PEER Lifelines Research Program

*"Program of Applied Earthquake Engineering Research
on Lifeline Systems"*

Michael Riemer

Program Manager

2003 PEER Annual Meeting

Objectives and Structure of Lifelines Program

- Increase safety and reliability of utility and transportation systems in earthquakes, through better characterization of the hazards ***and*** improved performance of system components.

- Identify lifeline user needs and prioritize research requirements.

- Focus on validation and implementation of results.

- Joint management of research by representatives of 4 primary research partners.

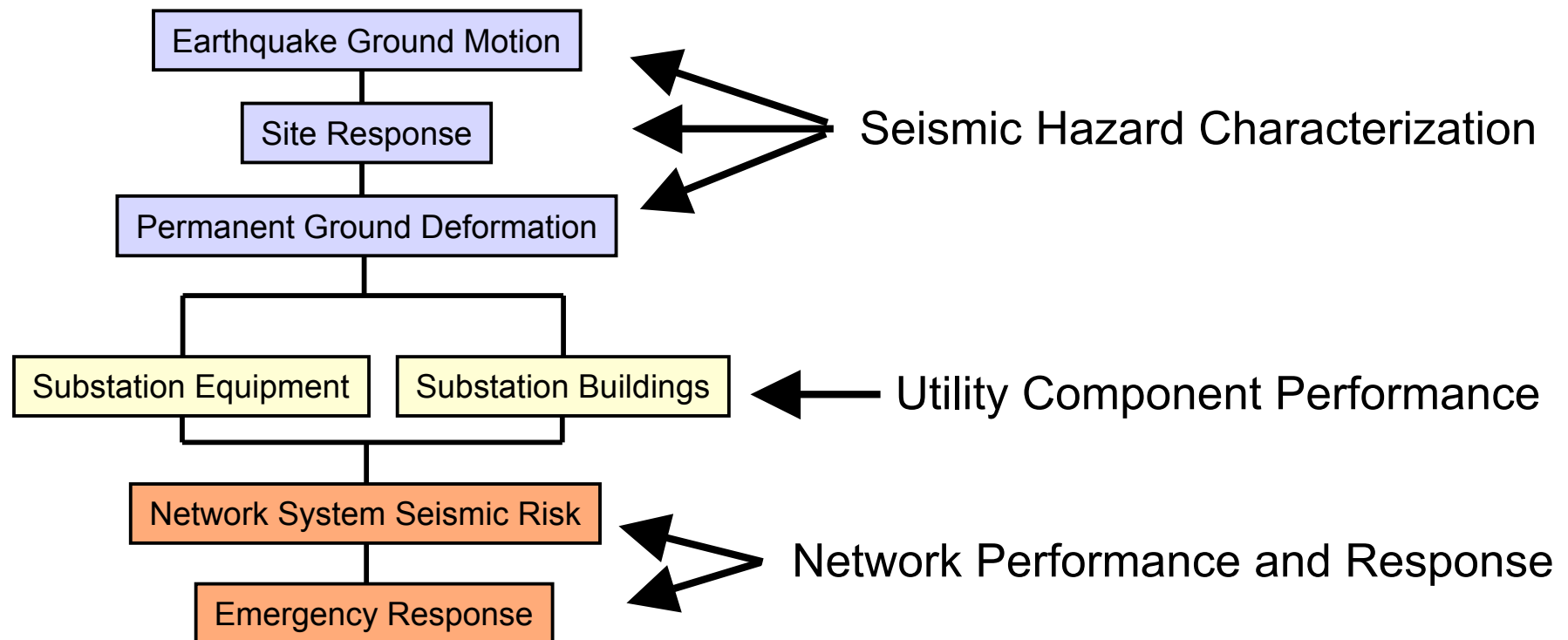**PEER**

Overview of Lifelines Program Sponsorship

Sponsor and Funding ($1000)						
Phase	Dates	PG&E	CEC	Caltrans	Other	Total
I	12/97 - 6/99	2,400				2,400
II	10/98 - 5/00		1,000		75	1,075
III	5/00 - 6/04	1,000	4,500	4,500 *	~2,000 ** ‑	12,000
						15,475

* Maximum match ($0.60/$1.00)

