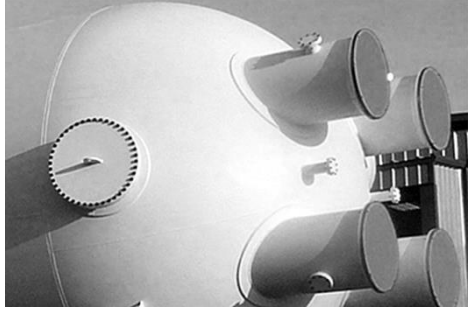

Use of HRA Insights
to Improve Decision-Making

IAEA Conference on Human Factors & Safety Culture , Vienna

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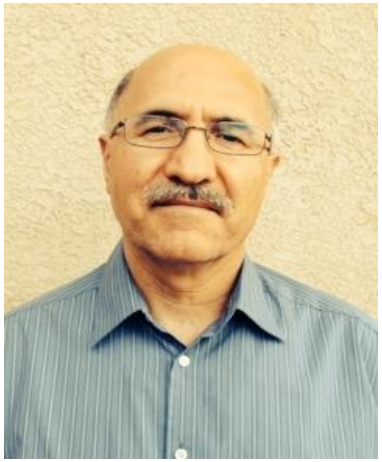

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Presentation Outline

Overview of HRA & PRA

- Human Reliability Analysis & Probabilistic Safety (Risk) Assessment Support of Decision-Making

EPRI HRA Users Group

- Mission & Members
- Halden Benchmarking

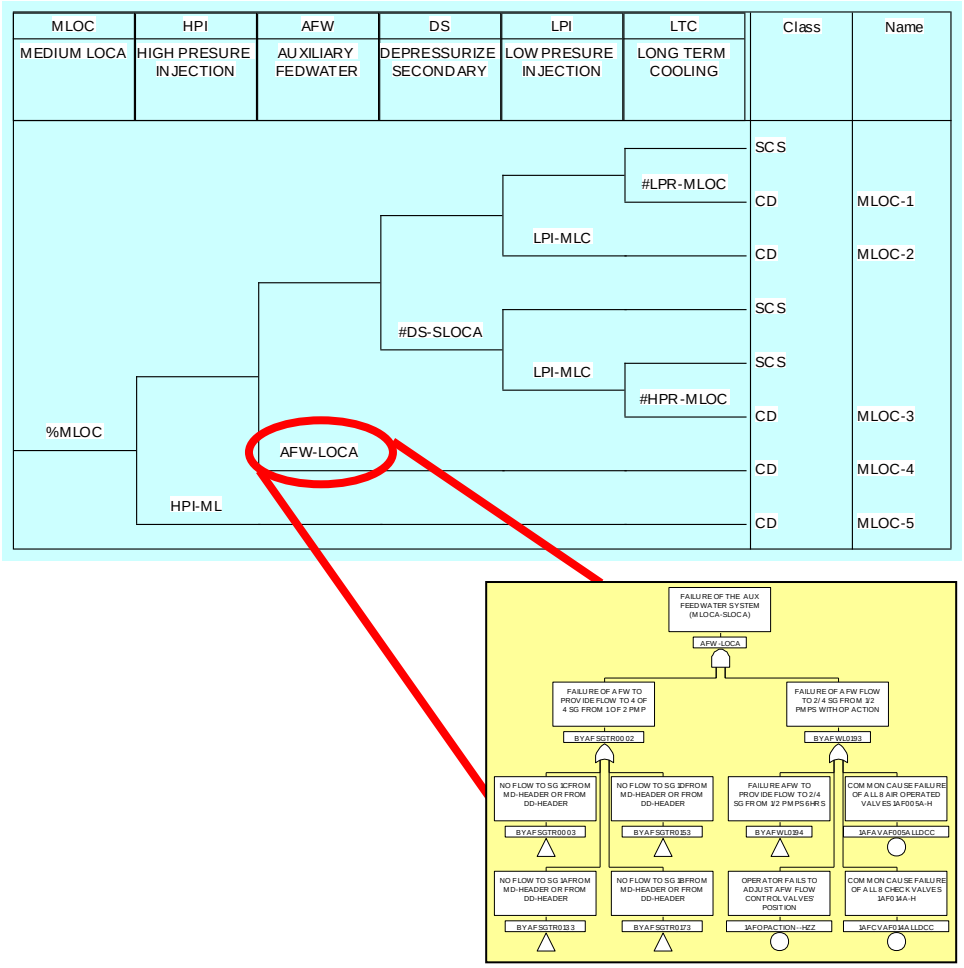
Examples of Using Risk Insights in Decision-Making

