Probabilistic Risk Assessment

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Introduction

- PRA: Probabilistic Risk Assessment.

The use of PRA technology should be increased in all regulatory matters to the extent supported by the state of the art in PRA methods and data and in a manner that complements the NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy.

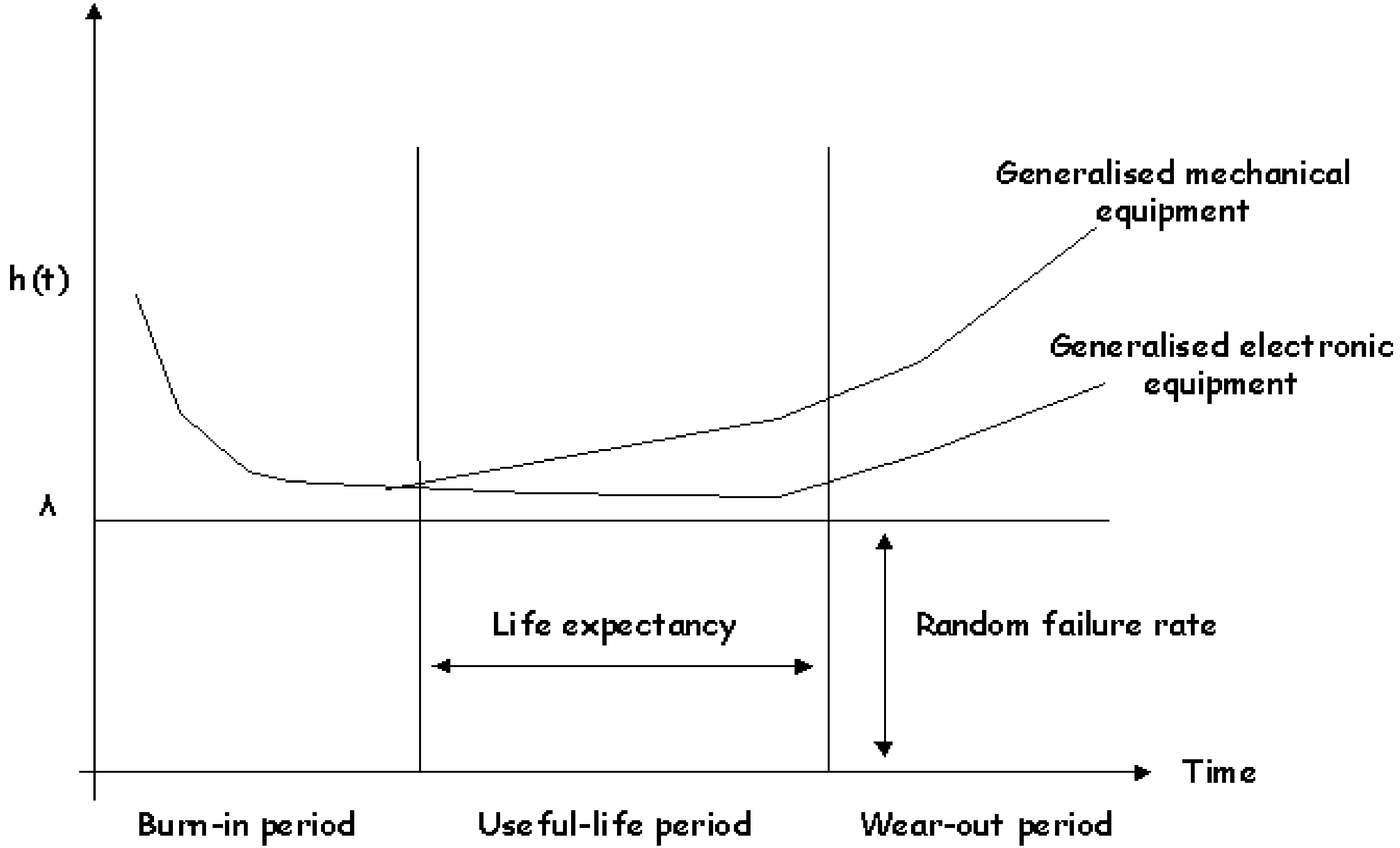
PRA and associated analyses (e.g., sensitivity studies, uncertainty analyses, and importance measures) should be used in regulatory matters, where practical within the bounds of the state of the art, to reduce unnecessary conservatism associated with current regulatory requirements, regulatory guides, license commitments, and staff practices.