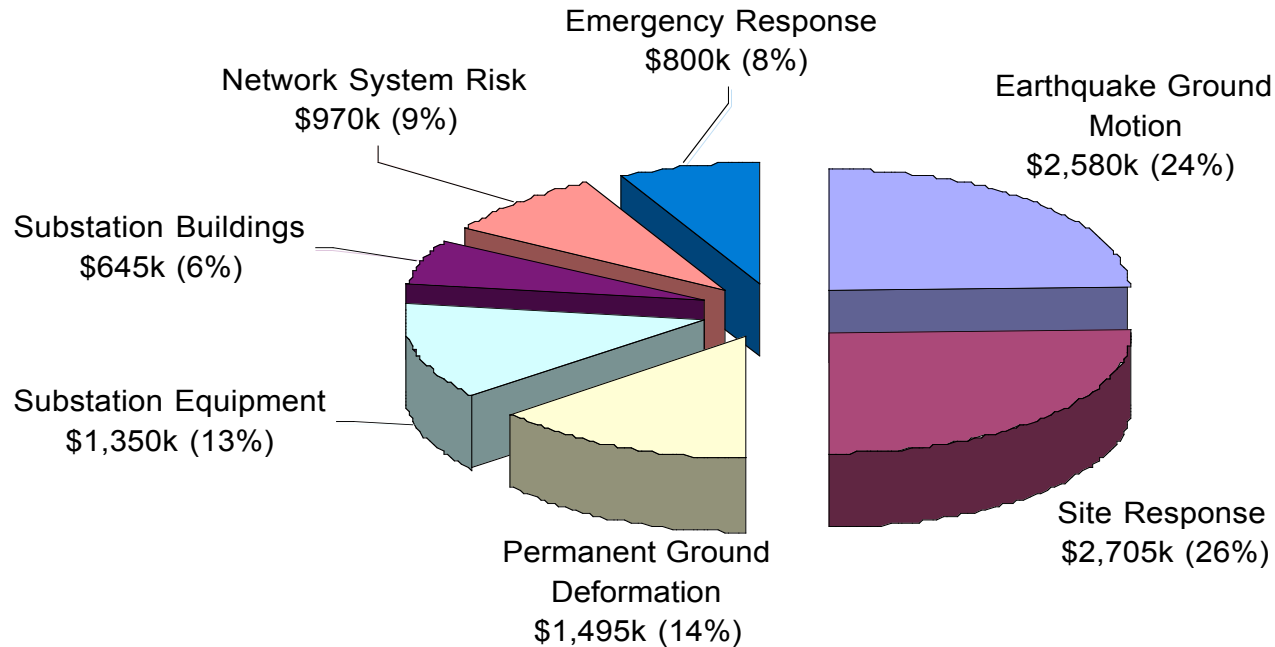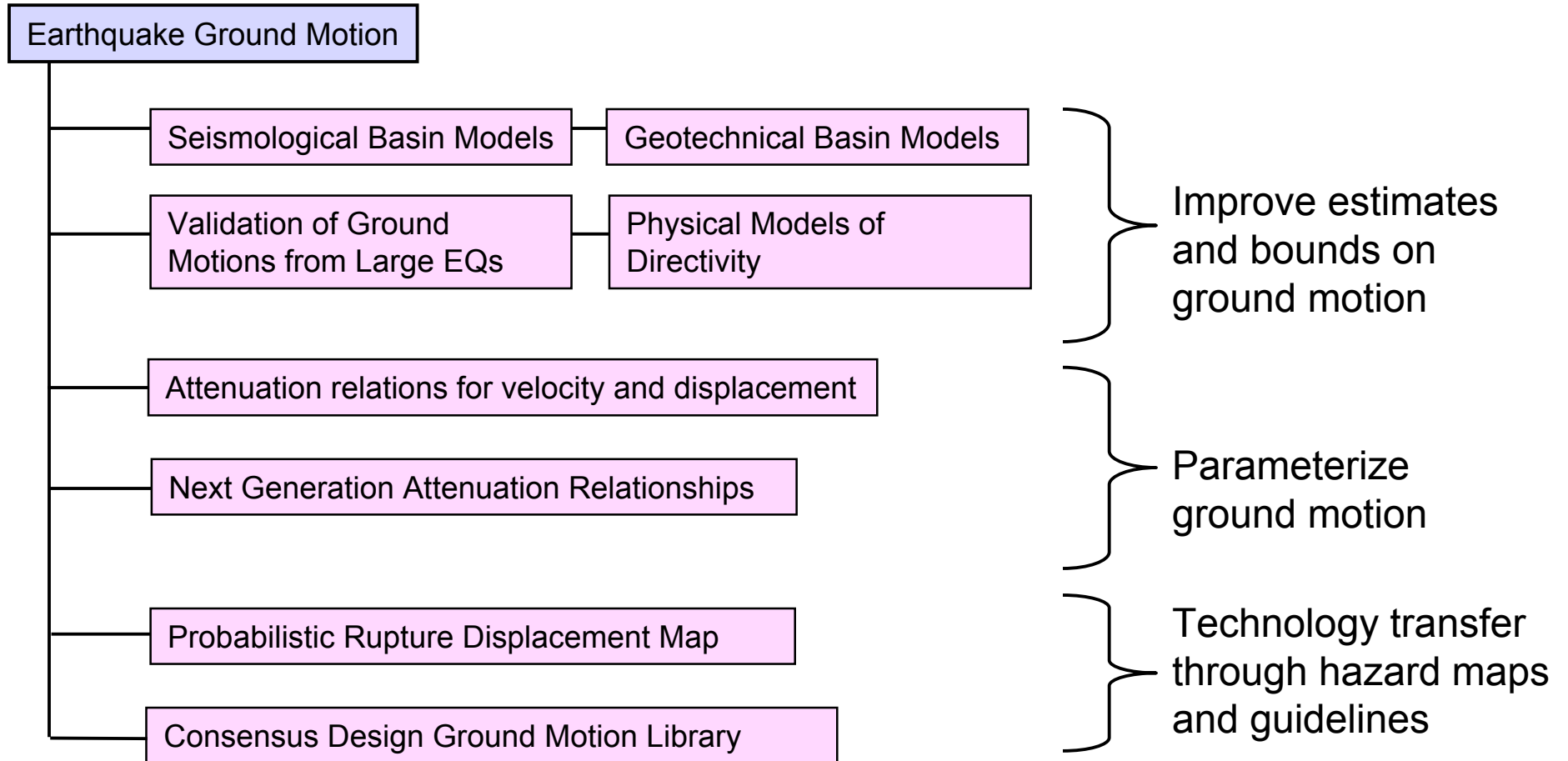** includes project-specific funding from FEMA, SCEC, NCREE, CSMIP and others

