The George E. Brown, Jr. Network for Earthquake Engineering Simulation

Seismic Risk Mitigation for Port Systems

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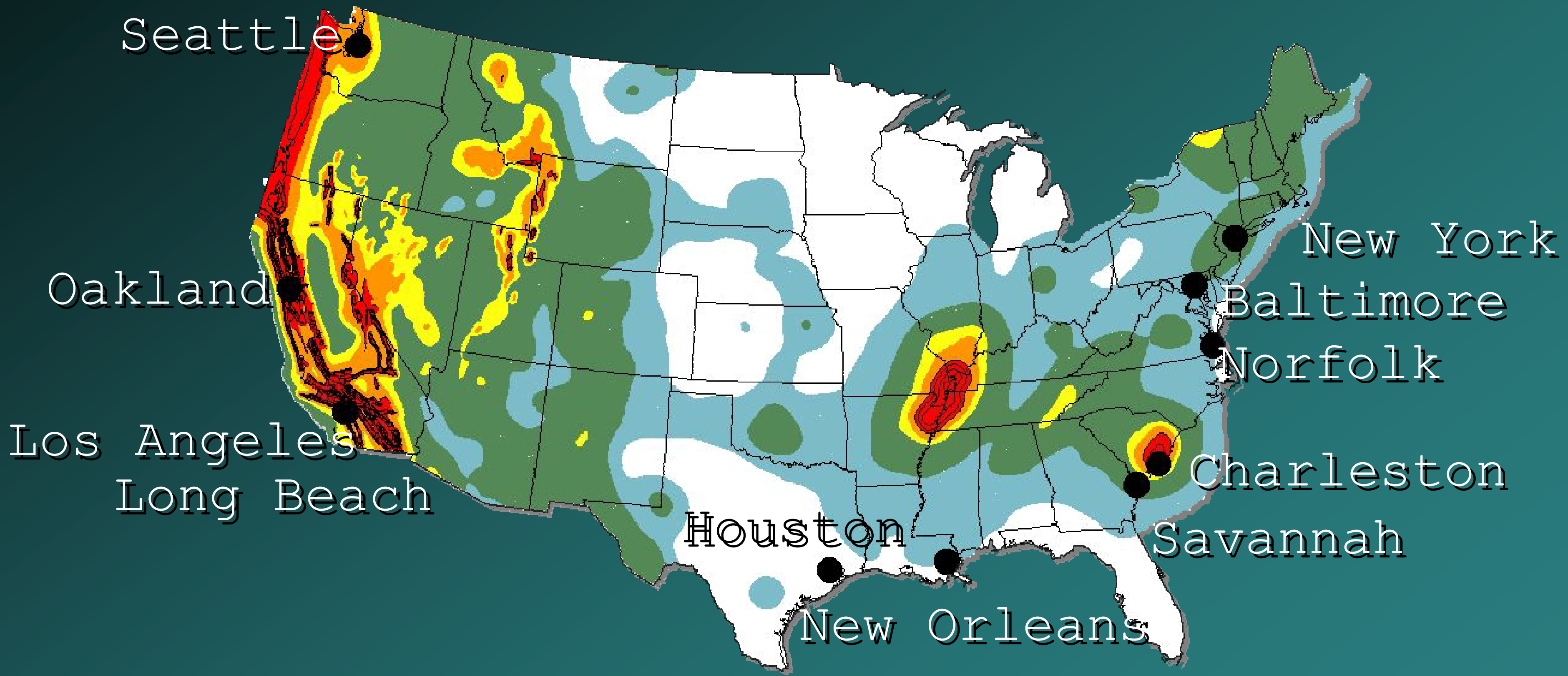
Seismic Hazard



