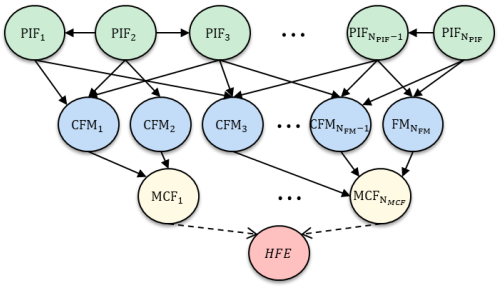
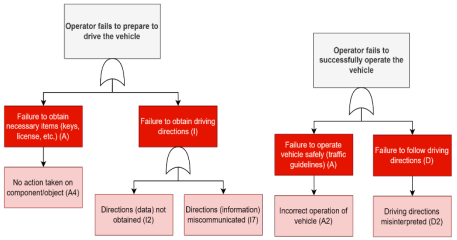




Identifying Human Failure Events (HFEs) for External Hazard Probabilistic Risk Assessment

Ahmad Al-Douri, Camille S. Levine, Katrina M. Groth

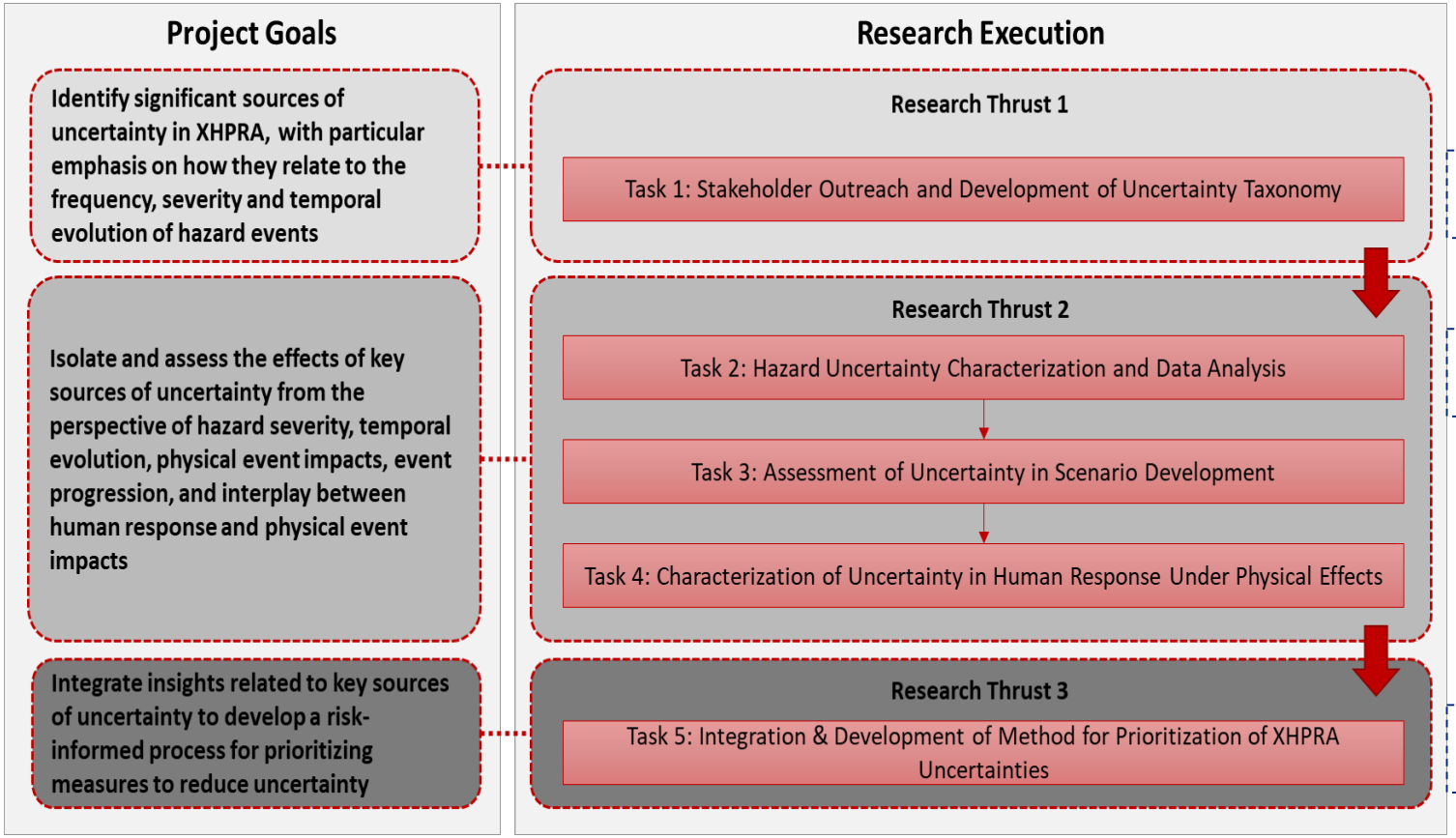
Systems Risk and Reliability Analysis (SyRRA) Lab

Center for Risk and Reliability

University of Maryland, College Park

This material is based upon work supported in part by the Department of Energy Office of Nuclear Energy under Award Number DE-NE0008974. This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Project Objective & Approach



MB157- Tuesday, 1:30 PM, External Events I

MB290- Tuesday, 10:30 AM, Infrastructure II

MB158- Tuesday, 3:30 PM, External Events II

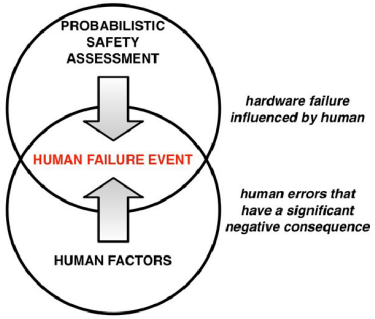
Objective: Development of a technically-sound method for identifying and prioritizing potentially risk significant uncertainty contributors in external hazard probabilistic risk assessment.

Michelle T. Bensi, Katrina M. Groth, Zeyun Wu, Zhegang Ma, Hongbin Zhang, Ray Schneider: Identifying and Prioritizing Sources of Uncertainty in External Hazard Probabilistic Risk Assessment (2020). DOE Office of Nuclear Energy Award DE-NE0008974

Task 4 Objective & Approach

Characterization of Uncertainty in Human Response Under Physical Effects

T4.1 Identification of human failure events (HFEs)



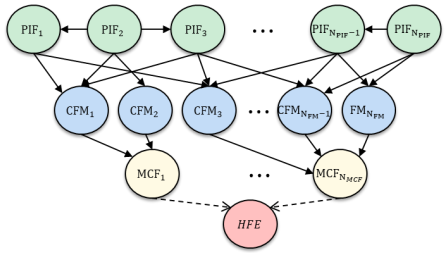
Human and human-machine actions and decisions involved in plant response.

