

# Informing HRA by Empirical Data, Halden Reactor Project Lessons Learned and Future Direction

Andreas Bye, OECD Halden Reactor Project,  
Institute for energy technology (IFE)

PSAM 14, UCLA  
September 16-21, 2018



# Three cases on data for HRA

1. Empirical study to evaluate HRA methods
2. Data to support consistent use of the HRA methods by improving the general knowledge of HRA practitioners through qualitative influential details of scenarios
3. Data to support basic questions on e.g., digital vs analog systems

Can data replace HRA methods?



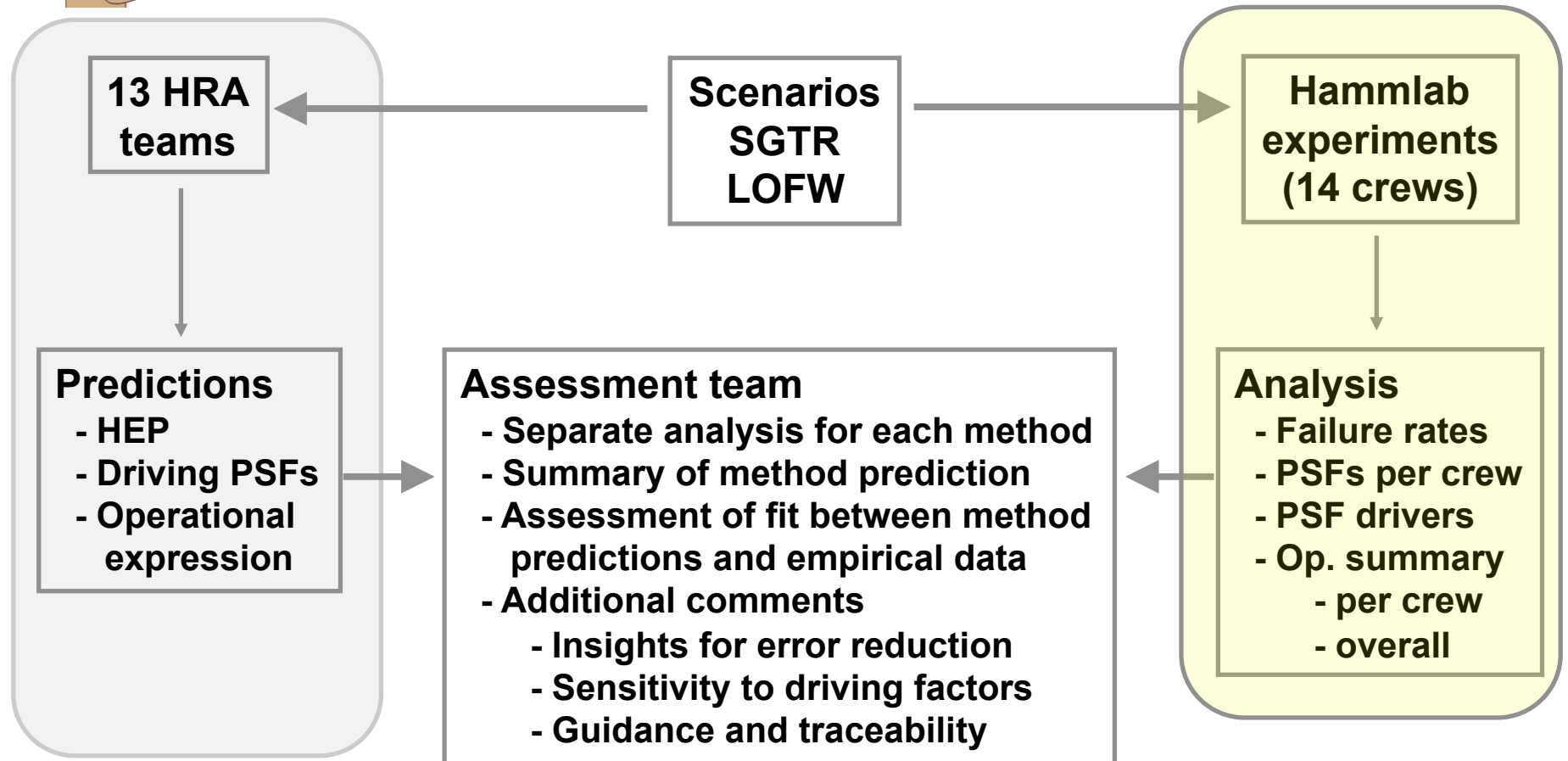
# 1. Empirical study to evaluate HRA methods

