Enhancing the resilience of acute care facilities against extreme events

Michel Bruneau

Director, Multidisciplinary Center for Earthquake Engineering Research

MCEER
MULTIDISCIPLINARY CENTER FOR EARTHQUAKE ENGINEERING RESEARCH
A National Center of Excellence in Advanced Technology Applications

VISION STATEMENT

The overall goal is to enhance the seismic resiliency of communities through improved engineering and management tools for critical infrastructure systems (water supply, electric power, and hospitals) and emergency management functions. Seismic resilience (technical, organizational, social, and economic) is characterized by reduced probability of system failure, reduced consequences due to failure, and reduced time to system restoration.

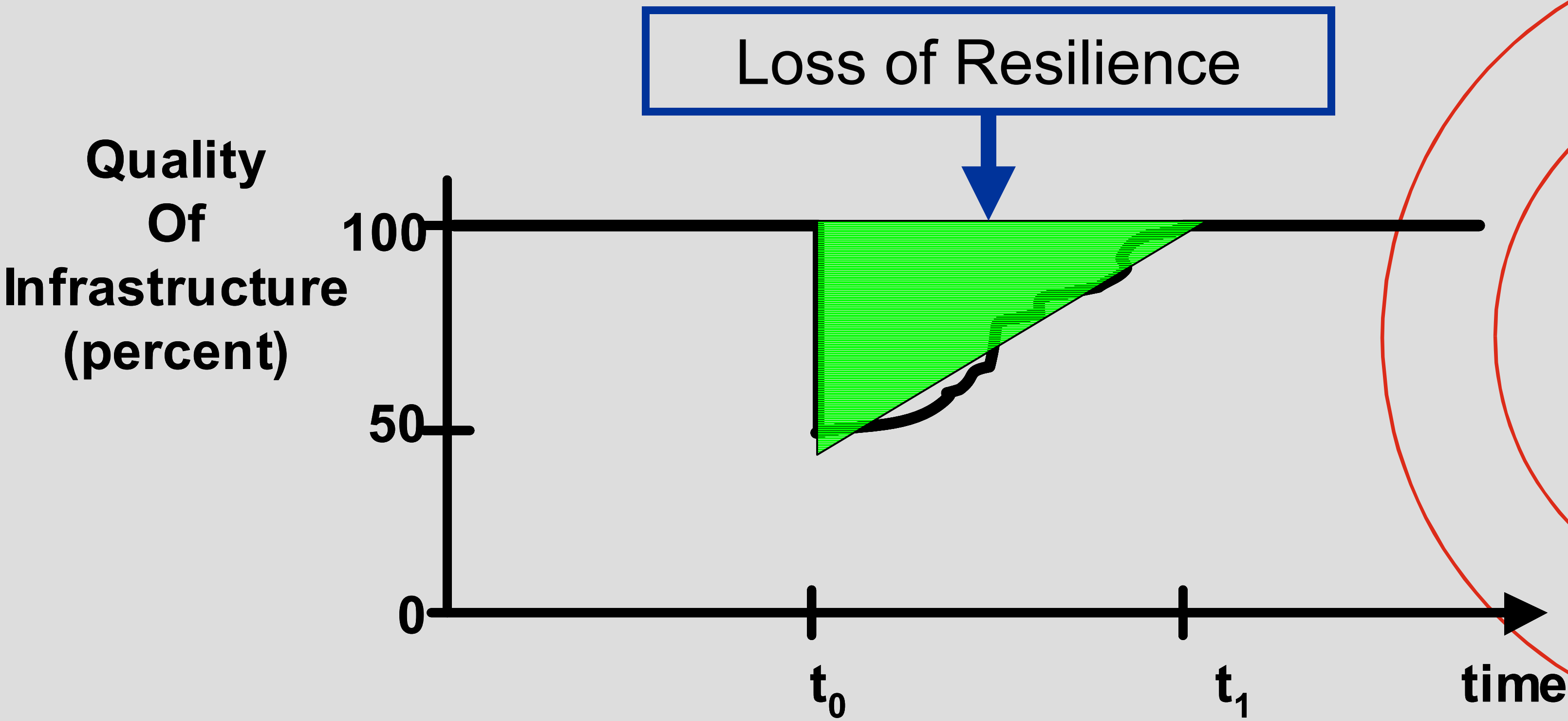
Reference: "A Framework to Quantitatively Assess and Enhance Seismic Resilience" Earthquake Spectra Journal

Michel BRUNEAU (MCEER/University at Buffalo)
Stephanie CHANG (University of British Columbia)
Ronald EGUCHI (Imagecat Inc.)
George C. LEE (MCEER)
Thomas D. O'ROURKE (Cornell University)
Andrei M. REINHORN (University at Buffalo)
Masanobu SHINOZUKA (University of California at Irvine)
Kathleen TIERNEY (University of Colorado)
William A. WALLACE (Rensselaer Polytechnic Institute)
Detlof VON WINTERFELDT (University of Southern California)

Resilience

- Framework that quantitatively measures
  - The “ends” of robustness and rapidity
  - The “means” of resourcefulness and redundancy
- Dimensions of resilience
  - Technical and Organizational (T & O)
  - Societal and Economic (S & E)

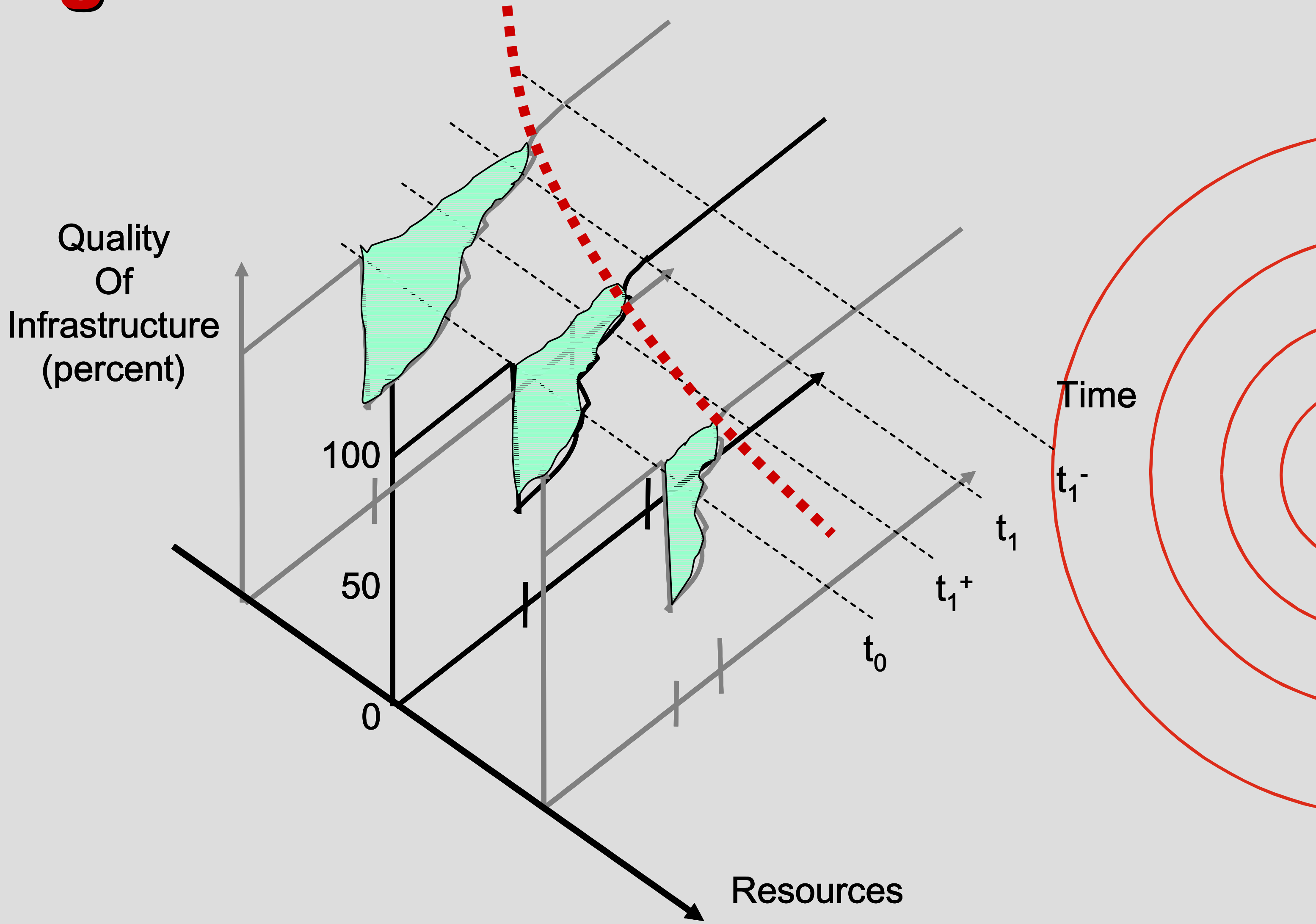
Measure of Seismic Resilience Conceptual Definition



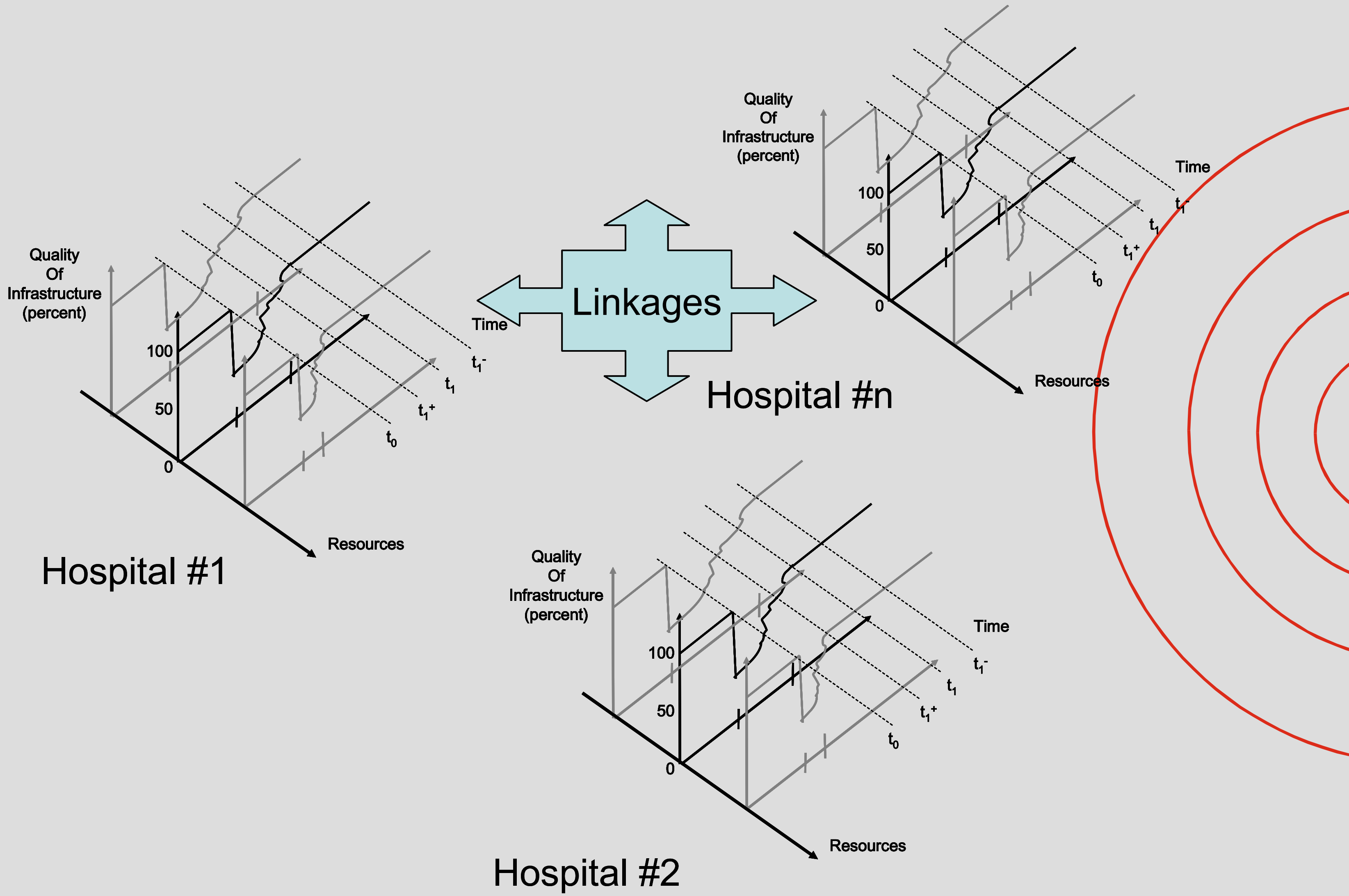
Resilience depends on "4Rs"

Robustness, Rapidity, Resourcefulness, Redundancy

Adding Resourcefulness Dimension



Adding Redundancy Dimension



1985
Mexico City

9,500 Lives
30,000 Injuries
$4B Loss

1989
Loma Prieta

62 Lives
3,750 Injuries
$8B Loss

1994
Northridge

57 Lives
1,500 Injuries
$20B Loss

1988
Armenia

25,000 Lives
20,000 Injuries
$16B Loss

1999
Turkey

17,000 Lives
46,000 Injuries
$7.8B Loss

1995
Kobe

5,000 Lives
26,000 Injuries
$120B Loss

1999
Taiwan

2,300 Lives
10,000 Injuries
$14B Loss

Research Strategies

- Observations:

- Seismic rehabilitation of existing, under-designed systems is most urgently needed.

