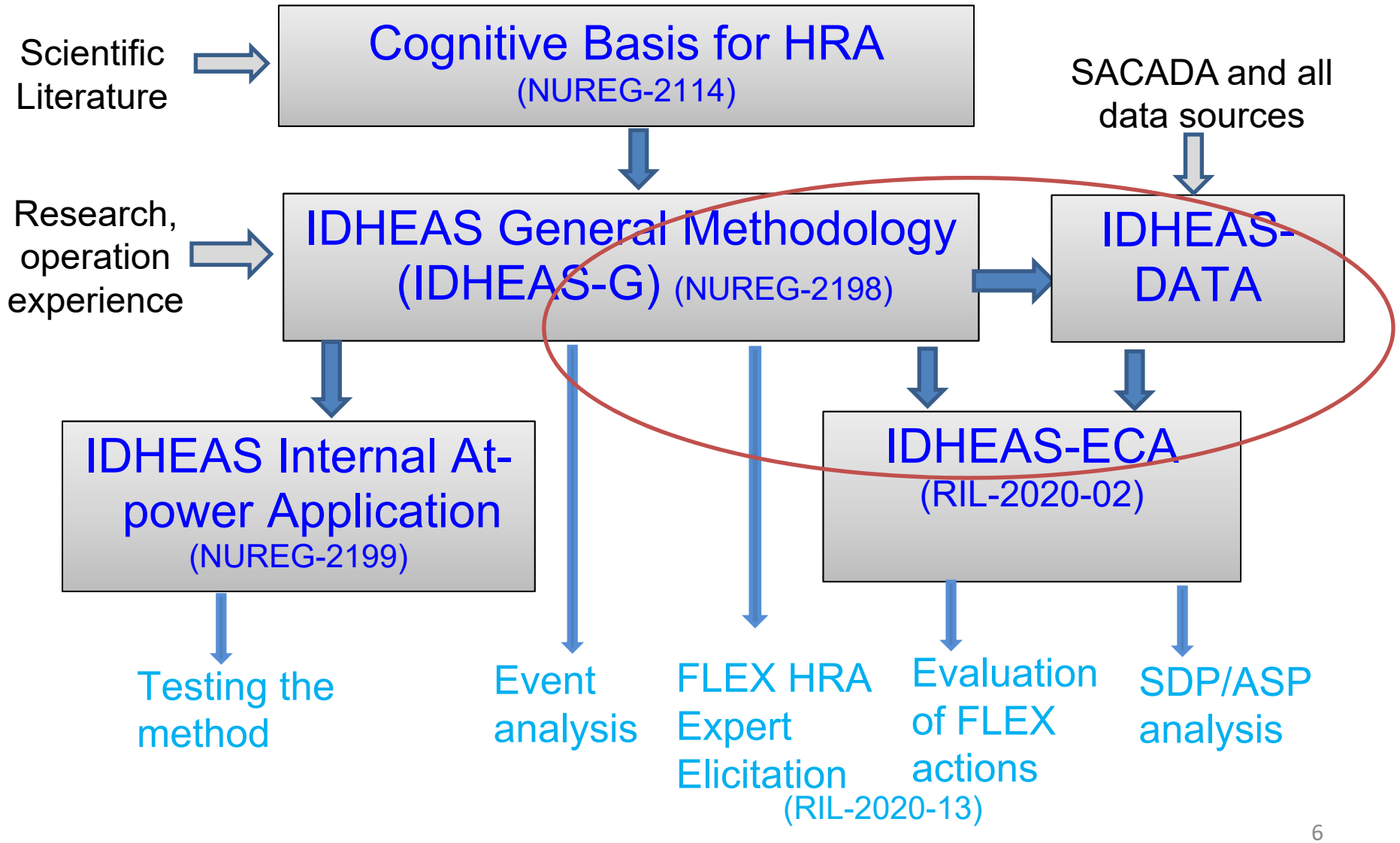

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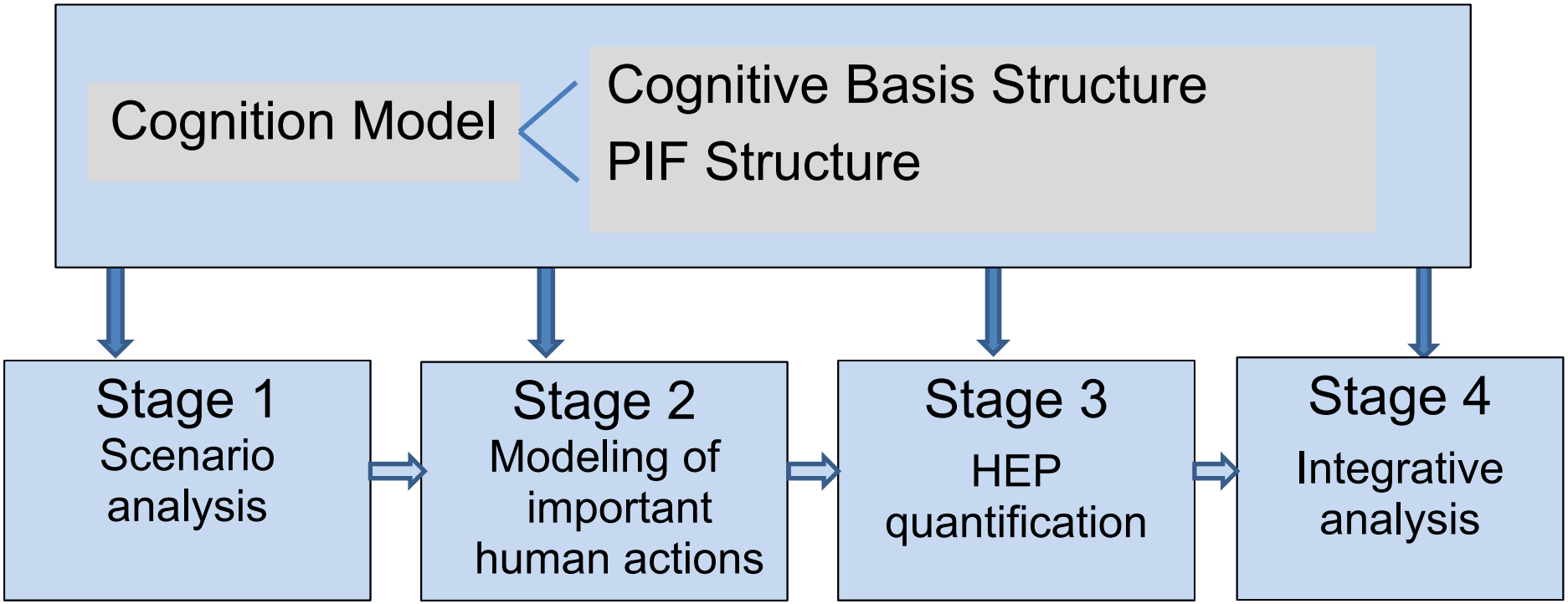
What is IDHEAS-G

- A methodology for developing application-specific HRA methods
- A platform for generalizing and integrating human error data to support HEP estimation
- A general HRA method for human event analysis and human error root causal analysis

Overview of IDHEAS-G

IDHEAS-G consists of a cognition model as the framework for HRA, its implementation in an HRA process, and detailed guidance for HRA applications.



