

Human reliability assessment for physical security: human responses under extreme threats

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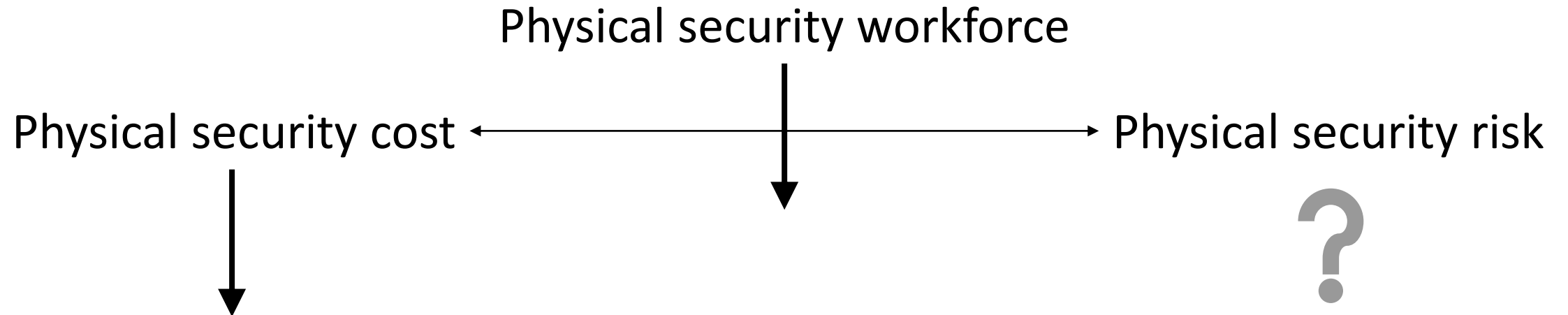


Background

- Nuclear power plant economic competitiveness
 - Operation & maintenance costs account for about 66% of the total operating cost in U.S. nuclear plants
 - Labor cost is significant
 - Physical security workforce accounts for about 20% of the total workforce in U.S. nuclear plants



Background (cont.)

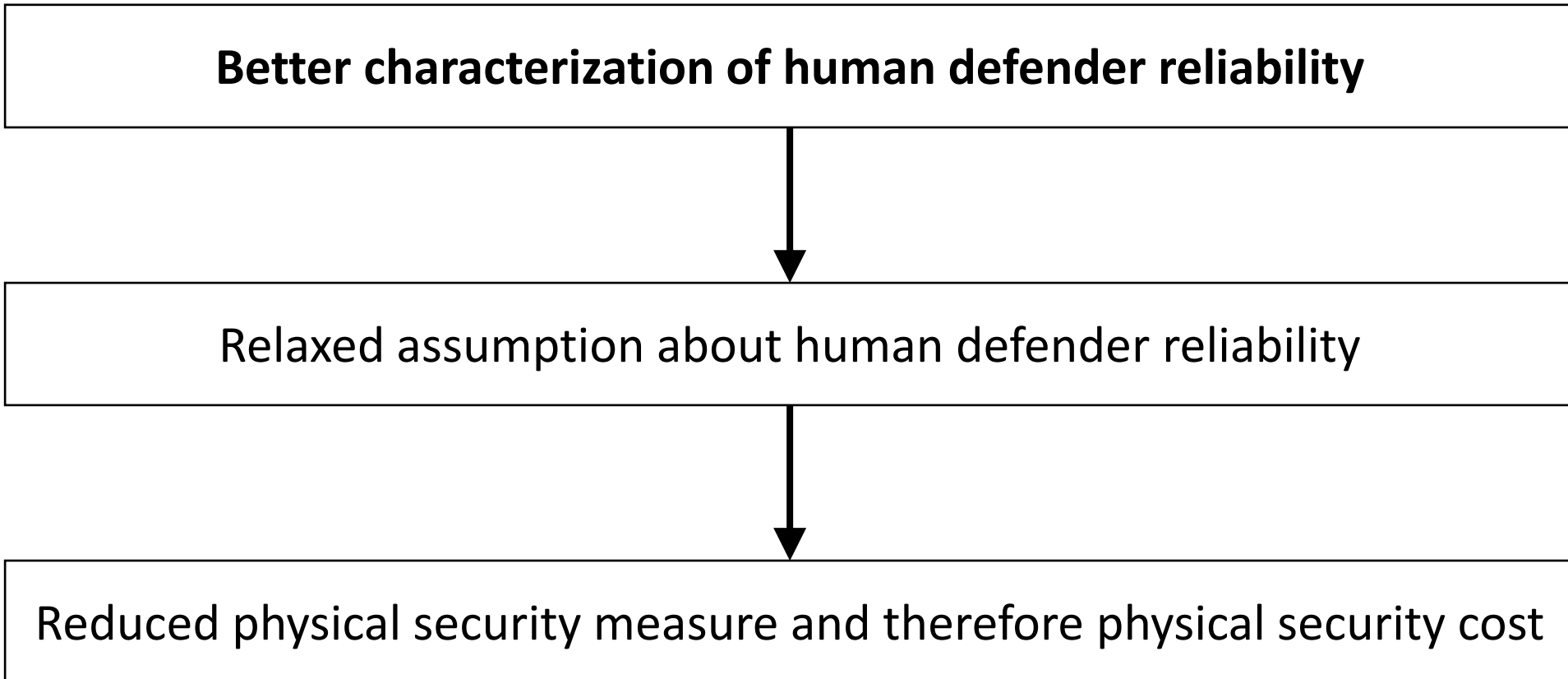


Background (cont.)

