IDD High Performance Resilience Program

Cutting-Edge Risk and Resiliency Tools

NIST – NEHRP
November 8-9, 2011

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Infrastructure Protection and Disaster Management Division

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 Buildings Workshop
- Security, Energy, and Environmental Summit
- Monitoring and Sensing of Near Collapse Buildings Workshop
- Near Collapse Buildings Workshop for Emergency Management Personnel
- Advanced Materials and the Infrastructure of the Future Workshop

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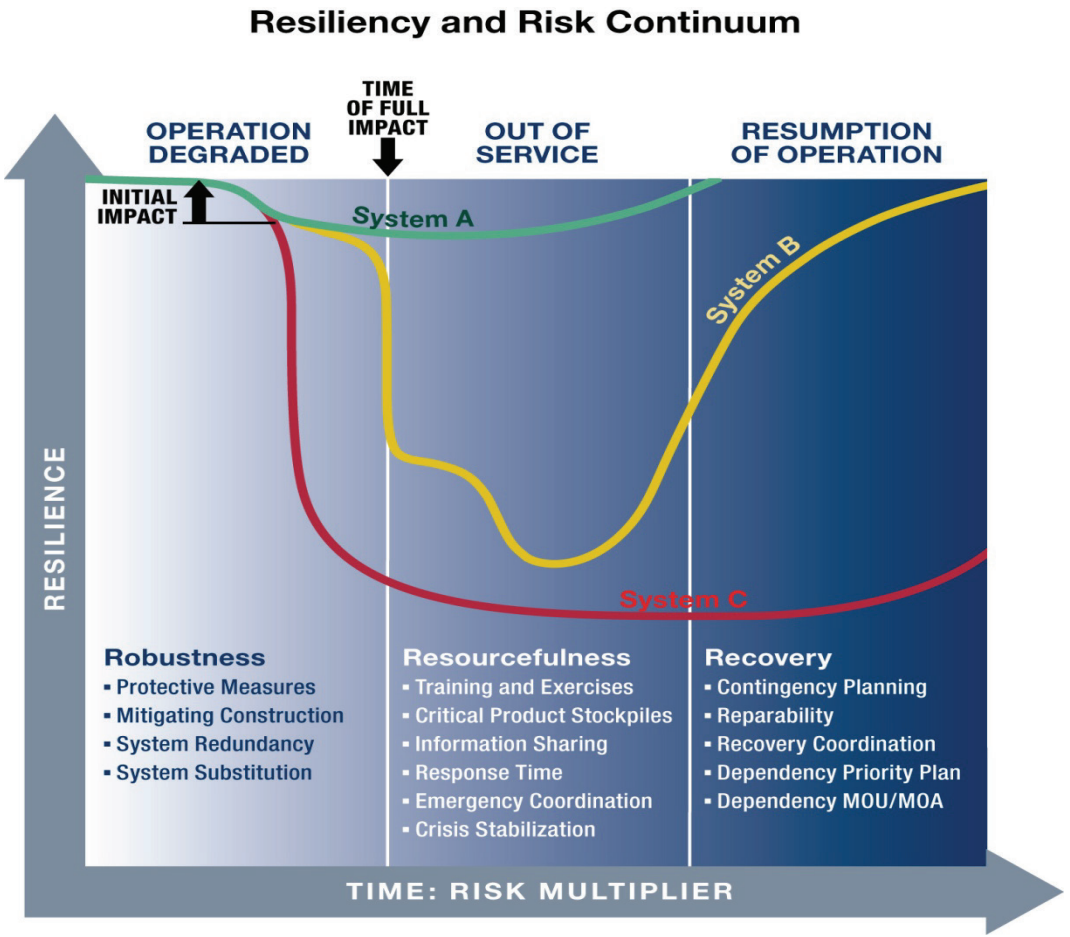
Resilience Definition

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. (NIAC, 2009)



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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