- Applications around the world

HRA Professional Society

PRA as a Tool Supporting Safety Culture

PRA is an analytical tool that systematically answers…….



1. **What can go wrong?**
2. **How likely is it ?**
3. **What are the consequences?**

PRA can **directly** support Safety Culture by identification and prioritization of issues based on risk-significance.

PRA can **indirectly** support Safety Culture by promoting organizational awareness of Risk and consider questions asked by PRA.

Overview of Human Reliability Analysis in U.S. PRA

PRA Starts with WASH-1400 (1975)

HRA lags ~10-years

30 Years! Periodic Safety Review and PRA Applications

HRA Society

CD's First Released

IPE

IPEE

Google Founded

Beijing Olympics

Today

1983 | 1988 | 1993 | 1998 | 2003 | 2008 | 2016

NRC

THERP (1983)
Pre-IE
Post-IE
Recovery
Dependency

ASEP (1987) Simplified THERP

ASP/SPAR (1994)

ATHEANA (1996)

ATHEANA (Rev.1 2000)

SPAR-H (2005)

Fire HRA NUREG-1921 (2012)

Seismic HRA (Draft, 2012)

SHARP (1984) HRA Framework

SHARP1 (1991) Revised Framework'

EPRI (2001-2016)
HRA Users Group

HCR (1984) First HCR

ORE (1989) Operator Reliability Experiments

CBDTM (1992) Cause-Based Decision Trees

EPRI

CURTISS-WRIGHT

Overview – Using HRA & PRA to Improve Decision-Making

Decision-Making:

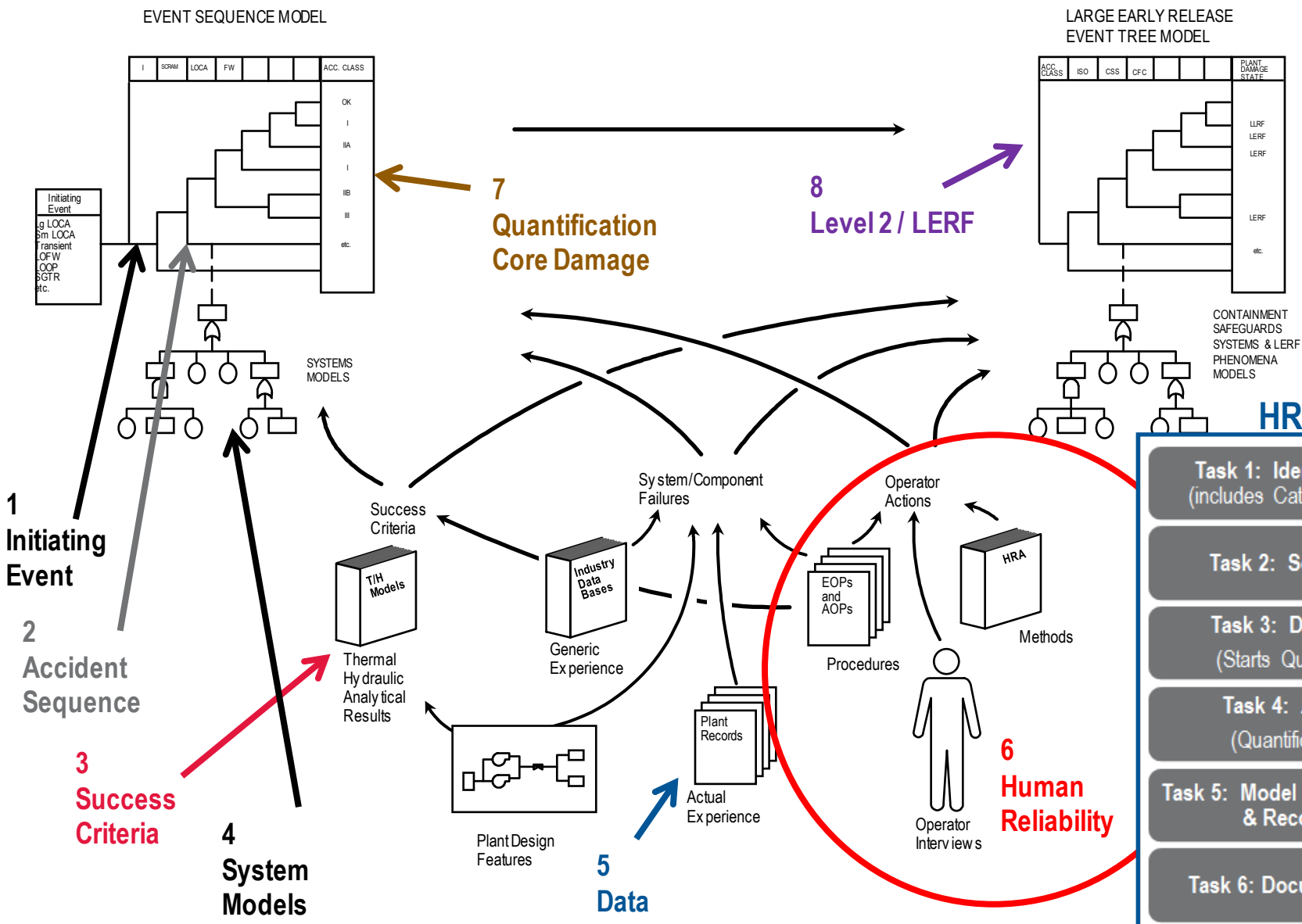
1. **Operation** of a NPP
   - Online maintenance
   - Training and procedure
2. **Maintenance** – infrequent tests also regular, scheduled T&M
3. **Licensing** of a NPP
   - Initial plant design
   - Periodic Safety Reviews
   - **Life extension**
4. Fire Protection Upgrade

Examples of HRA/PRA Insight:

1. **Operations**
   - Configuration Risk Management
   - Improve operator response
2. **Maintenance** reduced (e.g. ISI) or more on-line maintenance
3. **Licensing - plant mod evaluation**
   - Prioritize design changes
   - HRA has cross-cutting impact
   - Post-Fukushima Response
4. Fire Recovery Actions incl. Level 2

Improves Safety Culture by promoting Organization Awareness of Risk!

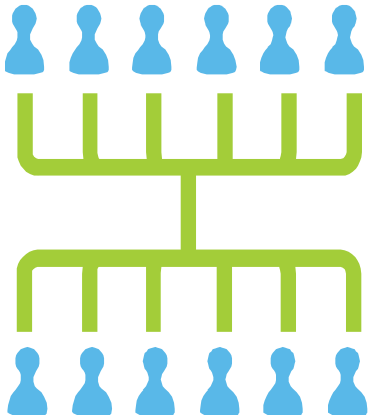
PRA and HRA Provides a Structured Approach & Models



HRA

- Task 1: Identification (includes Categorization)
- Task 2: Screening
- Task 3: Definition (Starts Qualitative)
- Task 4: Assess (Quantification)
- Task 5: Model Incorporation & Recovery
- Task 6: Documentation

EPRI HRA Users Group – Missions & Members



Missions:

1. Develop a software tool to enabling different analysts to obtain **comparable results** for same action & method at similar plants.
2. To develop **guidelines & training** for application of HRA methods.
3. Key goal is to enable industry to **converge on common methods**.
4. **Coordinate with industry groups** such as USNRC, Owners Groups, & within EPRI to develop guidelines and training materials.