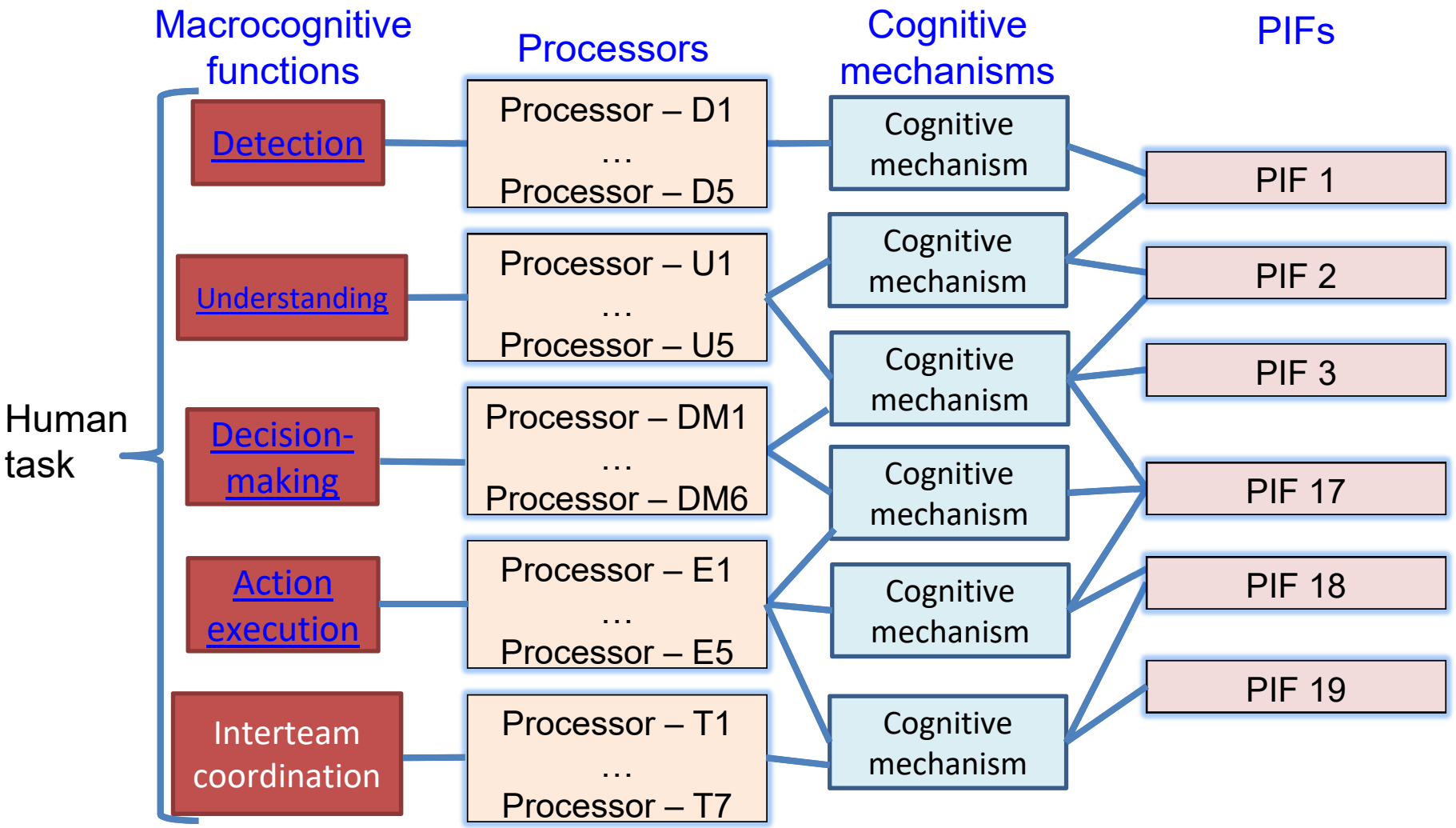
What's in IDHEAS-G report (NUREG-2198)