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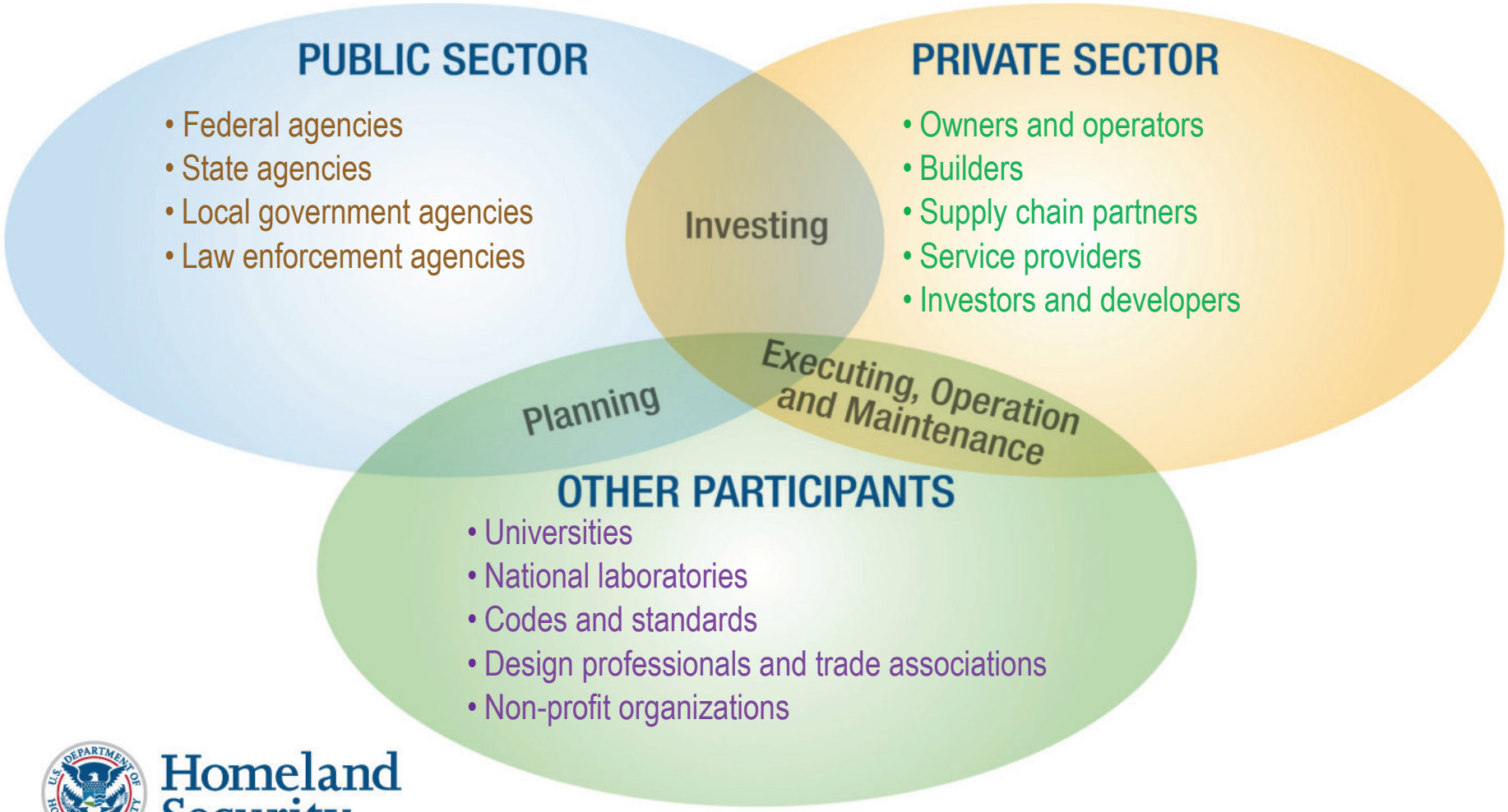
HP Resilience Stakeholders