NRC - REGULATORY GUIDE 1.177 An Approach for Plant-Specific, Risk-Informed Decision making: Technical Specifications

Hazard Analysis vs PRA

- FMECA - hazard analysis.
- PRA part of hazard analysis.
- What is the scope of this approach?
  - hardware failure rates (here)?
  - human error rates (here)?
  - software failure rates (later)?

The 'Bathtub' Model



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- Mechanical systems reflect bathtub model:
  - bed-down failure rates;
  - degrade failure rates;
- Electronic systems approximate stable fault rate?
- Software fault rates spike around upgrades…
- 0.2 failures per hour:
  - MTTF = 1 / 0.2 = 5 hrs.

PRA - Sources of Data

- MIL-HDBK-217:
  - Reliability Prediction of Electronic Equipment
- Failure rate models for:
  - ICs, transistors, diodes, resistors,
  - relays, switches, connectors etc.
- Field data + simplifying assumptions.
- Continual need for revision?

PRA: Military vs Industry

- MIL-HDBK-217:
  - too pessimistic for companies...
- Bellcore (Telcordia):
  - reliability prediction procedure;
  - AT&T's 173 Defects-Per-Million calls (99.98%).
  - Business critical not safety critical.
- Commercial reliability databases.
  - But MTTF doesn't consider repair;
  - MTTR considers observations.

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- MIL-HDBK-338B (1,000+ pages!).
- Gives no. of failures per hour per mode.
- CR = α x β x λ
  - CR - criticality level;
  - α - failure mode frequency ratio;
  - β - loss probability of item from mode;
  - λ - base failure rate for item.
- Criticality defined subjectively in FMECA.

MIL-HDBK-338B

Accumulator	Leaking Seized Worn Contaminated	.47 .23 .20 .10
Actuator	Spurious Position Change Binding Leaking Seized	.36 .27 .22 .15
Alarm	False Indication Failure to Operate Spurious Operation Degraded Alarm	.48 .29 .18 .05
Antenna	No Transmission Signal Leakage Spurious Transmission	.54 .21 .25
Battery, Lithium	Degraded Output Startup Delay Short Open	.78 .14 .06 .02
Battery, Lead Acid	Degraded Output Short Intermittent Output	.70 .20 .10
Battery, Ni-Cd	Degraded Output No Output	.72 .28

HRA: Human Reliability Analysis

- We focussed on hardware devices.
- PRA for human reliability?
- Probably not a good idea:
  - Do all people have same base error probability?
  - Performance Shaping Factors…
  - Mitigations – training, cross-checking etc.
- But for completeness...
  - THERP is a type of HRA…

Technique for Human Error Rate Prediction

“The THERP approach uses conventional reliability technology modified to account for greater variability and independence of human performance as compared with that of equipment performance... The procedures of THERP are similar to those employed in conventional reliability analysis, except that human task activities are substituted for equipment outputs." (Miller and Swain, 1987).

A.D. Swain and H.E. Guttman, Handbook of Human Reliability with Emphasis on Nuclear Power Plant Applications, NUREG-CR-1278, 1985.

Technique for Human Error Rate Prediction

- Pe = He + $\sum_{k=1}^{n} Psf_k * W_k$ + C

- Where:
  - Pe - probability of error;
  - He - raw human error probability;
  - C - numerical constant;
  - Psf_k - performance shaping factor;
  - W_k - weight associated with Psf_k;
  - n - total number of PSFs.