- Well Executed Disaster Management Could Significantly Reduce the Losses

Research Strategies

- Nationwide upgrading of existing inventory is not fiscally prudent.

- However, protecting critical and essential facilities together with efficient response and recovery is a socio-economically viable national strategy for earthquake loss reduction.

Lifelines: Power Systems

Lifelines: Pipeline Systems

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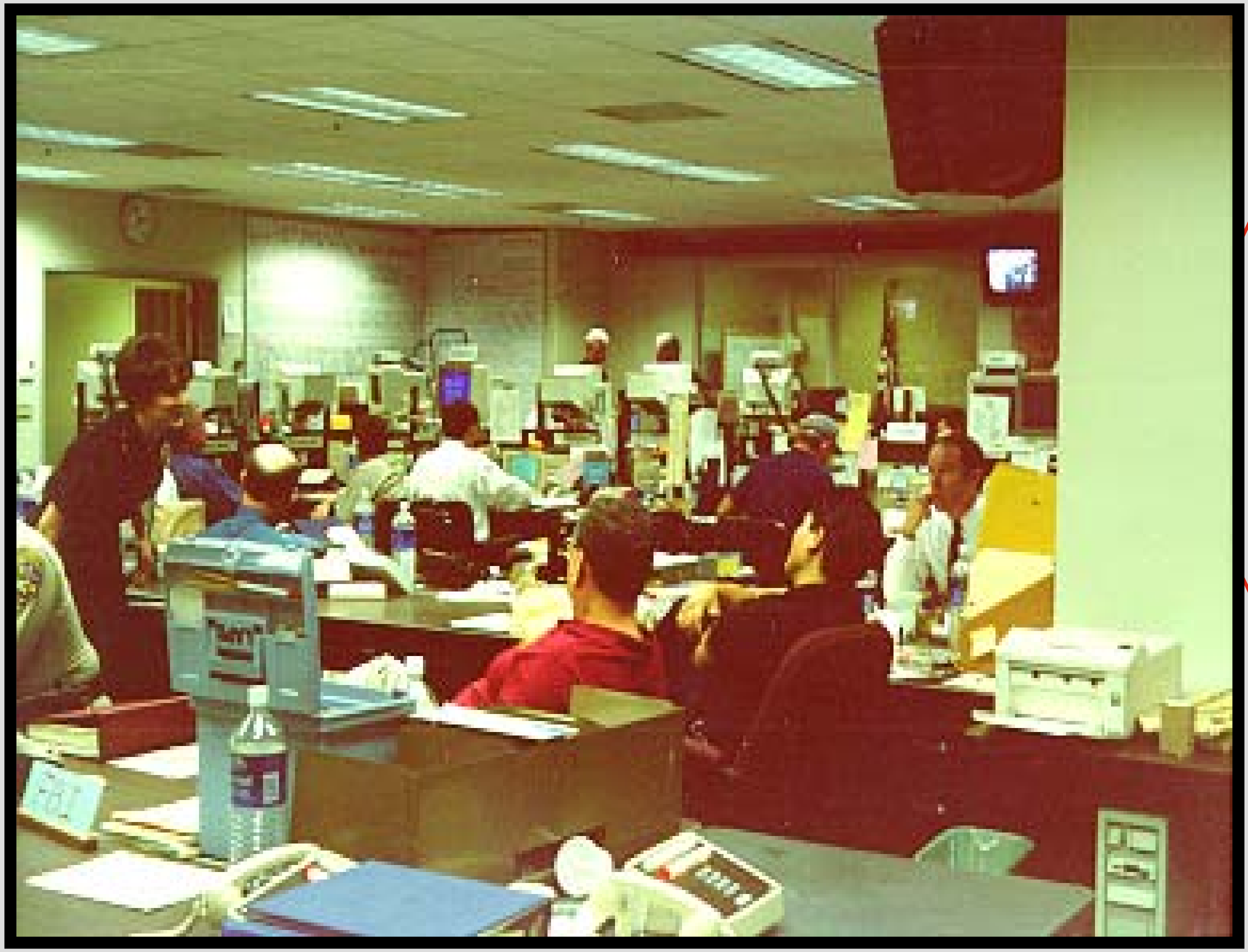
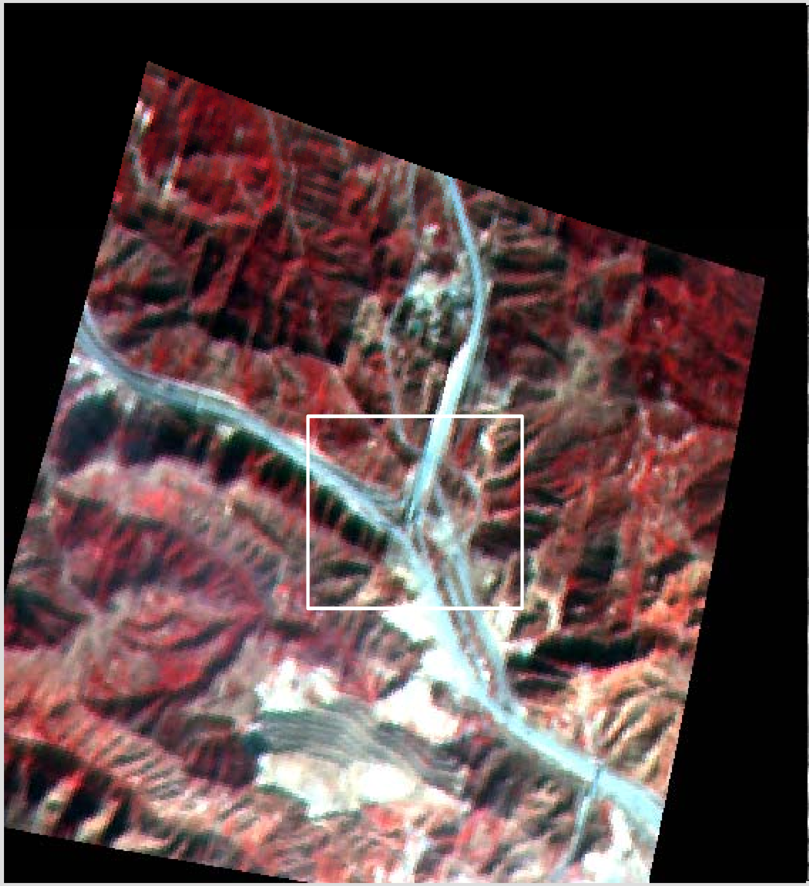
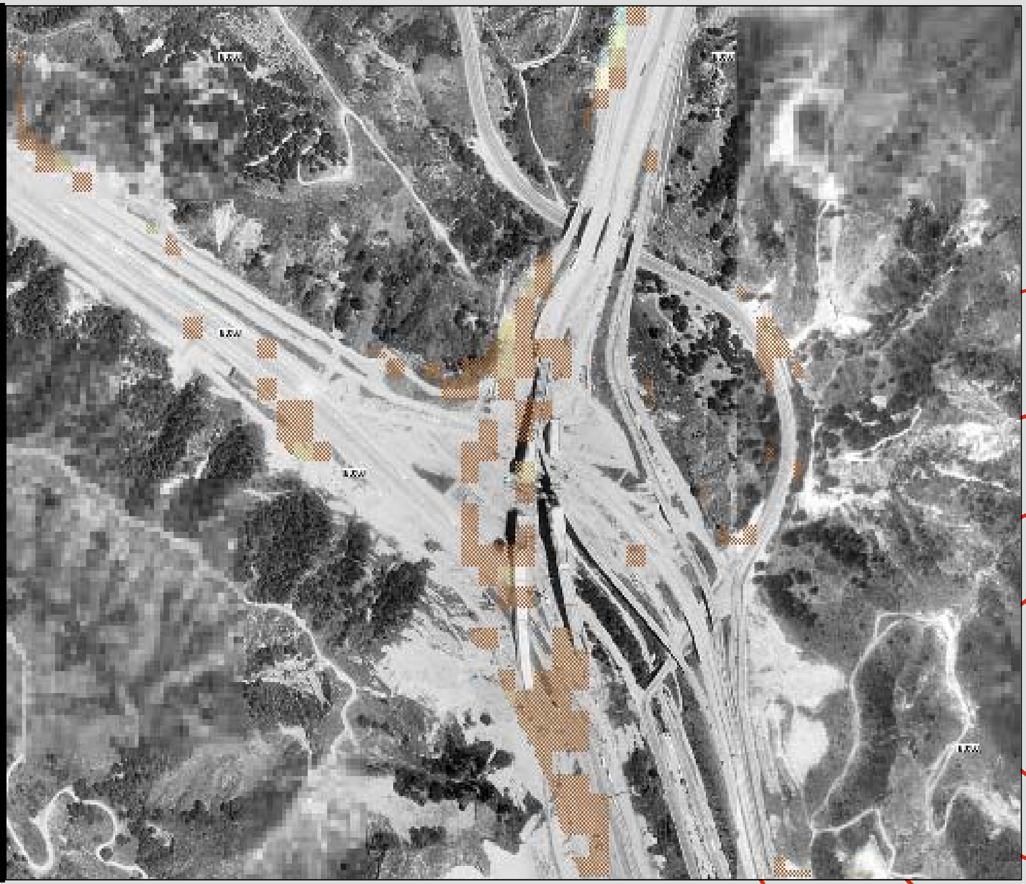
Highways

Earthquake Response and Recovery



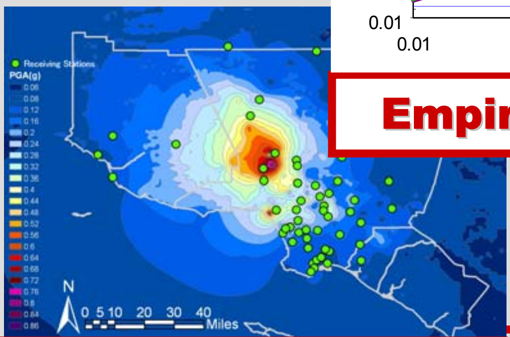


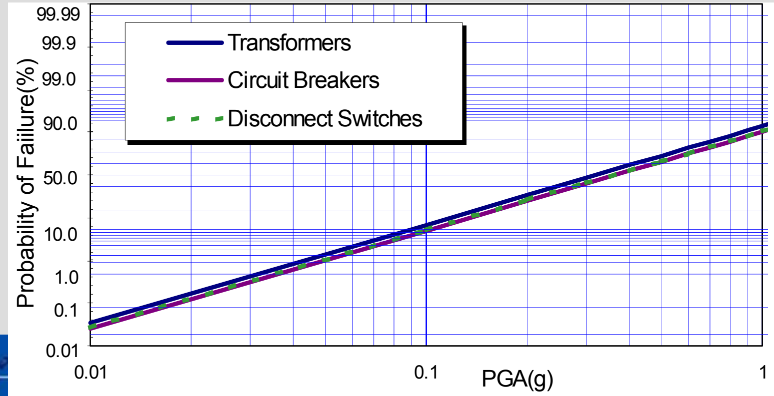
SPOT Image of the I-5/14 Interchange after the 1994 Northridge Earthquake (1/17/94)



