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Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut

Human Factors and Reliability – ESRA Technical Committee

Luca Podofillini
Laboratory for Energy Systems Analysis, Paul Scherrer Institute
Plenary Session, Friday 29th June 2012.

PSAM11-ESREL12, 25-29 June 2012, Helsinki, Finland

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Outlook

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- HRA empirical study – from a different perspective

- Decision Errors, Context-based HRA

- Some final remarks

Barrier analysis
Decision errors   data collection
performance modelling   Scope of HRA methods
maintenance errors
context modelling   simulator data   Context-based HRA
HRA method assessment   Performance Shaping Factors   model-based HRA
cognitive models   HRA Empirical Study
Bayesian Belief Nets   HF analysis
Oil and Gas   organizational factors
Nuclear   Fuzzy Logic   accident investigation   new HRA method development
Team-Dynamics   Safety Instrumented Systems   HRA Dependence

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Simulator Studies for HRA **"A turning point for HRA"**

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Background

- For the actions/tasks of interest in the PSAs of nuclear power plants, HRA data is scarce.
- Integrated risk-informed decision-making requires validated tools.
- HRA data is essential to validation of HRA (validity of methods, calibration of expert judgment)

Recent developments

Use of HRA data from dedicated simulator studies for HRA method assessment

Int'l HRA Empirical Study (2007-2011)

- SGTR (2 scenarios), LOFW (2 scenarios)
- 13 actions (HFEs)
- 14 licensed crews
- method vs. reference data. Could not address inter-analyst method reliability (consistency)

U.S. HRA Empirical Study (2010-2011)

- 3 scenarios: SGTR, LOFW+induc. SGTR, Loss of CCW and Seal LOCA
- 4 (+1) actions (HFEs)
- 4 licensed crews
- 2-3 analysis teams per method * 4 methods

Some references:
International HRA Empirical Study
NUREG/IA-0216, issued also as
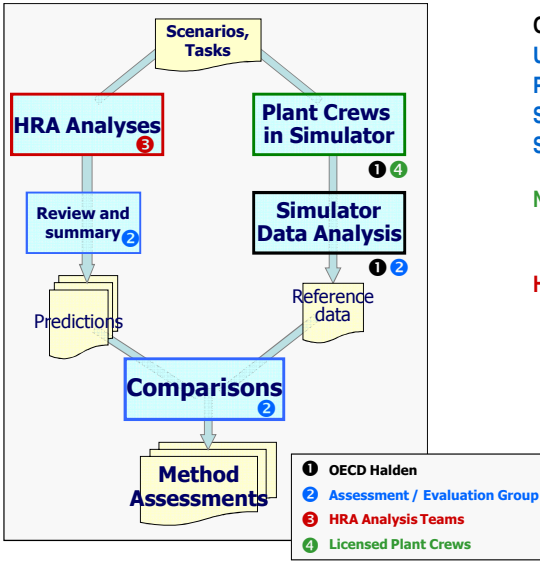HWR-844, HWR-915, HWR-915

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HRA Empirical Studies method benchmarks based on simulator data

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Scenarios, Tasks

HRA Analyses ❸

Plant Crews in Simulator ❶ ❹

Review and summary ❷

Simulator Data Analysis ❶ ❷

Predictions

Reference data

Comparisons ❷

Method Assessments

❶ OECD Halden
❷ Assessment / Evaluation Group
❸ HRA Analysis Teams
❹ Licensed Plant Crews

OECD Halden ❶ ❷
U.S. Nuclear Regulatory Commission ❷ ❸
Paul Scherrer Institute ❷ ❸
Scientech / EPRI ❷ ❸
Sandia Nat. Laboratories ❷

Nuclear power plant crews ❹

14 x 3-person licensed crews (same utility)

HRA Analysis Teams ❸

US: NRC, EPRI, INL
France: EDF, IRSN
Korean Atomic Energy Research Institute (KAERI)
Nuclear Research Institute Rez, Cz
Paul Scherrer Institute, CH
Ringhals/Vattenfall, Sweden
Technical Res. Centre of Finland (VTT)

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Simulator Studies for HRA

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Overall outcomes and conclusions

HRA

- **Reference data collected in simulator allows useful assessment of HRA methods**
  - both qualitative and quantitative results (performance issues and probabilities)
- **This benchmark against data provided strong indications for improving methods**
  - Methods focusing on wrong issues
  - Calibration of method
- **Benchmarking feasible with 4 crews**
  - with limitations, more would be better...