Model	Guidance

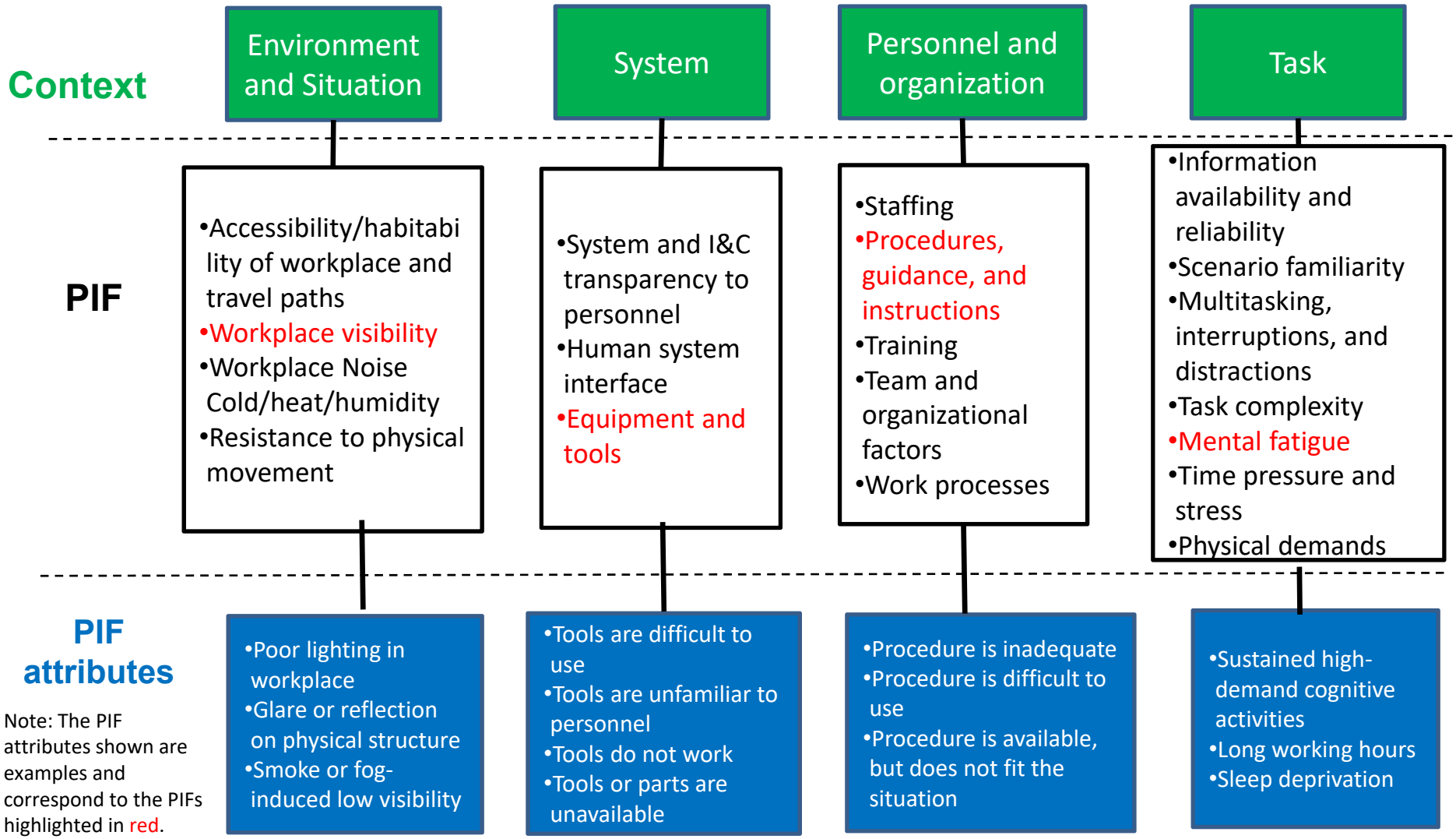
• Cognitive model
  - Cognitive basis structure
  - PIF structure
• Time uncertainty model
• HEP quantification model
• Dependency model
• Structure for generalizing human error data
	• Collecting data and information for HRA
	• Analyzing scenario and searching for context
	• Identifying and defining human failure events
	• Analyzing and characterizing tasks
	• Understanding and selecting applicable cognitive failure modes (CFMs)
	• Representing (mapping) context with performance influencing factors (PIFs)
	• Analyzing and documenting uncertainties
	• Developing application-specific IDHEAS methods from IDHEAS-G

A step-by-step HRA process integrating all the models and guidance	Three full examples demonstrating IDHEAS process

Cognitive Basis Structure



PIF Structure



Note: The PIF attributes shown are examples and correspond to the PIFs highlighted in red.

IDHEAS-G HRA process

PRA model

Human Failure Event (HFE)