- Probabilistic risk assessment for physical security
- Large uncertainties exist in probabilistic risk assessment
 - **Human defender reliability**
 - Physical protection system effectiveness
 - etc.
- Conservative assumptions are usually made for such uncertainties
- Such conservative assumptions lead to conservative physical security measures
 - e.g., an excessive number of physical security staff members



Objective



Human defenders in responding to a physical attack

- Onsite security guards
 - Detecting physical attacks, delay attackers, and neutralize attackers
- External security resources
 - It may take time for them to arrive onsite after they are notified
- Human operators
 - Mitigate the consequence caused by a physical attack by controlling reactor and other relevant systems and components



Human reliability analysis

- Human reliability analysis has been studied for over 50 years and many methods have been developed
- Existing methods for human reliability analysis focus on natural events
 - e.g., responding to a feedwater pump failure, performing a maintenance task
- Such events are very different from physical attacks
 - In a physical attack, human defenders are faced with intelligent attackers and intentional sabotages of the plant by the attackers



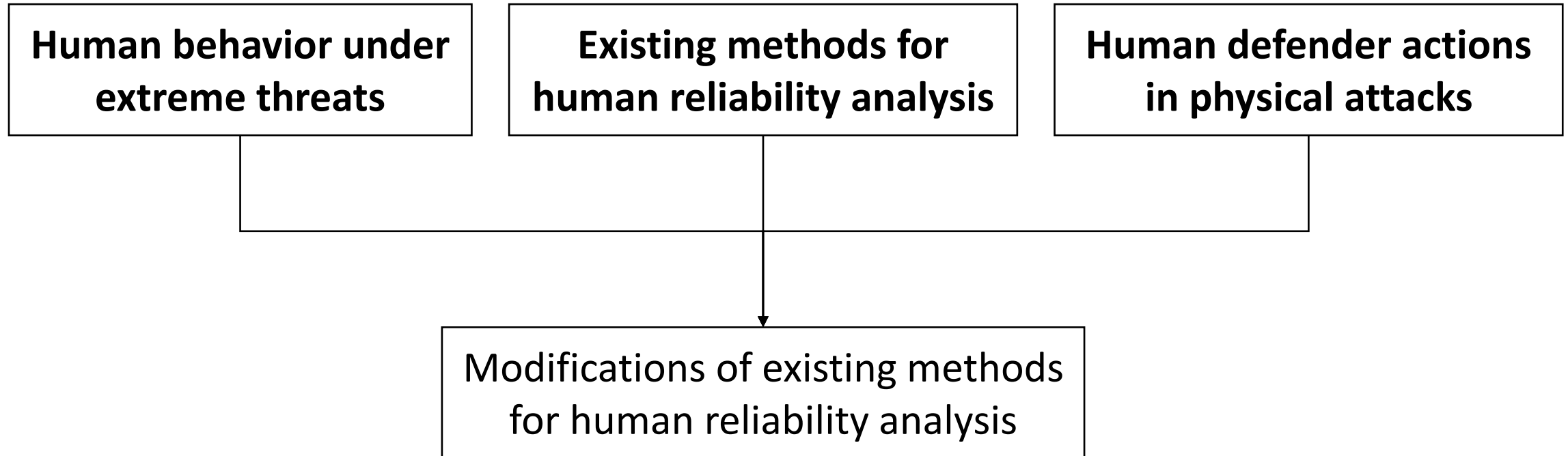
Human reliability analysis (cont.)

Physical security context

Existing methods for human reliability analysis need to be modified



Research pathway



Human behavior under extreme threats

- Response strategies in extreme conditions
 - **Flight**
 - **Fight**
 - Freeze
 - Fright
- Factors influencing human behavior
 - Physical, e.g., smoke, temperature
 - Physiological, e.g., fatigue
 - Psychological, stress
 - Individual characteristics, e.g., knowledge



Existing methods for human reliability analysis

- Reviewed six representative human reliability analysis methods
 - Task analysis
 - Performance shaping factors
 - Cognitive considerations
 - Requirement of analyst expert knowledge
 - etc.



Existing methods for human reliability analysis (cont.)

- SPAR-H: Standardized Plant Analysis Risk - Human Reliability Analysis
 - Diagnosis or Action
 - Performance shaping factor rating
 - Adjust the nominal human error probability
 - Calculate the overall human error probability
 - Adjustment based on dependency



Existing methods for human reliability analysis (cont.)

- HCR/ORE: Human Cognitive Reliability/Operator Reliability Experiments

- Operator non-response probability p as a function of elapsed time T

$$p = \Pr(T_r > T) = 1 - \Phi\left(\frac{\ln(T/T_{1/2})}{\sigma}\right)$$

- T_r is the time of response following a disturbance
- $\Phi(\cdot)$ is the standard normal cumulative distribution
- $T_{1/2}$ and σ are two model parameters



Human defender actions in physical attacks

- human operator actions
 - Use of Diverse and Flexible Mitigation Capability (FLEX) equipment, e.g., alignment of equipment
- Security guard actions
 - Security alarm acknowledgement and assessment
 - Notification of response force
 - Response initiation
 - Reaching critical interruption points
 - Engaging and neutralizing adversary



Thoughts on modifications of existing methods

- Consideration of additional human response modes, e.g., flight
- Consideration of additional performance shaping factors to characterize physical attack context
- Adjustment of performance shaping factor multipliers in existing methods
- Expert judgment or experiment data to inform such modifications



Summary and future work

- Better characterization of human defender reliability in responding to physical attacks can help reduce physical security cost
- Reviewed human behavior under extreme threats
- Reviewed representative methods for human reliability analysis
- Reviewed human defender actions in responding to physical attacks
- Future work:
 - Finalize the modifications of existing human reliability analysis methods
 - Conduct experiments and collect data to support such modifications



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Thank you!

