IDD HP Resilience Program

Cutting-Edge Risk and Resiliency Tools

NAS – Oct 5, 2011
HP Resilience Workshops (2009-2011)

- Designing for a Resilient America: A Stakeholder Summit on High Performance Resilient Buildings and Related Infrastructure
- The Ultra High Performance Concrete (UHPC) Workshop
- Aging Infrastructures Workshop
- Stabilization of Building Workshop
- Security, Energy, and Environmental Summit
- Monitoring and Sensing of Near Collapse Building Workshop
- Near Collapse Buildings Workshop for Emergency Management Personnel
- Advanced Materials and the Infrastructure of the Future Workshop
NIAC Definition:
Infrastructure resilience is the ability to **reduce** the magnitude and/or **duration** of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to **anticipate, absorb, adapt to, and/or rapidly recover** from a potentially disruptive event.
HP Resilience Model

- Promotes the adoption of high performance and resilience concepts in a comprehensive and cost effective manner
- Promotes an integrated approach that addresses the capacity of the physical environment to anticipate, absorb, adapt to, and rapidly recover from disruptive events
- Promotes an integrated approach that includes design and construction issues related to:
  - Blast, earthquake, high wind, and flood resistance and cyber security
  - Energy efficiency, environmental sustainability
  - Durability/extension of life and continuity of operations
HP Resilience Stakeholders

**PUBLIC SECTOR**
- Federal Agencies
- State Agencies
- Local Government Agencies
- Law enforcement Agencies

**PRIVATE SECTOR**
- Owners and operators
- Builders
- Supply chain partners
- Service providers
- Investors and developers

**OTHER PARTICIPANTS**
- Universities
- National Labs
- Codes and Standards
- Design Professionals and Trade Associations
- Non-Profit Organizations

**Diagram**
- Investing
- Executing, Operation and Maintenance
- Planning
HP Resilience Program Taxonomy

Selected Projects

Research and Design Tools
- Owners Performance Requirements (OPR)
- Advanced Materials Database (AMD)
- Security Information and Technology Exchange (SITE)
- Urban Blast Tool (UBT)

Risk Assessment Tools
- Buildings (EQs, Floods, and Winds, Fire, and CBRE)
- Mass Transit
- Tunnels
- Post Disaster Assessment Tool (PDAT)
- BIM for First Responders

BIPS Publications
- Primer to Design Safe Schools Against Terrorism and Shootings
- Blast Loads Effects in Urban Canyons
- Emergency Evacuation, Rescued and Recovery
- Aging Infrastructure
- Retrofit of Building High Dense Urban Settings

UHPC
- Research conducted at ERDC, Georgia Tech, Sandia, Oakridge, and MIT
- Working with the North American UHPC group
- Working with private sector to deconflict standards for commercialization
Urban Blast Tool (UBT)

NYC Financial District (completed) and Mid Manhattan

- Geared toward the design community and first responders
- Very fast running providing guidance on Airblast loads based on CFD analysis
- Addresses column damage and potential for progressive collapse
- Displays glass debris hazards
- Use for evaluating emergency evacuation rescue and recovery (EERR) systems after an event
UBT Codes

- Airblast Codes for data base computations
  - DTRA MAZ code for analyzing 3D propagation
- Navy’s Gemini code for simulation of underwater explosion and shock propagation in air to model failure of curtain walls or façade
- Gemini code coupled with DYNA or FLEX structural code to predict damage to nearby targets
UBT – Future Development

- Develop an interactive version to allow owners to input critical data
- Add ProCAT Model to increase column accuracy in terms of progressive collapse
- Develop UBTs tailored for other major cities in the US
- Create a generic version applicable to most cities in the US
- Analyze and add more structural detailed studies to the UBT models
- Improve accuracy and generate additional EERR equipment fragility models
UBT - Demo

Click button to start Computation
The OPR Tool is a web-based system that allows building owners to:

- Determine specific performance goals for new and existing buildings
- Analyze a range of high-performance requirements based on EISA 2007
- Evaluate tradeoffs between high performance attributes and performance goals required by energy and environmental demands, threats, hazards, and building functions
- Performance goals may range from minimum standards (baseline) to high performance solutions (benchmarks)
The model employs **multi-attribute analysis and performance modeling** that allows the owner to identify performance goals, by evaluating different scenarios based on the following attributes:

- **Energy Conservation**
  - Thermal Transfer
  - Air Leakage
- **Environment**
  - Environmental Footprint
  - Moisture Migration
  - Water Penetration
  - Acoustic Transmission
- **Safety**
  - Seismic
  - Wind
  - Flood
  - Fire
- **Security**
  - Blast
  - CBR
  - Ballistics
  - Continuity of Operations
Five expert committees were formed to provide the performance and cost data.

The OPR Tool is expected to be a part of the ASTM E06.55.09 Standard.

The OPR is being released for external review at: www.oprtool.org/demo

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**OPR Tool**

- **ATTRIBUTES**
  - Safety
  - Security
  - Energy
  - Environment
  - Durability

- **SYSTEMS**
  - Architectural
    - Mechanical
    - Fenestration
    - Structural

- **PERFORMANCE**
  - Baseline
  - Benchmarks
  - Higher levels
  - Other

**RISK**
- Relative/Monetary

**RESILIENCY**
- Continued Operations

**LCA**
- Costs

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**Homeland Security**

Science and Technology
OPR Tool

- **OPR outputs** are based on analyzing multiple attributes simultaneously.
- **OPR predictions** relies on the consensus and knowledge of the technical committees.
- The model is strictly **performance based** and does not identify prescriptive solutions.
The Owners Performance Requirements (OPR) Tool helps building owners identify priorities and prepare a performance plan for a project by selecting targets for each of the attributes identified as comprising high performance by the Energy Independence and Security Act of 2007 (EISA). The OPR Tool, focused in this version on the building envelope for office buildings, establishes a performance based plan for the owner to provide to the design team at the beginning of project programming. Learn more....

Please Sign In

Username: 
Password: 

Remember my login at this computer.

LOG IN  REGISTER

RESOURCES

- OPR Resource 1
- OPR Resource 1a
- OPR Resource 1b
- OPR Resource 2
- OPR Resource 2a
- OPR Resource 2b
- OPR Resource 3
- OPR Resource 3a
- OPR Resource 3b
## Project Information

- **Scenario Name:** Trial 1
- **Gross Building Area:** 100000 SF
- **Performance Targets:** P++ Enhanced Performance, Re++ Enhanced Resilience
- **Project Type:** Existing Building Retrofit
- **Number of Floors:** 3 (Including 1 below grade)
- **Location:** Pittsburgh, PA
- **Quality:** Class B
- **Risk:** Moderate

## Life Cycle Baseline Information

<table>
<thead>
<tr>
<th>Use Period (TCO)</th>
<th>25 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Cost</td>
<td></td>
</tr>
<tr>
<td>Energy Cost ($/Kbtu)</td>
<td>$0.05</td>
</tr>
<tr>
<td>Service &amp; Maintain Cost ($/GSF)</td>
<td>$0.25</td>
</tr>
<tr>
<td>Service Life (Years)</td>
<td></td>
</tr>
<tr>
<td>Whole-building</td>
<td>50 Years</td>
</tr>
<tr>
<td>Exterior Wall</td>
<td>30 Years</td>
</tr>
<tr>
<td>Exterior Glazing</td>
<td>20 Years</td>
</tr>
<tr>
<td>Roof System</td>
<td>15 Years</td>
</tr>
<tr>
<td>Annual Escalation Trend</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>5.0%</td>
</tr>
<tr>
<td>Service &amp; Maintain</td>
<td>5.0%</td>
</tr>
<tr>
<td>Present Value Discount Rate</td>
<td>5.0%</td>
</tr>
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</table>

## Occupancy Information

<table>
<thead>
<tr>
<th>Occupancy Information</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Census (GSF/Occupant)</td>
<td>150</td>
</tr>
<tr>
<td>Operation (Hours/Week)</td>
<td>40</td>
</tr>
<tr>
<td>Operation (Weeks/Year)</td>
<td>51</td>
</tr>
<tr>
<td>Indirect Project Cost</td>
<td></td>
</tr>
<tr>
<td>Construct</td>
<td>10%</td>
</tr>
<tr>
<td>Design, Test, Commission</td>
<td>12%</td>
</tr>
</tbody>
</table>