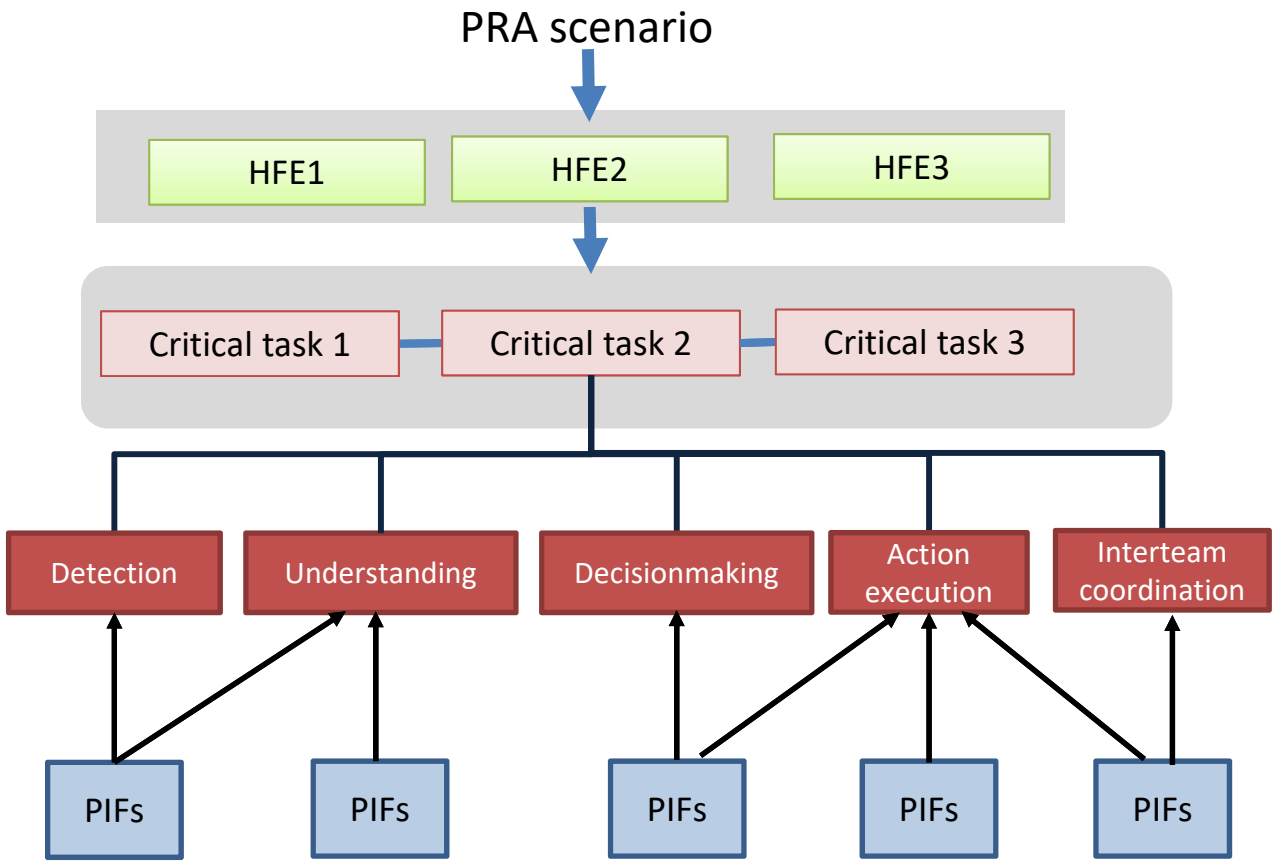
Critical tasks

Macrocognitive functions and cognitive failure modes (CFMs)

Performance influencing factors (PIFs)

Human error probability (HEP)