T4.2 Identification of performance influencing factors (PIFs)

Organization-based	Team-based	Person-based	Situation/stressor-based	Machine-based
Training program Availability Quality Corrective action program Availability Quality Other programs Availability Quality Safety culture Management activities Staffing Scheduling Workplace adequacy Resources Procedures Availability Quality Tools Availability Quality Necessary information Availability Quality	Communication Availability Quality Direct supervision Leadership Team coordination Team cohesion Role awareness	Attention To task To surroundings Physical & psychological abilities Alertness Fatigue Impairment Sensory limits Physical attributes Other Knowledge/experience Skills Bias Familiarity with situation Morale/motivation/attitude	External environment Conditioning events Task load Time load Other loads Non-task Passive information Task complexity Cognitive Execution Stress Perceived situation Severity Urgency Perceived decision Responsibility Impact Personal Plant Society	HSI Input Output System response

Focus on factors relevant to modeling/quantifying human-machine performance in flooding hazard response.

T4.3 Development of framework for PIF-human failure mechanisms for XHPRA

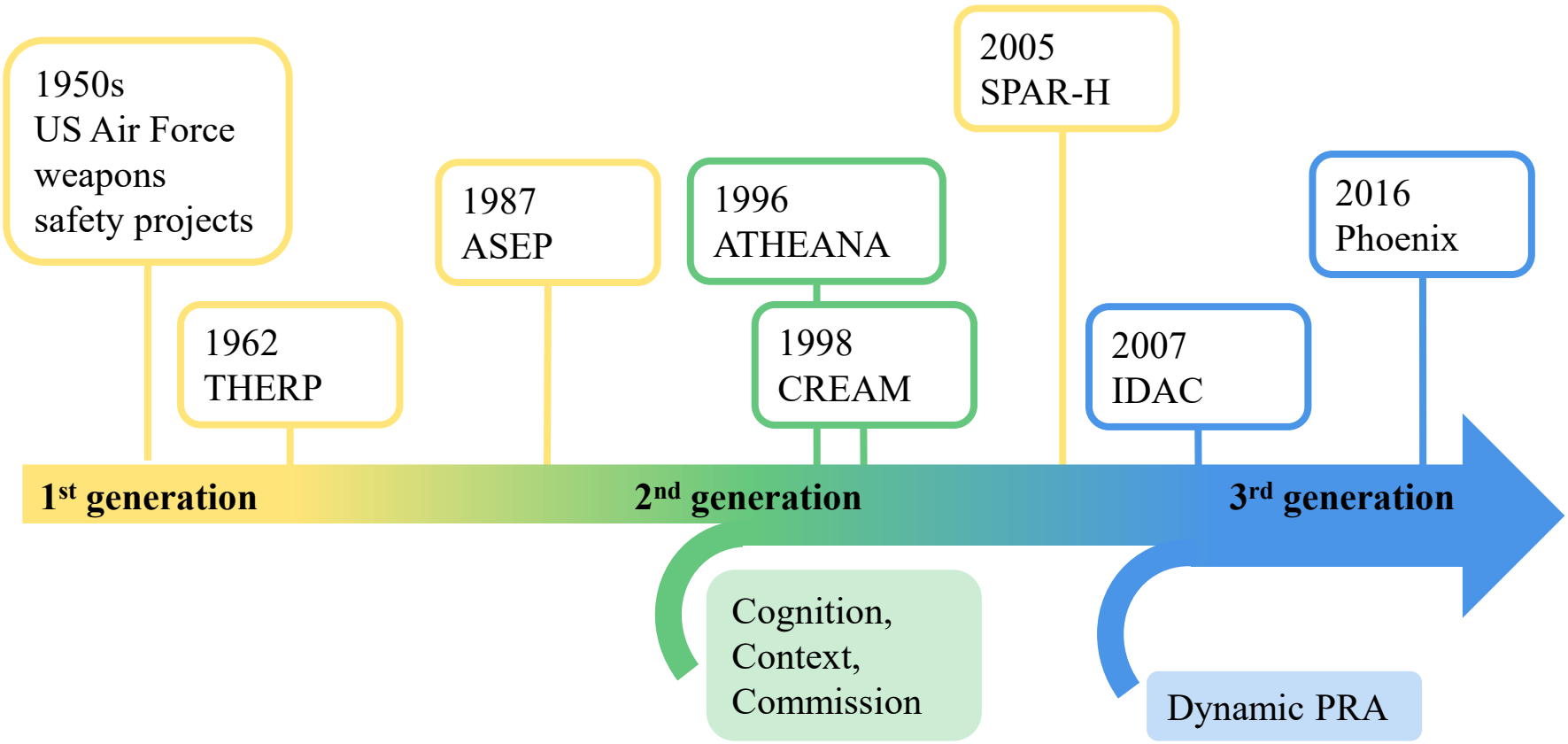


Encode causal relationships using Bayesian networks (BNs)

Research, education, and industry engagement

Provide a structure to enable inclusion of HRA within the framework for prioritizing hazard uncertainty drivers