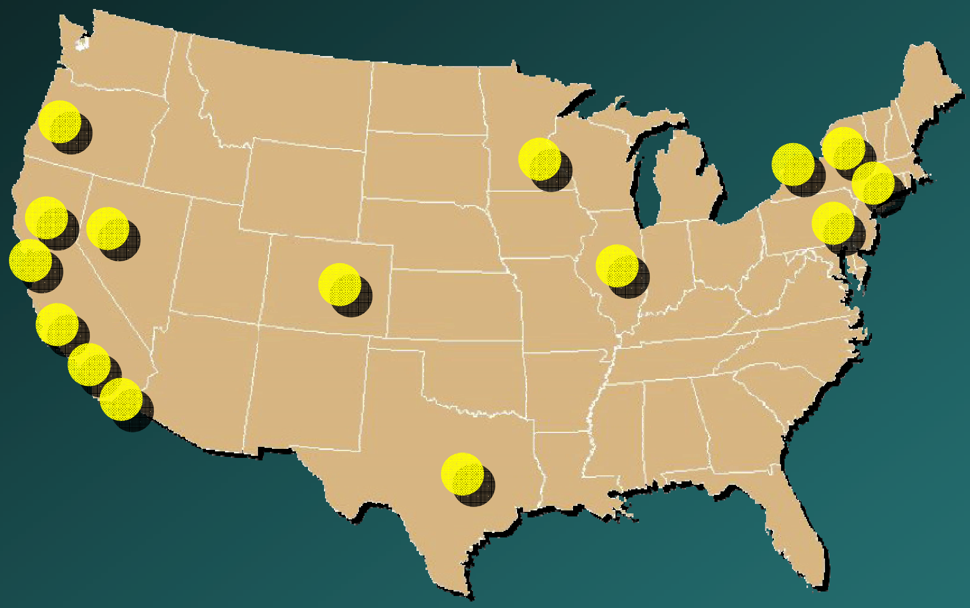
Current Practice

- Vaguely defined performance requirements
  - e.g., “minimal” damage and “no downtime” for ground motions with 50% probability of exceedance in 50 years; “repairable/controllable” damage and “acceptable downtime” for ground motions with 10% probability of exceedance in 50 years
- No direct consideration of business interruption losses

Vision

This NEESR Grand Challenge project integrates civil engineering, logistics, risk analysis, and behavioral decision disciplines to develop a seismic risk mitigation framework that uses the performance of the port system rather than its individual components as the basis of