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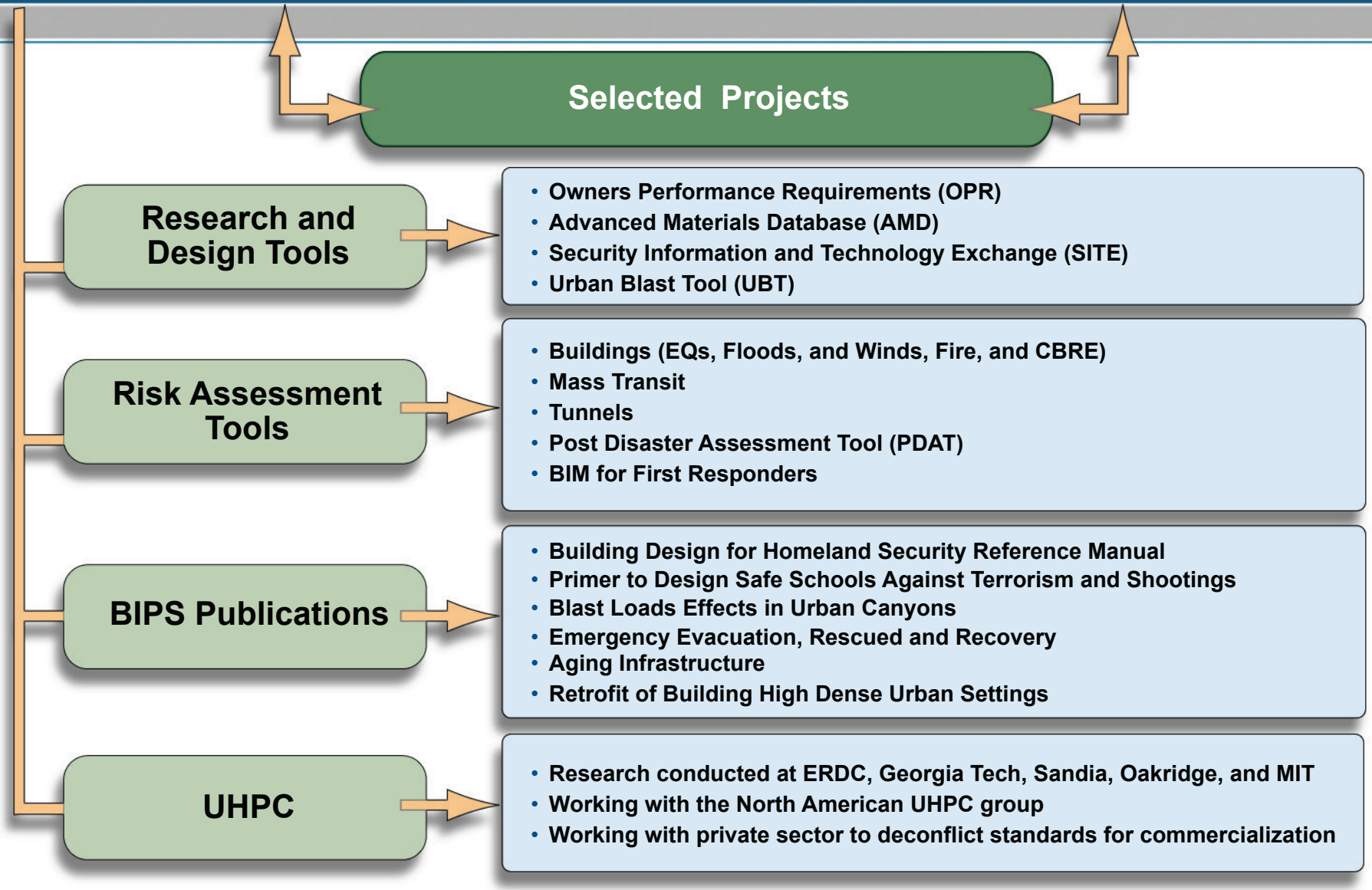
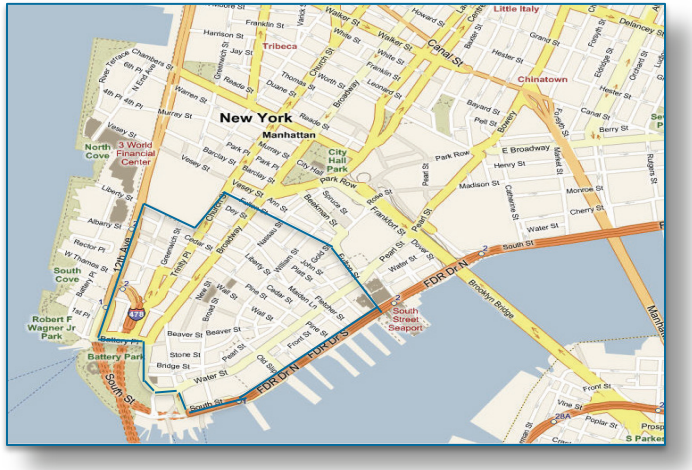
HP Resilience Program Taxonomy