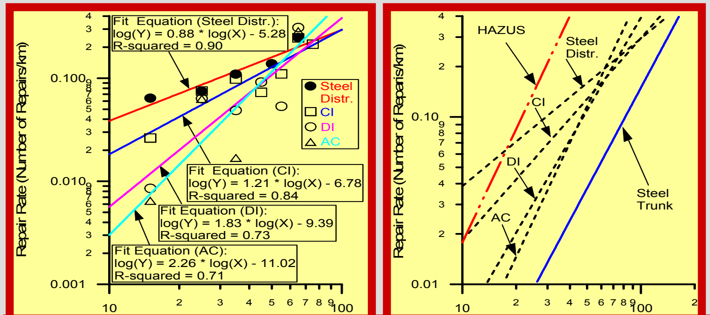
Change Detection Map Overlaid onto USGS Aerial Photo - I-5/14 Interchange

(Changes represented by brown shaded areas)





Empirical Fragility Functions



Loss Estimation Models

Advanced GIS

Experiments/Analyses

DECISION SUPPORT SYSTEMS

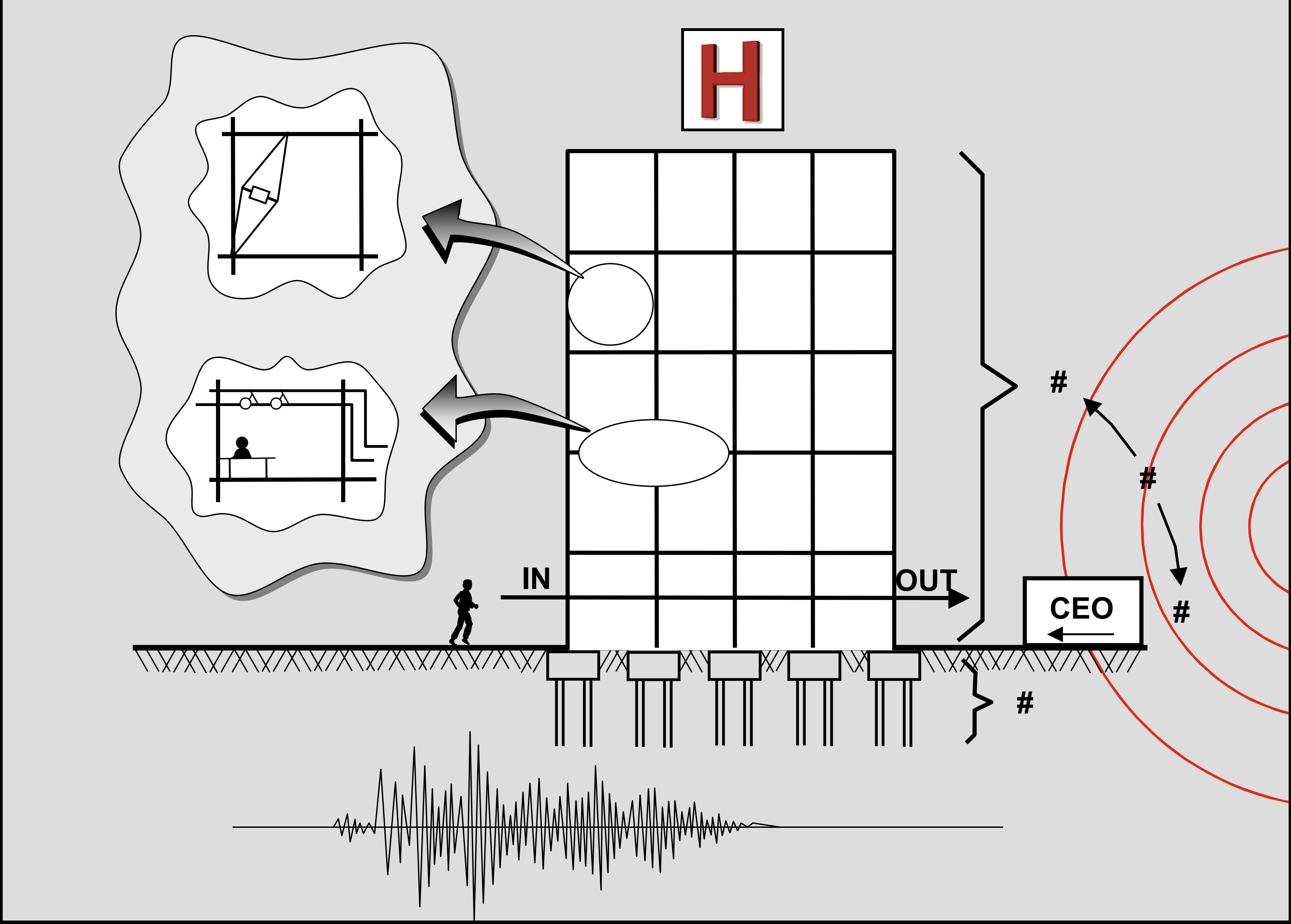
for

Preparedness, Emergency Response, and Restoration

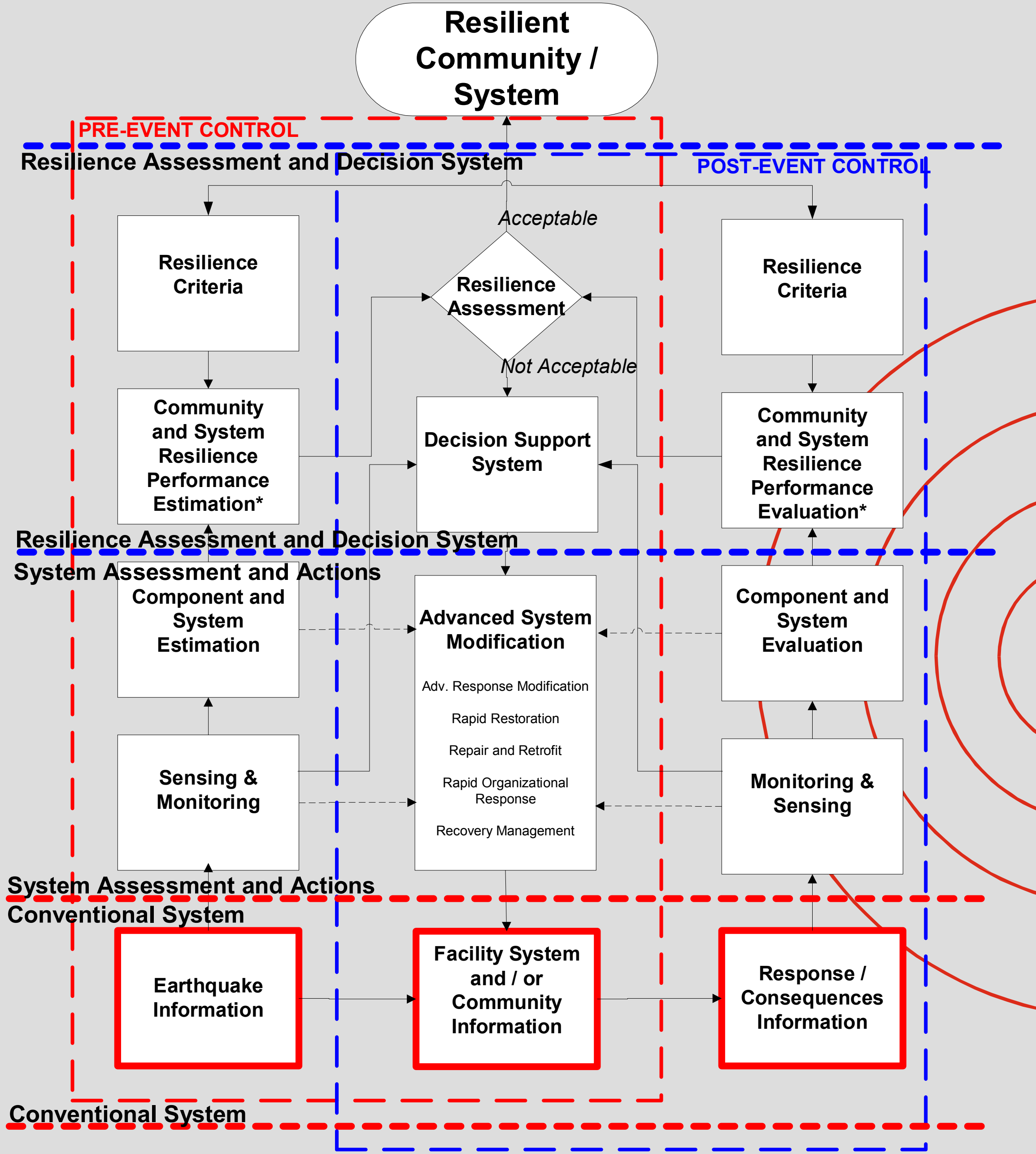
To Minimize

- **Human Suffering**
- **Physical Damage**
- **Restoration Time**
- **Economic Loss**
- **Interruption of Societal Activities**

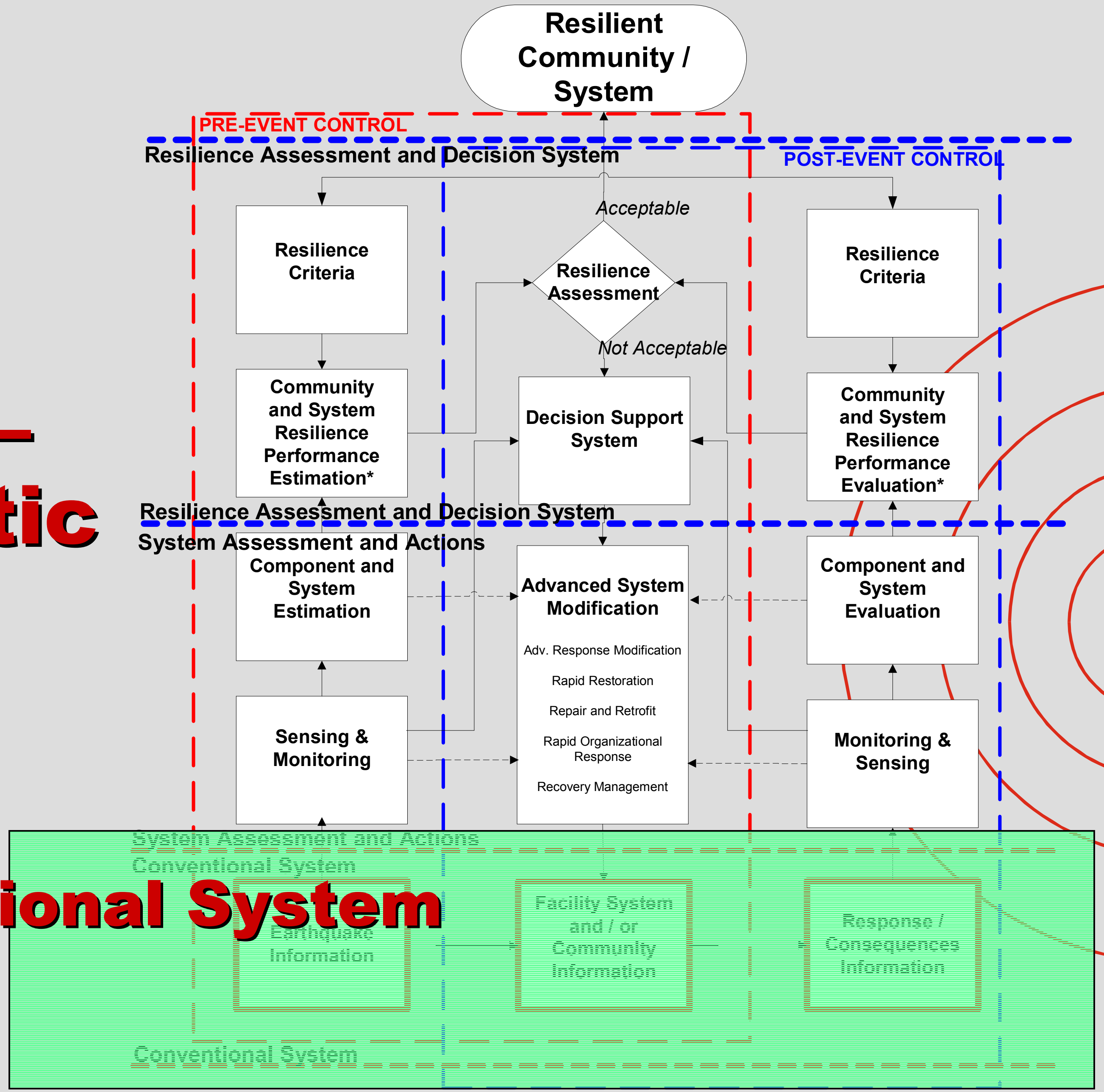
Seismic Retrofit of Hospitals


H
IN
OUT
CEO
#
#
#
#

System Diagram – (Schematic Level of Details)