THERP - External PSFs

Situational characteristics (PSFs general to one or more jobs in a work situation)	Architectural features. Quality of environment: (Temperature, humidity, air quality and radiation, lighting, noise and vibration, degree of general cleanliness). Work hours/work breaks. Availability/adequacy of special equipment, tools and supplies. Shift rotation.	Staffing parameters. Organisational structure (authority, responsibility, communication channels). Actions by supervisors, co-workers, union representatives and regulatory personnel. Rewards, recognition and benefits.
Job and task instructions; single most important tool for most tasks.	Procedures required (written or unwritten). Cautions and warnings.	Written or oral communications. Work methods. Plant policies (shop practices).
Task and equipment characteristics (PSFs specific to tasks in a job)	Perceptual requirements. Motor requirements (speed, strength, precision). Control-display relationships. Anticipatory requirements. Interpretation. Decision-making. Complexity (information load). Narrowness of task. Frequency and repetitiveness. Task criticality. Long and short-term memory	Calculation requirements. Feedback (knowledge of results). Dynamic vs step-by-step activities. Team structure and communication. Man-machine interface factors (design of prime/test/manufacturing equipment, job aids, tools, fixtures).

Ack: A.D. Swain, Comparative Evaluation of Methods for Human Reliability Analysis, (GRS-71), Garching FRG: Gesellschaft fur Reaktorsicherheit.

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THERP - Stressor PSFs

Psychological stressors (PSFs which directly affect mental stress)	Suddenness of onset. Duration of stress. Task speed. High jeopardy tasks. Threats (of failure, job loss etc). Monotonous, degrading or meaningless work. Long, uneventful vigilance periods.	Conflicts of motives about job performance. Reinforcement absent or negative. Sensory deprivation. Distractions (noise, glare, movement, flicker, colour). Inconsistent cueing.
Physiological stressors (PSFs that directly affect physical stress)	Duration of stress. Fatigue. Pain or discomfort. Hunger or thirst. Temperature extremes. Radiation. G-force extremes.	Atmospheric pressure extremes. Oxygen insufficiency. Vibration. Movement constriction. Lack of physical exercise. Disruption of circadian rhythm.

THERP - Internal PSFs

Organismic factors (characteristics of people resulting from internal and external influences)	Previous training/experience. State of current practice or skill. Personality and intelligence variables. Motivation and attitudes. Knowledge required (performance standards). Stress (mental or bodily tension).	Emotional state. Sex differences. Physical condition. Attitudes based on influence of family and other outside persons or agencies. Group identification.