## Facility Resilience

### Safety

#### Seismic

- **Seismic Design Category:** SDC C
- **Performance Benchmark:** Reduced Damage
- **Extent of Damage and Continuity of Operations:** Moderate damage to cladding may occur but cladding remains anchored to building structure. Seals and gaskets may tear and ability to provide weather protection is locally compromised. Glass edge damage may occur and glass may fall off setting blocks, but glass breakage is mitigated. The building remains safe to occupy; structural and nonstructural repairs are minor. There shall be no failure or gross permanent distortion of the building envelope system anchorage and framing. Minor cracking and deformation of cladding may occur, but is not expected. Interstory drift limits all structures: 0.0075h to 0.01h; h = story height
- **Performance Standard(s):**
  - IBC-2009
  - ASCE 7-05
  - ASCE 41-06
  - NEHRP Recommended Provisions for Seismic Regulations
  - FEMA E-74
  - ASTM E 2026
IRVS Family

- Designed to prepare rapid but comprehensive assessments
- A simple, quick, and reliable tool for obtaining a preliminary risk assessment rating.
- Reliability depends on time devoted to collection of information and field inspections
- Can support other more thorough assessments
- Expected to save millions of dollars to federal, state, local government, and private sector
- An all hazard approach
- Computes risk and resilience providing scores and ratings
- Flexible methodology based on dictionaries and scores which are easy to adapt to institutional needs
## IRVS: Buildings

### Consequences
- Locality Type
- Number of Occupants
- Replacement Value
- On Historic Registry
- Business Continuity
- Physical Loss Impact

### Threat Rating
- Occupancy Use
- Number of Occupants
- Site Population Density
- Visibility/Symbolic Value
- Target Density
- Overall Site Accessibility
- Target Potential

### Vulnerability
- Site
- Architecture
- Building Envelope
- Structural Components and Systems
- Mechanical/Electrical/Plumbing (MEP) Systems
- Security

![Image of buildings and diagram](image-url)
# IRVS: Mass Transit Stations

<table>
<thead>
<tr>
<th>Consequences</th>
<th>Threat Rating</th>
<th>Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Tracks</td>
<td>Visibility</td>
<td>Site</td>
</tr>
<tr>
<td>Number of Station Levels</td>
<td>Historic Nature/Landmark Status</td>
<td>Architectural</td>
</tr>
<tr>
<td>Impact of Physical Loss</td>
<td>Number of Riders per day</td>
<td>Structural</td>
</tr>
<tr>
<td>Number of Riders per day</td>
<td>Previous Threats</td>
<td>Ventilation (including HVAC)</td>
</tr>
<tr>
<td>Commercial, and Industrial Facilities</td>
<td>Accessibility</td>
<td>Fire Systems</td>
</tr>
<tr>
<td>Adjacent Stations</td>
<td>Elevation</td>
<td>Operations (including power supply, lighting, etc.)</td>
</tr>
<tr>
<td>Adjacent Critical Infrastructure</td>
<td>Site Locality</td>
<td>Non-Structural</td>
</tr>
<tr>
<td>Social Effect of Loss</td>
<td>Adjacent Critical Infrastructure</td>
<td>Physical Security</td>
</tr>
<tr>
<td>Replacement Value</td>
<td>Function Criticality</td>
<td></td>
</tr>
<tr>
<td>Operational Redundancy</td>
<td>Storage Use</td>
<td></td>
</tr>
<tr>
<td>Function Criticality</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: The table highlights various factors to be considered when assessing the risk and vulnerability of mass transit stations.*
## IRVS: Tunnels