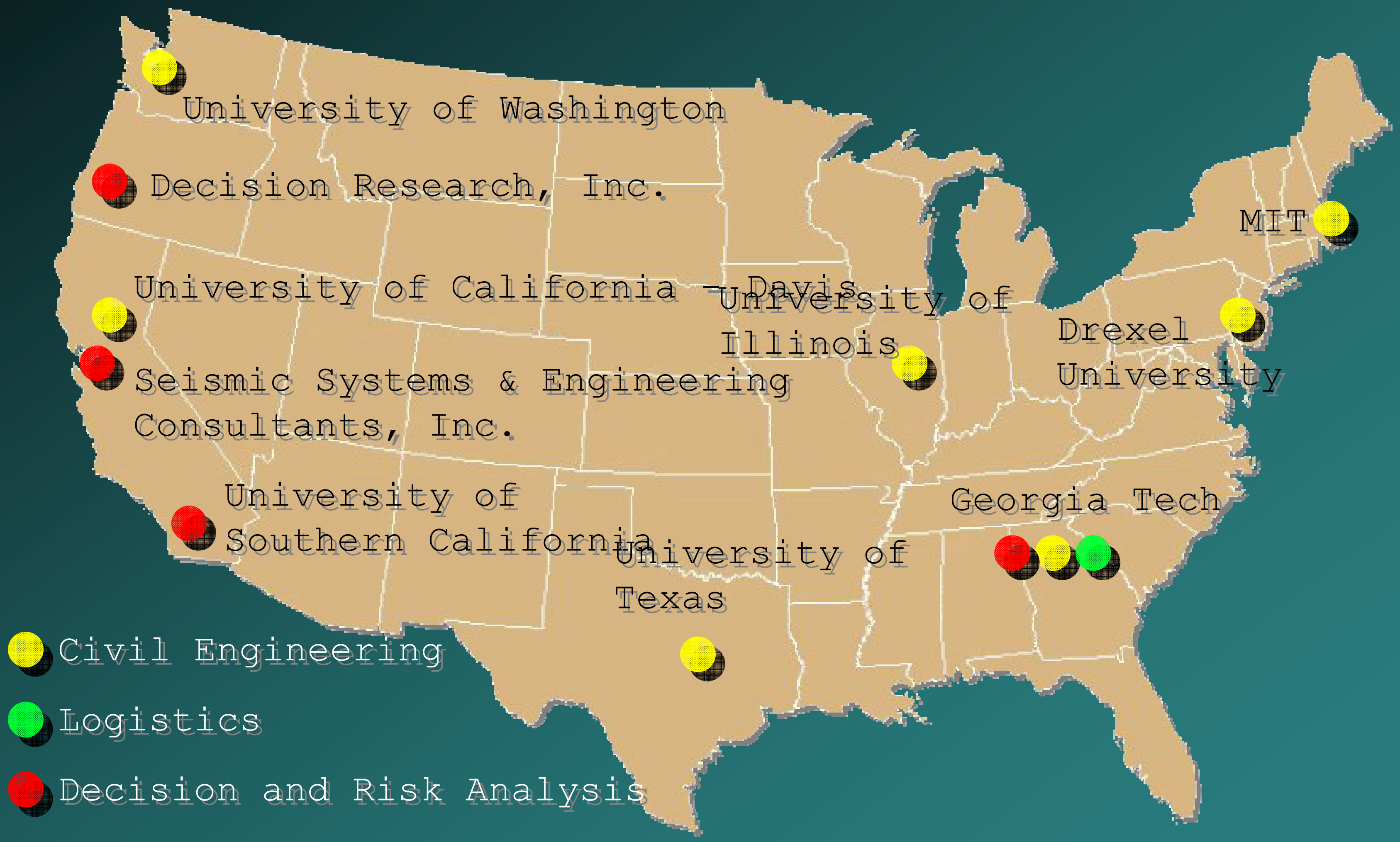
NEES Resources



NEES Equipment Sites

- Experimental facilities
  - Centrifuges
  - Large-scale tests
  - Shake tables
  - Mobile field equipment
  - Tsunami wave basin
- Cyberinfrastructure
  - Curated, central data repository
  - Tele-presence capabilities
  - Computational