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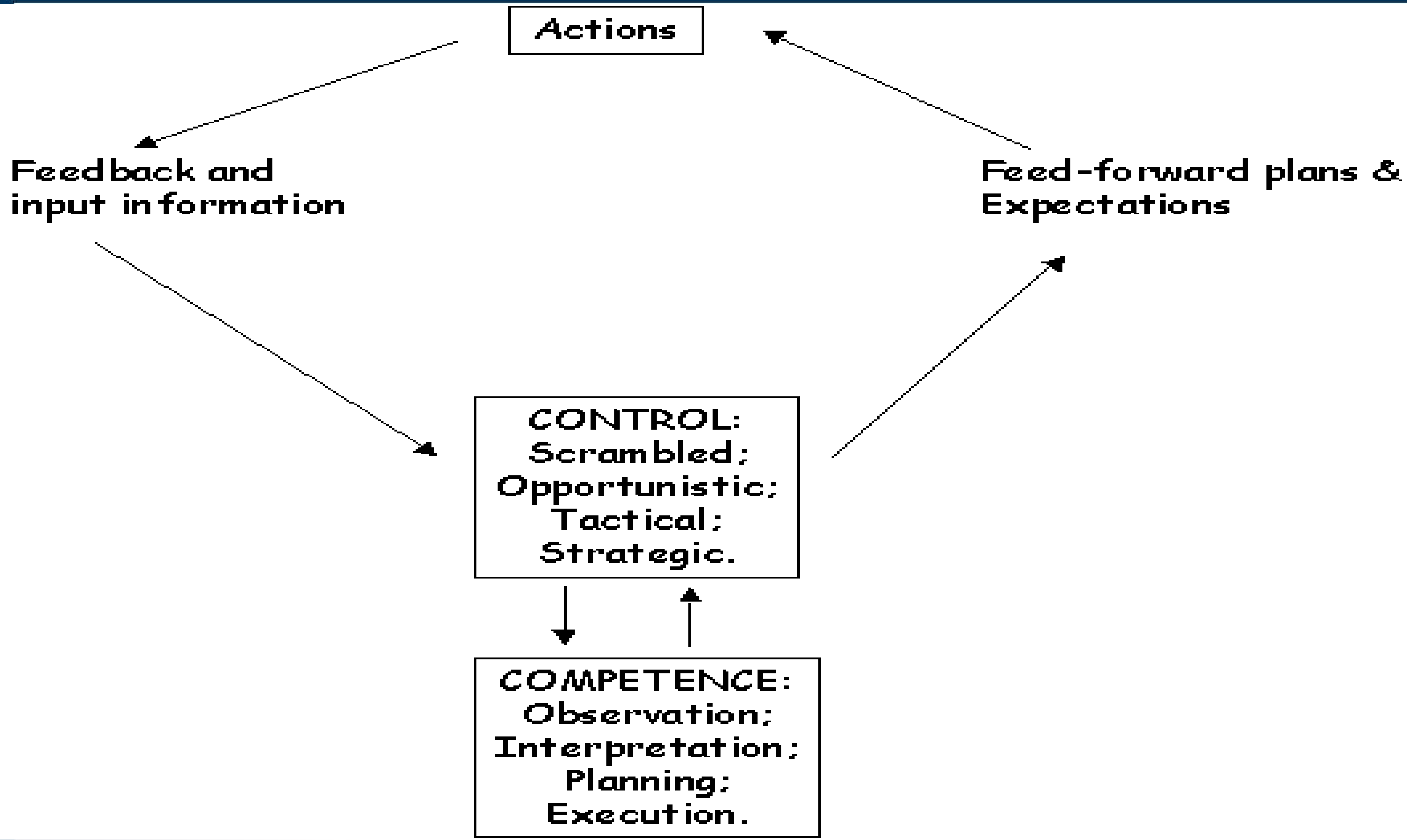
Technique for Human Error Rate Prediction

- Calculate effect of PSF on HEP
- - ignores WHY they affect performance.
- Succeeds or fails on Performance Shaping Factors (PSFs).
- “Psychological vacuous” (Hollnagel).
- No model of cognition etc.