Program Plan

Distribution of Lifelines funding by Topic

Intended distribution of sponsor funding over four year program

Emergency Response
$800k (8%)

Network System Risk
$970k (9%)

Earthquake Ground
Motion
$2,580k (24%)

Substation Buildings
$645k (6%)

Substation Equipment
$1,350k (13%)

Permanent Ground
Deformation
$1,495k (14%)

Site Response
$2,705k (26%)

Approximately 80% of funding has been allocated to date

Technical objectives of program: Earthquake Ground Motion

Earthquake Ground Motion

- Seismological Basin Models
- Geotechnical Basin Models
- Validation of Ground Motions from Large EQs
- Physical Models of Directivity

→ Improve estimates and bounds on ground motion

- Attenuation relations for velocity and displacement
- Next Generation Attenuation Relationships

→ Parameterize ground motion

- Probabilistic Rupture Displacement Map
- Consensus Design Ground Motion Library

→ Technology transfer through hazard maps and guidelines

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Selected Research Results and Developments: Seismic Hazard

Ground Motion Simulation
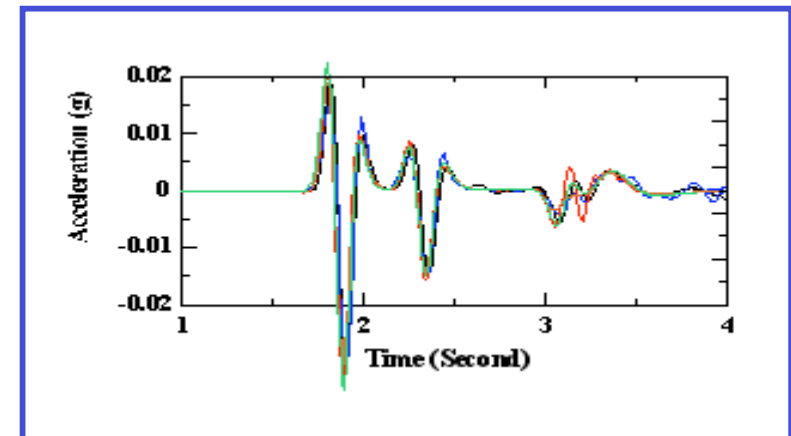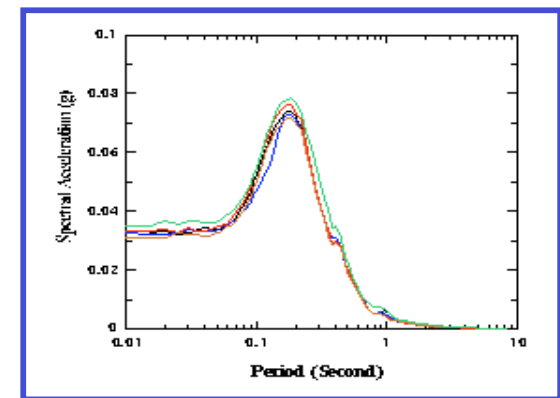
Jointly validate simulation procedures for:
- 1-D kinematic methods for near fault events,
- 3-D methods used to evaluate basin effects

Value: with adequate validation, these codes can supply valuable information on likely motions over a range of conditions for which recordings may not be available.

Investigators:
Somerville (URS), Silva (PEA), Zeng (UNR);
Day (SDSU), Bielak (CMU), Dreger and Larsen (UCB),
Graves and Pitarka (URS), Olsen (UCSB)