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



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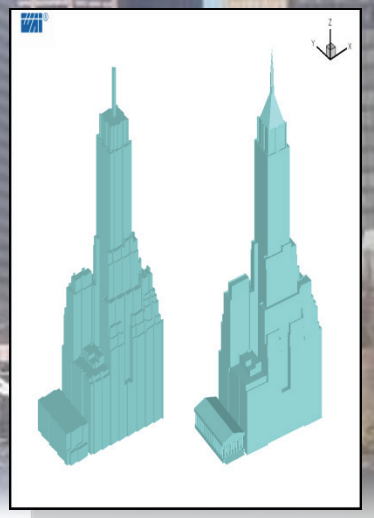
UBT Codes

- Airblast Codes for data base computations
- DTRA MAZ code for analyzing 3D propagation
- FLEX finite element software is used to analyze structural performance in response to explosive loading
- ProCAT module to be evaluated against FLEX analyses of typical construction



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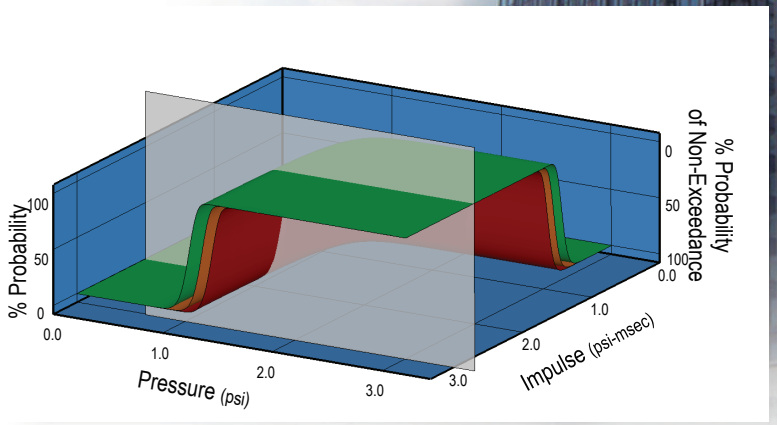
UBT and EQ Related Issues

- **Progressive collapse potential**
  - Use lateral structural systems in the algorithms and logic for assessing progressive collapse potential
- **Emergency, Evacuation, Recovery, and Response (EERR) fragilities**
  - Use seismic non-structural components design methods in validating the results for some of the EERR blast fragilities
  - With appropriate consideration of the essential differences between seismic and blast responses



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UBT Future Development

- Create a generic version applicable to most cities in the US
- Develop an interactive version to allow owners to input detailed building data
- Add the Air Force Progressive Collapse Analysis Tool to improve current UBT assessments
- Analyze and add more structural detailed studies to the UBT models
- Improve accuracy and generate additional emergency and evacuation equipment fragility models