Members:

- **All USA Utilities; recently added US NRC**
- **Vendors – Areva, Bechtel-Bettis, KEPCO E&C, PBMR, Rolls Royce, & Westinghouse**
- **International: CANDU Owners Group, Europe, Africa and Asia**

EPRI HRA Users Group – Approach and Methods

Framework:

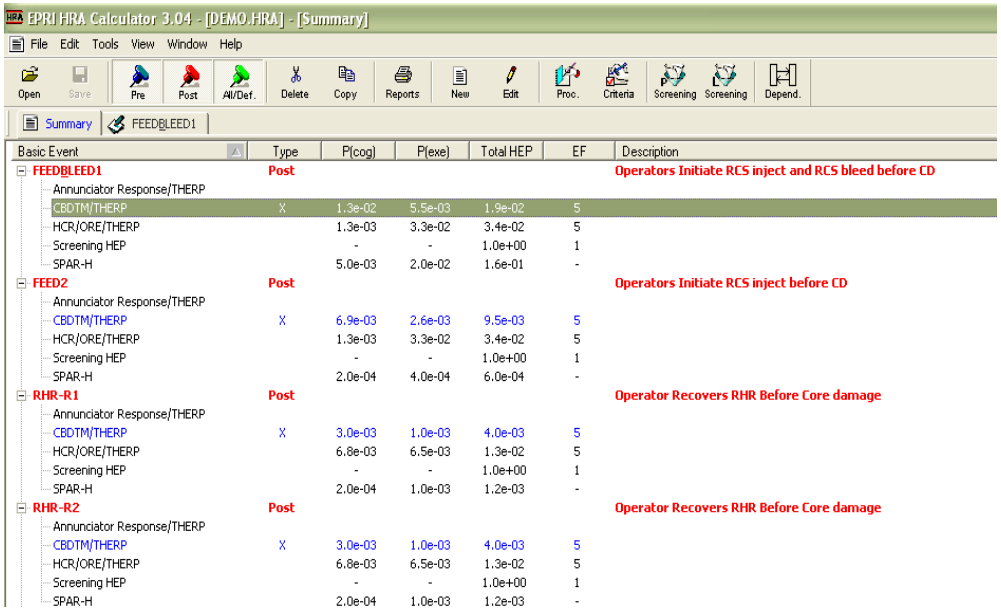
- **SHARP & SHARP1**
  (EPRI NP-3583, 1984 & EPRI NP 7183-M, 1990)
  - Qualitative analysis considering Context
  - Cues, procedures, training, timing
  - Quantitative analysis using various methods

Latent/Pre-Initiator HRAs:

- **THERP Model** (NUREG/CR-1278, 1983)
- **ASEP Model** (NUREG/CR-4772, 1987)

Dynamic/Post-Initiator HRAs:

- **CBDTM (cognitive) / THERP (execution) combination**
  - Combination consists of "cognitive" & "execution" errors
  - CBDTM (EPRI TR 100259, 1992)
- **HCR/ORE (cognition) /THERP (execution) combination**
  - HCR/ORE replaces THERP Time-Reliability Correlation (EPRI TR 100259, 1992)
- **Alternative Approaches**
  - Annunciator Response Model (NUREG/CR-1278, 1983)
  - SPAR-H for cognition & execution