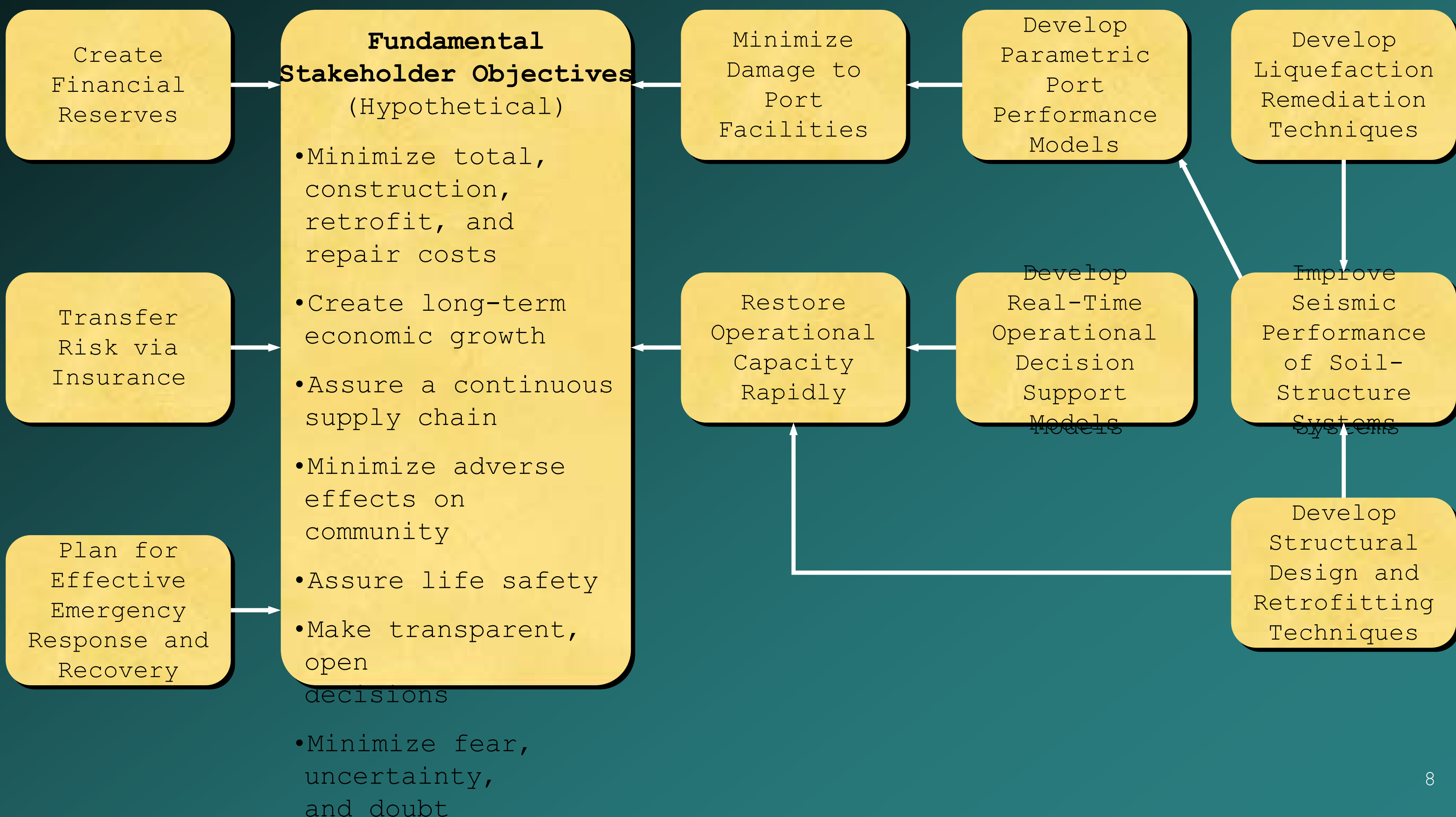
Project Team



Structured, Decision-Aiding Evaluation of Risks

1. Define the port system including stakeholders, physical infrastructure, and operational data
2. Define fundamental stakeholder objectives, alternative means of achieving them, and appropriate metrics