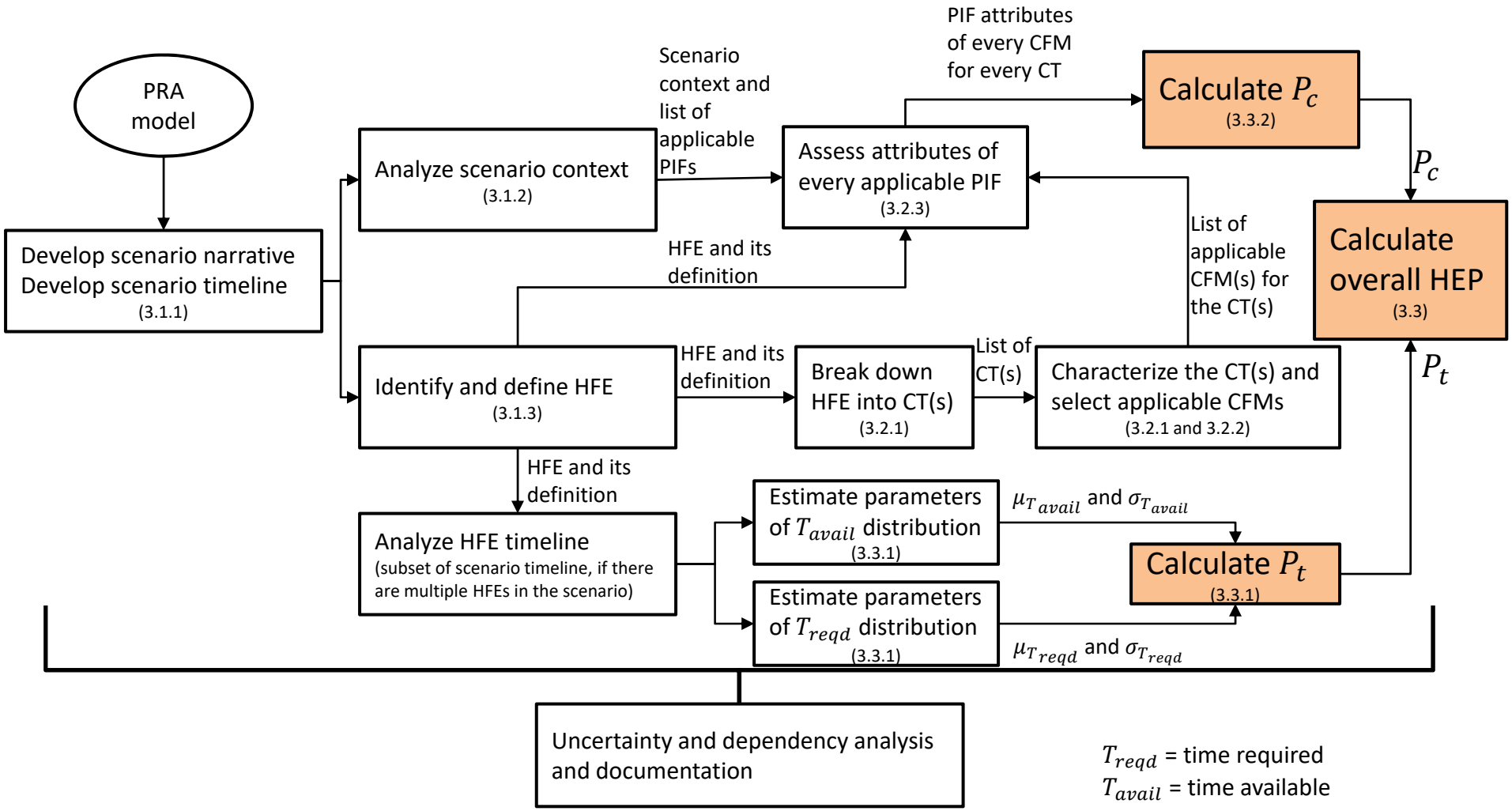
Integration to PRA



Pc - HEP of a CFM = f(PIFs); Pt - HEP of time uncertainty

Dependency analysis and Uncertainty analysis

IDHEAS-G HRA Process



T_{reqd} = time required
T_{avail} = time available

CFM = cognitive failure mode
CT = critical task
HEP = human error probability
HFE = human failure event

PIF = performance-influencing factor
PRA = probabilistic risk assessment
P_c = error probability due to CFMs
P_t = error probability due variability in T_{avail} and T_{reqd}

$\mu_{T_{avail}}$ and $\sigma_{T_{avail}}$ = mean and standard deviation of T_{avail}
$\mu_{T_{reqd}}$ and $\sigma_{T_{reqd}}$ = mean and standard deviation of T_{reqd}

HEP Quantification—P_c

- Probability of CFM, P_{CFM}, can be estimated in one or a combination of the following three ways:
  - Calculation from the number of errors divided by number of occurrences
  - Expert judgment
  - HEP quantification model

- IDHEAS-G provides a data structure of generalizing human error data to support the three ways.