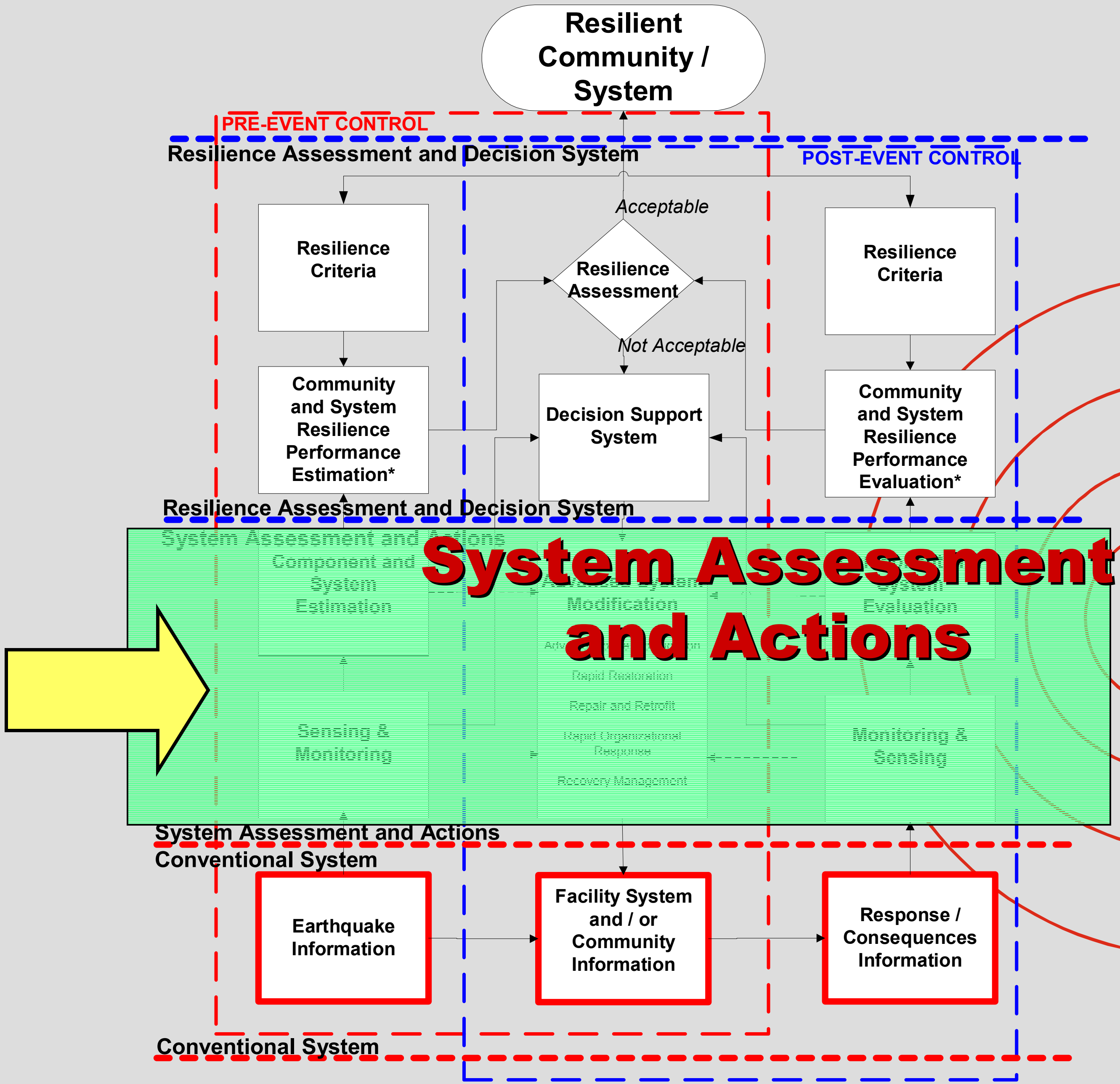


System Diagram – (Schematic Level of Details)



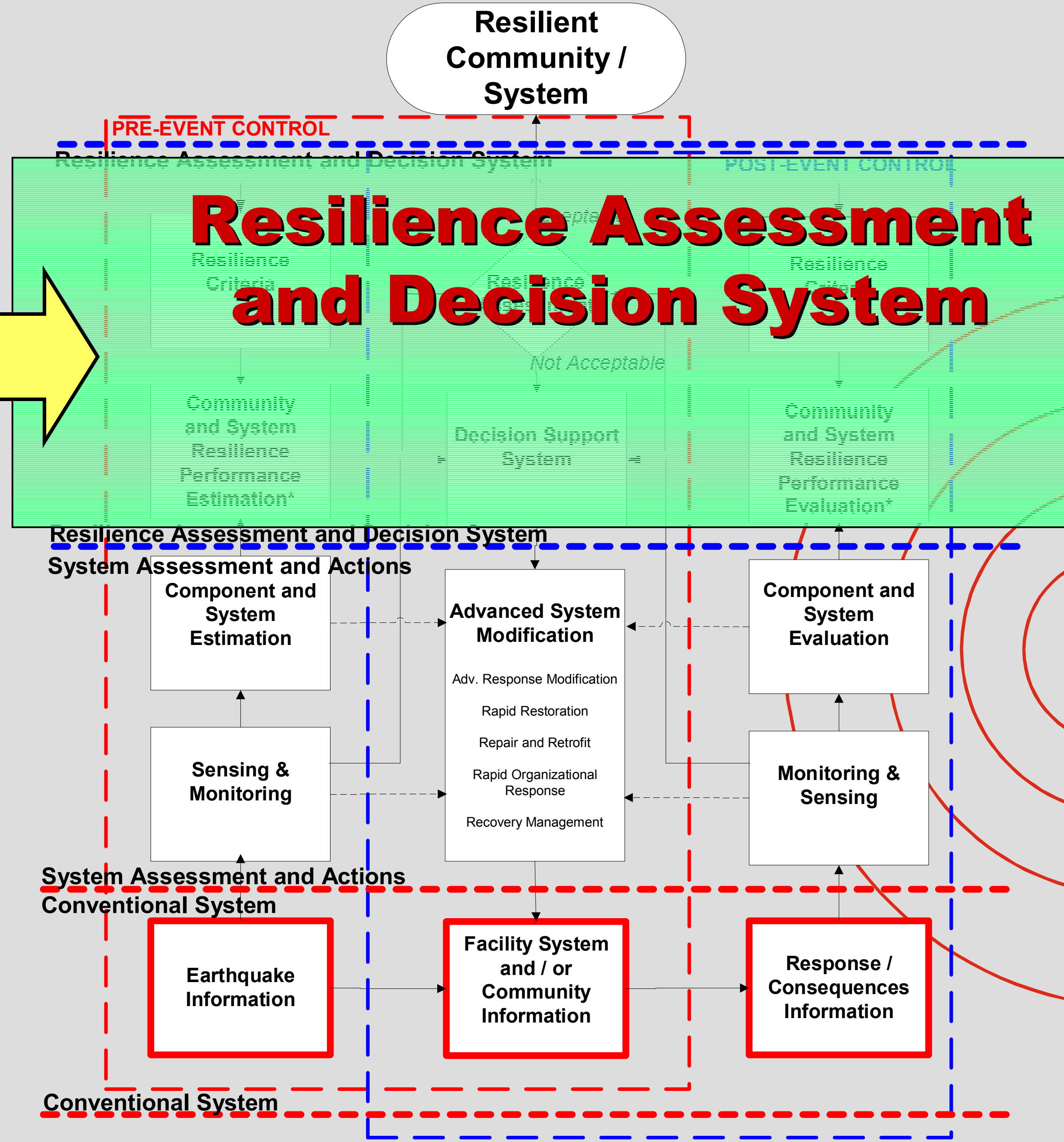
Conventional System

Current State-of-the-Art



Knowledge Needed for New Decision Tools

Resilience Assessment and Decision System



Resiliency Targets

- Example: There is a 95% chance that 80% of hospitals can operate at 90% of their capacity within 5 days
- Communities cannot articulate such resiliency objectives
  - Tools to support such statements don't exist
  - Communities do not operate at this level yet
- MCEER to develop knowledge needed to create the tools that could provide such formulation (not the numbers themselves)

Deliverables

- A methodical framework that can be used to construct decision support system for critical facilities
  - Lifelines and Hospitals as a stand-alones first
  - Integrate into framework for all critical systems
  - Demonstrate how could work using demonstration projects and specific advanced technologies

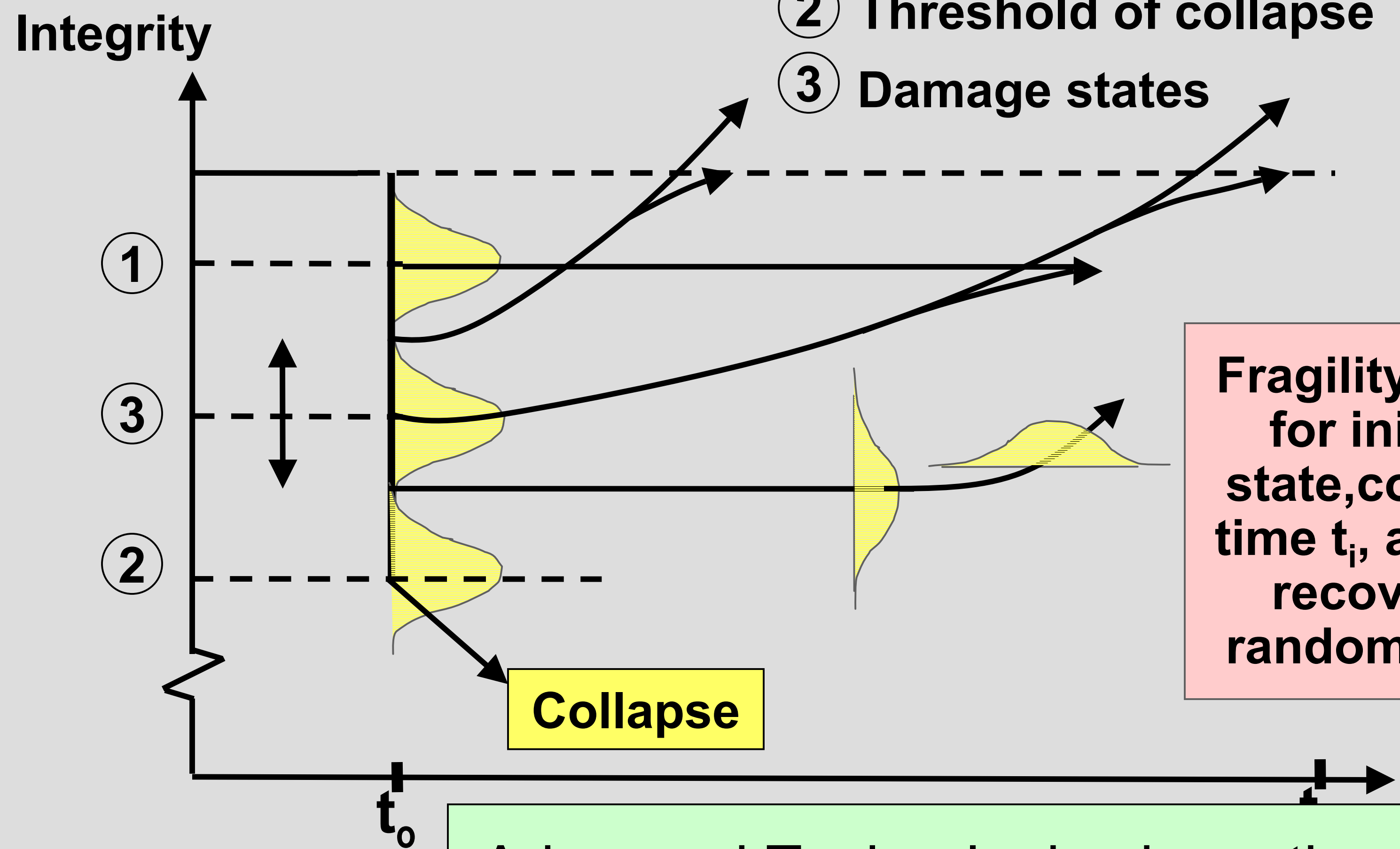
Decision Support Tools

Structural System Considerations

1 Serviceability – “clean aesthetic”

2 Threshold of collapse

3 Damage states



Fragility functions for initial limit state,condition at time t_i, and time to recovery also random variables