Evolution of HRA Methods



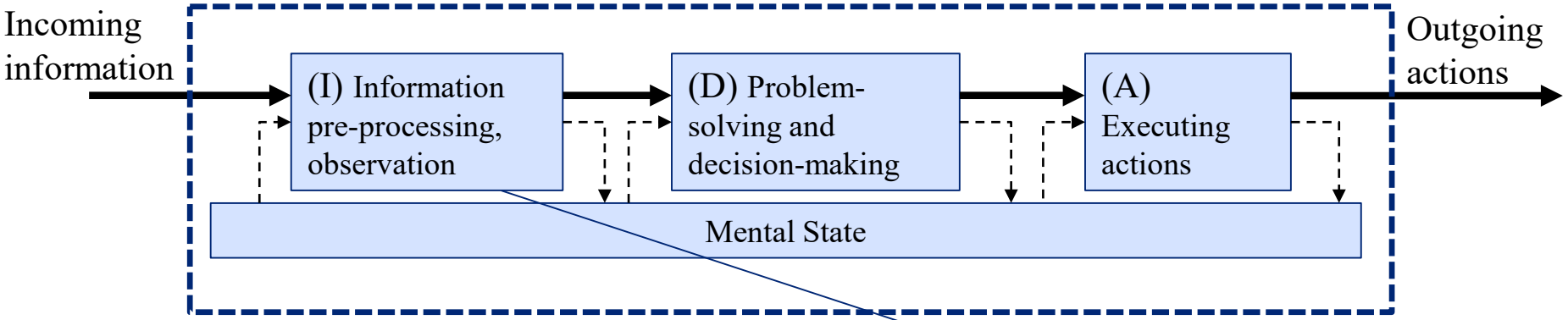
Motivation & Objectives

- Responses to a hazard event are reliant on human actions to a significant degree.
- Human response and human-plant interactions are key elements of successful prioritization of uncertainties within any PRA.
- Most existing human reliability analysis (HRA) models are built for control room (CR) actions.
- During a flooding event, most of the response actions are *ex-CR*.
- How to identify potential human failure events and associated uncertainties given available tools?

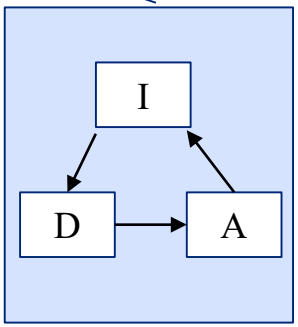
To address this shortcoming, we will modify and exercise the cognitive-based Phoenix model to support identification of human activities, causal factors, and uncertainties.

Methods: IDAC

- Information, Decision, and Action in Crew Context (IDAC) method considers three main stages of human response, all affected by mental state:



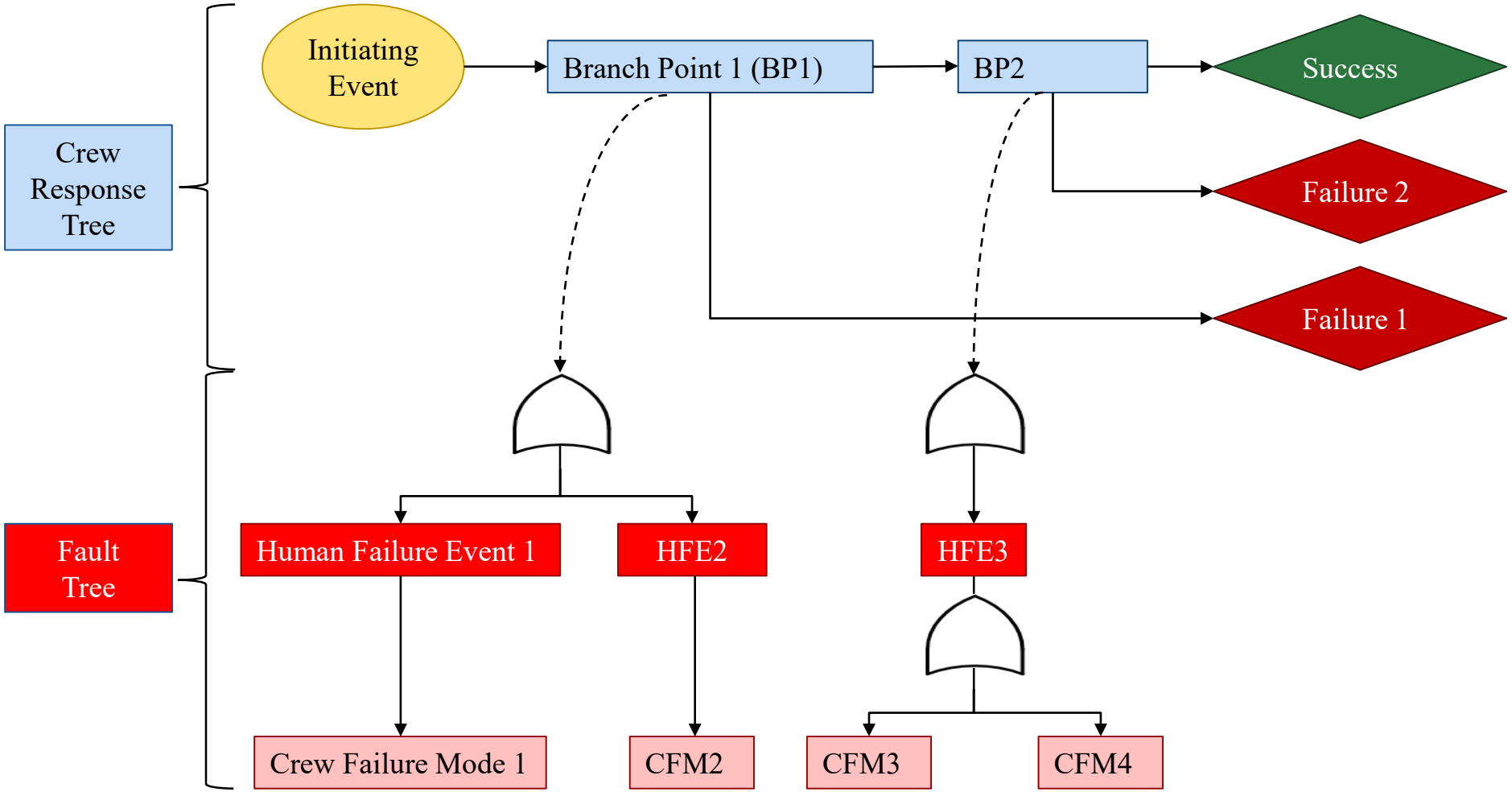
- Allows for a nested structure: each block can contain I, D, and A sub-processes



Chang, Y. H. J., & Mosleh, A. (2007). Cognitive modeling and dynamic probabilistic simulation of operating crew response to complex system accidents: Part 1: Overview of the IDAC Model. *Reliability Engineering & System Safety*, *92*(8), 997-1013.

Methods: Phoenix

- The Phoenix HRA method builds upon this as a layered qualitative analysis



Ekanem, N. J., Mosleh, A., & Shen, S. H. (2016). Phoenix–a model-based human reliability analysis methodology: qualitative analysis procedure. *Reliability Engineering & System Safety*, *145*, 301-315.