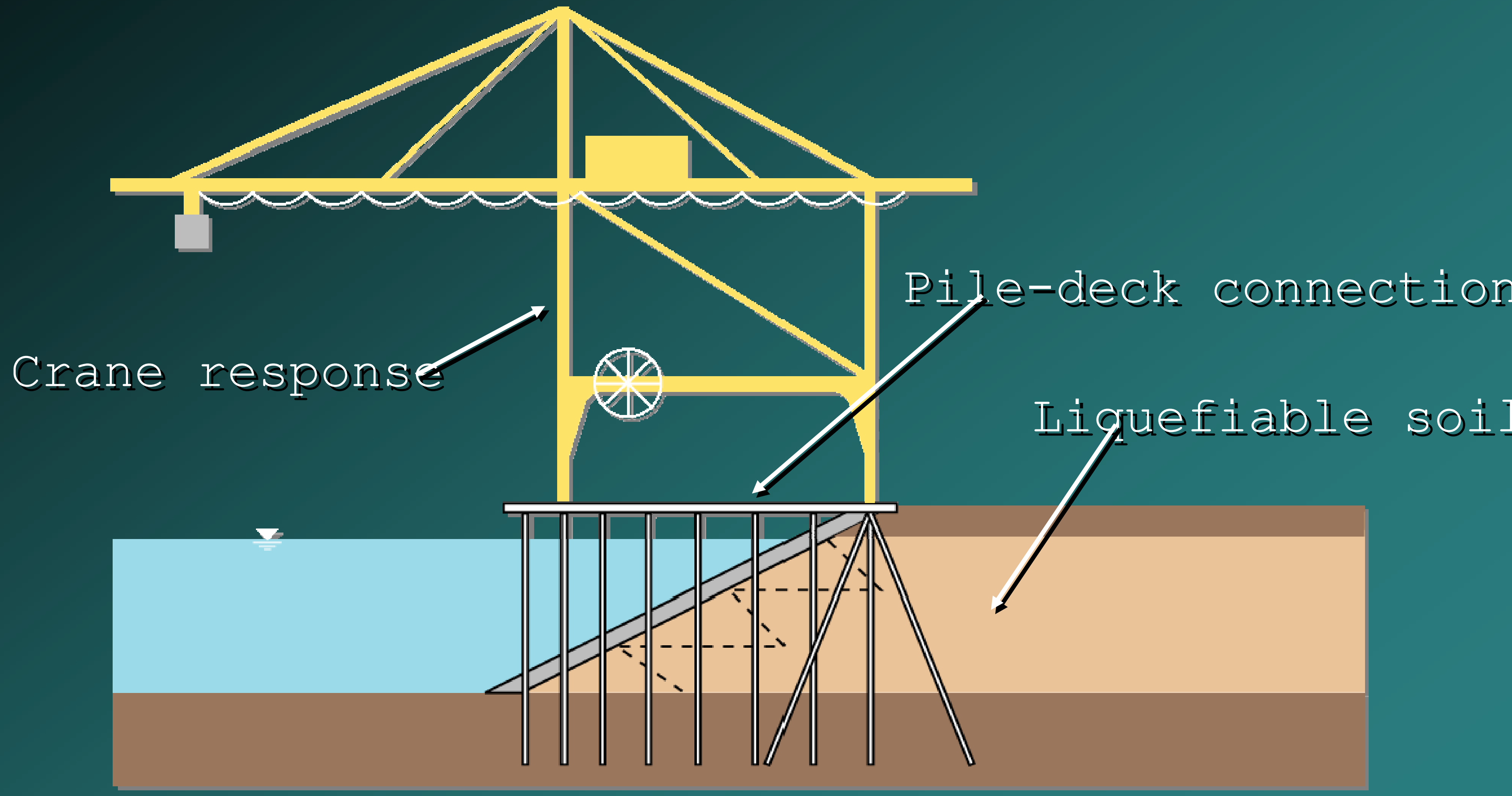
Means-Ends Network