Basic Event	Type	P(cog)	P(exe)	Total HEP	EF	Description
FEEDBLEED1	Post					Operators Initiate RCS inject and RCS bleed before CD
Annunciator Response/THERP						
CBDTM/THERP	X	1.3e-02	5.5e-03	1.9e-02	5	
HCR/ORE/THERP		1.3e-03	3.3e-02	3.4e-02	5	
Screening HEP		-	-	1.0e+00	1	
SPAR-H		5.0e-03	2.0e-02	1.6e-01	-	
FEED2	Post					Operators Initiate RCS inject before CD
Annunciator Response/THERP						
CBDTM/THERP	X	6.9e-03	2.6e-03	9.5e-03	5	
HCR/ORE/THERP		1.3e-03	3.3e-02	3.4e-02	5	
Screening HEP		-	-	1.0e+00	1	
SPAR-H		2.0e-04	4.0e-04	6.0e-04	-	
RHR-R1	Post					Operator Recovers RHR Before Core damage
Annunciator Response/THERP						
CBDTM/THERP	X	3.0e-03	1.0e-03	4.0e-03	5	
HCR/ORE/THERP		6.8e-03	6.5e-03	1.3e-02	5	
Screening HEP		-	-	1.0e+00	1	
SPAR-H		2.0e-04	1.0e-03	1.2e-03	-	
RHR-R2	Post					Operator Recovers RHR Before Core damage
Annunciator Response/THERP						
CBDTM/THERP	X	3.0e-03	1.0e-03	4.0e-03	5	
HCR/ORE/THERP		6.8e-03	6.5e-03	1.3e-02	5	
Screening HEP		-	-	1.0e+00	1	
SPAR-H		2.0e-04	1.0e-03	1.2e-03	-	

EPRI HRA Users Group - Halden Benchmarking

Compare HRA predictions with Simulator Observations

- **CBDT/THERP: EPRI (Scientech)**
- THERP: NRC staff + Consultants
- THERP w Bayesian Enhancement : VTT
- ATHEANA: NRC staff+Consultants
- SPAR-H: NRC staff+Consultants, INL
- Decision Trees + ASEP: NRI
- MERMOS: EDF
- PANAME: IRSN
- HEART: Vattenfall & Ringhals
- KHRA: KAERI
- CREAM: NRI
- CESA: PSI

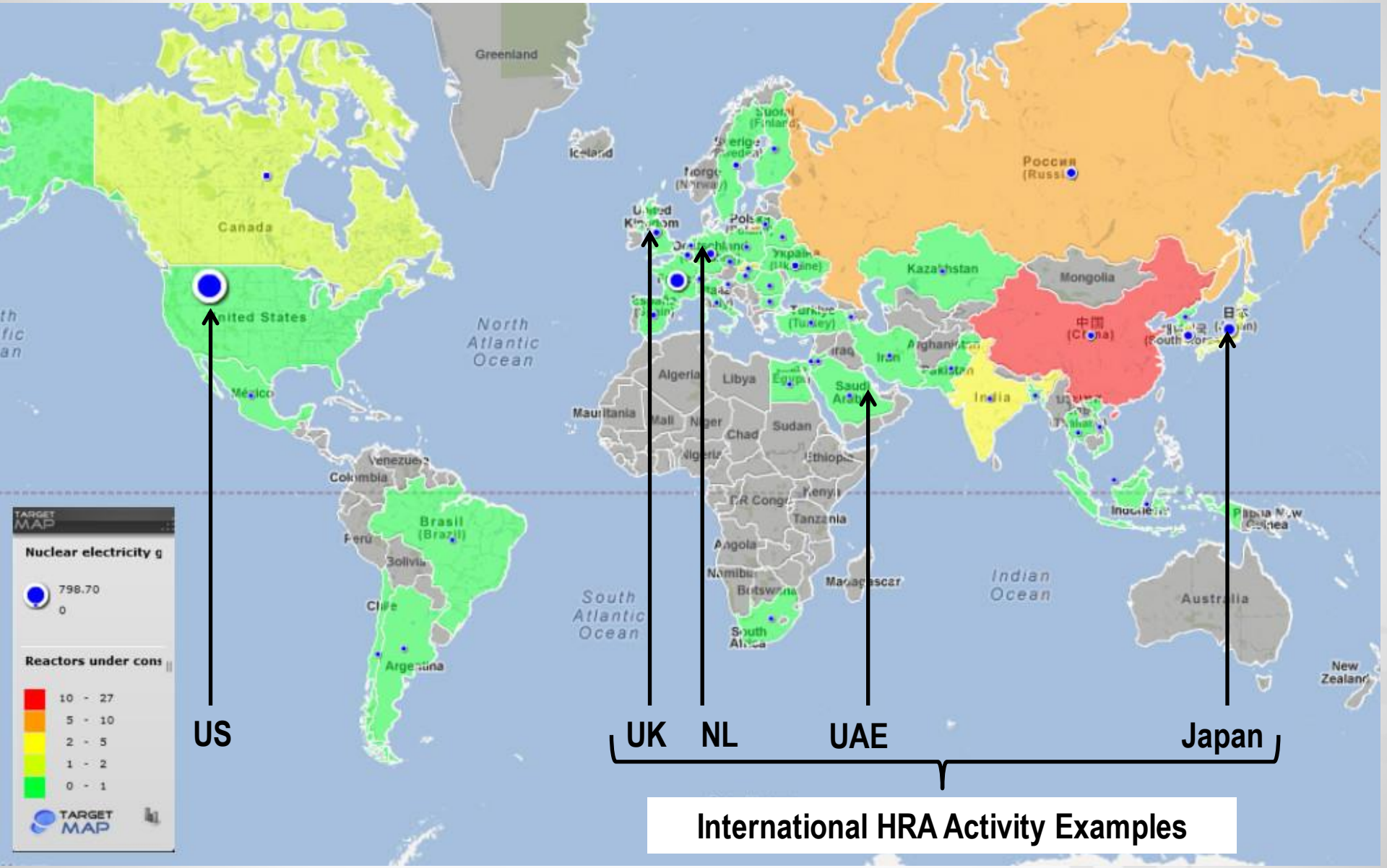
  – *Simulations* –
- Microsaint: Alion
- IDAC: University of Maryland
- QUEST-HP: Riso

