Human Reliability Analysis
Methods for Space Safety

RMC, Session G: Human Error and Risk Assessment

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December 7, 2005
Human Reliability Analysis (HRA)

Definition
• The use of systems engineering and behavioral science methods in order to render a complete description of the human contribution to risk and to identify ways to reduce that risk

Scope of Talk
• Review current HRA methods
• Apply these HRA methods to NASA
Snapshot of Current HRA Methods

Some Popular Methods (Out of 50+ Contenders)
• THERP (Swain & Guttman, 1983)
  – Technique for Human Error Rate Prediction
• CREAM (Hollnagel, 1998)
  – Cognitive Reliability and Error Analysis Method
• ATHEANA (NRC, 2000)
  – A Technique for Human Event ANAlysis
• SPAR-H (Gertman et al., 2005)
  – Standardized Plant Analysis Risk-Human Reliability Analysis

Advantages of Methods
• All methods have successfully accounted for contribution of human performance to overall risk and reliability
• All methods allow quantification of human error probability
• All methods have been applied extensively to nuclear power plants, and some to the space domain
Differentiating HRA Methods

With 50+ HRA methods to choose from, how do you decide the best one for NASA applications?

• **Current HRA methods are different on a number of dimensions**
  – Qualitative v. Quantitative HRA Methods
  – *First* v. *Second Generation* HRA Methods
  – Holistic v. Analytic HRA Methods
  – Few v. Many Performance Shaping Factors in HRA
Qualitative v. Quantitative HRA

Qualitative HRA
- Focused on identification of the event or error
- Common result of task analysis or incident investigation

Quantitative HRA
- Focused on translating identified event or error into a Human Error Probability (HEP)

Qualitative and quantitative are complementary
- Not all events are well enough understood to be quantified
Quantitative HRA Methods

Expert Estimation
• Determination of an HEP based on expert knowledge of the likelihood that a person would falter in a given context

Performance Shaping Factors (PSFs)
• Use of factors known to degrade or improve human performance over an established baseline
• PSFs often treated as multipliers on a nominal HEP

Frequency Based Estimation
• Use of performance data derived from observation of similar events or contexts
• Error is the number of observed failures divided by the number of observed trials in which the human performed the task
**First v. Second Generation Methods**

**First Generation HRA Methods**
- *Use a simple error taxonomy*
- *Use a simple “fits”/“doesn’t fit” dichotomy to match error scenario to error identification and quantification*

**Second Generation HRA Methods**
- *Use a theory-based error taxonomy*
  - *Often coincides with cognitive model of human behavior*
- *Use a complex match of error scenarios to error identification and quantification*
  - *PSFs with multiple levels of assignment to indicate degrees of degraded or enhance performance relative to nominal*
Holistic v. Analytic Methods

Holistic HRA Methods

- View human performance as indivisible part of whole situation that cannot be broken into smaller parts
- Analyze event without having fixed list of root cause contributors

Analytic HRA Methods

- View human performance as a composite of its individual elements of human performance
- These elements may be decomposed and analyzed individually
- Analyze an event or error using rubric of root cause contributors

<table>
<thead>
<tr>
<th>Cause of Incident</th>
<th>Judgment Strategy</th>
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<tbody>
<tr>
<td>Atomistic Univariate</td>
<td>Works well if one of the items on rubric/checklist matches the cause of the event.</td>
</tr>
<tr>
<td>Holistic Multivariate</td>
<td>Works well if analyst avoids extraneous factors.</td>
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<tr>
<td></td>
<td>Rubric/checklist helps analyst focus on relevant contributors to multivariate events.</td>
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<tr>
<td></td>
<td>Prone to inclusion of extraneous factors or scaling biases for multivariate events.</td>
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Few v. Many PSFs in HRA Methods

Few PSFs

• Focus on high-level PSFs that encompass many categories of performance contribution
  – environment | organization | individual (Galyean, 2006)

Many PSFs

• Attempt to provide comprehensive model of contributors to human performance
  – From 8 PSFs in SPAR-H to ~50 in IDAC
• PSFs may not always be orthogonal, but methods may attempt to control for double-counting of related influences
• Not all PSFs count for every event or error
**Meaningful Distinctions**

HRA Methods were developed for different purposes

- Distinctions between HRA methods reflect the usage requirements for different HRA applications
- To the extent that space safety meets these intended uses, these methods may be effectively used in NASA

**Limitations**

- No HRA method designed specifically for NASA domains
- No HRA method baselined to human performance data from NASA domains
  - Beyond ground processing and control, spaceflight domains do not closely overlap nuclear power plants from which most HRA quantification is derived
Path Forward for HRA in Space Safety

Qualitative HRA Methods for NASA

- NASA mishap investigations identify current and historical sources which may have human contributors
- Human Factors Process Failure Modes and Effects Analysis (HF PFMEA)

- Root cause analysis
- Task analysis
Path Forward for HRA in Space Safety

Quantifying HRA for NASA

- **Research literature**
  - Extensive available literature on human performance in extreme environments
  - Match applicable domains (e.g., underwater diving) to determine probable performance in space

- **NASA operating history**
  - Extensive logging of events through simulators can provide indication of situations that may challenge human to perform optimally

- **Determination of space specific PSFs**
  - Bioastronautics Roadmap

Quantification information is being compiled in HRA database created by INL for NASA

- **Goal:** Allow future HRA quantification efforts at NASA to be informed by most relevant space data sources
Path Forward for HRA in Space Safety

Quantification through Simulation: “Third Generation” HRA?

• Use of modeling and simulation system with virtual representation of humans to determine situations that may challenge human performance in space missions

• Process
  – System extensively calibrated to human performance in known situations
  – Across many Monte Carlo style trials, performance extrapolated to novel situation (e.g., long-duration space flight) for which actual human performance data have not been collected
  – Provides preliminary estimates of human error as well as “red flags” for situations that need to be further investigated to determine actual risk to humans or risk of human error
Path Forward for HRA in Space Safety

Quantification through Simulation: “Third Generation” HRA?

- Example NASA simulation architecture: MIDAS
Existing HRA methods may produce error estimates that don’t fully reflect what is known about human performance in space domains

- Augmenting NASA tools and methods to existing HRA methods increases the ease and fidelity of making HRA estimates for space safety