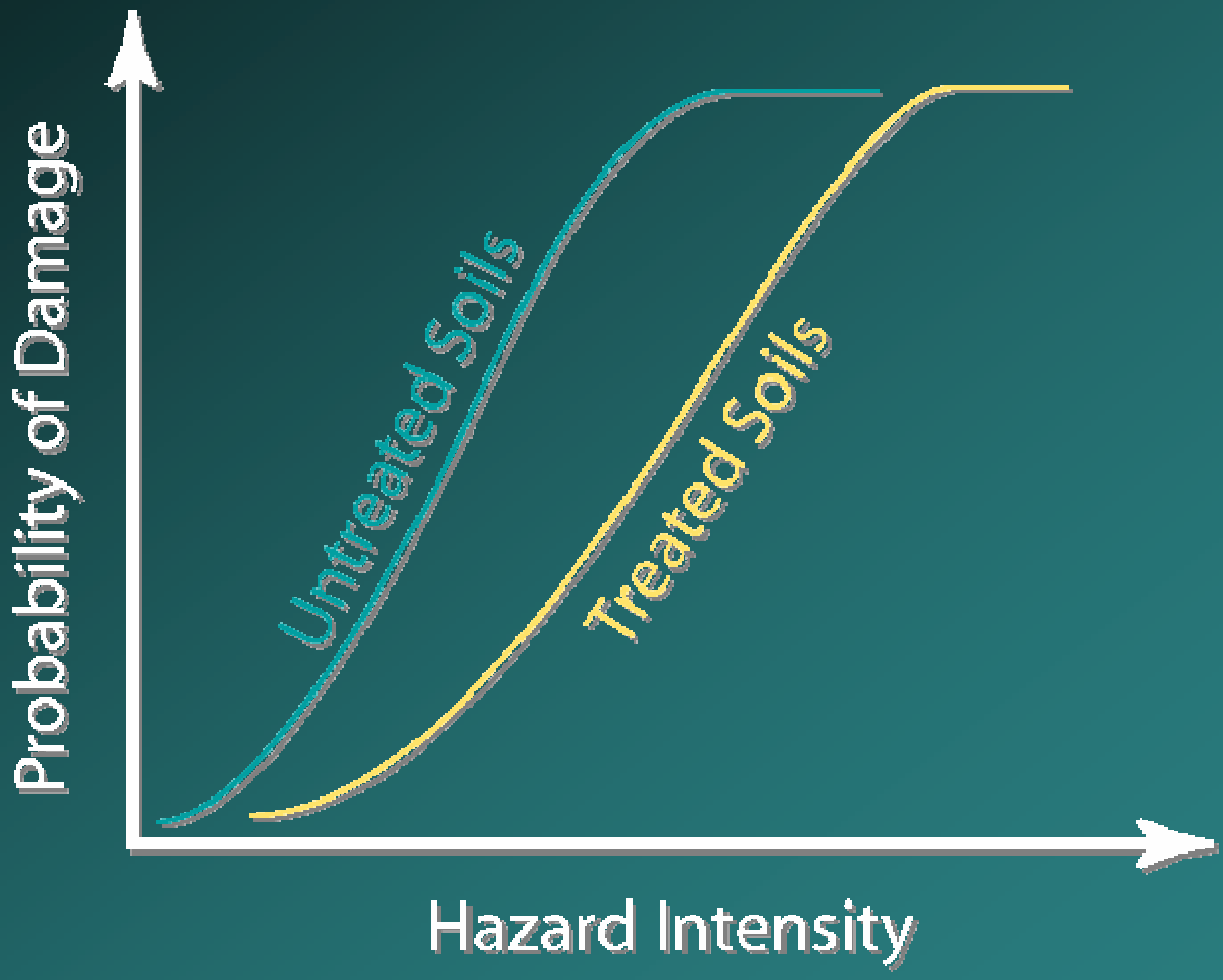
Structured, Decision-Aiding Evaluation of Risks