Bottom Line – Qualitative Analysis is Important!

Examples of Using Risk Insights in Decision-Making

- Increasing number of PRA & HRA applications in the USA
- Increasing number of international users in the EPRI HRA Users Group
  - Europe – recent training class conducted in Spain
  - Middle East – UAE is using the HRA Calculator to help start-up 4 plants
  - Asia – Korea & Japan recently joined (or joining this year)
  - Africa - long-time interest
- HRA analysts in other countries may have different applications/uses and thus different needs from the EPRI Users Group.
- This presentation addresses:
  1) Five examples of HRA insights from different countries
  2) An overview of the HRA Society, a professional organization

World List of Nuclear Power Plants



HRA Use in PRA Models & Applications

In the United States (Example-1):

- **Fire Protection Program change to NFPA 805, risk-informed performance-based:**
  - Recovery Actions to mitigate variances from design requirements
  - Recovery Actions to reduce radioactive release such as Containment Isolation & H2 Igniters
- **Configuration Risk Management:**
  - Develop contingencies for events occurring in certain plant line-ups
  - Examples, protected train & high risk evolutions
- **Feedback to Operator Training:**
  - Identification of PRA-important Scenarios & Procedures
- **Address Licensing Issues:**
  - Impact of plant design modification such as Timing/Instrumentation
  - Post-Fukushima insights such as actions in advance of External Flooding
    - Timeline & cues from other organizations
- **Evaluation or prioritization of proposed plant changes**

USA focus has been on Operating Plants where International HRA applications focuses more on Licensing and New Build

Example-2 PRA & HRA Application in The Netherlands

- **Part of the 10-Year Periodic Safety Review.**
- **Level 1 Insights to Reducing Risk:**
  - In 2015, plant conducted its 3rd Periodic Safety Review
  - Hardware modifications have eliminated significant operator actions
  - HRA provided insights into staggering calibration
  - Still finding / addressing new challenging, potential initiating events
- **Level 2 Insights to Reducing Risk:**
  - Impact on Public Health & Safety is important
  - Plant, like all NL industries, has individual risk and societal risk goals
- **All Modes, All Hazards PSA:**
  - Peer Review.2013

Example-3 PRA & HRA Application in the United Kingdom

Some plants in the General Design Assessment (GDA) phase of licensing.