<table>
<thead>
<tr>
<th>Consequences</th>
<th>Threat Rating</th>
<th>Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Impact of Physical Loss</td>
<td>• Visibility</td>
<td>• Site</td>
</tr>
<tr>
<td>• Number of Vehicles/Trains per Day</td>
<td>• Historic Nature</td>
<td>• Architectural</td>
</tr>
<tr>
<td>• Nearby Commercial Facilities</td>
<td>• Number of Vehicles/Trains per day</td>
<td>• Structural</td>
</tr>
<tr>
<td>• Adjacent Critical Infrastructure</td>
<td>• Previous Threats</td>
<td>• Ventilation (including HVAC)</td>
</tr>
<tr>
<td>• Social Effect of Loss</td>
<td>• Accessibility</td>
<td>• Fire Systems</td>
</tr>
<tr>
<td>• Replacement Value</td>
<td>• Elevation</td>
<td>• Operations (including power supply, lighting, etc.)</td>
</tr>
<tr>
<td>• Operational Redundancy</td>
<td>• Site Locality</td>
<td>• Non-Structural</td>
</tr>
<tr>
<td>• Function Criticality</td>
<td>• Adjacent Critical Infrastructure</td>
<td>• Physical Security</td>
</tr>
<tr>
<td></td>
<td>• Function Criticality</td>
<td></td>
</tr>
</tbody>
</table>

- **Function Criticality**
  - Architectural
  - Structural
  - Ventilation (including HVAC)
  - Fire Systems
  - Operations (including power supply, lighting, etc.)
  - Non-Structural
  - Physical Security
**Methodology**: knowledge is embedded in the tool. Major tool interactions are automatically calculated. Pre assigned weights, interaction logic, and context-based algorithms based on knowledge and tool validations.

**Risk**: For man made hazards, deals with target attractiveness. For natural hazards, it uses probability of occurrence. Risk is calculated as follows: \( R = C \times T \times V \)

**Resilience**: computes robustness (R1), resourcefulness (R2), and recovery (R3) using information, such as hardening, training, and redundancies. Resilience is calculated as follows: \( \text{Resilience} = R1 \times R2 \times R3 \)
## IRVS Scores

### Risk and Resiliency Summary

<table>
<thead>
<tr>
<th>Summary Categories</th>
<th>Internal Intrusion</th>
<th>Internal Explosive</th>
<th>Internal CBR</th>
<th>Explosive Zone 1</th>
<th>Explosive Zone 2</th>
<th>Explosive Zone 3</th>
<th>CBR Zone 1</th>
<th>CBR Zone 2</th>
<th>CBR Zone 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Consequences (%)</td>
<td>66.63%</td>
<td>59.61%</td>
<td>57.91%</td>
<td>61.97%</td>
<td>59.33%</td>
<td>69.13%</td>
<td>57.41%</td>
<td>61.75%</td>
<td>65.10%</td>
</tr>
<tr>
<td>Total Threat (%)</td>
<td>27.18%</td>
<td>68.34%</td>
<td>62.83%</td>
<td>85.34%</td>
<td>58.67%</td>
<td>49.69%</td>
<td>84.08%</td>
<td>71.12%</td>
<td>53.30%</td>
</tr>
<tr>
<td>Total Vulnerabilities (%)</td>
<td>0.95%</td>
<td>61.04%</td>
<td>61.62%</td>
<td>56.01%</td>
<td>57.20%</td>
<td>57.19%</td>
<td>57.42%</td>
<td>56.99%</td>
<td>60.93%</td>
</tr>
<tr>
<td>Total Risk Percent (%)</td>
<td>25.30%</td>
<td>62.26%</td>
<td>60.75%</td>
<td>68.66%</td>
<td>58.42%</td>
<td>58.10%</td>
<td>65.18%</td>
<td>63.03%</td>
<td>59.57%</td>
</tr>
</tbody>
</table>