Task Data

- Few task analyses available for NPP ex-control room actions
- NUREG-7256, "Effects of Environmental Conditions on Manual Actions for Flood Protection and Mitigation", contains hierarchical task analyses of three representative flooding mitigation actions:
  - **Install a portable pump**
  - Install flood barriers on structure exterior walls
  - Build a sandbag berm around service water strainer pit
- Identifies manual actions via NRC staff assessments and plant-specific procedures

Subtask 2.4 – Load Equipment from Outdoor Container on Transport Vehicle			
Open the large container door	Unsheltered	Fixed	Involves unlocking and opening the Sea-Van container.
Load equipment (i.e., hoses and fittings) on the transport vehicle	Unsheltered	Semi-fixed	Involves gathering (gripping and lifting) hoses and fittings from the storage container and loading them onto the transport vehicle. This subtask is assumed to be mostly unsheltered and to occur when opening the container.
Perform manual work with simple equipment (i.e., secure equipment onto the transport vehicle)	Unsheltered	Fixed	This task primarily involves physical movements, such as gripping and pulling, to apply load restraints.

Crew Failure Mode Identification

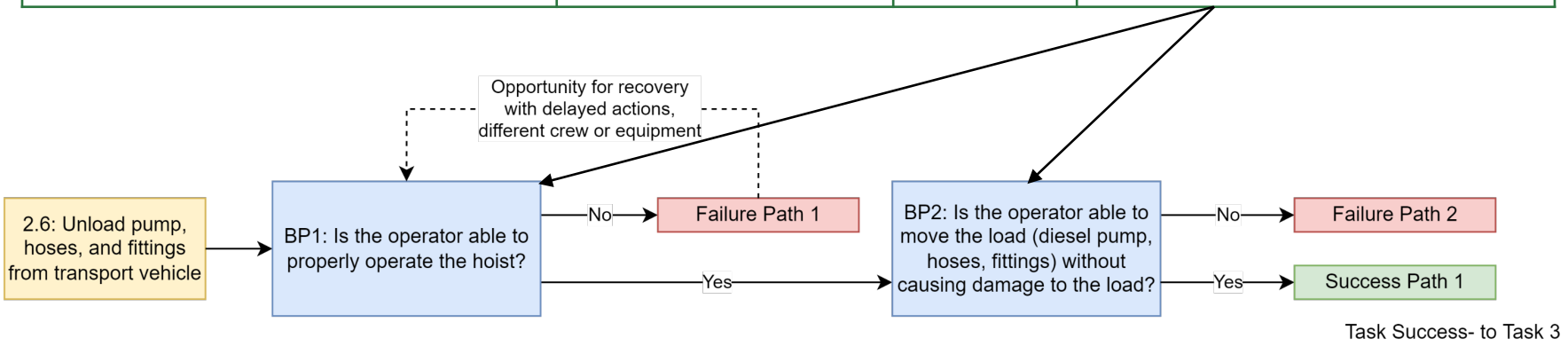
- 19 Phoenix CFMs: Generic functional modes of failure
  - Aggregated from a variety of sources: operating experience, relevant literature, expert discussion, and NRC-defined failure modes from SACADA

ID	Crew Failure Modes in "I" phase	ID	Crew Failure Modes in "D" phase	ID	Crew Failure Modes in "A" phase
I1	Key alarm not responded to (intentional or unintentional)	**D1**	Plant/system state misdiagnosed	**A1**	Incorrect timing of action
I2	Data not obtained	**D2**	Procedure misinterpreted	**A2**	Incorrect operation of component/object
I3	Data discounted	**D3**	Failure to adapt procedures to the situation	**A3**	Action on wrong component/object
I4	Decision to stop gathering data	**D4**	Procedure step omitted (intentional)		
I5	Data incorrectly processed	**D5**	Inappropriate transfer to a different procedure		
I6	Reading error	**D6**	Decision to delay action		
I7	Information miscommunicated	**D7**	Inappropriate strategy chosen		
I8	Wrong data source attended to				
I9	Data not checked with appropriate frequency				

Ekanem, N. J., Mosleh, A., & Shen, S. H. (2016). Phoenix–a model-based human reliability analysis methodology: qualitative analysis procedure. *Reliability Engineering & System Safety*, *145*, 301-315.

Development of CRTs from Hierarchical Task Decomposition

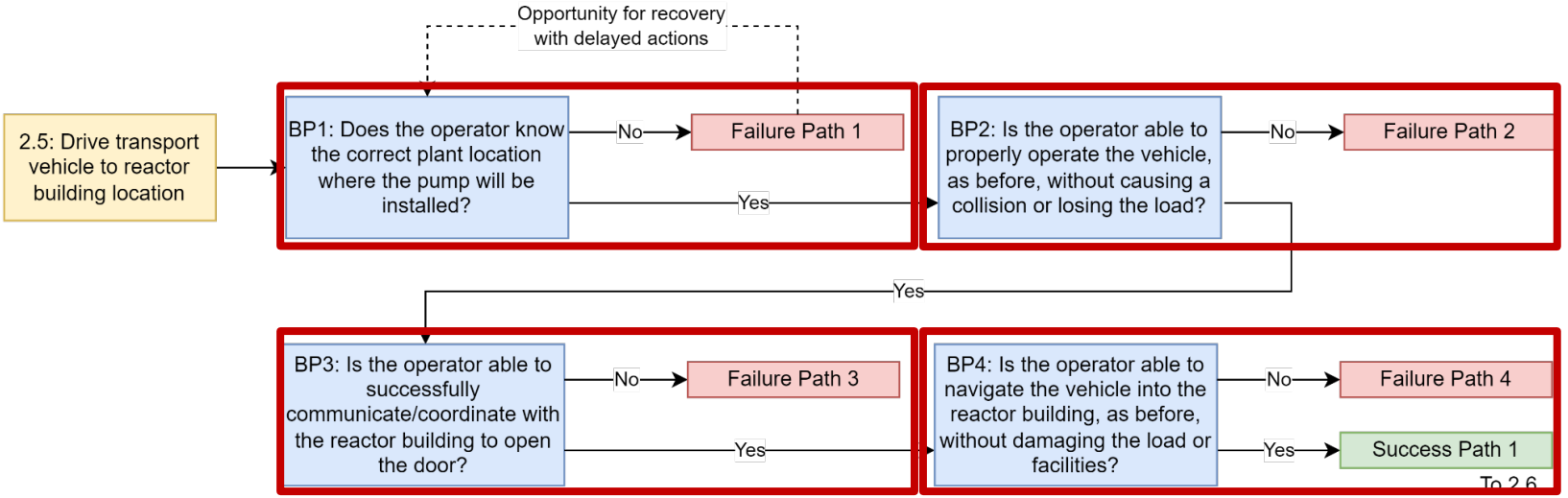
Subtask 2.6 – Unload Pump, Hoses, and Fittings from Transport Vehicle			
Specific Actions	**Degree of Sheltering**	**Location**	**Comments**
Operate the powered hoist to unload the pump and other equipment from the transport vehicle	Sheltered	Fixed	Involves positioning the hoist over the load, and lifting, moving, and lowering the load using the hoist controls and physical movements.