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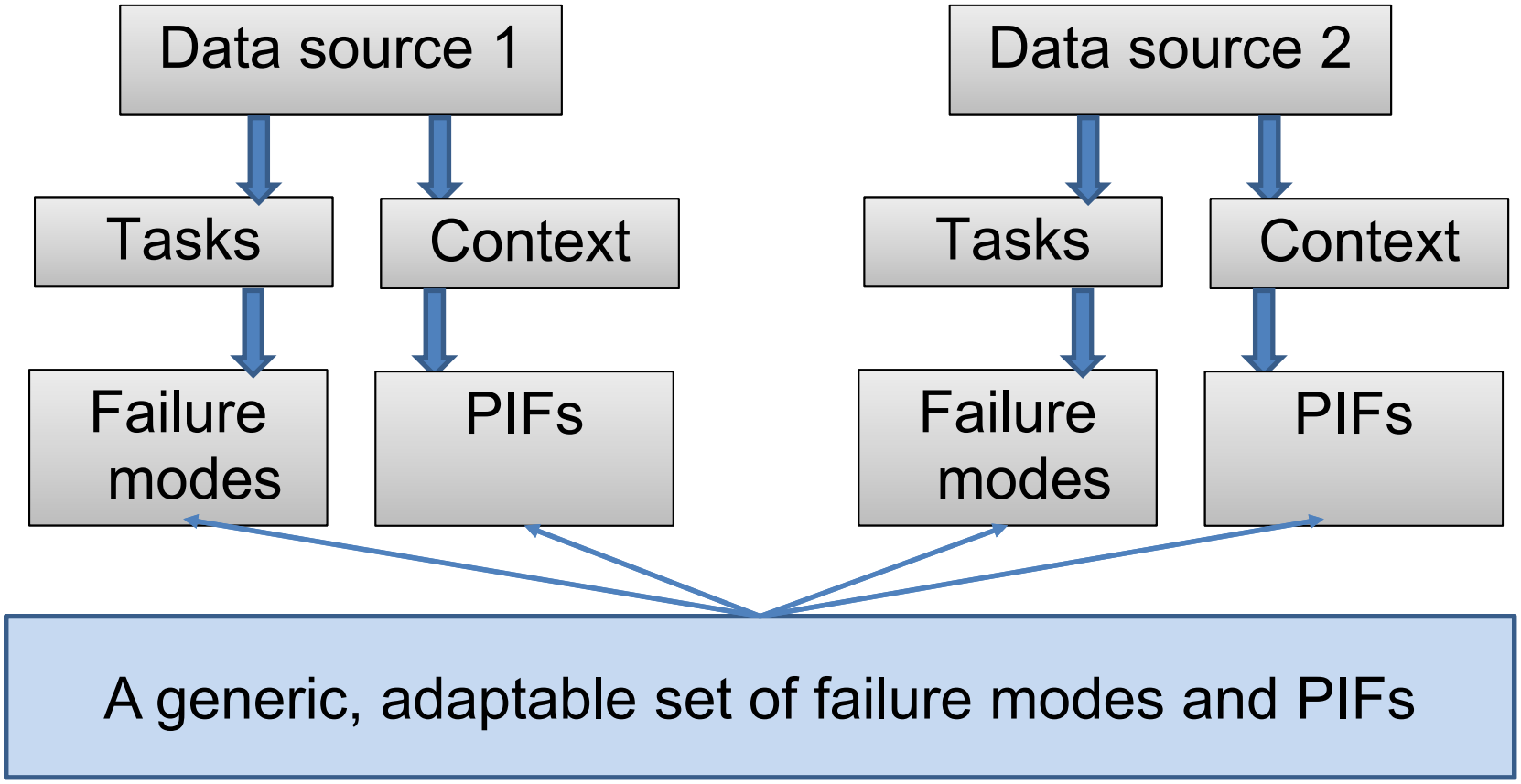