### Earthquake

<table>
<thead>
<tr>
<th>Summary Categories</th>
<th>Earthquake General Shaking</th>
<th>Earthquake Ground Failure</th>
<th>Flood Stillwater</th>
<th>Flood Velocity Surge</th>
<th>Wind Hurricane</th>
<th>Wind Tornado</th>
<th>Wind Other</th>
<th>Landslide Rainfall</th>
<th>Fire From Earthquake</th>
<th>Fire From Blast</th>
<th>Fire From Arson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Consequences (%)</td>
<td>61.31%</td>
<td>59.46%</td>
<td>61.04%</td>
<td>55.30%</td>
<td>61.30%</td>
<td>61.97%</td>
<td>61.33%</td>
<td>61.47%</td>
<td>61.15%</td>
<td>63.67%</td>
<td>62.99%</td>
</tr>
<tr>
<td>Total Threat (%)</td>
<td>0.00%</td>
<td>0.00%</td>
<td>57.76%</td>
<td>72.32%</td>
<td>54.31%</td>
<td>48.44%</td>
<td>52.10%</td>
<td>52.05%</td>
<td>0.00%</td>
<td>67.69%</td>
<td>29.08%</td>
</tr>
<tr>
<td>Total Vulnerabilities (%)</td>
<td>30.30%</td>
<td>35.30%</td>
<td>35.34%</td>
<td>41.30%</td>
<td>42.99%</td>
<td>38.99%</td>
<td>33.50%</td>
<td>33.16%</td>
<td>2.04%</td>
<td>3.19%</td>
<td>3.19%</td>
</tr>
<tr>
<td>Total Risk Percent (%)</td>
<td>30.00%</td>
<td>30.00%</td>
<td>35.15%</td>
<td>55.15%</td>
<td>55.71%</td>
<td>48.92%</td>
<td>50.16%</td>
<td>50.19%</td>
<td>0.00%</td>
<td>23.57%</td>
<td>18.08%</td>
</tr>
</tbody>
</table>

### Resiliency Scales (%)

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Time Measure</th>
<th>Robustness Measure</th>
<th>Resourcefulness Measure</th>
<th>Recovery Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>49.6%</td>
<td>47.3%</td>
<td>43.4%</td>
<td>48.2%</td>
<td>49.3%</td>
</tr>
</tbody>
</table>

### Total Risk

<table>
<thead>
<tr>
<th>All Scenarios (%)</th>
<th>Resiliency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60.88%</td>
<td>23%</td>
</tr>
</tbody>
</table>

### Multihazards Interaction Matrix

... will result in this change for other hazards:

- a change in Blast: 100.0% | 9.3% | 33.0% | 9.7% | 47.5% | 22.6%
- a change in CBR: 12.7% | 100.0% | 0.0% | 16.8% | 1.2% | 5.2%
- a change in Seismic: 55.5% | 0.0% | 100.0% | 35.9% | 50.7% | 16.3%
- a change in Flood: 7.5% | 9.6% | 16.7% | 100.0% | 8.8% | 10.2%
- a change in Wind: 68.2% | 1.3% | 43.3% | 16.3% | 100.0% | 16.1%
- a change in Fire: 83.2% | 14.1% | 35.7% | 48.4% | 41.5% | 100.0%
### IRVS Scores

#### Total Risk Summaries - All Assessments

<table>
<thead>
<tr>
<th>Buildings</th>
<th>Facility ID#</th>
<th>Assessment Date</th>
<th>Total Risk All Scenarios</th>
<th>Total Resiliency</th>
<th>Intuition</th>
<th>Blast Interior</th>
<th>CBR Interior</th>
<th>Blast Exterior</th>
<th>CBR Exterior</th>
<th>Seismic</th>
<th>Flood</th>
<th>Wind</th>
<th>Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test site 2</td>
<td>232</td>
<td>3/10/2011</td>
<td>52.2</td>
<td>18.2</td>
<td>55.8</td>
<td>49.5</td>
<td>60.4</td>
<td>53.8</td>
<td>55.5</td>
<td>72.1</td>
<td>71.9</td>
<td>77.7</td>
<td>57.3</td>
</tr>
<tr>
<td>Test site 3</td>
<td>333</td>
<td>3/11/2011</td>
<td>47.6</td>
<td>35.4</td>
<td>51.5</td>
<td>46.1</td>
<td>53.3</td>
<td>53.5</td>
<td>56.7</td>
<td>38.0</td>
<td>51.3</td>
<td>55.5</td>
<td>45.7</td>
</tr>
<tr>
<td>Test site 4</td>
<td>4444</td>
<td>3/14/2011</td>
<td>19.5</td>
<td>71.5</td>
<td>11.7</td>
<td>15.2</td>
<td>11.2</td>
<td>20.8</td>
<td>20.2</td>
<td>17.8</td>
<td>13.9</td>
<td>24.3</td>
<td>13.9</td>
</tr>
</tbody>
</table>