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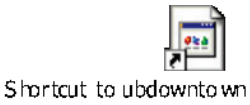
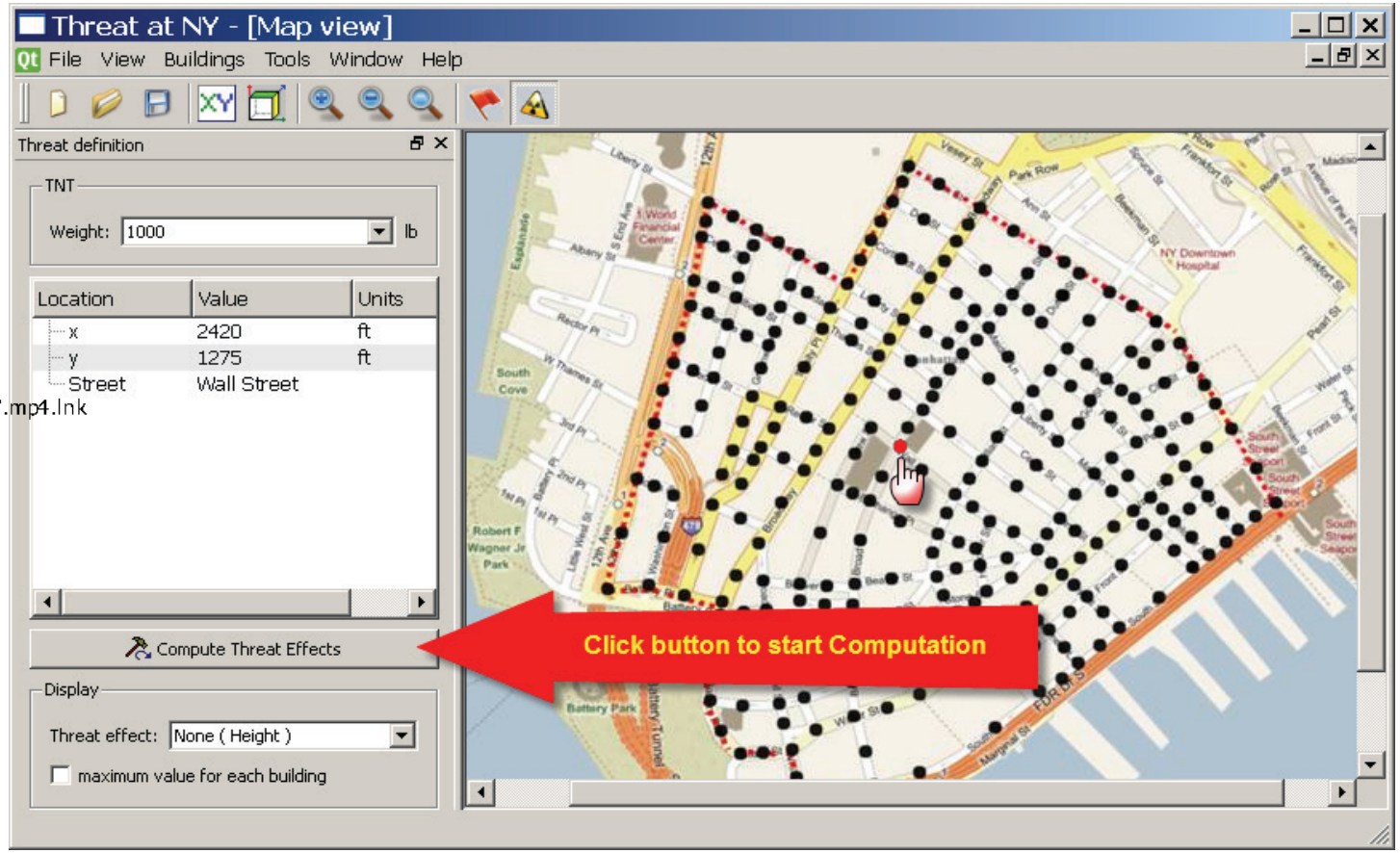
UBT - Demo



Shortcut to ubdowntownusav7.mp4.lnk



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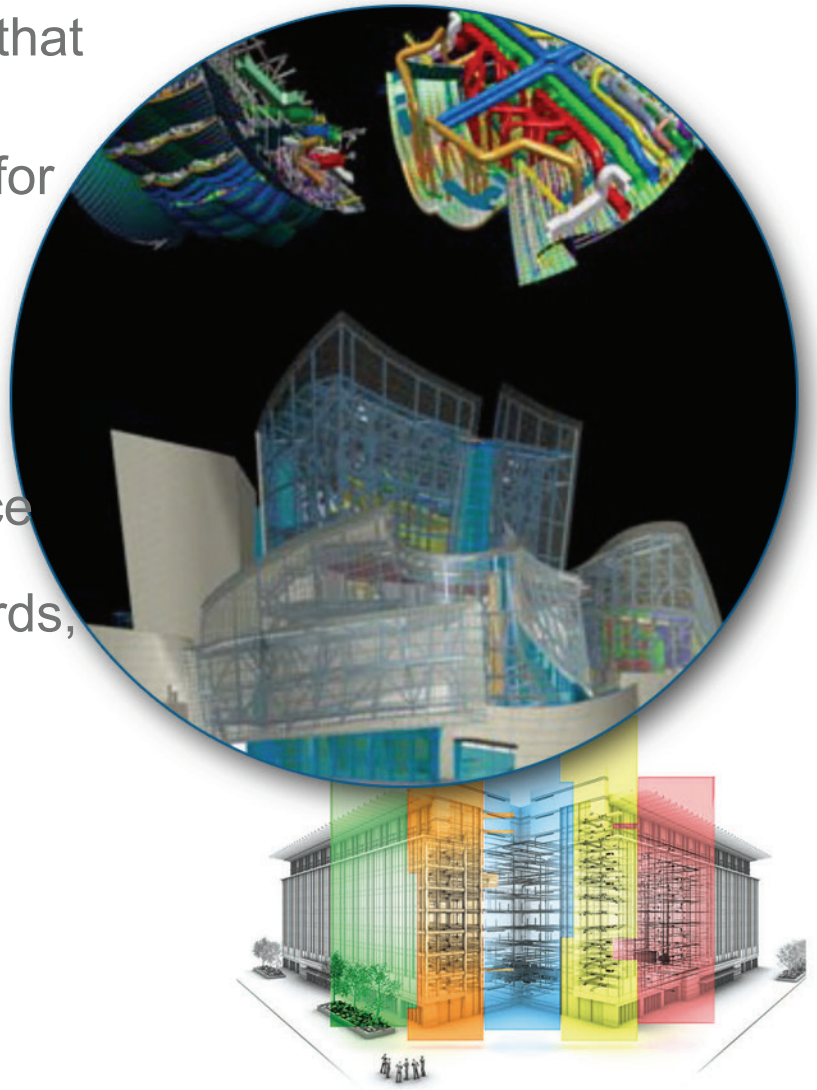
Owners Performance Requirements Tool (OPR)