- **PRA (Level 1, 2 & 3 PRAs) is assessed against Regulator requirements as well as the ASME/ANS PRA Standard:**
  - Some supporting requirements (SRs) cannot be met by a plant in the design phase.
    - Example, operator interviews.
    - SRs that cannot be met are not assessed.
  - Intent of some SRs can be met.
    - Example by considering generic information or information from similar plant/s.
- **Some inputs often need to be assumed to perform HRA:**
  - Appropriate operator-information interface will be developed.
  - Procedures will be developed.
  - Operators will be trained to perform their procedures.
  - Such inputs will need to be validated in later phases of design (or transition to operation).
- **Inputs available at this stage:**
  - Timing & Success criteria

Example-3 PRA & HRA Application in the UK (cont'd)

- **Uncertainties in applicability of current HRA methods to digital I&C as well as the digital plant interface.**
  - THERP was used based on analog instrumentation & data from 1980's or before
  - New failure modes e.g. "tunnel vision"?
  - CCF of digital interface a concern warranting analog backup I&C for systems important to safe shutdown
  - All HEPs can be considered screening HEPs as many inputs are assumed, so OK for GDA process
- **Apparently less reliance on operator actions than earlier generation:**
  - PRA does not credit operator actions within first 30 minutes per the design basis, but may have to in future iterations if PRA needs them (e.g. ATWS)
  - At-Power: About a dozen post-initiator Level 1 operator actions, similar for Level 2
  - LPSD: About 10 Level 1 operator actions, no additional operator actions for Level 2
  - SFP: Several operator actions for Level 1, with 1 late action for Level 2

Example-4 PRA & HRA Application in the United Arab Emirates

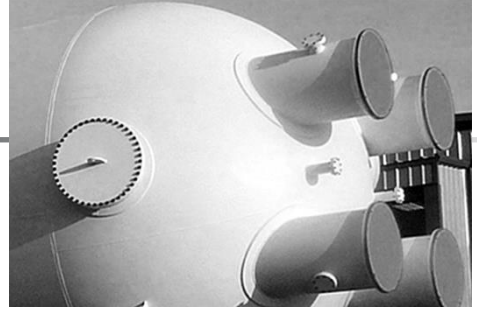
- **First 4 plants developing all modes, all hazards PRA as part of the FSAR to support obtaining an operating license.**
- **Similar experience to the UK (see Example-1):**
  - PRA (Level 1, 2 & 3 PRAs) is assessed against Regulator requirements as well as the ASME/ANS PRA Standard.
  - Some inputs often need to be assumed to perform HRA:
  - Inputs available at this stage are limited to Timing & Success Criteria, and some procedures.
  - Uncertainties in applicability of current HRA methods to digital I&C as well as the digital plant interface.
- **Generally less reliance on operator actions than the earlier generation:**
  - Example, MCR Abandonment is low as the plant essentially has a 2nd MCR.
  - Exception: reduced safety goal levels have increased the importance of beyond design basis events, which has led to the need for more operator actions.

Example-5 PRA & HRA Application in Japan

- **Many plants in re-start, or working on re-start.**
- **Level 1 internal events:**
  - In 2015 EPRI provided Risk Professionals training, including HRA.
  - Working on incorporating insights from new methods (IDHEAS).
- **Fire PRA:**
  - After re-start, some plants working on Fire PRA.
  - Generally follow the NUREG/CR-6850 FPRA approach, including NUREG-1921 guidance.
- **Seismic PRA:**
  - All have re-evaluated their peak ground acceleration.
  - Looking at HRA improvements to better support larger earthquakes.

