THE NEW NORMAL FOR NATURAL DISASTERS

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TOPICS

- Tohoku Earthquake
- Canterbury EQ Sequence
- Hurricanes
  - New Orleans
  - New York City
- New Normal
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TOHOKU EARTHQUAKE

- 9.0 Mw (~ 4th Largest EQ Measured)
- 10-25 cm Shift in Earth’s Axis
- 1000 x more power than 1995 Kobe EQ
- 600 million x more power than Hiroshima bomb
TOHOKU EARTHQUAKE

- 15,846 Deaths
- 3,320 Missing
- 112,000 Buildings Destroyed
- $235 B Direct Losses
- $620 B for Nuclear Decontamination & Decommissioning

TOHOKU TSUNAMI

- Inundation = 561 km²
- Tsunami Heights = 3 to 7.3 m
- 50 km Run-up on Kitakami River
- 190 of 300 km Seawalls Heavily Damaged
FUKUSHIMA DAIICHI NUCLEAR PLANT

Fukushima Units 1-4

BOILING WATER REACTOR
**BOILING WATER REACTOR**

Zirconium cladding of fuel rods decomposes to generate hydrogen

\[ \text{Zr} + 2\text{H}_2\text{O} \rightarrow \text{ZrO}_2 + 2\text{H}_2 \]

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**FUKUSHIMA DAIICHI NUCLEAR PLANT**

- Electric power to plant lost, including steel tower failure
- Tsunami flooded all diesel generators (DGs) except one air-cooled DG at higher elevation
- Sea water cooling system destroyed
**FUKUSHIMA DAIICHI NUCLEAR PLANT**

- Partial meltdowns in Units 1, 2, & 3 in primary reactor pressure vessels (RPVs) and primary containment vessels (PCVs)
- Loss of cooling in Unit 4 spent fuel pool
- Hydrogen explosions at all 4 units

**FUKUSHIMA INDEPENDENT PANEL**

(Hatamura Panel)

- Loss of Off-Site Emergency Center
- Failure to Delegate Authority
- Poor Coordination with Prime Minister’s Office
- Errors in Use of Critical Equipment
- Inadequate Radiation Monitoring & Dissemination of Information
- Evacuation Mistakes
**2007 NIIGATAKEN CHUETSU EARTHQUAKE**

- **Main Shock of the Niigata Chuetsu-Oki Earthquake in 2007 (Mw = 6.6)**

- **TEPCO Kashiwazaki Kariwa: 7 Reactors**
  - Boiling Water Reactors Total Capacity - 8.2MW

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**869 SANRIKU EQ AND TSUNAMI**

- Trenches & Soil Coring Revealed Tsunami Deposits
- Sand Layers Between Peat Layers, Carbon Dating of Organics
- Historical Documents Confirm Tsunami
- Models Show ~ 8.4 Mw EQ
- Current Studies Suggest Tsunami Run-up > Extent of Sand Deposits
- 800-1100 Yr. Recurrence
JAPAN’S NUCLEAR POWER PLANTS

- In March 2012 only 2 of 54 nuclear reactors working, or ~ 4% of total nuclear capacity
- Last reactors to shut down in April 2012

- Japan imports 84% of energy
- Nuclear reactors supplied ~ 30% electricity
- Japan planned to increase to 40% by 2017
- Nuclear was part of CO2 reduction strategy

WORLDWIDE EFFECTS: NUCLEAR POWER

- Germany to Close Out Nuclear Power (22.4% Electricity, 2010)
- Switzerland to Terminate Nuclear (40% Electricity, 2008)
- Italy Referendum (2011): > 94% Voters Oppose Plans to Resume Nuclear Power (abandoned 1980s)
NEW ZEALAND

EERI Distinguished Lecture

CANTERBURY EARTHQUAKE SEQUENCE

EERI Distinguished Lecture
CANTERBURY EARTHQUAKE SEQUENCE

• ~ 190 Deaths
• CBD Destroyed
  – ~ 1000 CBD Bldgs. Demolished
  – 20,000 Residences Damaged
• $25 B Direct Losses, 20% GDP
• Massive Liquefaction & Infrastructure Damage

STRONG MOTION RECORDS
(Christchurch Earthquake)
STRONG MOTION RECORDS

EERI Distinguished Lecture

EERI Distinguished Lecture
CHRISTCHURCH LIQUEFACTION

EERI Distinguished Lecture
NEW ZEALAND INSURANCE

- Prior to EQs, Residential Building Insurance Provided by EQC
- After EQs, No Reinsurance
- Four-fold Increase in Insurance Rates, with More Projected
- Termination of Local Authorities Protection Program (LAPP)

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HURRICANE KATRINA

- Greatest U.S. Disaster
- 2000 Dead & Missing
- > $ 100 Billion Losses
- 80% New Orleans Flooded, 53 Days to Dewater
- Impacts on Gulf Offshore Infrastructure & Energy Delivery System
- Complete Failure of Hurricane Protection System
- Hurricane Hazard
- Incomplete Design & Construction
- Poor Maintenance
- I Walls & Foundations
- Poor Preparation
- Inadequate Response