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)



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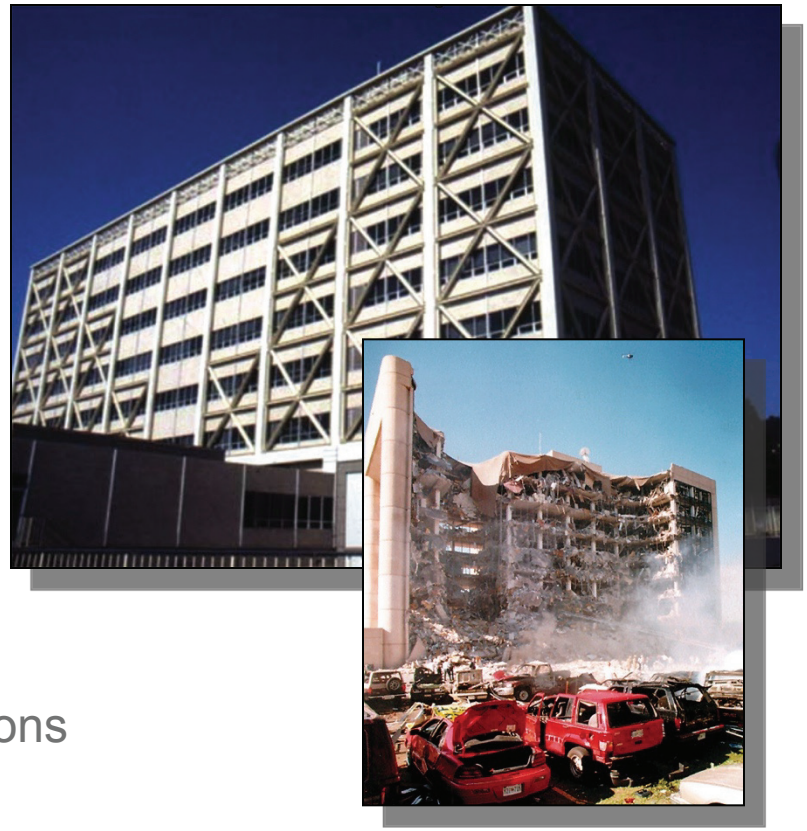
OPR Tool