Safety

- **Simulator study including very challenging scenarios provided insights for safety**
  - Ambiguity in specific items of procedural guidance
  - Factors affecting time performance of tasks (operational difficulties or issues leading to delays)
- **Insights for PSA/HRA analyses**
  - Identification of potential performance issues to be considered for specific scenarios and HFEs

Heritage

- **Quantitative use of simulator studies does not always require 10-100+ observations**
- **Good qualitative analysis is key to get valid results (and safety insights)**
  - Informed by plant operational knowledge
- **Guidance to apply HRA methods should be improved**
  - Qualitative analysis
  - Factors considered (their scope, assessment, impact on error probability)
- **Simulator studies for HRA should be extended**
  - consensus methodology is needed
  - data relevant for current human factors issues and modern interfaces is needed
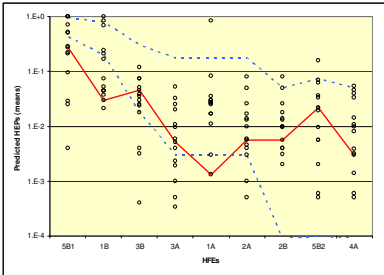
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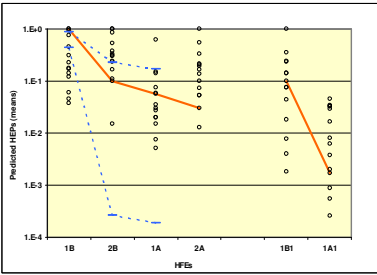
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Quantitative results – CESA-q

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- **Method: CESA-q, quantification module of Commission Errors Search and Assessment - PSI, Switzerland (B. Reer)**
- **HRA team: L. Podofillini (PSI), B. Reer (ENSI)**

- **HEPs sensitive to the conditions addressed in the analysis (Discriminating power)**
- **Generally good correspondence between predicted HEPs and crew data (ranking and uncertainty bounds)**
- **Some optimism in certain HEP predictions (in SGTR)**
  - Conditions for the operators more challenging than we expedited
  - Method focuses on decision errors: execution difficulties possibly underestimated

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Turning insights into method revision

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Assessment in Intl. HRA Empirical Study
- moderately good predictive performance
- traceability, guidance questioned

CESA-q Human Error Quantification based on
- identifying an EOC with a similar factor profile from database
- Quantification based on similarity

- **Database of 26 EOC events from operational experience, analyzed and quantified**

ID	Event Title	EOC	Evaluations of CESA-Q adjustment factors									Mean HEP
			VH	VM	VD	VE	BP	DP	PR	TP	EFI	
AE.1	High Voltage Exposure (restricted)	Bypass of Door Blockage	1	1	1	1	1	1	0	1	4	5.2E-3
...												
AE.3	LOCA through Shutdown Cooling Suction Valve (San Onofre 2, 1995)	Opening of LPI Mini-Flow Isolation Valves	0.2	1	1	1	1	0	1	1	2	7.2E-2

Database dimension is limited (26 events)
- Difficult to find a close match
- Guidance for adjustment is limited (and difficult to develop)

Revision of CESA-Q to address benchmark insights and outcomes
- Model-based (BBN) quantification
- Represent relationships among factors and EOC likelihood
- Model informed by the database
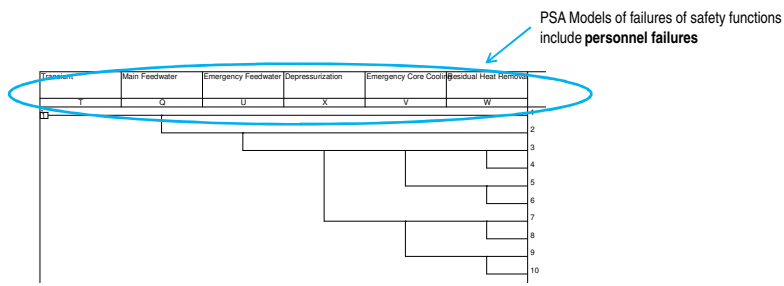
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Probabilistic Safety Assessment and HRA

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- Standard HRA practice (current ASME/ANS Standard) analyzes personnel **failures to perform required responses**, Errors of Omission (EOOs), in HRA terminology

PSA Models of failures of safety functions include **personnel failures**

Transient	Main Feedwater	Emergency Feedwater	Depressurization	Emergency Core Cooling	Residual Heat Removal	
T	Q	U	X	V	W	1
						2
						3
						4
						5
						6
						7
						8
						9
						10

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The EOC issue

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- Errors Of Commission (EOCs): inappropriate actions that aggravate a scenario
  (e.g. Three Mile Island, 1979; Air Florida 90, 1982; Operational event analyses)

- Challenge: to identify **plausible**, **risk-significant** EOC situations
  - The **number of inappropriate actions** that can potentially be performed is very large (in principle)