Advanced Technologies have the potential to reduce some of these uncertainties

Example of Integrated Research Project to Seismic Resilience of Acute Care Facilities

Importance of nonstructural components and contents

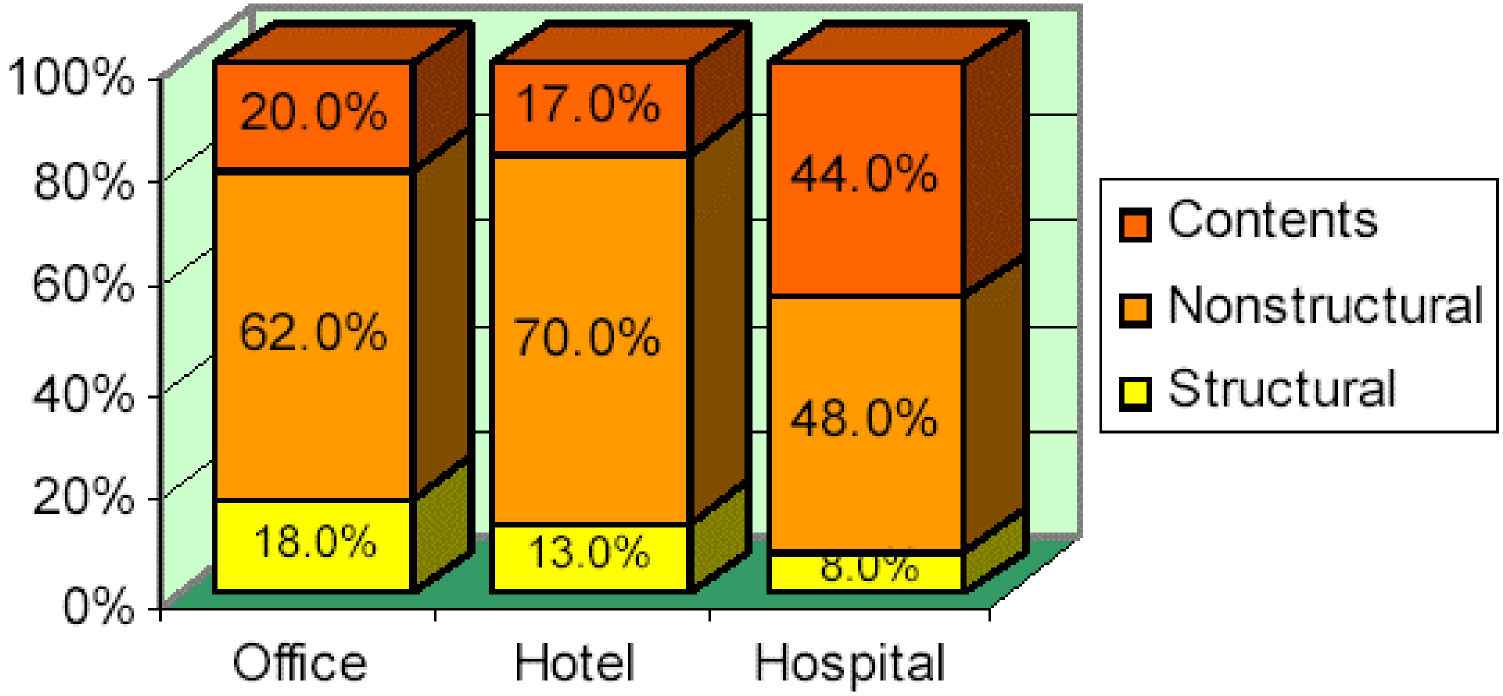
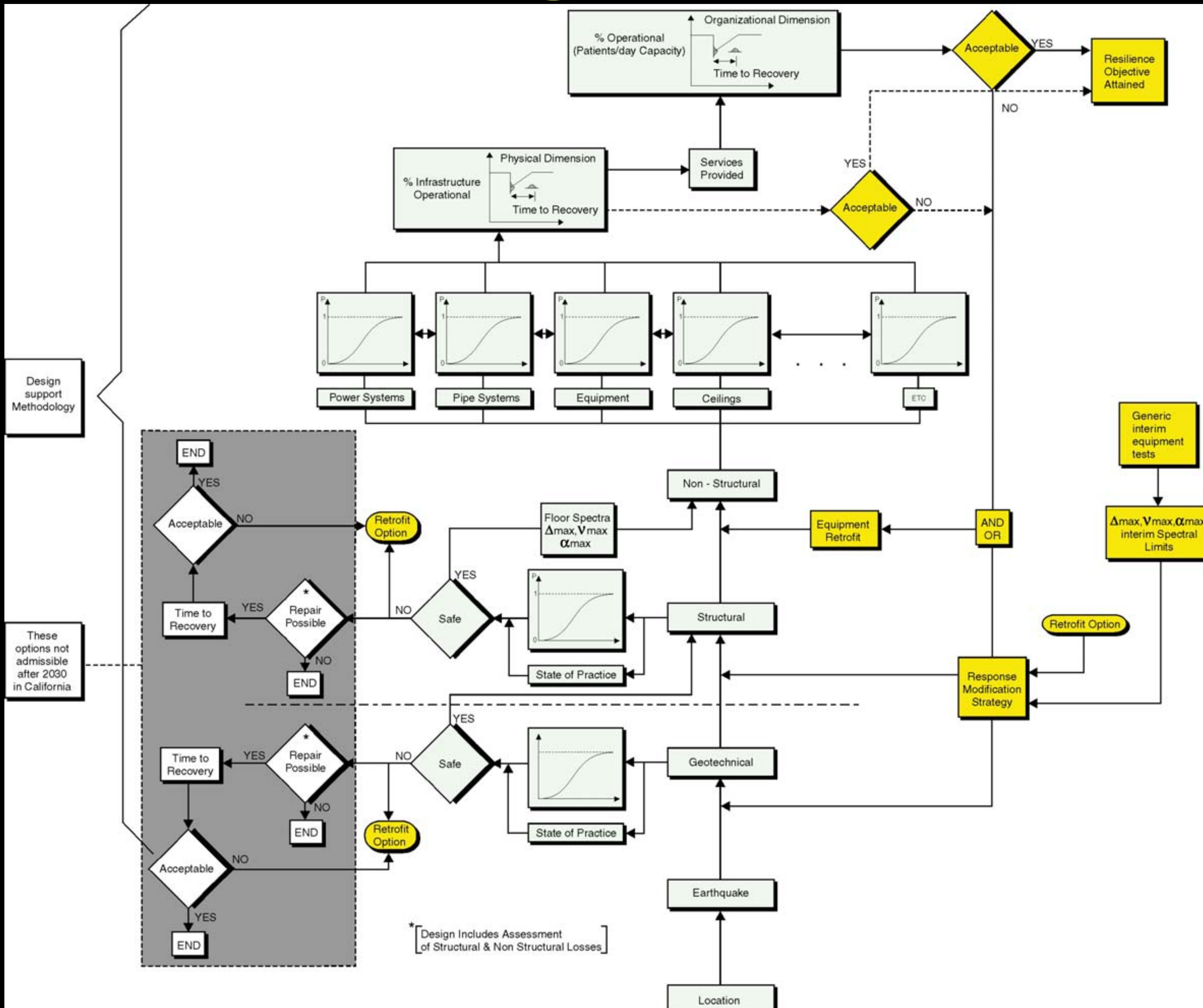


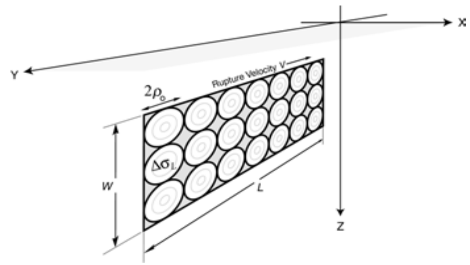
Figure 1. Typical investments in building construction (after E. Miranda)