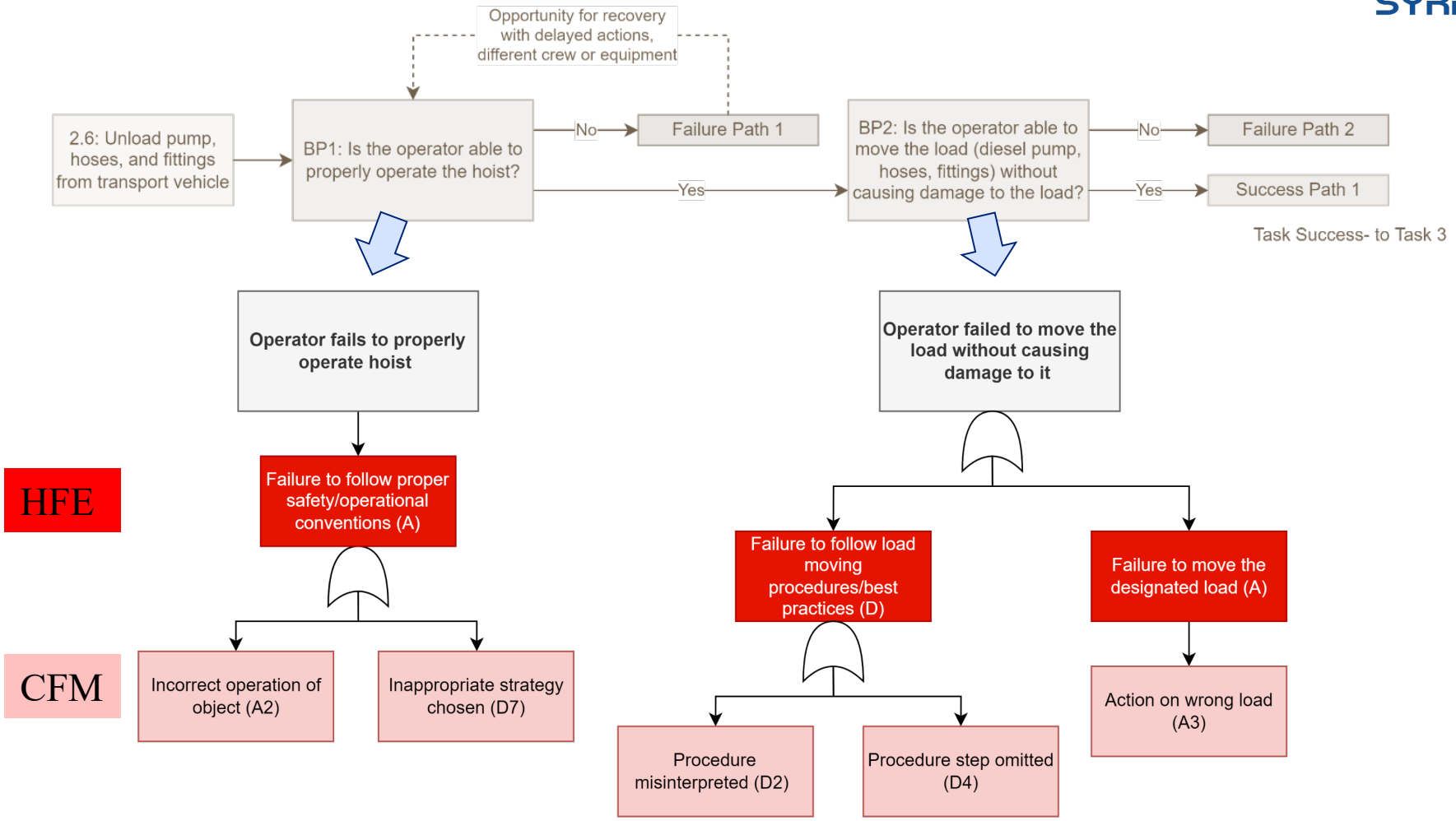
Portable pumps at the Diablo Canyon NPP ready for deployment.

Results: Development of CRTs

Subtask 2.5 – Drive Transport Vehicle to Reactor Building Location Where Equipment Will Be Unloaded			
Specific Actions	**Degree of Sheltering**	**Location**	**Comments**
Enter the transport vehicle	Unsheltered	Fixed	Personnel must unlock and open the vehicle.
Operate the transport vehicle from the equipment storage container location to the reactor building	Semi- sheltered	Variable	Includes driving the transport vehicle from the storage container location to the reactor building where the pump will be unloaded. Considered semi-sheltered because weather could affect visibility and hearing.
Exit the transport vehicle	Semi- sheltered	Fixed	
Communicate electronically outside the reactor building (i.e., to get the high bay door open)	Semi- sheltered	Semi-fixed	Involves communication and coordination with individuals in the reactor building to have the high bay door opened
Operate the transport vehicle to move it inside the reactor building	Semi- sheltered	Semi-fixed	Includes driving transport vehicle into the reactor building.
Exit the transport vehicle	Semi- sheltered	Fixed	