1. Define the port system including stakeholders, physical infrastructure, and operational data
2. Define fundamental stakeholder objectives, alternative means of achieving them, and appropriate metrics
3. Evaluate component and systems-level performance of each alternative including uncertainties

Component Performance



Component Performance

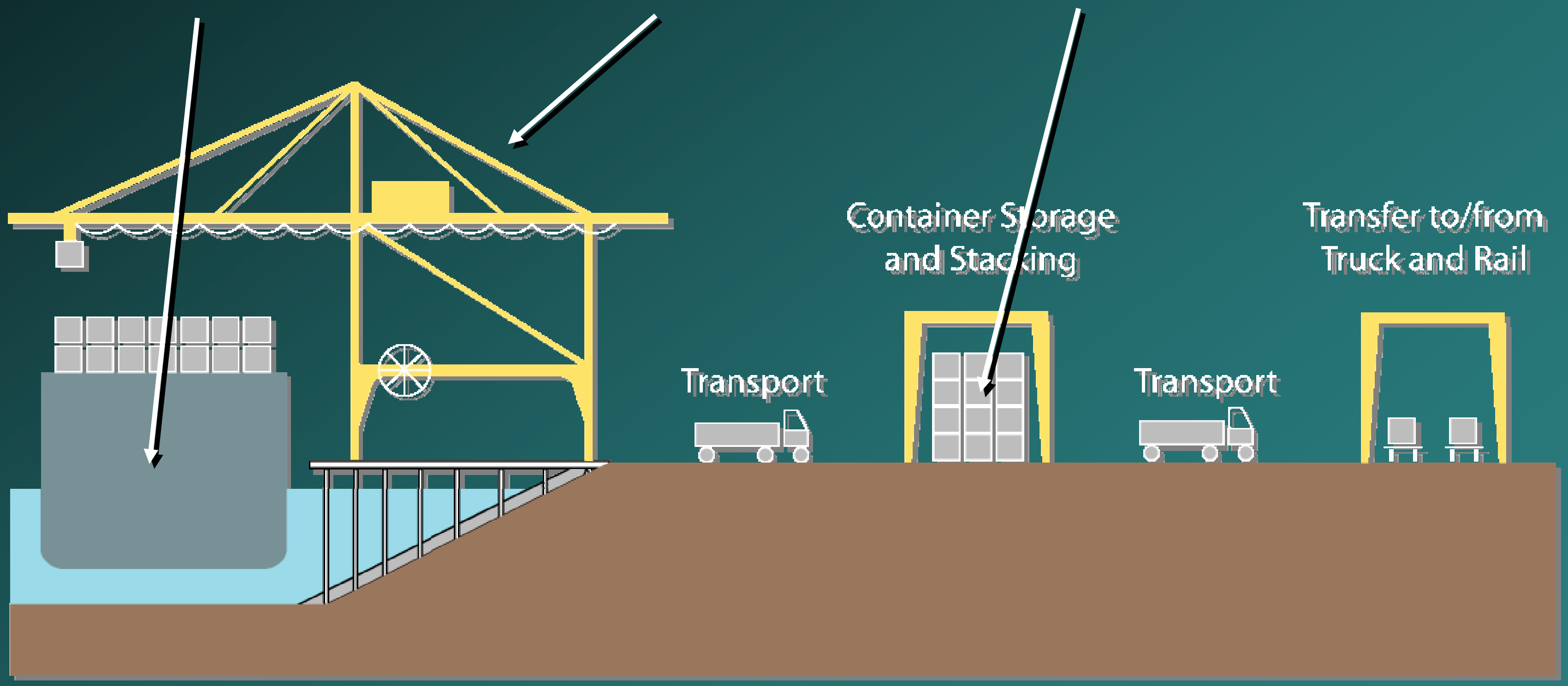


System Performance

Berth allocation

Crane scheduling

Container location



System Performance

- Develop functional relationships between port performance metrics (such as container throughput) and the state of operational components
  - Approximate port performance given parametric representation of a damage state
  - Rapid evaluation
  - Potential integration within risk-based decision framework
- Why not just simulate?
  - Always an option, but usually difficult to integrate into risk decision models
  - Requires enumerating a potentially large space of possible damage states and

System Performance

- Develop real-time operational decision support tools to improve port system performance given a (potentially restricted) state of port operational resources
  - Existing port operational models are not equipped to:
    - Handle dynamic and stochastic information
    - Integrate decisions for multiple port components
    - Solve large-scale problems faced by modern ports
  - Real-time systems optimization has the potential to dramatically improve decisions

Structured, Decision-Aiding Evaluation of Risks

1. Define the port system including stakeholders, physical infrastructure, and operational data
2. Define fundamental stakeholder objectives, alternative means of achieving them, and appropriate metrics
3. Evaluate component and systems-level performance of each alternative including uncertainties
4. Present results in a manner to enhance stakeholder comprehension, clarify underlying choices, and explicitly address tradeoffs

Consequence Matrix

- Consequence matrices help to develop an understanding of how stakeholders respond to each alternative mitigation strategy and inform the decision-making process

Alternatives

Objectives

	A	B	C
1	✘	✔	✔
2	✔	✔	✔
3	✘	✘	✔

Structured, Decision-Aiding Evaluation of Risks

1. Define the port system including stakeholders, physical infrastructure, and operational data
2. Define fundamental stakeholder objectives, alternative means of achieving them, and appropriate metrics
3. Evaluate component and systems-level performance of each alternative including uncertainties
4. Present results in a manner to enhance stakeholder comprehension, clarify underlying choices, and explicitly address tradeoffs
5. Learn and iterate

Engineering

- Develop soil remediation techniques, pile and pile-deck connection configurations, and crane design and retrofitting techniques that improve seismic performance
- Develop fragility relationships to discern and communicate the effects of engineering-based mitigation options

Port Operations and Logistics

- Develop parametric approximation models to predict port system performance metrics as a function of the time-dependent functionality of port components
- Develop real-time decision-support tools to optimize vessel berthing, crane scheduling, and container location following a disruptive event

Decision Research and Risk Analysis

- Integrate value-focused, behavioral decision research, research on mental models of seismic risks, enterprise risk criteria, and formal port stakeholder participation to develop:
  - a means-ends network with alternative risk mitigation actions and their effect on performance objectives for ports.
  - consequence-by-alternatives matrices illustrating the tradeoffs port stakeholders are willing to make

Summary

- The overall goal is to develop a seismic risk mitigation framework that uses the performance of the port system rather than its individual components as the basis for choosing among risk mitigation options
- We believe that such a framework will have applications to other civil infrastructure systems and other natural and man-made hazards