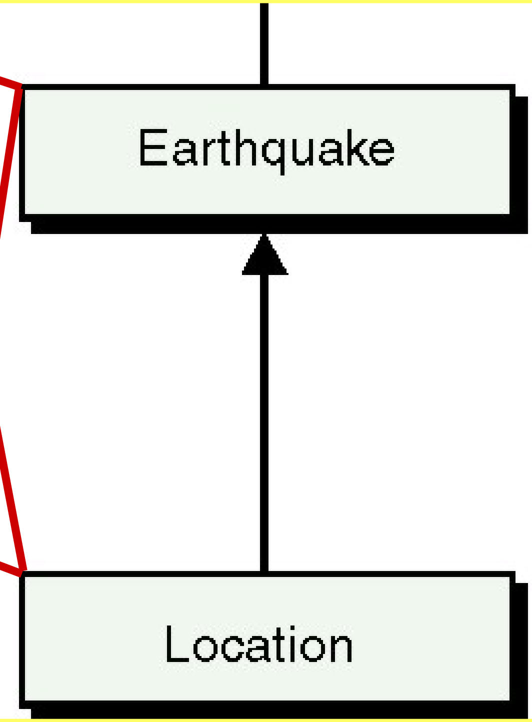
Research Integration Road Map

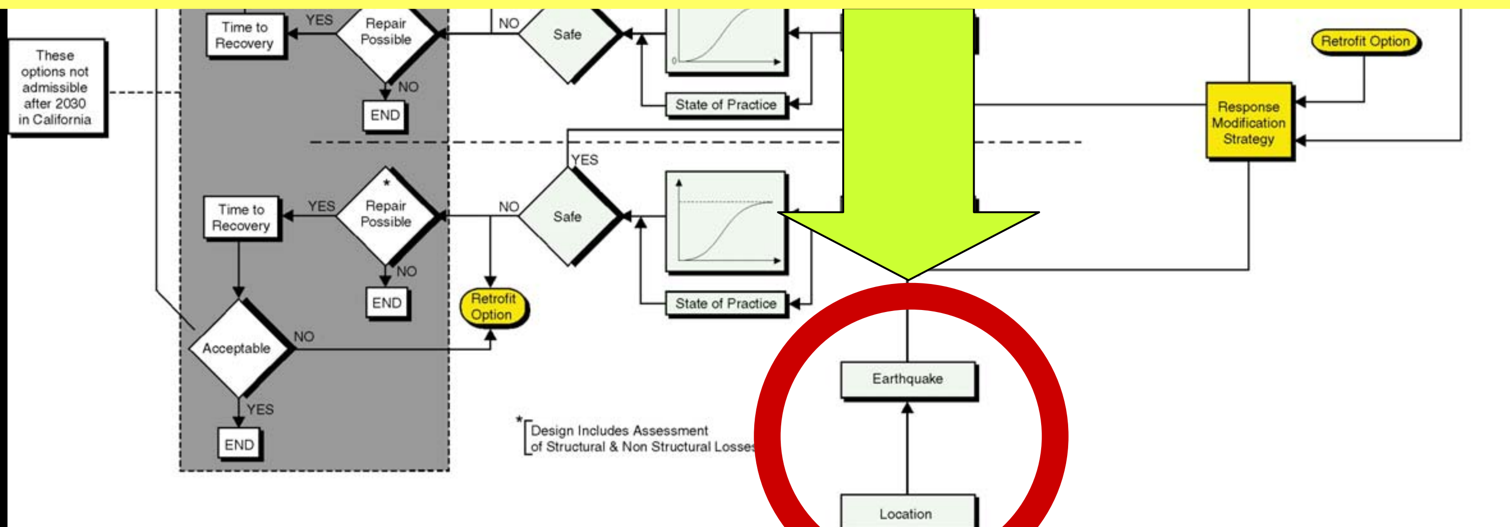


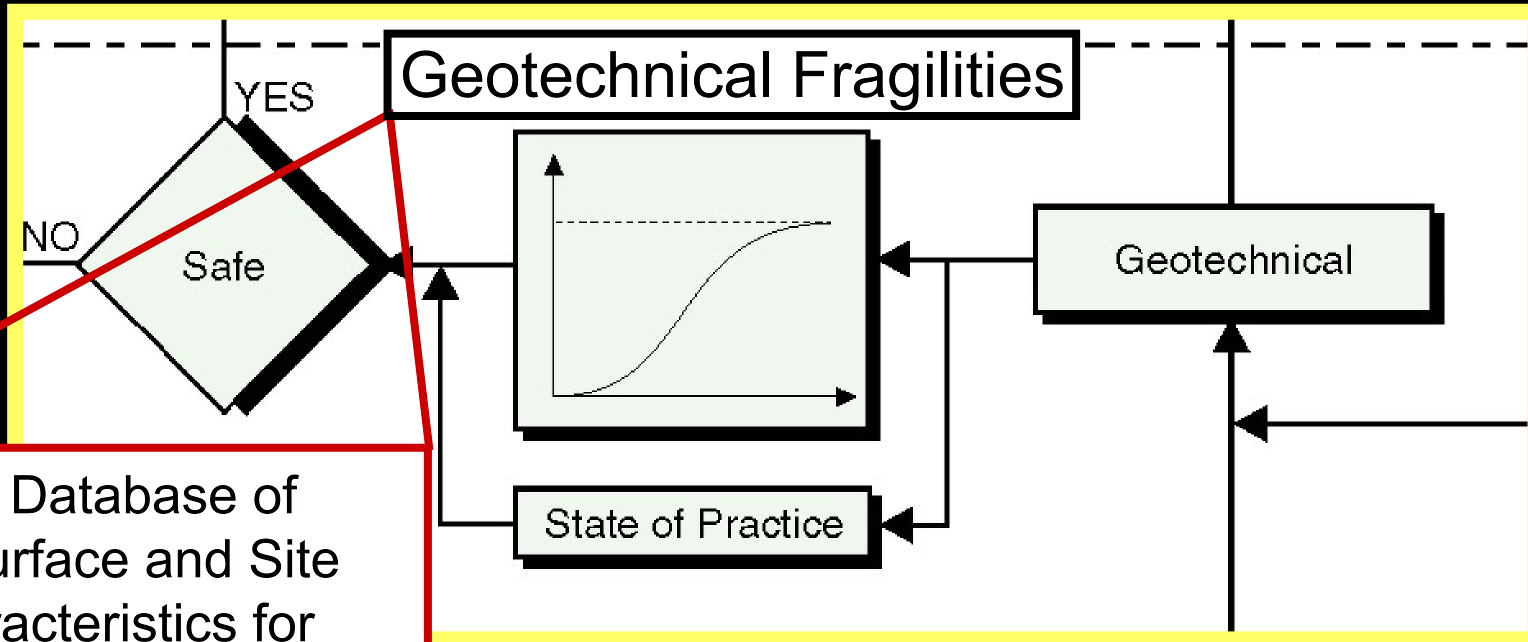
MCEER Specific Barrier Ground Motion Model (A. Papageorgiou, UB)

- Stochastic Modeling Approach
- Magnitude-Distance Scenarios
- East and West Coast Ground Motions
- Near-Field Effects

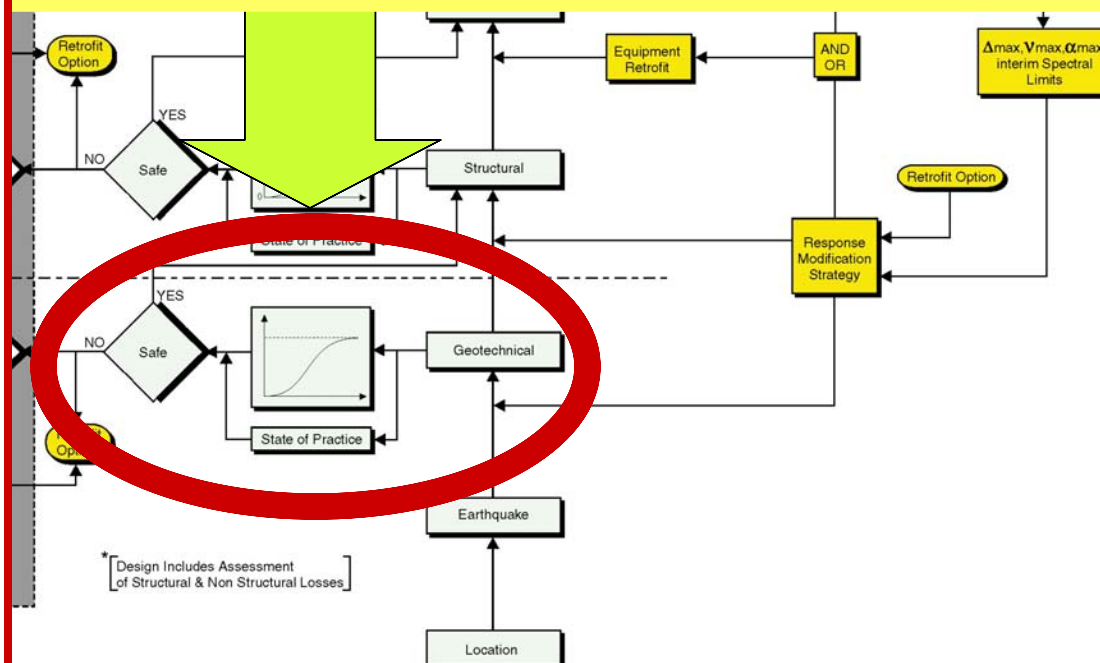


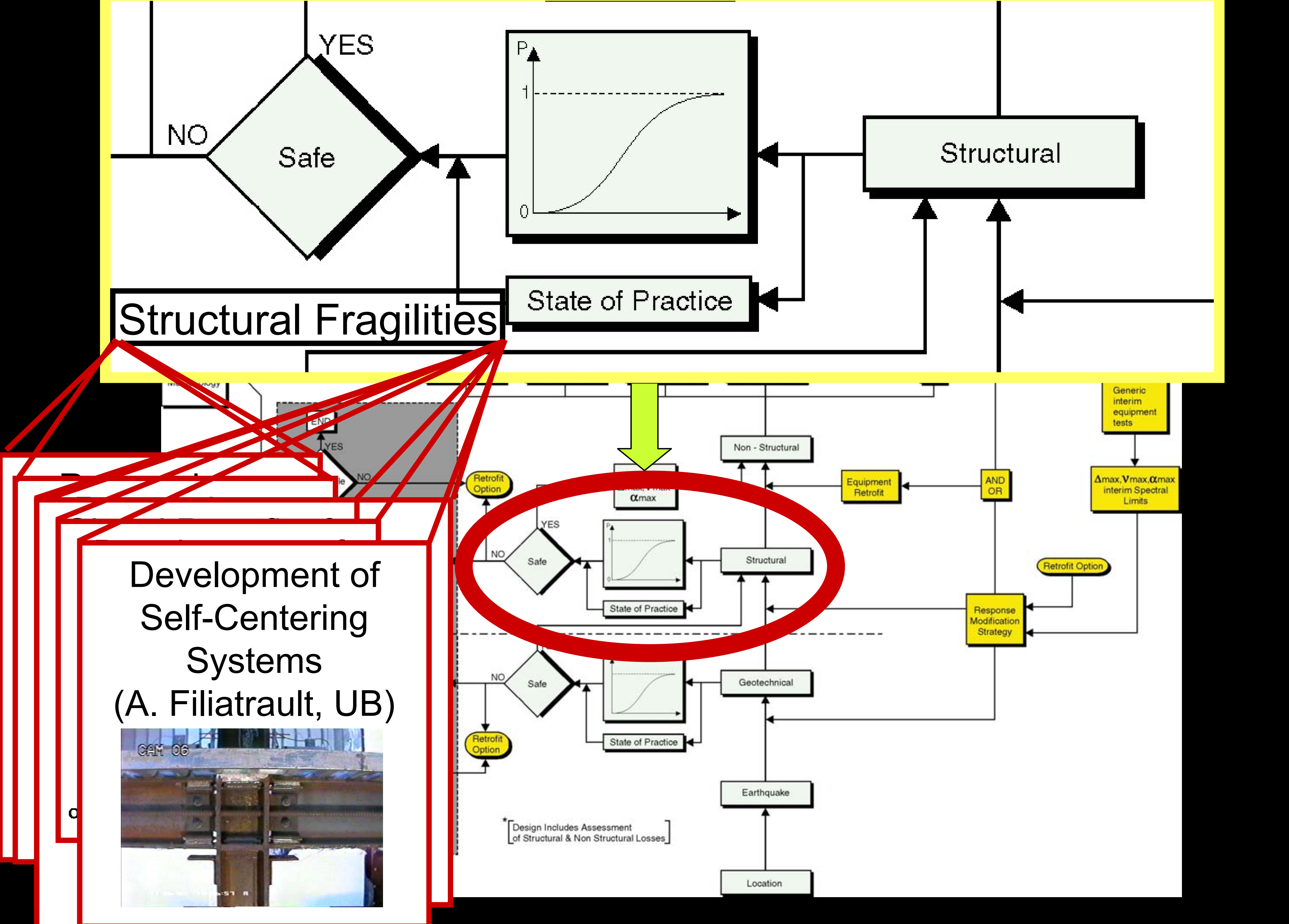






GIS Database of Subsurface and Site Characteristics for California Hospital Facilities
(T. O'Rourke, Cornell)





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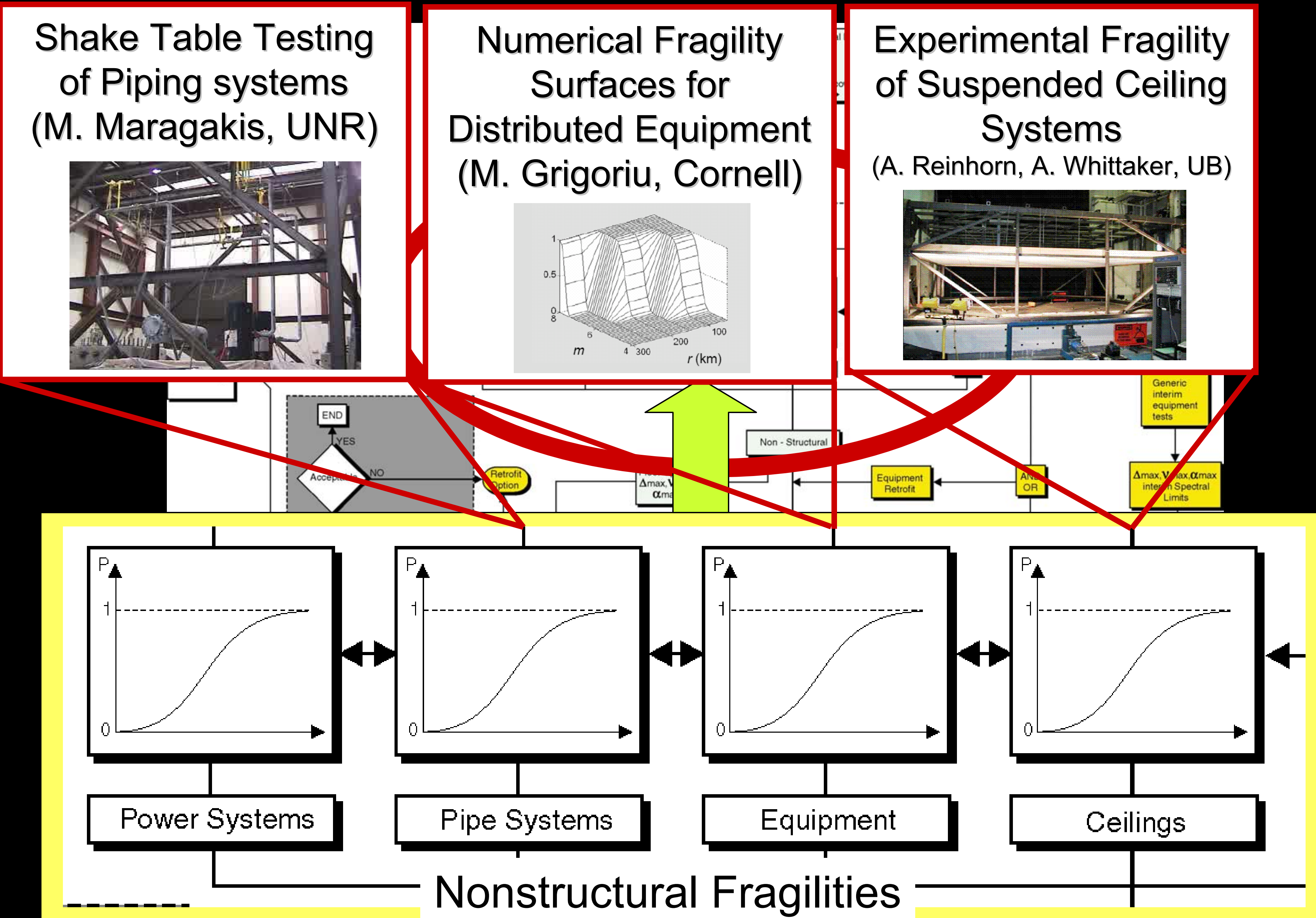
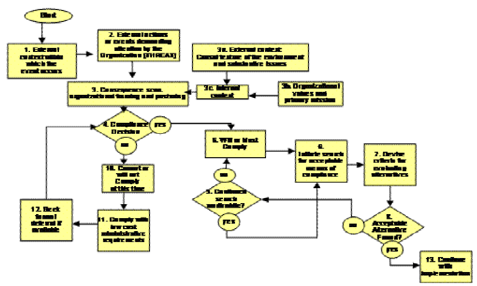
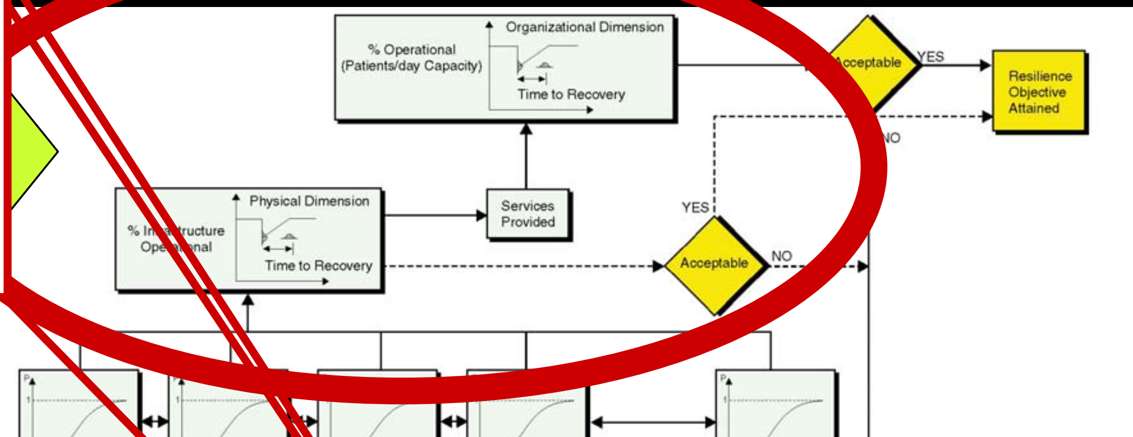