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Selected Research Results and Developments: Seismic Hazard
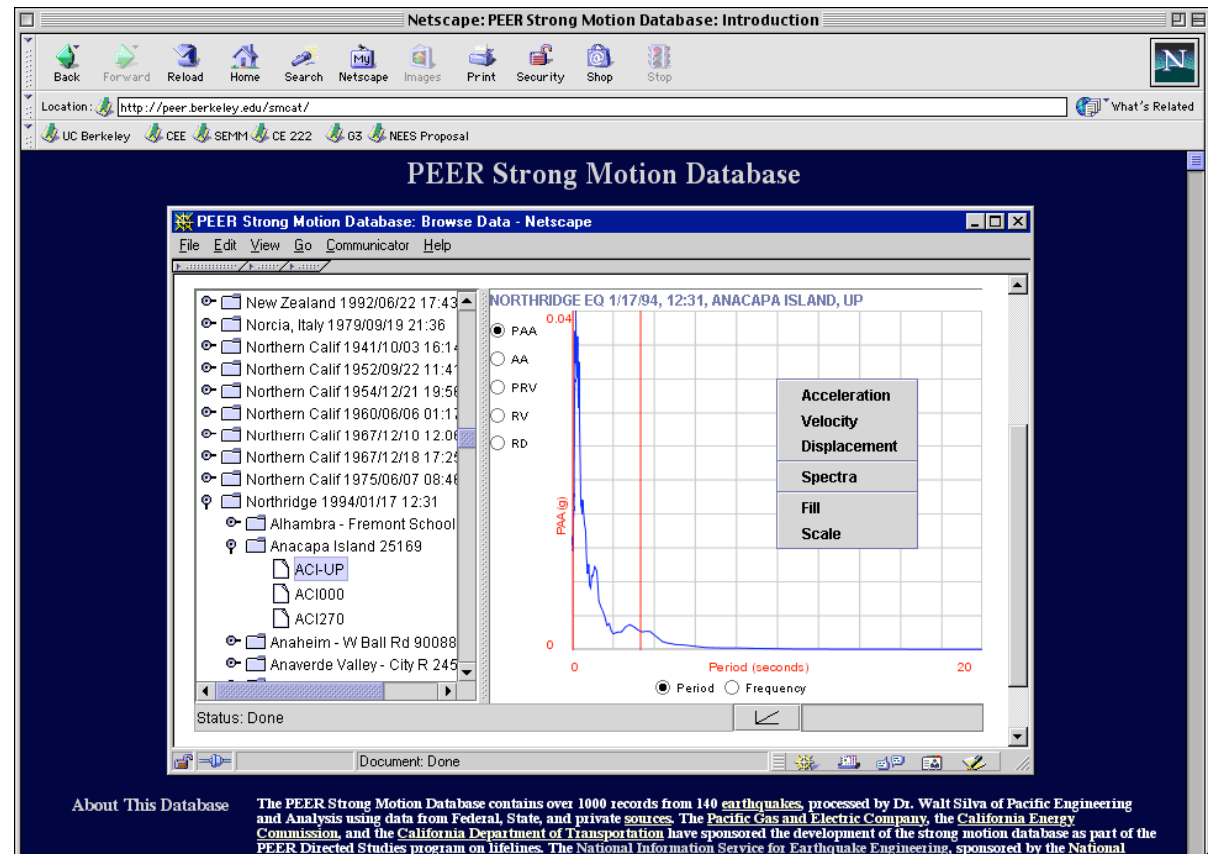
Earthquake Ground Motion

Update of PEER Strong Motion Database

Support engineering studies with consistent processing of records from many events.
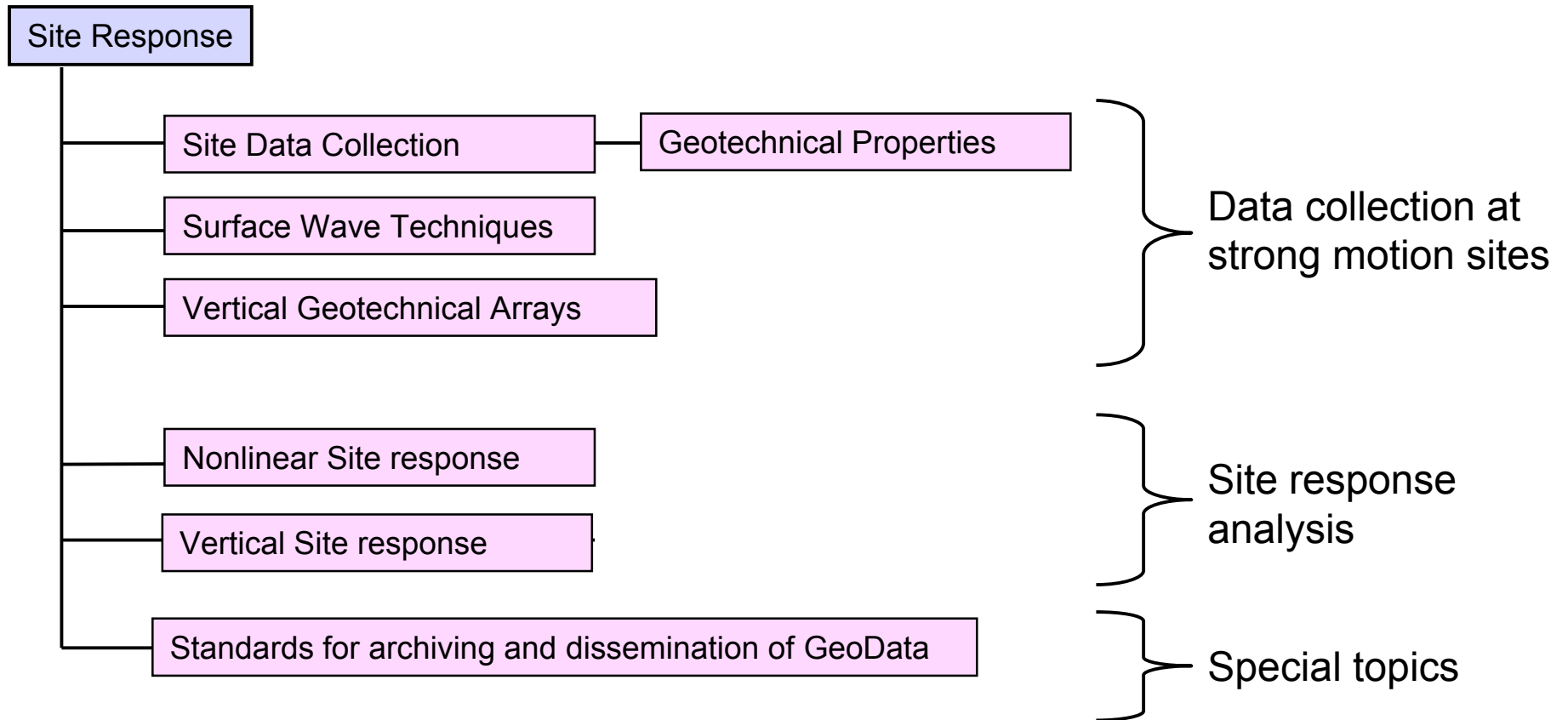
Updated data now includes Duzce, Kocaeli, and Chi Chi events, with extensive plans for additional records.