- Challenge: to assess their probability
  - Decisions can be driven by **very specific contextual factors** (e.g., conflicting goals, misleading indications, multiple aggravating factors acting simultaneously)
  - Lack of empirical data

- *A pioneering study:*
  - *Julius JA, Jorgenson EJ, Parry GW, Mosleh A. A procedure for the analysis of errors of commission in a probabilistic safety assessment of a nuclear power plant at full power, Reliability Engineering & System Safety, 1995; 50:189–201*

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Interest in EOC is growing

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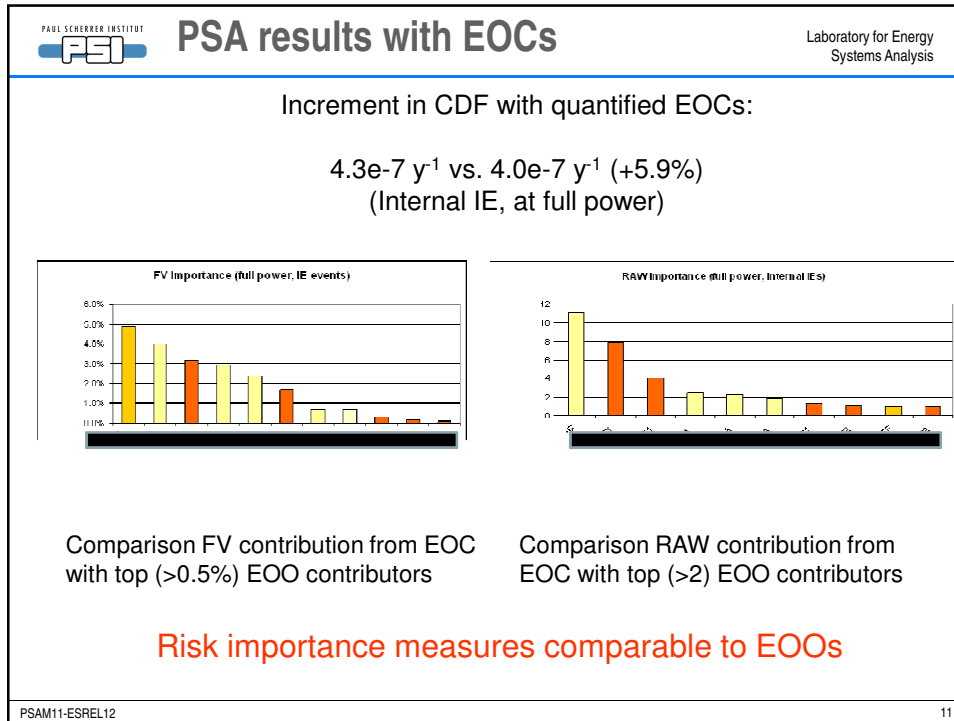PSI

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- Newer **HRA methods**: ATHEANA (US NRC), MERMOS (EDF), CESA (PSI)
- NUREG-1792, "**Good practices for implementing HRA**" dedicates a chapter to EOC
  - Good practice #1: Address EOCs in Future HRAs/PSAs (recommended)
  - Good practice #2: As a minimum, search for conditions that may make EOCs more likely

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PSA results with EOCs   Laboratory for Energy
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Increment in CDF with quantified EOCs:

$4.3e{-}7 \text{ y}^{-1}$ vs. $4.0e{-}7 \text{ y}^{-1}$ $(+5.9\%)$
(Internal IE, at full power)

Comparison FV contribution from EOC
with top (>0.5%) EOO contributors

Comparison RAW contribution from
EOC with top (>2) EOO contributors

Risk importance measures comparable to EOOs

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EOCs, where is the bar?   Laboratory for Energy
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- **Identification:**
    - Conceptually, we know what we want (plausibility, risk significance)
    - Methods exist (ATHEANA, MERMOS, CESA, …)
    - Experience with comprehensive studies on EOCs is limited worldwide, so is the use of results from previous studies to inform new ones
        - EOCs identified in one plant study can be taken for consideration for another plant
        - Towards a library of relevant EOCs to be systematically addressed

Recommend that efforts on large-scale applications be undertaken

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EOCs, where is the bar?

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- ## EOC quantification
  - Difficult (treating decisions, multiple interacting factors)
  - Existing methods heavily based on expert judgment
  - We need to build consensus on what **types of decisions** we want to model and **what factors characterize them**.
    - Key for another, underexplored area for HRA: severe accident management response

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The HRA Society

"Improving Safety for Society"
through better human performance prediction

Aims of the HRAS

• **foster the discipline**
• **support HRA professionals**
• **exchange expertise and experience**

building a shared vision, organizing events, contributing and participating

Interested?

www.hrasociety.org

Scientific, non-profit society

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