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



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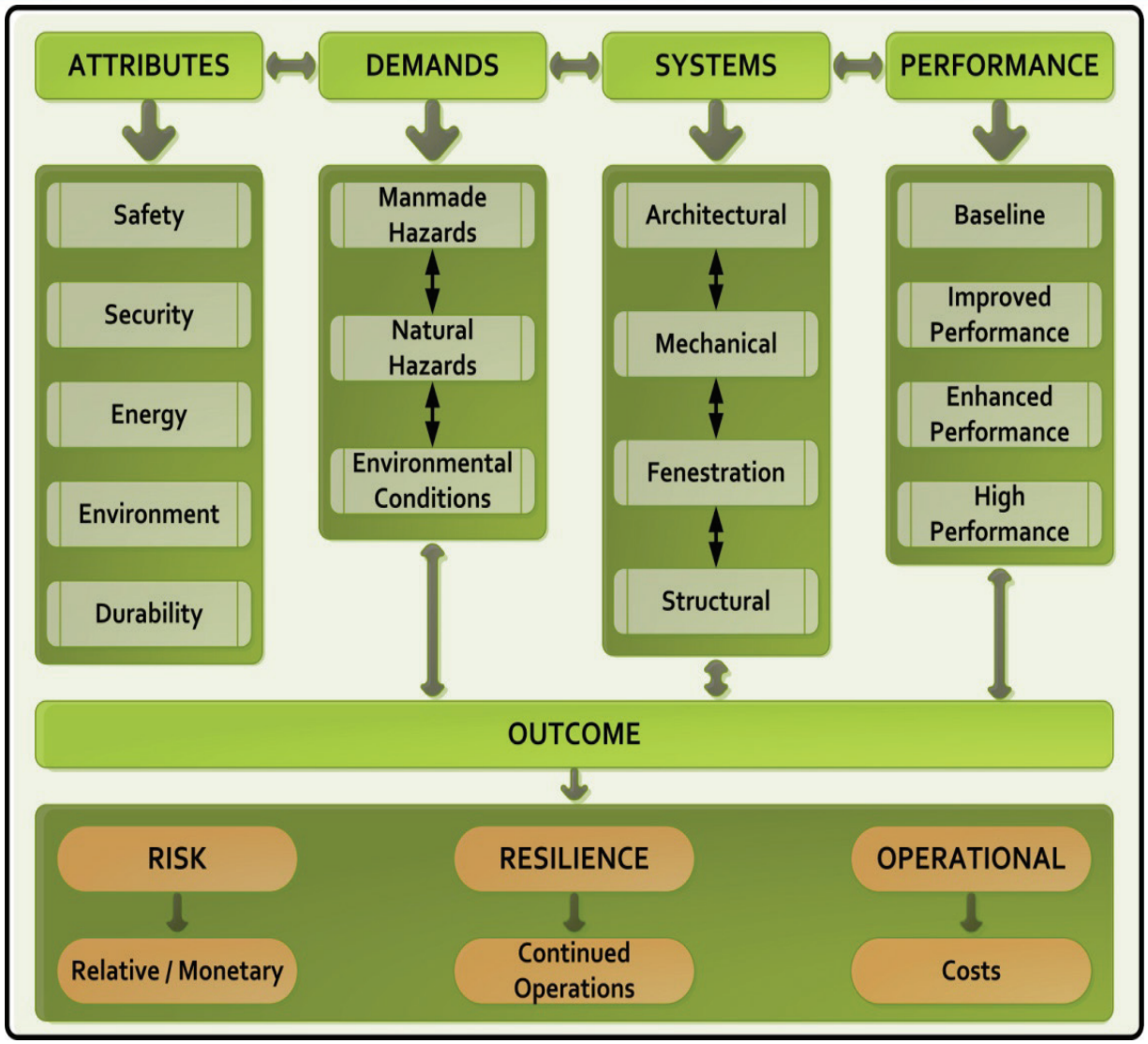
OPR Tool

- Five expert committees were formed to provide the performance and cost data.
- The OPR Tool is expected to be part of the ASTM E06.55.09 Standard
- The OPR Tool is being released for external review at: www.oprtool.org/demo