Ongoing efforts include collecting and posting extensive supporting data, which will allow more sophisticated use of the motions.

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Technical objectives of program:
Site Response

Selected Research Results and Developments:
Seismic Hazard

Next Generation of Attenuation Models

Use the enhanced Ground Motion Database, and include recent research results on topics such as directivity, basin effects and more complex predictor variables, to reduce uncertainty in attenuation models.

Five major attenuation models are represented, and many researchers and other stakeholders are contributing to the development.

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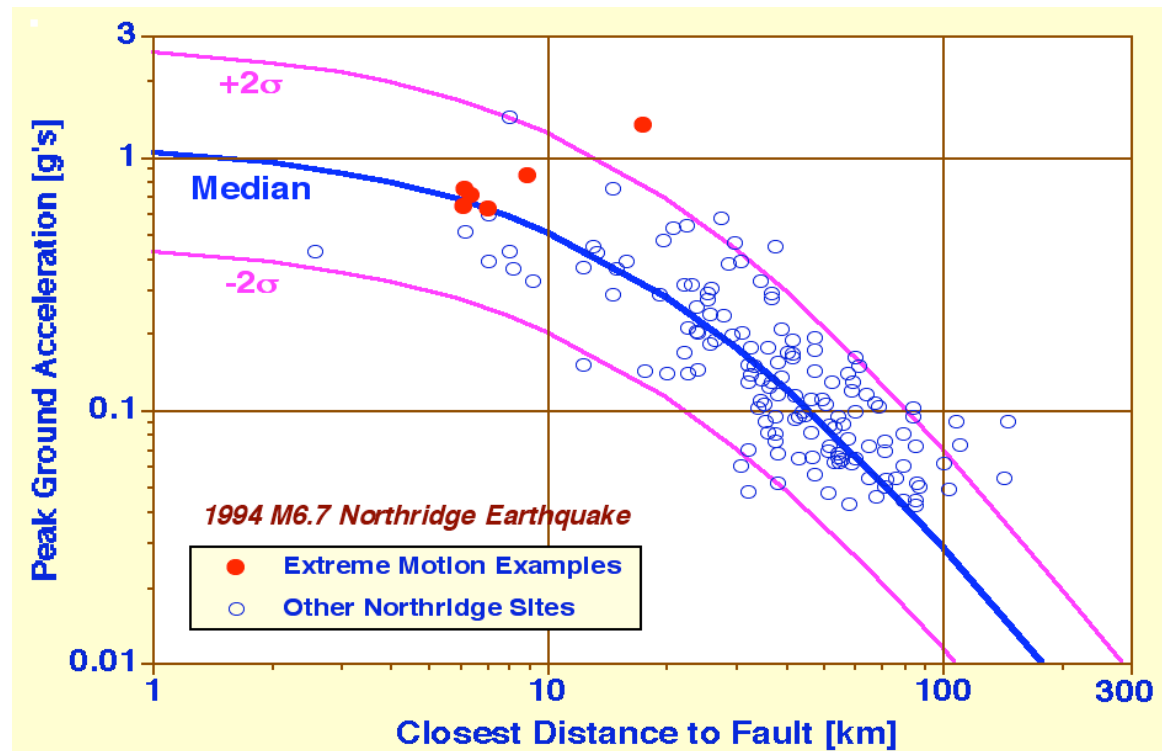
Technical objectives of program:
Permanent Ground Deformation

Permanent Ground Deformation

- Empirical Liquefaction Database
- Experimental Liquefaction Deformation Database
- Probabilistic Models for Liquefaction Onset
- Probabilistic Models for Ground Deformation