Summary of PRA & HRA Insights Internationally

- **Technically**
  - HRA needs to support **an increased PRA Scope**, such as
    - Level 1 Spatial Hazards (internal and external)
      - Examples: Fire, Flood with plant & site impact
      - Examples: Seismic, External Flood, High Winds with regional impact
    - Level 2 & Level 3
    - Shutdown PRA including Spent Fuel Pool PRA
  - HRA for Digital Control systems is an issue
- **Organizationally**
  - Support for new PRA/HRA practitioners
    - Training
    - Guidelines
    - HRA Tools implementing new/updated methods
- EPRI HRA UG supports each of these



HRA Society

January 2016

Jan Grobbelaar
Scientech

Human Reliability Analysis Society

- **A new professional society to promote the sharing of research, methods and data.**
- **A short history:**
  - Initial meeting in Seattle at PSAM conference (2010)
  - Follow-up meeting in Honolulu at PSAM'12
  - HRA Master Class in Paris, 2015
    - Largest meeting, ~50 participants from 8 countries
    - Surveyed recent activities
- **Members include regulator, research labs, consultants & utility staff.**

Vision for the HRA Society

- **Support Various Aspects of Human Reliability**
  - ***Human Reliability Analysis as part of PRA for Decision-Making***
  - Human Factors
  - Human Error reduction programs
- **Improve Technical Bases**
  - HRA methods, data & guidance
  - HRA for Digital Control systems
  - HRA for increased PRA Scope such as External Hazards & Level 2/3
- **Support Expansion & Growth**
  - Support for emerging countries – Regulators & Utilities
  - Open to new members

HRA Society – Upcoming Events

- **PSAM'13, Seoul, October 2-7**
  - HRA master class/meeting/workshop
  - Plenary session
  - Evening social event
- **PSAM Topical Meeting – Germany 2017**
  - In the planning phase to decide the number of tracks
  - HRA methods, data & guidance
- **Support Expansion & Growth**
  - Looking to expand with "regional" chapters such as USA & EU
  - Looking to support expansion of the nuclear industry

Summary

- **PRA & HRA have provided insights to improve decision-making for over 30 years**.
- EPRI HRA Calculator® approach meets all the current U.S. industry needs for PRAs used in regulatory requirements.
- **EPRI HRA UG has 15 years of successful HRA improvements** and the approach meets all the current U.S. industry needs for PRAs used in regulatory requirements.
- Approach/methods satisfies the ASME PRA Standard & the NRC Good Practices in Implementing HRA.
- Annual Users Group Meeting – January, Juno Beach, Florida
    - Sharing technical improvements & best-practices
- Developing new methods and monitoring research work by others to determine if other improvements can add value to its mission using these criteria:
    - Traceable, Defensible, Consistent
    - Extend HRA beyond Level 1, internal events PRA

Summary (cont'd)

- **PRA & HRA provides a structured, systematic approach.**
  - Address challenging issues and situations
  - Evaluate with a model
  - Address considerations such as Uncertainty
- **A strong Safety Culture considers risk insights and makes risk information available to decision-makers:**
  - Plant Design and Engineering
  - Plant Operations, Maintenance, and Training
- **PRA process and results (risk-significance) can support Safety Culture.**
  - Directly by identification and prioritization of issues based on risk-significance.
  - Indirectly by promoting organizational awareness of risk, to consider the questions asked by PRA - "what is the most likely thing to go wrong" & "what is the most consequential"

EPRI HRA Users Group – Points of Contact

Points of Contact:

- Websites
  - **Public website:** http://hra.epri.com/
  - **HRA UG Support site:** http://www.epri.com/hra
    - **Used for bug reporting, suggestions, downloads**
- HRA Users Group Executive Committee
  - **Chair: Mark Averett** Mark.Averett@fpl.com 561 694.3857
  - **EPRI HRA UG PM: Mary Presley** mpresley@epri.com 704 595.2821
  - **Scientech PM: Jan Grobbelaar** jgrobbelaar@curtisswright.com 800 862.6702
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