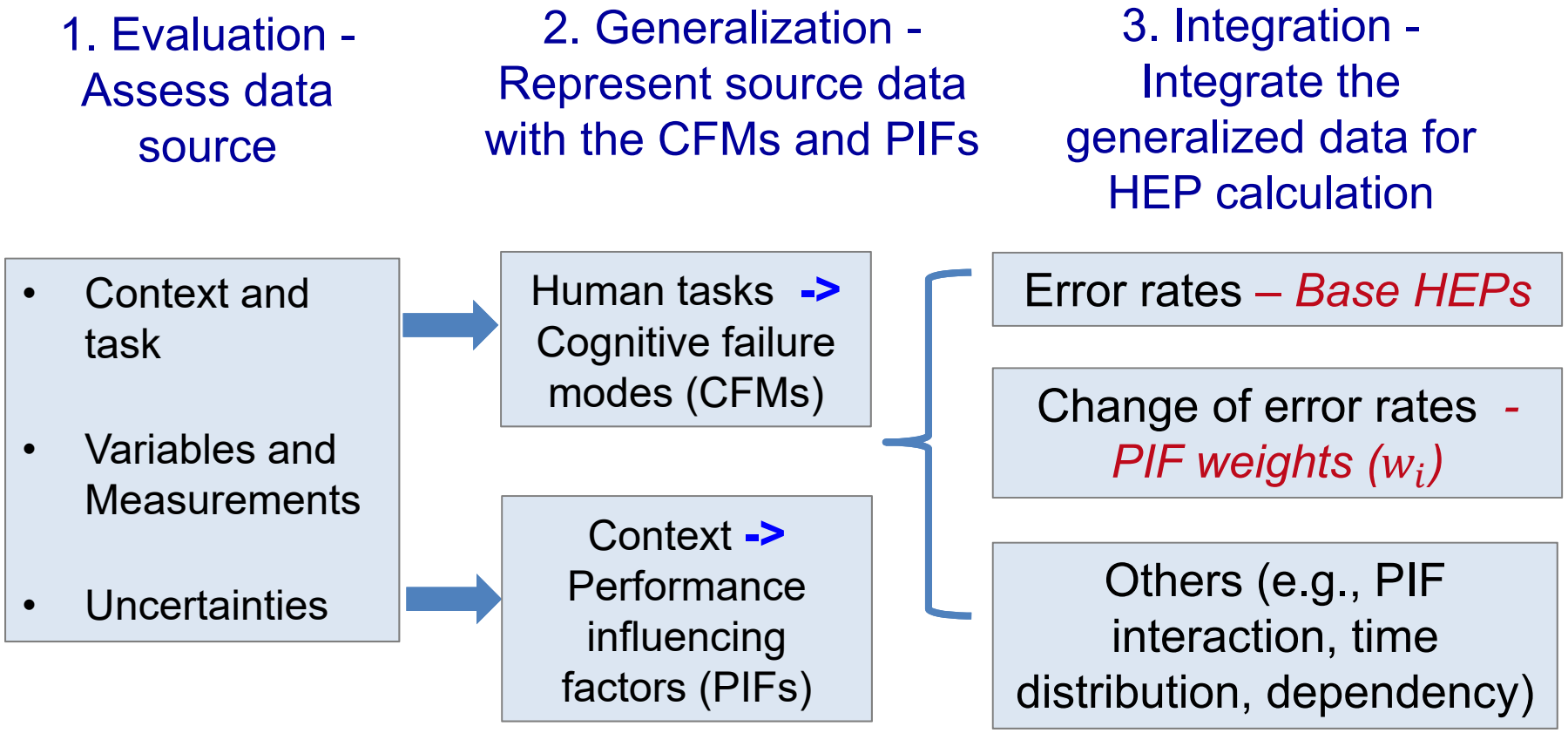
Generalizing human error data to inform HEPs