Liquefaction data and models

- Evaluating Regional Liquefaction Deformation Hazard

Simulation of ground deformation

- Load Transfer Mechanisms in Liquefied Soil

Special topics

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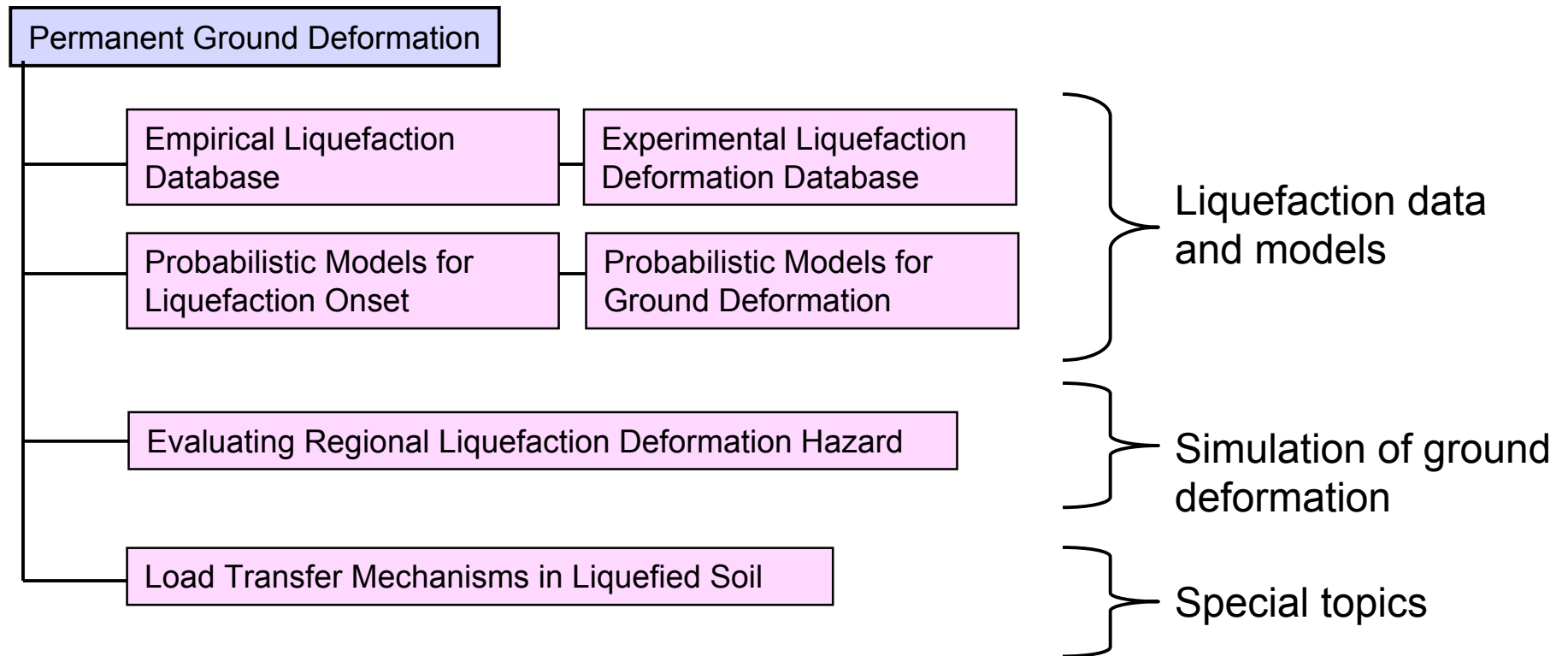
Selected Research Results and Developments: Ground Deformations

Permanent Ground Deformations

Full scale experiment of SSI w/ liquefied soil

Conduct full-scale field experiment examining the loading imparted to pile groups and buried utilities by laterally spreading liquefied soil.

- Useful for confirming load path
- Compare with data from centrifuge
- Use to validate/calibrate simulations

Investigators:
Ashford, Elgamal, Uang (SDSU)

Bridge Superstructure

Bridge Column

Pile Cap

Underground Utility Pipeline

Foundation Piles

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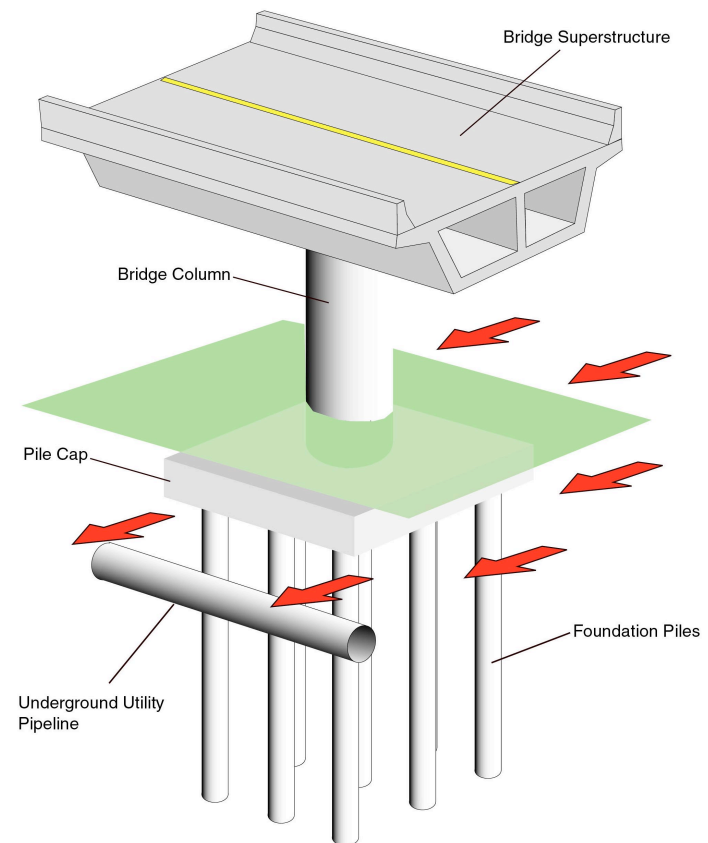
Technical objectives of program:
Utility Component Performance

Substation Equipment

- Substation Equipment Interaction
- Analytical Models for Substation Equipment/Systems
- Seismic Qualification and Testing Protocols

Substation Buildings

- Application of Loss Estimation Methods
- Building-specific Fragility Curves
- Development of Simplified Models and Methods for specific building types