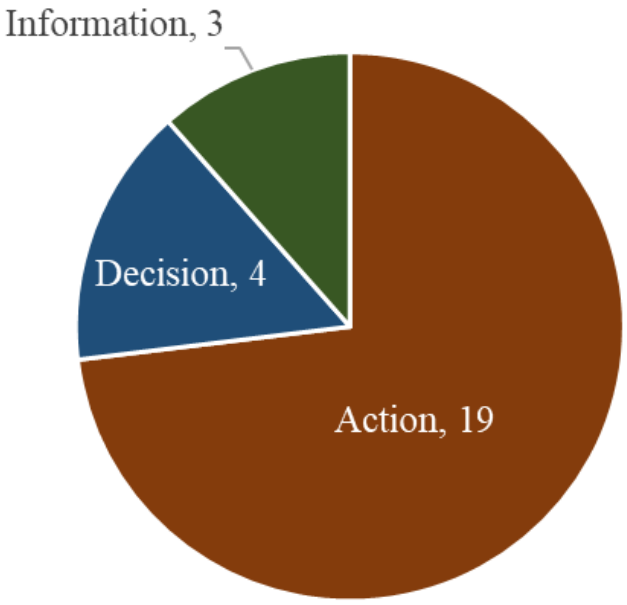


Results: Development of FTs

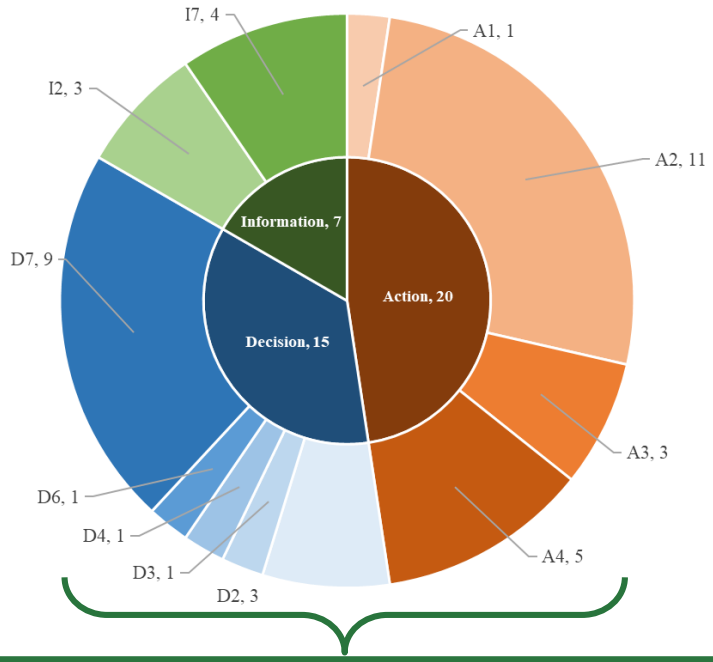


Results: Phase & CFM Occurrences

HFE Phases



CFM Phases



ID	Crew Failure Modes in "I" phase	ID	Crew Failure Modes in "D" phase	ID	Crew Failure Modes in "A" phase
I2	Data not obtained	**D2**	Procedure misinterpreted	**A1**	Incorrect timing of action
I7	Information miscommunicated	**D3**	Failure to adapt procedures to the situation	**A2**	Incorrect operation of component/object
		D4	Procedure step omitted (intentional)	**A3**	Action on wrong component/object
		D6	Decision to delay action	***A4***	*No action taken*
		D7	Inappropriate strategy chosen		

Contributions

- Demonstrated applicability of Phoenix method to ex-CR actions
  - Cognitive-based methods (third-generation HRA) are better suited than older methods (first- and second-generation HRA)
- CFMs provided in method are mostly relevant
  - Further refinement needed for Action phase CFMs, but Information and Decision CFMs sufficient to describe scenarios

This work sets the stage for a systematic treatment of human actions in external environments, allowing for the future development of the causal basis of HRA.

Future Work Directions

- Validation on two more ex-CR tasks
  - Then, seeking expert feedback on these analyses
- Issue of coordination & communication between multiple teams or individuals
  - Introduces complexities not currently modeled
- Mapping of PIF causal chains to identified CFMs (Task 4.2)
  - Using Groth's 2012 PIF hierarchy and Phoenix CFMs
- Quantification through resultant Bayesian Network (Task 4.3)

Thank you!

Ahmad Al-Douri
aaldouri@umd.edu

Camille S. Levine
clevine1@umd.edu

Katrina M. Groth
kgroth@umd.edu

SYRRA

Systems Risk and Reliability Analysis Laboratory

UNIVERSITY OF MARYLAND 1856

A. JAMES CLARK SCHOOL OF ENGINEERING

NUREG-7256 Task Analysis for Task 2

Task 2 – Load and Unload Portable Pump			
Specific Actions	**Degree of Sheltering**	**Location**	**Comments**
Subtask 2.1 – Drive Transport Vehicle to Equipment Storage Building			
Walk to the transport vehicle location from reactor building	Unsheltered	Variable	Transport vehicle is located away from reactor building and equipment storage building
Enter the transport vehicle	Unsheltered	Fixed	Personnel must unlock and open the vehicle.
Operate the transport vehicle to move it from its location to the equipment storage building	Semi-sheltered	Variable	This involves driving to a location away from the reactor buildings. Considered semi-sheltered because weather could affect visibility and hearing.
Exit the transport vehicle	Semi-sheltered	Fixed	
Open the equipment storage building door (i.e., high bay door of the storag the building)	Unsheltered	Fixed	This task involves unlocking the door and operating the door mechanism.
Enter the transport vehicle	Semi-sheltered	Fixed	
Operate the transport vehicle to move it into the equipment storage building	Semi-sheltered	Variable	Involves pulling the transport vehicle into the storage facility.
Exit the vehicle	Semi-sheltered	Fixed	