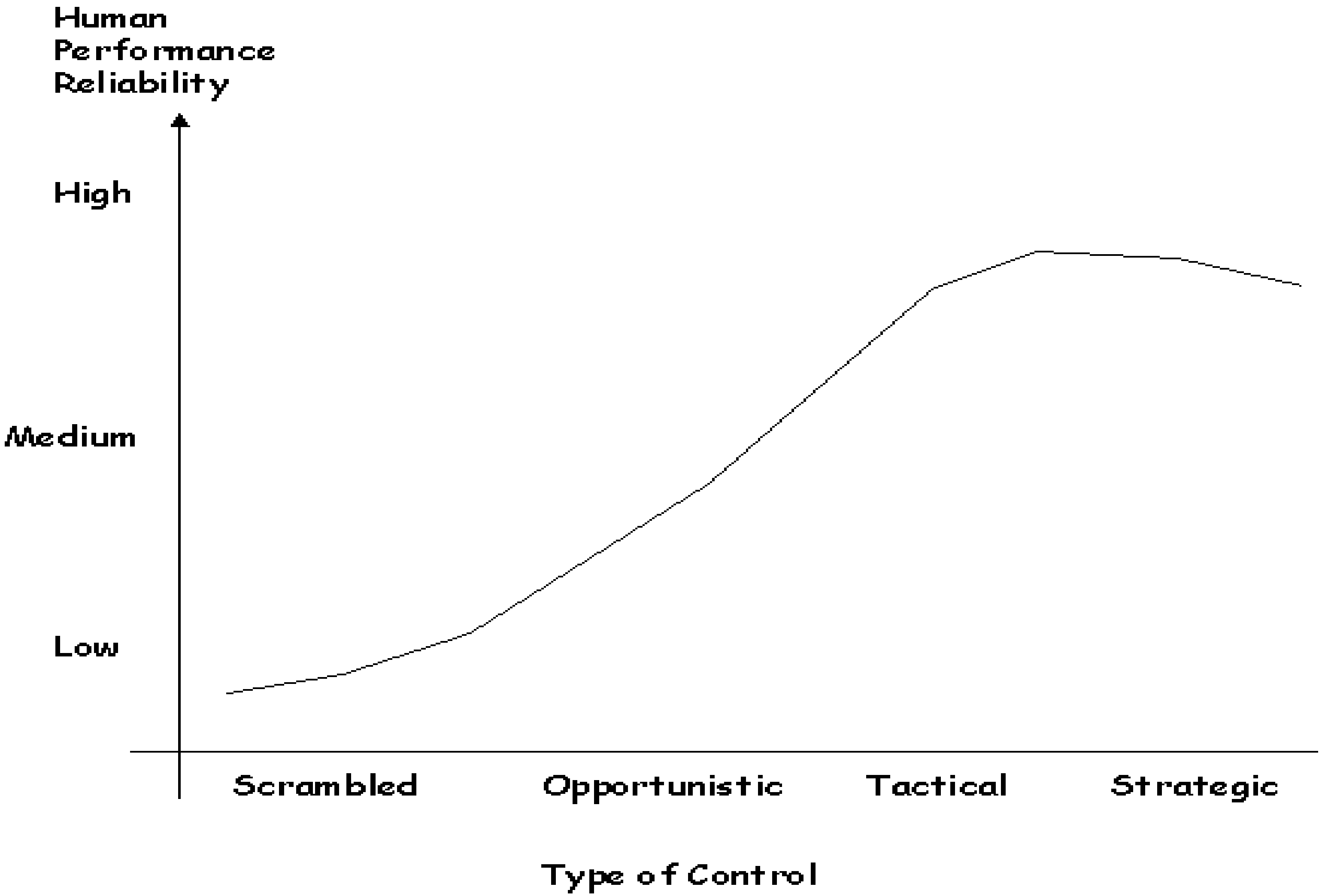
CREAM

- E. Hollnagel, Cognitive Reliability and Error Analysis Method, Elsevier, Holland, 1998.
- HRA + theoretical basis.
- Simple model of control:
  – scrambled - unpredictable actions;
  – opportunistic - react dont plan;
  – tactical - procedures and rules;
  – strategic - consider full context.

CREAM - Simple Model of Control



CREAM - Simple Model of Control



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CREAM

- Much more to the technique...

- But in the end...
  - Strategic = $0.000005 < p < 0.01$
  - Tactic = $0.001 < p < 0.1$
  - Opportunistic = $0.01 < p < 0.5$
  - Scrambled = $0.1 < p < 1.0$

- Common performance conditions to:
  - probable control mode then to
  - reliability estimate from literature.

Conclusions

- PRA for hardware:
  - widely accepted with good data.
- PRA for human performance:
  - - many are skeptical;
  - - THERP -> CREAM -> ???
- PRA for software?
  - Will cover this soon…

Any Questions…