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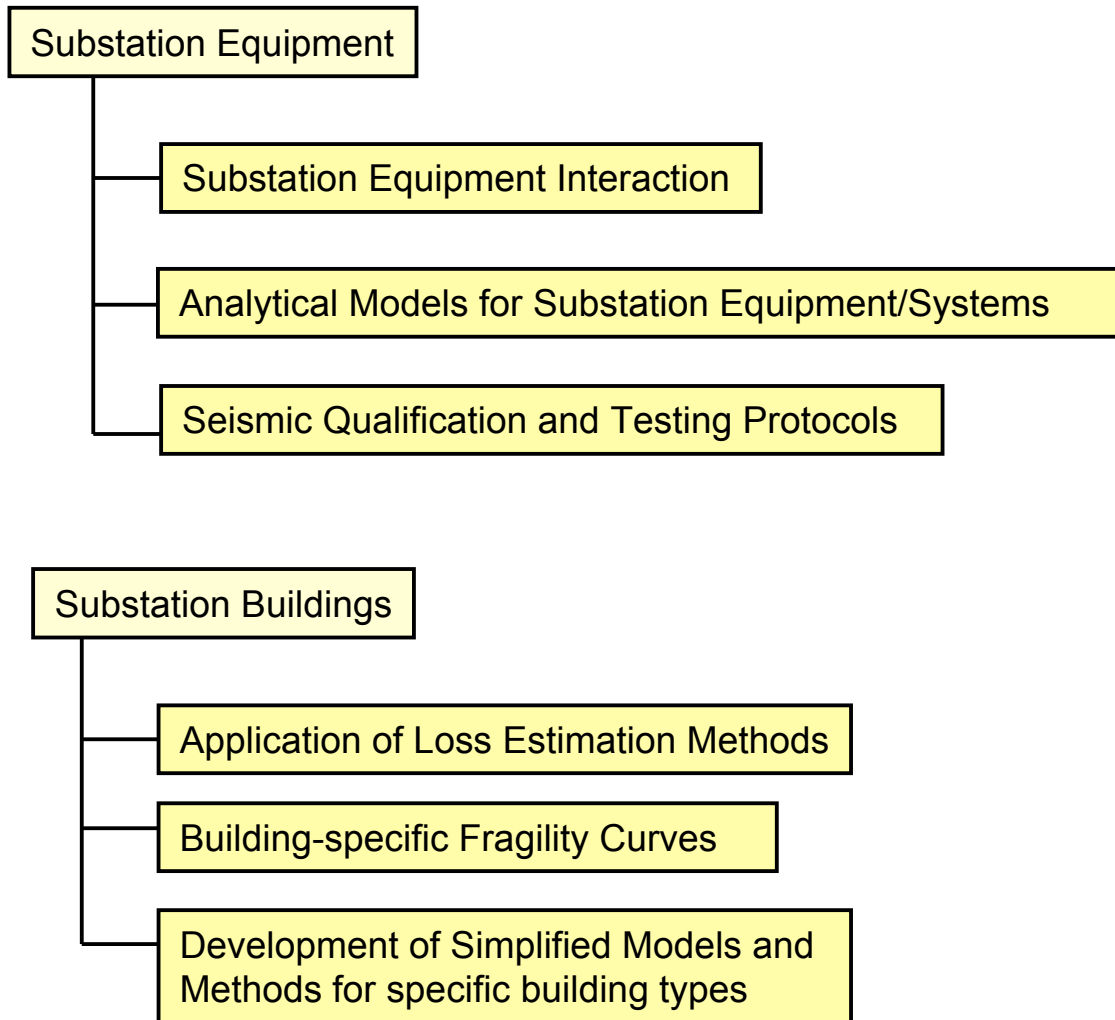
Selected Research Results and Developments:
Utility Component Performance

Dynamics of Interconnected Systems

Quantifying additional demand placed on stiff components due to interactions with equipment to which they are connected
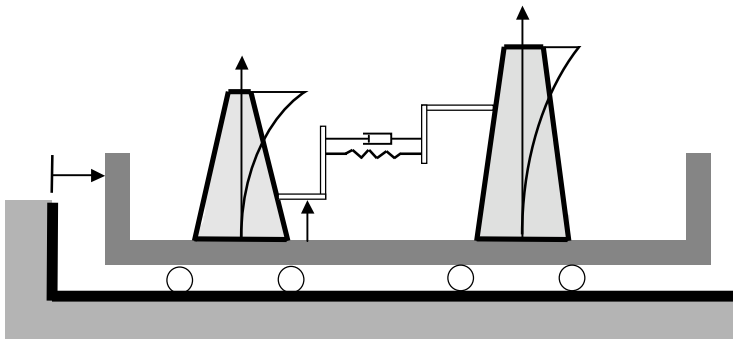
Investigators: A. Der Kiureghian (UCB), J. Sackman (UCB), A. Filiatrault (UCSD)

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Technical objectives of program:
Lifeline Network Planning/Operation

Network System Seismic Risk

- Earthquake Risk Decision Making in Lifeline Organizations
- Integrated Network Risk Models for Electric Power and Highway Systems
- Validation of Probabilistic Seismic Hazard Codes

Emergency Response

- Rapid Ground Motion Estimates
- Real-time Damage Alerting — Rapid Post-earthquake Damage Assessment