- “The International HRA Empirical Study”, NUREG-2127; NUREG/IA-0216, Volumes 1, 2 and 3
- “The U.S. HRA Empirical Study”, NUREG-2156





# Method

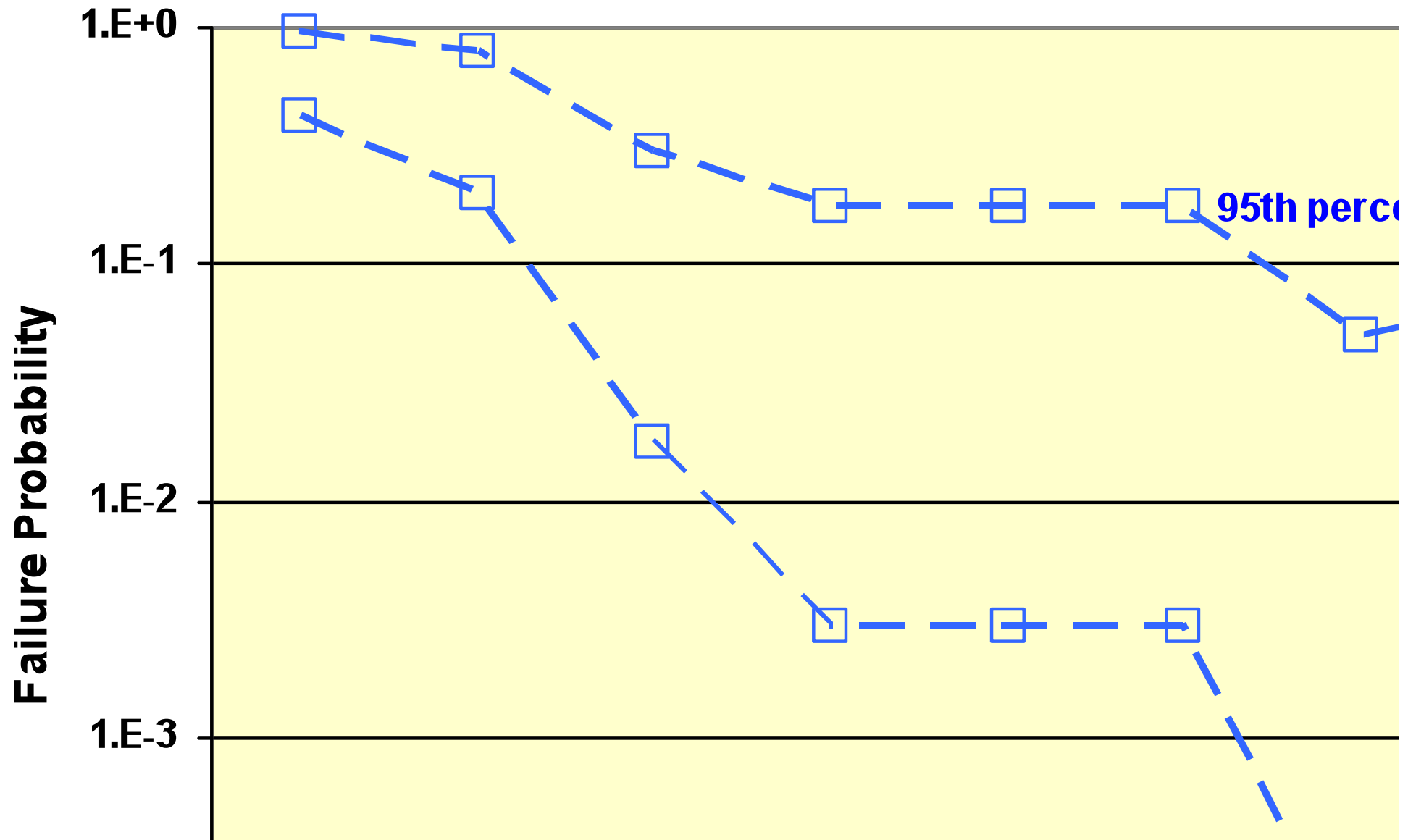


# Three kinds of data

- Quantitative
- Qualitative
  - Crew stories
  - PSF impact



# Confidence Bounds Estimated for Empirical



# Quantitative data

- Utilizing Bayesian methods,
- 7 out of 7 failing crews gives a strong update and is good evidence
- 14 out of 14 successful crews is a weak update
  - Not possible to know whether this is a  $10E-2$  or a  $10E-5$  number
- This is worth recognizing when collecting data from training sessions