EVOLUTION OF CONCEPT

September 11:
- Protection of Critical Infrastructure

Hurricane Katrina:
- Resilient Communities
Mississippi River Drains 41% of US

65 Kilo-tonnes/s 1927, ‘37. ‘73

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100 km², 1-2m Deep per Year

200 Million Tonnes of Sediment/Yr.
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2005 Hurricanes
- Rita
- Katrina
- Wilma
- Emily
- 28 Storms
- 15 Hurricanes
- > $120 Billion

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Government
- Corps of Engineers
- Communities & Infrastructure

Storm Surge
- Control
- Loss of Wetlands

River
**HURRICANE IRENE**

- 56 Killed
- $10-15 Billion Direct Losses
- 7.4 Million Homes & Businesses Without Power
- NYC Evacuation & Shutdown of MTA & Public Transportation
- Record Flooding
- Near Miss

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**HURRICANE IRENE SIMULATION**

(N. Lin, 2012)

- Physics Based Hydrodynamic Model: ADCIRC
- Excellent Agreement with Hydrograph at Battery
HURRICANE SIMULATION (N. Lin, 2012)

- Simulated 5000 Storm Tracks Within 200 km of Battery

LONG ISLAND SOUND SURGE
NEW YORK CITY HURRICANE FLOOD ZONES

NEW YORK CITY HURRICANE EVACUATION ZONES

MAP KEY:
- Zone A: Flood risk from ANY hurricane that makes landfall close to NYC.
- Zone B: Flood risk from a category 2 or higher hurricane.
- Zone C: Flood risk from a category 3 or higher hurricane.

Battery

NYU Hospital

NEW YORK CITY ELECTRIC POWER

120/208-Volt Distribution Network

13,800-Volt Feeders

Transmission System

Area Substation

120/208-Volt Distribution Network
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OBSERVATIONS

• Anything But Normal
  • Target nuclear failure probability $\approx 1 \times 10^{-5}/yr$
  • 5 major nuclear releases in 14,000 reactor years $= 3 \times 10^{-4}/yr$
  • Probability tails control

• Problems Compounded by Institutional Constraints, Politics, Lack of Perspective, & Dysfunction
NEW NORMAL

• Too Big To Fail
  • Reassess Risk Related to Critical Infrastructure
  • Reassess & Identify Critical Infrastructure

• Local Coalitions
  • Coalitions to Protect Critical Infrastructure Too Big to Fail

• Punctuated Resilience

SOUTHERN CALIFORNIA WATER SUPPLY

70% Imported Water:
  • California Aqueduct
  • Los Angeles Aqueducts
  • Colorado River Aqueduct

30 % Ground Water

Southern California highly dependent on imported water
  • Population: 22 Million
SOUTHERN CALIFORNIA WATER SUPPLY
(after Davis, 2010)

• CA Aqueduct (CA DWR)
  • 49 billion m³/yr
  • Faulting Rupture in >15 places

• LA Aqueducts (LADWP)
  • 390 million m³/yr
  • Elizabeth Tunnel

• Colorado River Aqueduct (MWD)
  • 900 million m³/yr
  • Multiple fault ruptures & ~ 4 m uplift

LOS ANGELES AQUEDUCTS

• 3.3m Horizontal Fault Displacement
• 2.9m Wide Elizabeth Tunnel
  • Cuts off tunnel
LA WATER SUPPLY CROSSES SAN ANDREAS FAULT

- San Joaquin Valley
- Lake Hughes
- Palmdale
- Los Angeles
- San Bernardino
- Salton Sea
- San Fernando Valley
- Ventura
- Los Angeles
- Palm Springs

WELLINGTON SEISMIC RISK

- Urgent Need to Apply Christchurch Lessons
  - Harbor Facilities
  - Water Supply
  - Fire Hazards
  - Major Highways
  - Electric Power System
  - Telecommunications
  - National Government
CRITICAL INFRASTRUCTURE PROJECTS

- Southern California Water Supply
- Sacramento River Delta Flood Protection System
- San Francisco Fire Protection System & Auxiliary Water Supply
- New York City Water Supply
- New Madrid Zone Transportation & Liquid Fuel Lifelines
- Mississippi Delta Flood Management

LEADERSHIP & PUBLIC OUTREACH
ENGAGE ENGINEERS IN THE DIALOGUE

The Future of Cities 2011
Centres of innovation for urban solutions
28th February - 1st March 2011 | Chatham House, London

No Engineers of 28 Speakers

< 10 % Engineers

3 Engineers of 300 Participants

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Canterbury Earthquake Sequence

Tohoku Earthquake

Punctuated Resilience to Protect Against What is Possible Beyond What is Probable
Daily Siren Tests:
0700  Edelweiss
1200  Traditional
1700  Purple Haze

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U.S. NRC TASK FORCE RECOMMENDATIONS

- Fukushima Event Unlikely
- Defense in Depth Integration of emergency preparedness & operating procedures
- Seismic & Flood Hazards
- Station Black-out Procedures
- Hardening BWR Vents
- Spent Fuel Pool Instruments
- Tens of $ Millions New Work
- Feb 12 NRC Approval for 2 Reactors at Vogtle Plant, GA

Diablo Canyon, CA