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

- Human error data exist from various domains, in different formats, varying context and levels of detail.



Use human error data to inform HEPs



Data sources

A. Nuclear simulator data and operational data
   (e.g., SACADA, HuREX, German NPP maintenance database analysis)

B. Operation performance data from other domains
(e.g., transportation, off-shore oil, military operations, manufacturing)

C. Experimental studies in the literature
   (e.g., cognitive and behavior science, human factors, neuroscience)

D. Expert judgment of human reliability in the nuclear domain

E. Unspecified context
   (e.g., statistical data, ranking, frequencies of errors or causal analysis)

IDHEAS-DATA Structure

- IDHEAS-DATA has 27 tables (**IDTABLEs**) documenting generalized human error data and empirical evidence
- Human error data are generalized to IDHEAS-G CFMs and PIF attributes

IDHEAS-DATA IDTABLE	
IDTABLE 1-3 Base HEPs	IDTABLE-21 Lowest HEPs of CFMs
IDTABLE-1 Scenario Familiarity	IDTABLE-22 PIF Interaction
IDTABLE-2 Information	IDTABLE-23 Distribution of Task Needed
IDTABLE-3 Task Complexity	IDTABLE-24 Modification to Time Needed
IDTABLE 4--20 PIF Weights	IDTABLE-25 Dependency of Human Actions
IDTABLE 4-8 Environment PIFs	IDTABLE-26 Recovery of Human Actions
IDTABLE 9-11 System PIFs	IDTABLE-27 Main drivers to human events
IDTABLE 11-16 Personnel PIFs	
IDTABLE 17-20 Task PIFs	

Example datapoints from SACADA database

- SACADA collects operators' task performance data in simulator training.
- The unsatisfactory performance rates ("UNSAT") for training objective tasks were calculated from the SACADA data before April 2019 and used for IDHEAS-ECA.
- For example, SACADA characterizes operators' scenario familiarity as three options: Standard, Novel, and Anomaly. The datapoints are used for the base HEPs of PIF Scenario Familiarity (SF3.1) for CFMs *Failure of Understanding* (U) and *Failure of Decisionmaking* (DM), as shown in the table below

SACADA data			IDHEAS-DATA		
Task (Training Objectives)	Situation factors	Error rates	CFM	PIF	Uncertainties
Operators diagnose in simulator training	Anomaly scenario	1.2E-1 (8/69)	U	SF3.1	Other PIFs may exist
Operators make decisions in simulator training	Anomaly scenario	1.1E-2 (1/92)	DM	SF3.1	Other PIFs may exist

Summary of IDHEAS-DATA

By 2020:

- Use of nuclear operation/simulation data (SACADA, HuREX, Halden studies)
- ~300+ literature generalized; another 200+ evaluated and selected for generalization
- The generalized data were independently verified and reviewed
- The generalized data were integrated for HEP calculation in IDHEAS-ECA

In the future:

- Human error data needed in teamwork and organizational factors
- Data generalization is an on-going, continuous effort; Data integration should be periodically updated.