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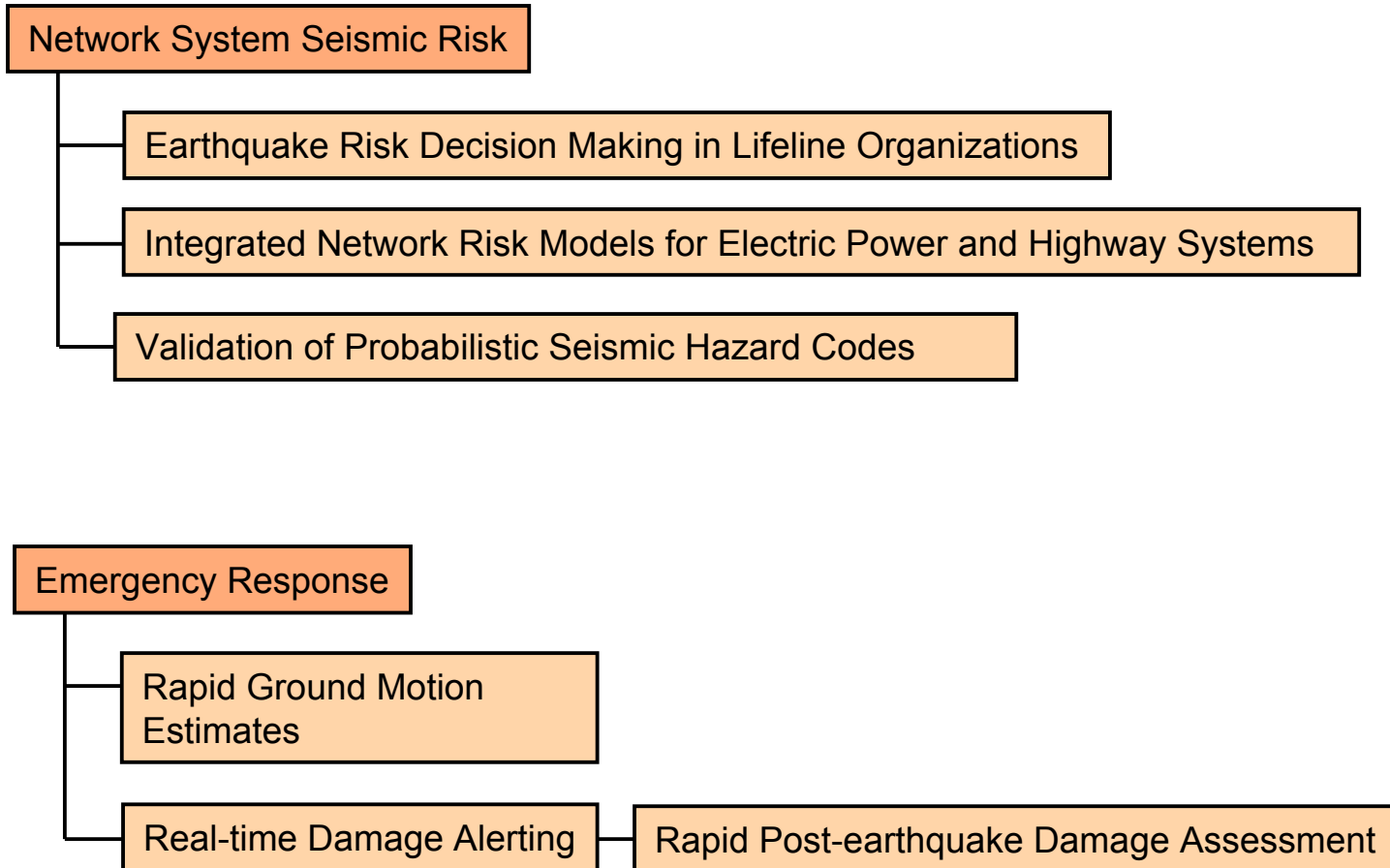
Selected Research Results and Developments:
Network Modeling of Systems

SEISMIC HAZARD ASSESSMENT

| Surface Fault Rupture | Strong Ground Shaking | Liquefaction Ground Failure | Landslide Effects |

INVENTORY AND OPERATIONS DATA

| Network Data | Customer Loads |

EQUIPMENT FRAGILITY MODELING

| Empirical Data | Analytical Model | Shake Table |

COMPONENT PERFORMANCE STATES

| Equipment Capacities | Performance States |

SYSTEM PERFORMANCE MODELS

| System Operations (IPFLOW) | Load/Demand Curves |

REPAIR MODELS

| Repair and Replacement Costs | Restoration Times |

DIRECT ECONOMIC LOSSES
System Repair Costs
Business Interruption Losses

REGIONAL ECONOMIC LOSSES

| Building Inventory Data | Regional I-O Model |
| Socio-Economic Data | Business Loss of Function Model |

INDIRECT ECONOMIC LOSSES
Final Demand Losses
Secondary Losses due to Business Interruption

Network System Risk

Ref: R. Eguchi (ImageCat)

UNCERTAINTY TREATED

| Hazard | Fragility | Traffic | Loss Output |

SOFTWARE CANISTER

| Input / Output Visualization | GUI / DB management |

Comprehensive Loss Estimation Framework for Electric Power Systems

Summary of Lifelines Status

- Approximately 70 projects have been initiated.

- Future work will focus on integrating results of earlier projects into products for implementation, and incorporating results into the network framework where applicable.

- Current phase runs through June 2004.