#### Mass Transit Stations

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Facility ID#</th>
<th>Assessment Date</th>
<th>Total Risk All Scenarios</th>
<th>Total Resiliency</th>
<th>Details per Threat / Hazard</th>
<th>Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass Transit 1</td>
<td>666</td>
<td>3/14/2011</td>
<td>17.6</td>
<td>33.4</td>
<td>Blast Internal</td>
<td>5.8</td>
</tr>
<tr>
<td>Mass Transit 1</td>
<td>666</td>
<td>3/14/2011</td>
<td>20.0</td>
<td>30.0</td>
<td>Blast External Direct</td>
<td>9.0</td>
</tr>
<tr>
<td>Mass Transit 1</td>
<td>666</td>
<td>3/14/2011</td>
<td>25.0</td>
<td>30.0</td>
<td>Blast External Collateral</td>
<td>24.5</td>
</tr>
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<td>Mass Transit 1</td>
<td>666</td>
<td>3/14/2011</td>
<td>30.0</td>
<td>30.0</td>
<td>CBR Interior</td>
<td>23.3</td>
</tr>
<tr>
<td>Mass Transit 1</td>
<td>666</td>
<td>3/14/2011</td>
<td>35.0</td>
<td>30.0</td>
<td>CBR External</td>
<td>25.7</td>
</tr>
<tr>
<td>Mass Transit 1</td>
<td>666</td>
<td>3/14/2011</td>
<td>40.0</td>
<td>30.0</td>
<td>Fire Internal</td>
<td>24.0</td>
</tr>
<tr>
<td>Mass Transit 1</td>
<td>666</td>
<td>3/14/2011</td>
<td>45.0</td>
<td>30.0</td>
<td>Fire External</td>
<td>29.7</td>
</tr>
<tr>
<td>Mass Transit 1</td>
<td>666</td>
<td>3/14/2011</td>
<td>50.0</td>
<td>30.0</td>
<td>Tunnel Track Smoke</td>
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<td>Mass Transit 1</td>
<td>666</td>
<td>3/14/2011</td>
<td>55.0</td>
<td>30.0</td>
<td>Other Flood</td>
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<td>3/14/2011</td>
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<td>30.0</td>
<td>Other Collision</td>
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<td>Mass Transit 1</td>
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<td>3/14/2011</td>
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#### Tunnels

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<th>Total Resiliency</th>
<th>Details per Threat / Hazard</th>
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HP Materials Databases

- **AMD** provides a platform for the systematic organization of advanced materials through the documentation and search ability of their high-performance properties.

- **SITE**, an online database for security products meeting ISC, VA, and DOD requirements.
Publications

- Aging Infrastructure
- RVS Manuals
- Update of FEMA 426
- Update of FEMA 428
- Preventing Structures from Collapsing
- Designing for a Resilient America
- Security, Energy, and the Environment
The High Performance – Integrated Design Resilience Program

The High Performance – Integrated Design Resilience program’s overall goal is to provide the built environment with enhanced blast and CBR resistance that meets all performance requirements needed by our nation’s buildings and infrastructure at the highest possible level. The program promotes an integrated approach that combines all hazards (natural and man-made), aging/extension of life, and continuity of operations to anticipate, absorb, adapt to, and rapidly recover from a disruptive event. The achieved resilience reduces the impact of the event and the duration of its effect through resourcefulness, robustness, and rapid recovery. The program is supported by three primary paradigms: 1) that it is possible to provide a built environment that has the highest level of performance and resiliency in a comprehensive and cost effective manner; 2) that to achieve this, all facets of the process from design to operation must be integrated and 3) that through high performance and integrated design infrastructure can achieve resilience from a disruptive event.