Resilience Roundtable:
Designing and Building 22nd Century Infrastructure
April 25, 2016; 7:30 a.m. – 3:30 p.m.
George Mason University, Arlington, Virginia
A Philosophy for Designing 22nd Century Infrastructure

Steven D. Hart, Ph.D., P.E.
Chief Engineer, Hart Engineering LLC

hart.engineering@yahoo.com
Agenda

• Observations on Infrastructure
• Observations on Design Codes
• Now for something completely different...
Infrastructure problems are social problems
Infrastructure constrains the future

Panama Canal: 1910
USS Iowa 1942
Picture: 2001
Infrastructure use exceeds our vision
When will we tear these down?
Adverse events are not binary...
Design codes solve technical problems

\[ \varphi R_n > \Sigma \Upsilon Q_i \]

Design Strength > Effects of Loads

(a) Gravity loads
(b) Lateral forces
Design codes presume a design life...

Eurocode 0/ BS EN 1990

- **Category 1** – Temporary structures – 10 years
- **Category 2** – Replaceable structural parts – 10 to 25 years
- **Category 3** – Agricultural and similar buildings – 15 to 30 years
- **Category 4** – Buildings and other common structures – 50 years
- **Category 5** – Monumental building structures, bridges and other civil engineering structures – 100 years

**1-3.1 Permanent Construction**

Buildings and facilities designed and constructed to serve a life expectancy of more than 25 years.
...which sets binary loads and return intervals...

- Earthquake: 1 in 2,500 years
- Wind: 1 in 50 years to 1 in 700 years
- Flood: 1 in 100 years
- Office live load: 50 pounds per square foot
...and then we tear it down.
Designing to Enable the Infrastructure After Next
Plan for perpetuity

- Design
- Finance
- Build
- Renovate
- Remodel
- Operate
- Repurpose
- Repeat
Manage risk to design for success...

<table>
<thead>
<tr>
<th>Event</th>
<th>Probability of Occurrence in any given year</th>
<th>Cumulative probability in 100 years</th>
<th>Cumulative probability in 200 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Year Flood</td>
<td>10%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>50 Year Flood</td>
<td>2%</td>
<td>87%</td>
<td>98%</td>
</tr>
<tr>
<td>100 Year Flood</td>
<td>1%</td>
<td>63%</td>
<td>87%</td>
</tr>
<tr>
<td>500 Year Flood</td>
<td>0.2%</td>
<td>18%</td>
<td>33%</td>
</tr>
</tbody>
</table>
...and manage failure

“Designed to the 100 year storm, resilient in the 500 year storm.”

Resilience as a Function of Hazard

<table>
<thead>
<tr>
<th>Quality of Infrastructure</th>
<th>T-1</th>
<th>T-0</th>
<th>T+1</th>
<th>T+2</th>
<th>T+3</th>
<th>T+4</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-year event</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>250-year event</td>
<td></td>
<td></td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-year event</td>
<td></td>
<td></td>
<td></td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biblical Proportions</td>
<td></td>
<td></td>
<td></td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor Event</td>
<td></td>
<td></td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-year event</td>
<td></td>
<td></td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250-year event</td>
<td></td>
<td></td>
<td></td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500-year event</td>
<td></td>
<td></td>
<td></td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biblical Proportions</td>
<td></td>
<td></td>
<td></td>
<td>85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Graph showing the resilience as a function of hazard with different events and quality of infrastructure.
Right is good. Adaptable is better.

- Design for Resilience, Reparability, Renovation, Restoration, Remodeling, and Repurposing from the beginning
- Anticipate our great-grand-children’s hopes and needs
- Make uncertainty irrelevant
Designing the 22\textsuperscript{nd} Century

- Leadership
- Determination

Creativity
- Vision

Technical Expertise
- John Cleese: "Nothing will stop you from being creative so effectively as the fear of making a mistake."
TISP Resilience Roundtable

• Panel 1: Owners’ Perspectives on Enduring Infrastructure
• Panel 2: Moving Resilience from Bolt-on to Built-in
• Lunch
• Keynote: Managing a Building with a Past, Present, and Future
• Panel 3: Delivering Quality Infrastructure