Shake Table Testing of Piping systems (M. Maragakis, UNR)
Numerical Fragility Surfaces for Distributed Equipment (M. Grigoriu, Cornell)
m
r (km)
Experimental Fragility of Suspended Ceiling Systems (A. Reinhorn, A. Whittaker, UB)
END
YES
NO
Retrofit Option
Non - Structural
Equipment Retrofit
Generic interim equipment tests
P
1
0
Power Systems
Pipe Systems
Equipment
Ceilings
Nonstructural Fragilities

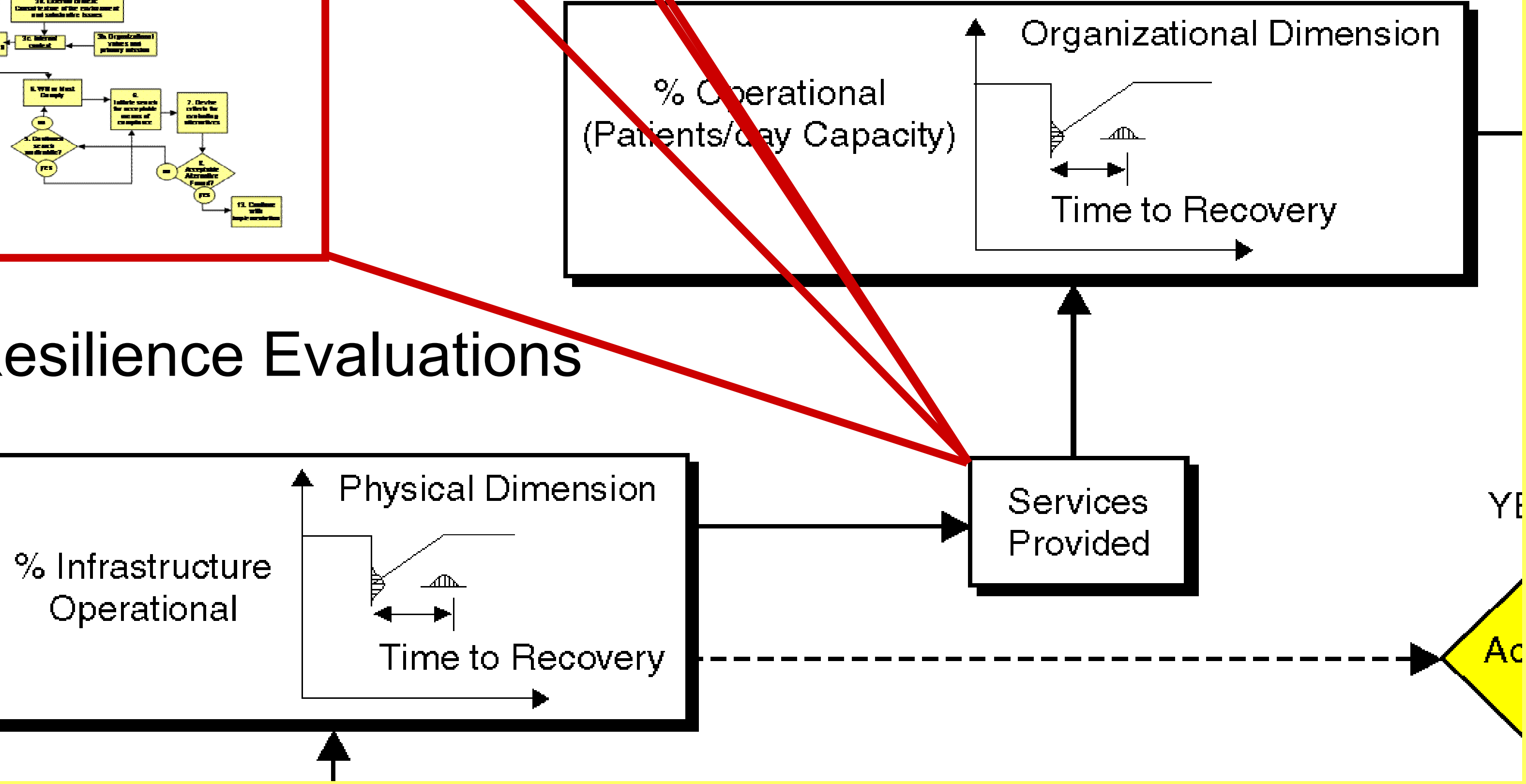
Rehabilitation Decision Analysis Model

D. Von Winterfeldt, USC
W. Petak, USC
D. Alesch, UW



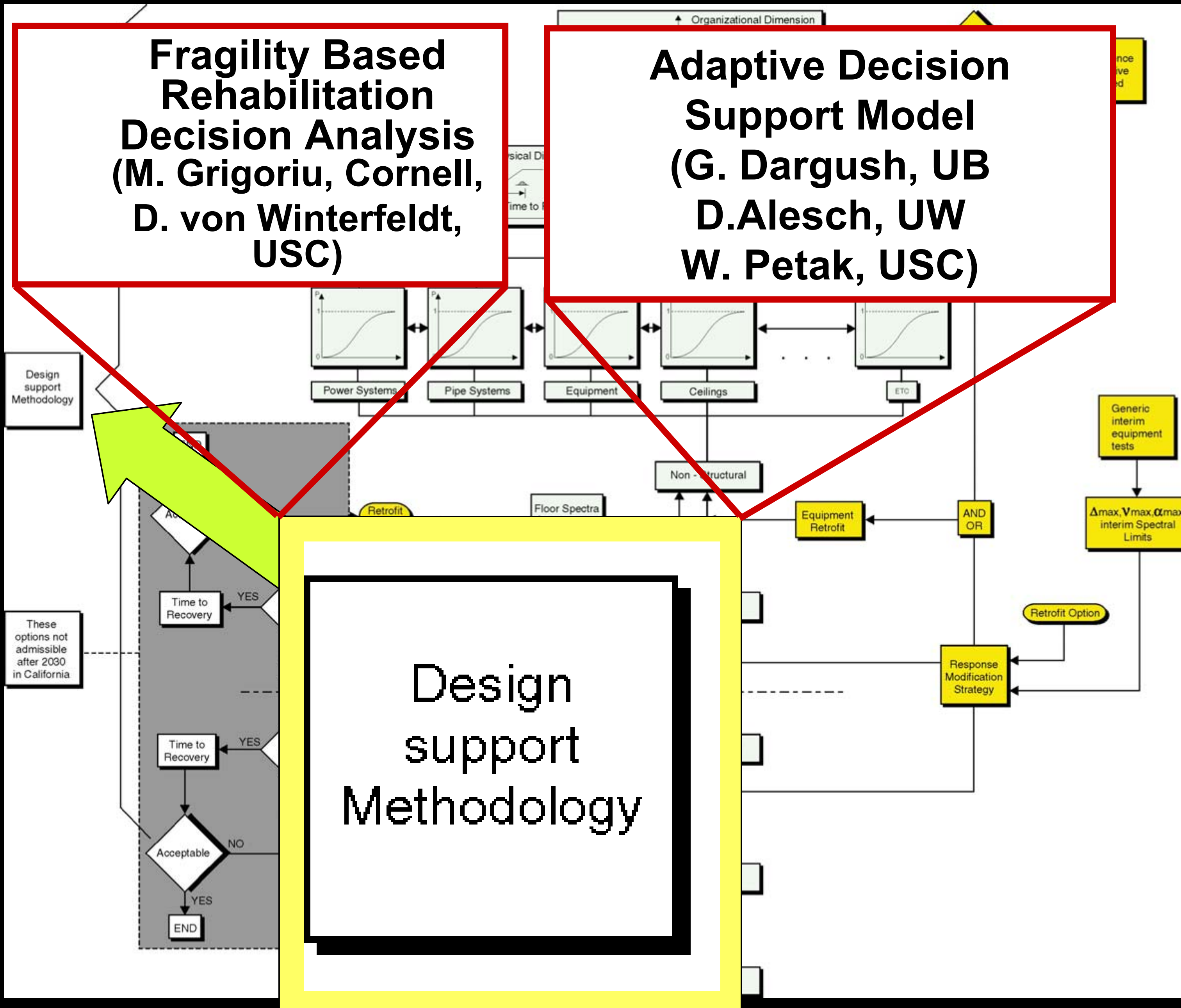


Resilience Evaluations



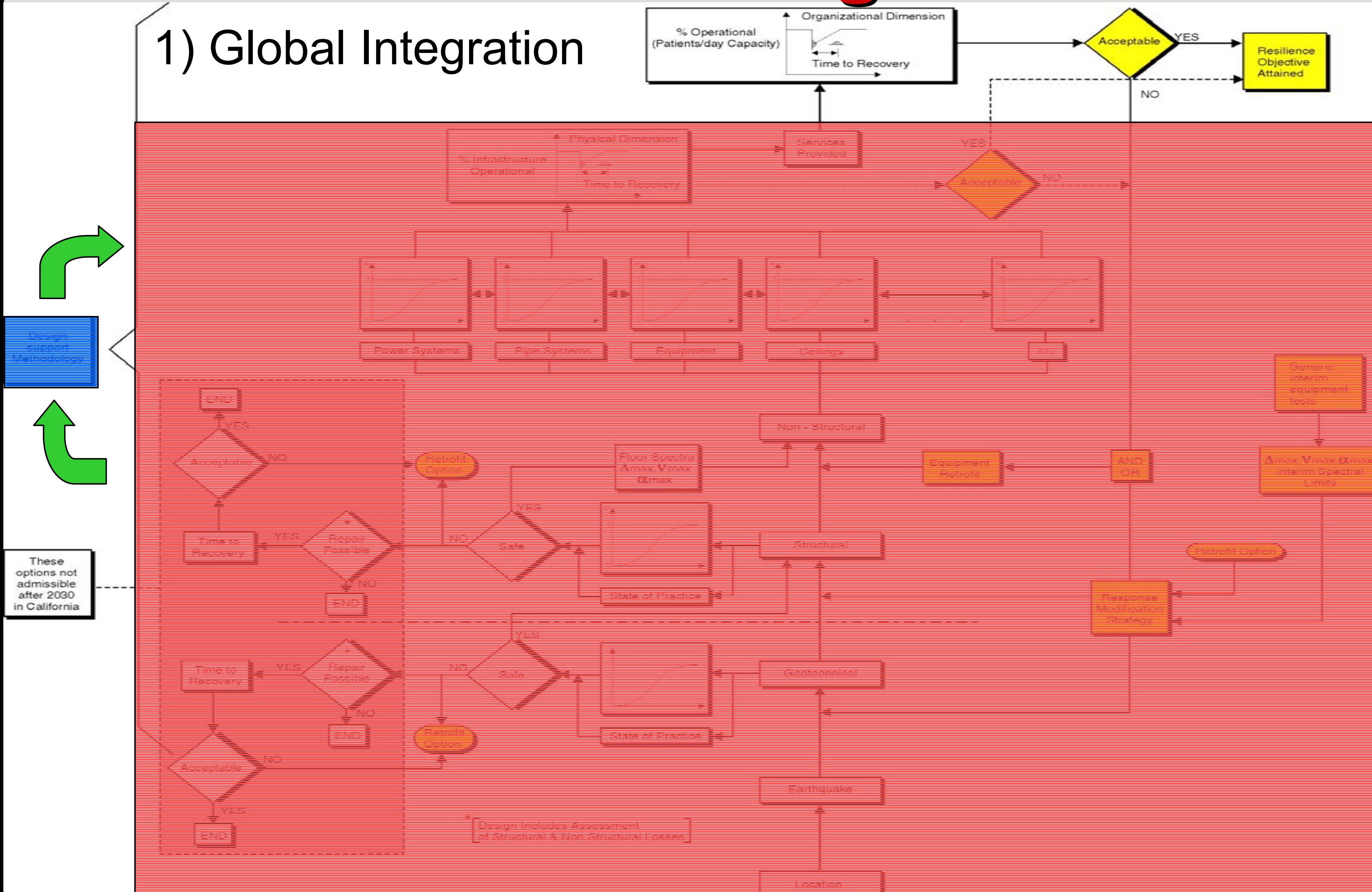
Fragility Based Rehabilitation Decision Analysis (M. Grigoriu, Cornell, D. von Winterfeldt, USC)

Adaptive Decision Support Model (G. Dargush, UB D.Alesch, UW W. Petak, USC)



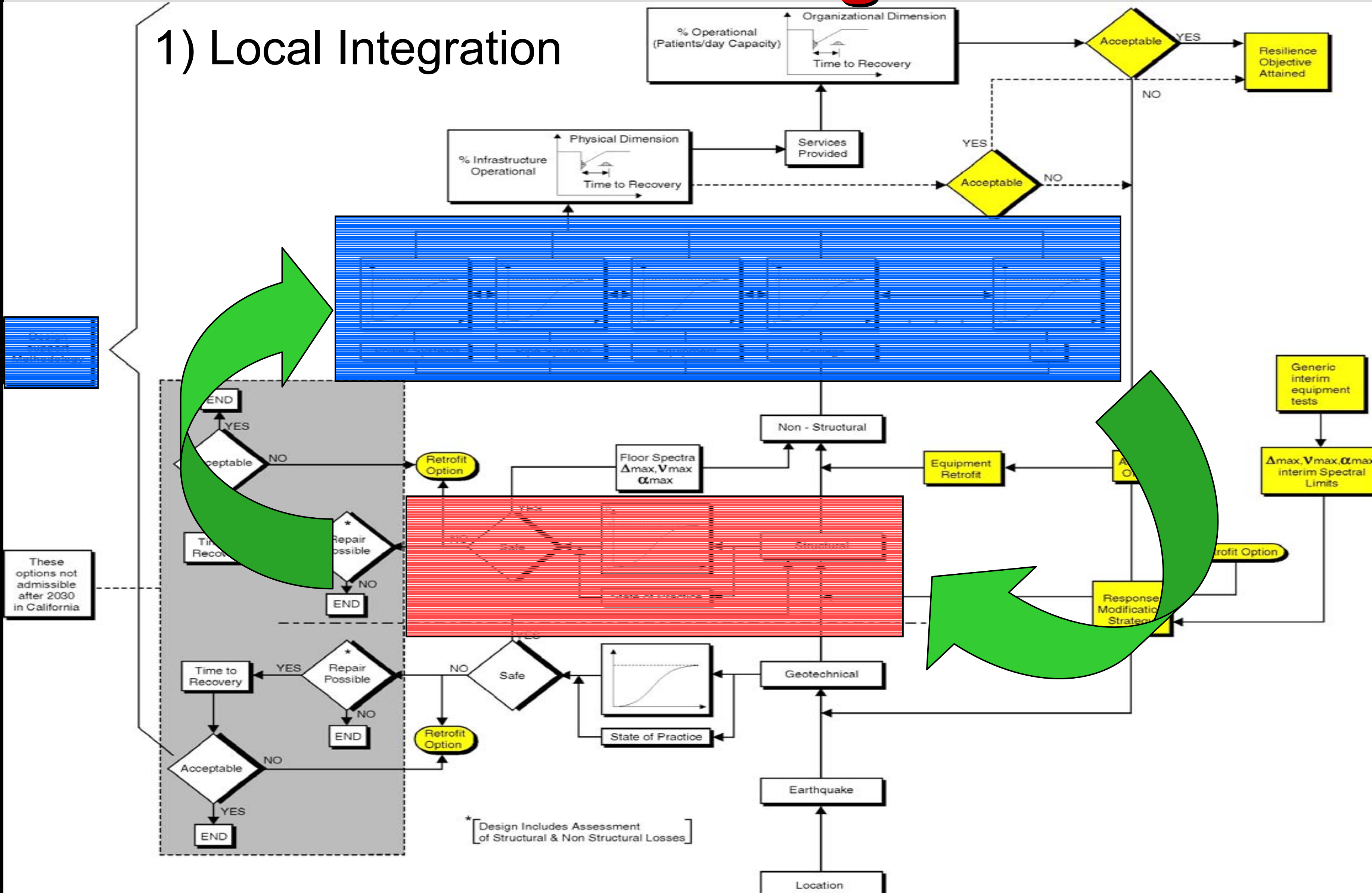
Research Integration

1) Global Integration



Research Integration

1) Local Integration



Vision

- The same approach can be adopted for the development of innovative and integrated solutions to enhance the resilience of infrastructure against extreme events (natural disasters, technological disasters, and acts of terrorism against our society), and is known worldwide for its ability to deliver superior products to its sponsors.

Steps to Enhance Resilience Spectrum of Needs

Pre-Event

- Risk and vulnerability assessment, including the development of risk and vulnerability assessment methodologies, to prioritize the allocation of limited resources;
- System analysis and design, to investigate the ultimate behavior of systems and foster capacity-design principles for fail-safe outcomes;
- Improved materials, devices, or systems, to enhance the ability of infrastructure components and systems to withstand hazards;
- Retrofitting prior to an event.

Steps to Enhance Resilience
Spectrum of Needs

During Event