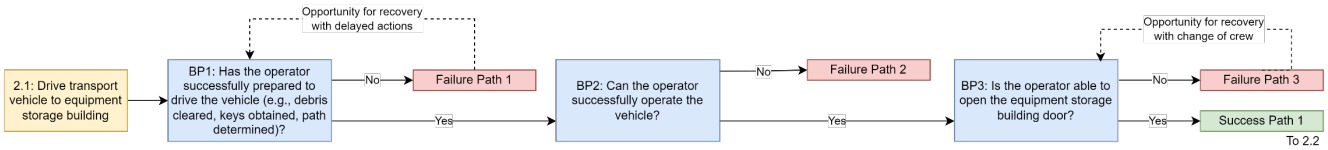
NUREG-7256 Task Analysis for Task 2

Task 2 – Load and Unload Portable Pump			
Specific Actions	**Degree of Sheltering**	**Location**	**Comments**
Subtask 2.2 – Load Diesel Driven Pump into Transport Vehicle			
Operate the powered hoist to load the pump on the transport vehicle	Sheltered	Fixed	This task involves positioning the hoist over the load, and lifting, moving, and lowering the load into place using the hoist controls.
Perform manual work with simple equipment (i.e., secure pump on the transport vehicle)	Sheltered	Fixed	This task involves primarily physical movements, such as gripping and pulling, to apply load constraints.
Subtask 2.3 – Drive Transport Vehicle to Equipment Storage Container			
Enter the transport vehicle	Unsheltered	Fixed	Personnel must unlock and open the vehicle.
Operate the transport vehicle to move the pump from the equipment storage building to the equipment storage container location	Semi-sheltered	Variable	Includes driving the transport vehicle from the equipment storage building to the equipment storage container location. Considered semi-sheltered because weather could affect visibility and hearing.
Exit the transport vehicle	Semi-sheltered	Fixed	
Subtask 2.4 – Load Equipment from Outdoor Container on Transport Vehicle			
Open the large container door	Unsheltered	Fixed	Involves unlocking and opening the Sea-Van container.
Load equipment (i.e., hoses and fittings) on the transport vehicle	Unsheltered	Semi-fixed	Involves gathering (gripping and lifting) hoses and fittings from the storage container and loading them onto the transport vehicle. This subtask is assumed to be mostly unsheltered and to occur when opening the container.
Perform manual work with simple equipment (i.e., secure equipment onto the transport vehicle)	Unsheltered	Fixed	This task primarily involves physical movements, such as gripping and pulling, to apply load restraints.

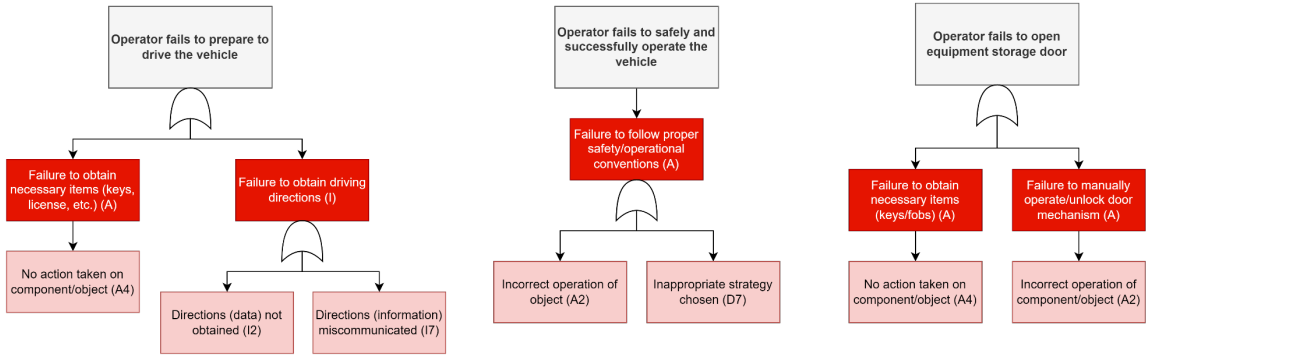
NUREG-7256 Task Analysis for Task 2

Subtask 2.5 – Drive Transport Vehicle to Reactor Building Location Where Equipment Will Be Unloaded			
Enter the transport vehicle	Unsheltered	Fixed	Personnel must unlock and open the vehicle.
Operate the transport vehicle from the equipment storage container location to the reactor building	Semi-sheltered	Variable	Includes driving the transport vehicle from the storage container location to the reactor building where the pump will be unloaded. Considered semi-sheltered because weather could affect visibility and hearing.
Exit the transport vehicle	Semi-sheltered	Fixed	
Communicate electronically outside the reactor building (i.e., to get the high bay door open)	Semi-sheltered	Semi-fixed	Involves communication and coordination with individuals in the reactor building to have the high bay door opened.
Operate the transport vehicle to move it inside the reactor building	Semi-sheltered	Semi-fixed	Includes driving transport vehicle into the reactor building.
Exit the transport vehicle	Semi-sheltered	Fixed	
Subtask 2.6 – Unload Pump, Hoses, and Fittings from Transport Vehicle			
Operate the powered hoist to unload the pump and other equipment from the transport vehicle	Sheltered	Fixed	Involves positioning the hoist over the load, and lifting, moving, and lowering the load using the hoist controls and physical movements.