# Evaluating the HRA methods

- Could they identify the difficult Human Failure Events (HFEs) with their method?
  - Utilized crew stories and details of procedures
  - If not, why?
  - Qualitative scenario analysis was important, to identify operational issues
    - Which method prescribed the best analysis of the scenarios?
    - Were any methods prone to “misuse”?
- Finding the impact of single PSFs was not so easy in an empirical study
  - PSFs interact
  - One PSF may cover for another





# Conclusions from the empirical studies

- *“The predictive performance of HRA methods could be evaluated by reference data from a simulator study.”* (NUREG-2127)
- *“The studies have shown that simulator data are highly useful for HRA studies.”* (NUREG-2156)



## **2. Data to support consistent use of HRA methods by improving the general knowledge of HRA practitioners through qualitative influential details of scenarios**

- Complex scenarios: What matters for crew performance?



# Experiments in the Halden Project

## 2002 – 2018

- **15+ data collections**
- **60+ operator crews**
  - 13 U.S. crews (2011, 2014 and 2018)
- **30+ scenarios, focus on**
  - SGTR (Steam Generator Tube Rupture) (incl multiple)
  - LOFW (Loss of Feedwater) (and combined with SGTR)
  - ISLOCA (Interfacing System Loss of Coolant Accident, LOCA outside containment)
  - H.B. Robinson fire
- **250+ simulator runs**
- **40+ Halden work reports**





**HAMMLAB experiments**



# Masking and Complexity

- The more complex the tasks get, the more does (bad) teamwork impact performance
- Teamwork dimensions
  - “Mission analysis - Cognition beyond procedure guidance”
  - “Process of consultation while performing technical work”
  - “Distributed leadership (mainly between Supervisor and Reactor operator)”
  - “Team orientation”
  - “Backup and support”



- Team Cognition important for diagnosis time in Complex situations

- Less important for diagnosis time in “base” (prototypical) situations

- Ref Braarud, Johansson (2010)