- Sensing technologies, for structural health monitoring, with possible applications for detection, surveillance and prevention

Steps to Enhance Resilience Spectrum of Needs

Post-Event

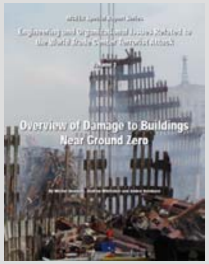
- Post-event assessment, including the use of remote sensing (airborne or satellite-based) to rapidly locate areas impacted by a disaster, the type of damage suffered, and rapid assessment of losses;
- Post-event on-site screening methodologies, to assess safety of structures after an event using simple tools based on expert knowledge;
- Advanced technologies for repair and restoration following an event;
- Evaluation test-beds, to test and validate new technologies proposed to achieve above objectives.

Steps to Enhance Resilience

- In that perspective, much research results from the field of earthquake engineering could be modified to contribute to this objective. Earthquake engineering research has provided practical solutions to address a number of needs that are similar (although not identical) for a number of hazards.

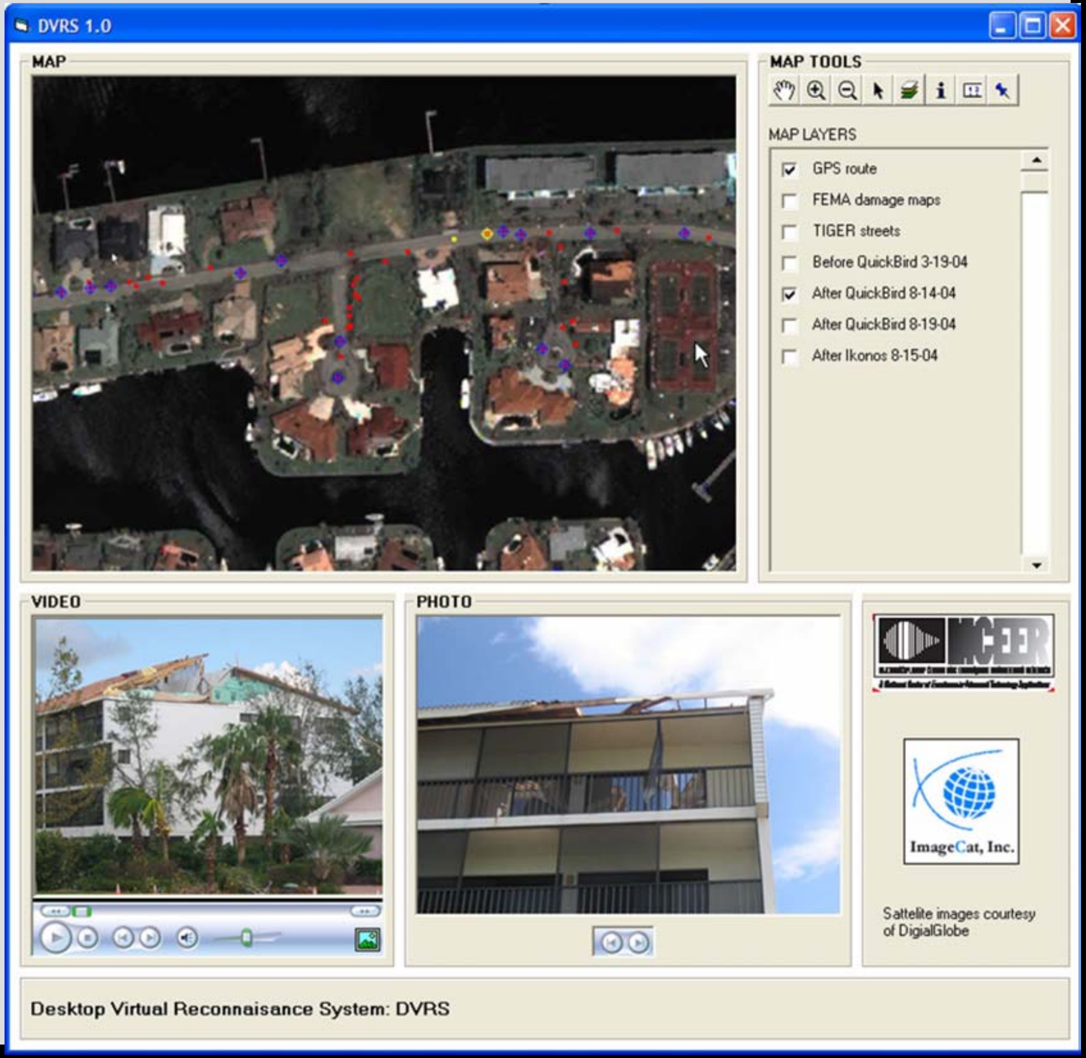
Major Accomplishments

- World Trade Center Research: Comparing and Contrasting Natural and Human-Induced Disasters
  - Data analysis will advance the conceptualization and quantification of a community's resilience to disasters
  - Engineering and social science knowledge to address the impact of major urban earthquakes



Major Accomplishment

- Hurricane Charley Reconnaissance Report
  - Satellite-Referenced Building Damage Information in the Aftermath of Hurricane Charley



Conclusion

- Definition of resilience allows to frame objectives in a global integrated model that focus on key issues
- On-going research important to develop the models and technologies to deliver such a framework for acute care facilities
- Select advanced technologies and demonstration project will be used to provide quantitative data and benchmark for validation

Thank you!

Questions?