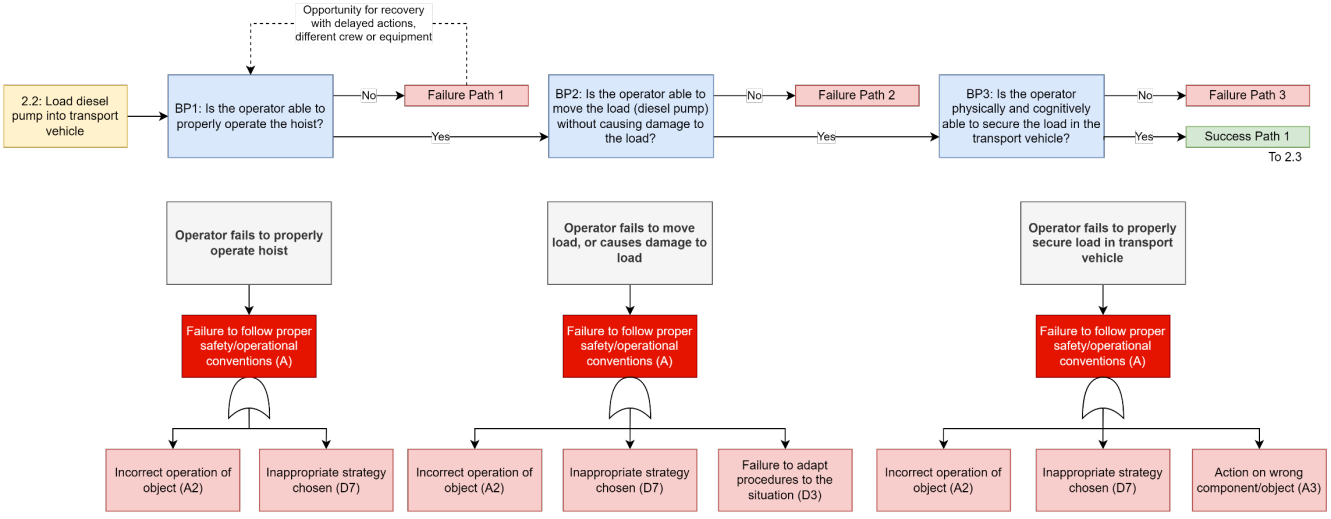
All CRTs & FTs



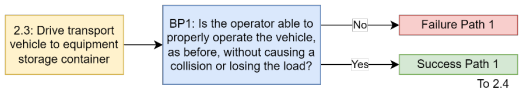
Task 2.3



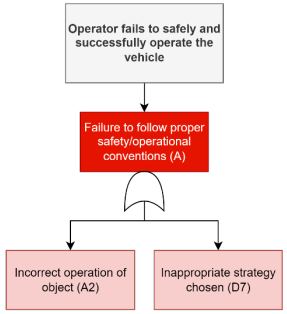
Task 2.4

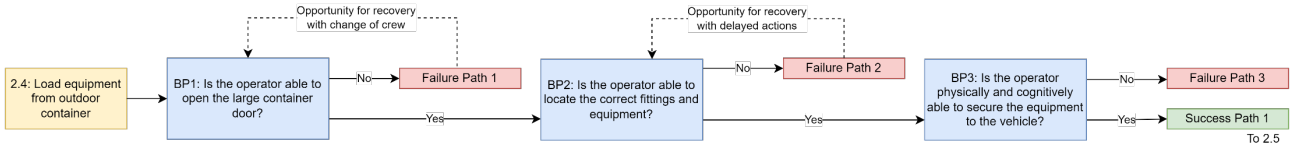


All CRTs & FTs

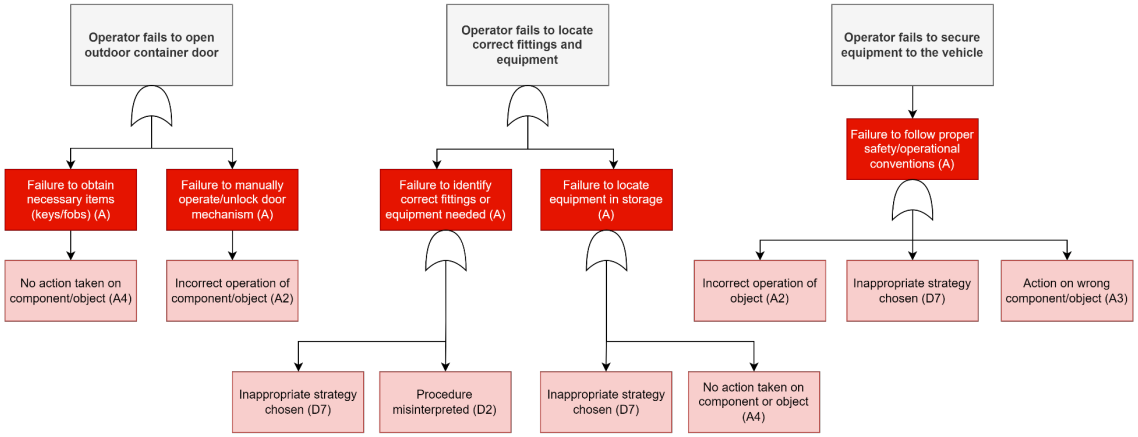


Task 2.3



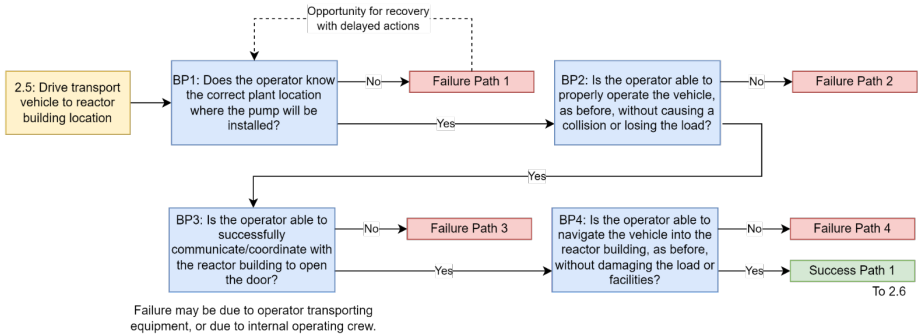


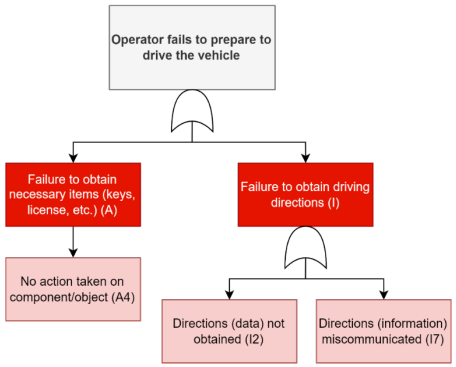
Task 2.4

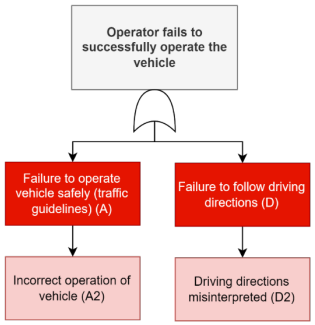


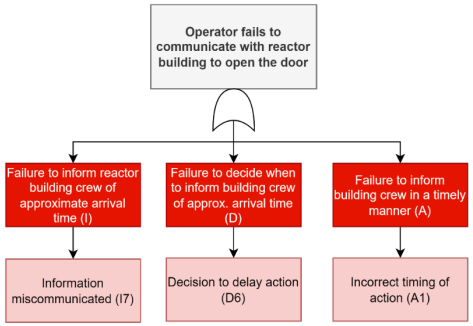
All CRTs & FTs

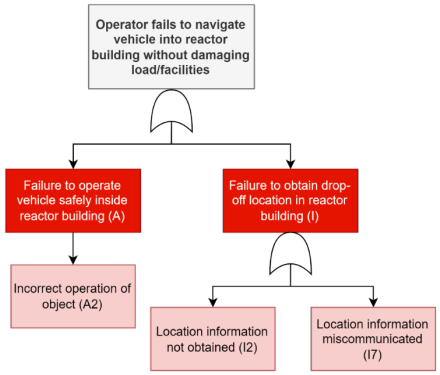
Task 2.5



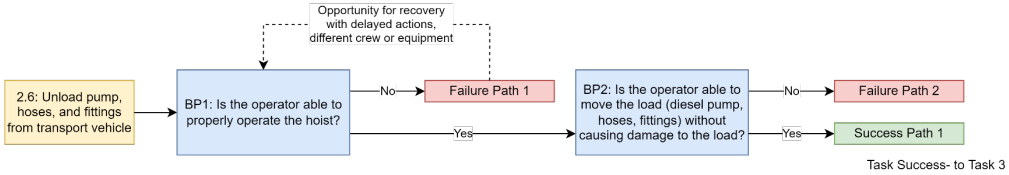








All CRTs & FTs



Task 2.6