Complex

Base

# Procedure use

- Mismatch between procedures and plant situation in non-typical conditions

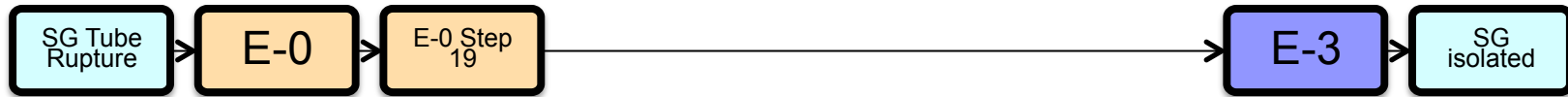


# HAMMLAB, monitoring procedure use

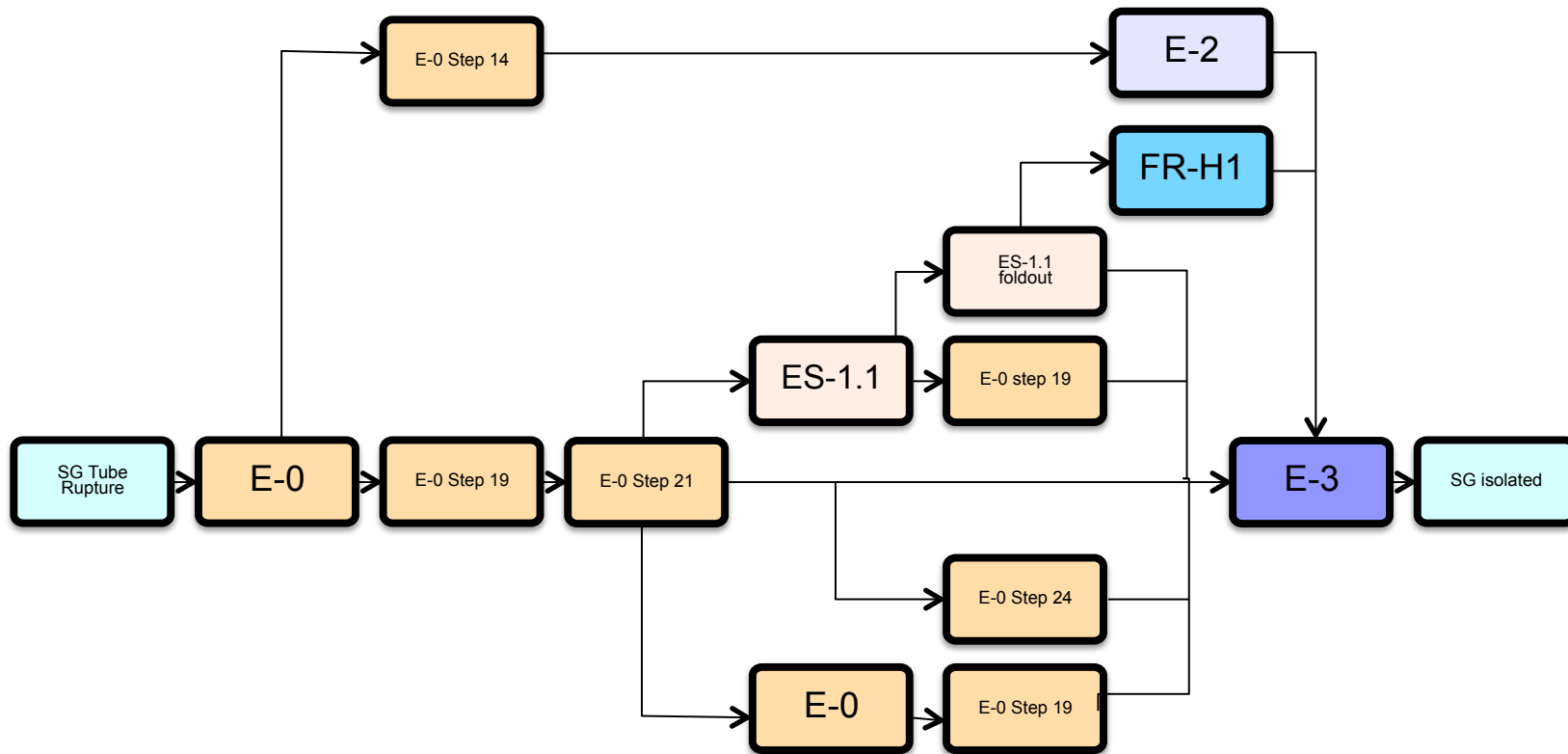




# Typical conditions



# Non-typical conditions



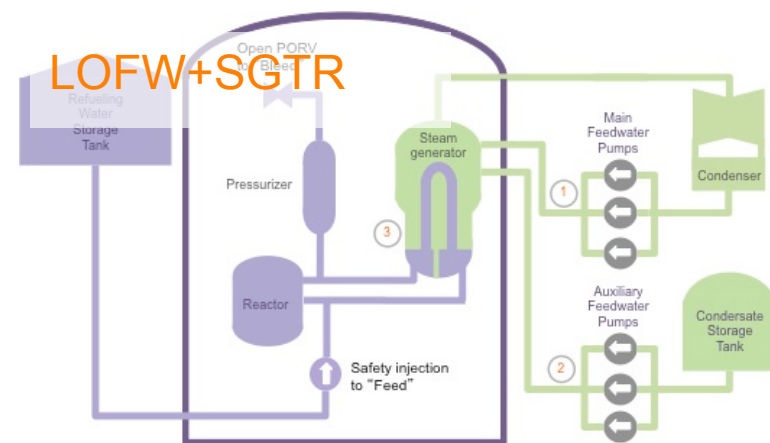
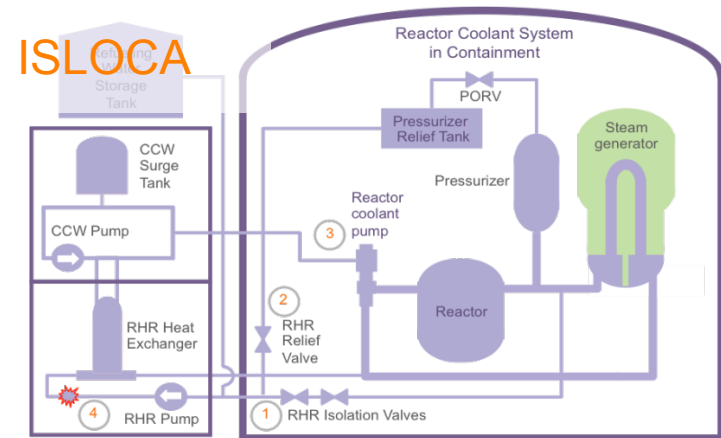
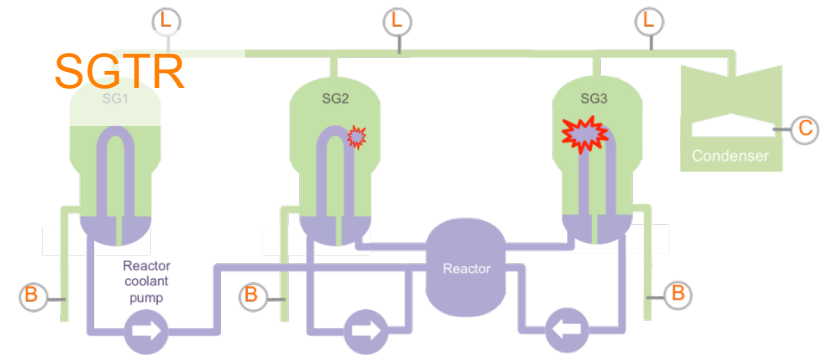
# Scenarios and mismatches

Aspects of the procedures did not match the situation

1. Inserted multiple malfunctions
2. Key indicators referred in the EOPs unreliable
3. Situation not fully covered by the relevant EOP
4. Ambiguous guidance/conflict between documents

Also, mismatches late into all the events

could not follow step-by-step



# Recurring themes

- High crew-to-crew performance variability
  - In within-design-basis accidents covered by EOPs
- Difficulties when the EOPs
  - Lacked detailed guidance
  - Required interpretation
- The more so in non-typical conditions
- Degraded indications (instrument failures, overlapping malfunctions, and miscommunications) are extremely challenging to the crews and can seriously affect plant safety



# What we learned – HRA

- Do not over-emphasize procedure following, not enough to analyze Error of Omission
  - After the first-hour into an emergency the procedure-situation fit is likely to decrease while fatigue effects arise: Higher likelihood for operators' autonomous decisions... and errors
- Always include analysis of cognitive aspects
  - Interpretations may be required also to apparently straightforward steps
- Extreme scenarios require lots of cognitive work from the crew:
  - Analyze procedures to identify possible procedure-situation mismatches. Degraded indications will result in mismatches
  - A deeper understanding of the nature of the difficulties for the crews is required, hence a thorough scenario analysis is needed for HRA (tasks/procedures)
  - Crew aspects must be analyzed, not only individual factors



# What we learned – crew organization

- Team factors and crew cognition critical for performance in difficult scenarios
  - E.g., role of the supervisor, distributed leadership, team orientation, backup and support
- Quality of teamwork decreases with complexity and fatigue
  - Less structured meetings, poor quality of briefings/discussions
  - Communication errors
- Role of STA and independence of STA
  - Tendency of STAs to work mainly as “procedure following double-checker”
- Importance of local information (e.g., local radiation measurements)



# Conclusions on qualitative data

- Insights from simulated PRA scenarios including challenging situations outside the normal training envelope does improve HRA
  - Increased knowledge for HRA practitioners and regulatory reviewers
  - A better basis for **asking the right questions** in an analysis
  - Basis for updating methods, especially the context-influencing part (e.g., PSF multipliers)
  - Data has been used as input to SACADA



### **3. Data to support basic questions on e.g., digital vs analog systems**



# Is Human Performance wrt safety impact similar in analog and computerized control rooms?

- New method: Micro-tasks (Ref. HWR-1130, HWR-1169, Hildebrandt et al., 2016)
  - Decontextualized tasks, typically identification/verification tasks
  - Frozen state of the plant, or mini-scenarios
  - Short data collections
  - Accuracy and speed (response time)





# Micro-Task study: Analog boards vs tablet displays



# Micro-tasks on analog and digital CRs: Preliminary results and lessons learned

- More data is needed to consolidate findings
  - Collects more data, stores in Halden Project Human Performance DB
  - Methods and tools are in place to do this now
- Cognitive task types are as important as analog or digital presentation
  - Big difference in error rates in simple checks and calculation tasks
- No final conclusions yet, but interesting patterns emerge
  - Ex: Comparisons and calculations can be better in (new) digital solutions
  - Preliminary: Digital displays do not increase the error rates.



# Conclusions, data for HRA

- Validate HRA methods ✓
- Adapting HRA methods to new digital systems:
  - Basic task probabilities may be defined/adapted based on micro-task methodologies (decontextualized). Quantative data.
  - Context adaptations (e.g., PSF multipliers) in the methods may be adjusted based on simulator experiments, mainly qualitative insights
    - Since these situations are context dependent, quantitative generalizations are not that easy
- Data can support consistent use of the HRA methods
  - Qualitative insights can improve the HRA practitioner's knowledge (and reviewer's)
    - Ask the right questions for the given scenario
    - Better analysis of the impact of the PSF on human performance
    - Better knowledge on the degree of detailed analysis that is needed (when to stop the task analysis)



# Can data replace HRA methods?

- No
- ..... eeh maybe ... for well defined situations...
- Discussed in next session, panel on the future of HRA data



# Conclusions

- Various types of data are needed for different tasks and task types
- Quantitative and qualitative data can really support HRA
  - HRA method developers
  - HRA analysts