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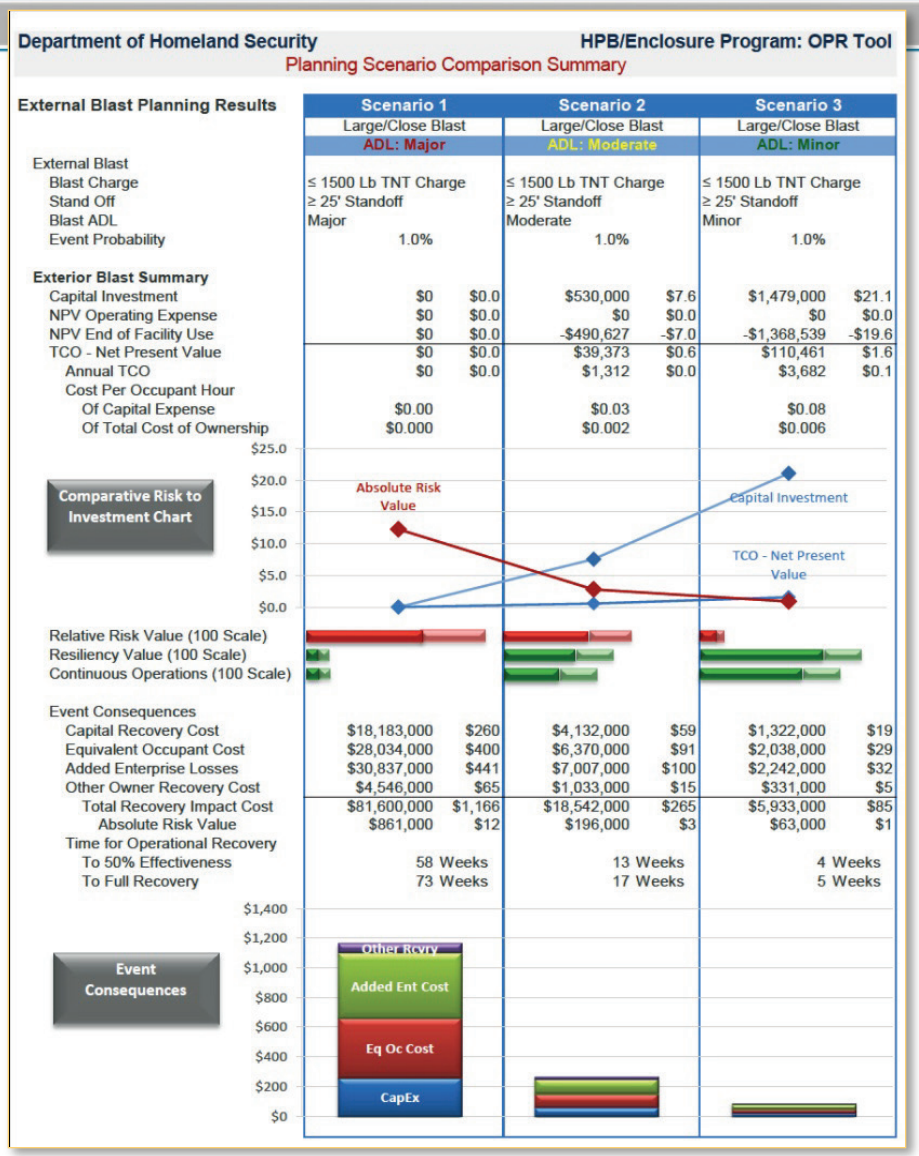
OPR Tool

- **OPR outputs** are based on analyzing multiple attributes simultaneously
- **OPR cost outcomes** rely on the consensus and knowledge of the technical committees
- The model is strictly **performance based** and does not identify prescriptive solutions



Department of Homeland Security — HPB/Enclosure Program: OPR Tool

Planning Scenario Comparison Summary

External Blast Planning Results	Scenario 1		Scenario 2		Scenario 3	
	Large/Close Blast		Large/Close Blast		Large/Close Blast	
	ADL: Major		ADL: Moderate		ADL: Minor	
External Blast						
Blast Charge	≤ 1500 Lb TNT Charge		≤ 1500 Lb TNT Charge		≤ 1500 Lb TNT Charge	
Stand Off	≥ 25' Standoff		≥ 25' Standoff		≥ 25' Standoff	
Blast ADL	Major		Moderate		Minor	
Event Probability	1.0%		1.0%		1.0%	
Exterior Blast Summary						
Capital Investment	$0	$0.0	$530,000	$7.6	$1,479,000	$21.1
NPV Operating Expense	$0	$0.0	$0	$0.0	$0	$0.0
NPV End of Facility Use	$0	$0.0	-$490,627	-$7.0	-$1,368,539	-$19.6
TCO - Net Present Value	$0	$0.0	$39,373	$0.6	$110,461	$1.6
Annual TCO	$0	$0.0	$1,312	$0.0	$3,682	$0.1
Cost Per Occupant Hour						
Of Capital Expense	$0.00		$0.03		$0.08	
Of Total Cost of Ownership	$0.000		$0.002		$0.006	
Relative Risk Value (100 Scale)						
Resiliency Value (100 Scale)						
Continuous Operations (100 Scale)						
Event Consequences						
Capital Recovery Cost	$18,183,000	$260	$4,132,000	$59	$1,322,000	$19
Equivalent Occupant Cost	$28,034,000	$400	$6,370,000	$91	$2,038,000	$29
Added Enterprise Losses	$30,837,000	$441	$7,007,000	$100	$2,242,000	$32
Other Owner Recovery Cost	$4,546,000	$65	$1,033,000	$15	$331,000	$5
Total Recovery Impact Cost	$81,600,000	$1,166	$18,542,000	$265	$5,933,000	$85
Absolute Risk Value	$861,000	$12	$196,000	$3	$63,000	$1
Time for Operational Recovery						
To 50% Effectiveness	58 Weeks		13 Weeks		4 Weeks	
To Full Recovery	73 Weeks		17 Weeks		5 Weeks	

Comparative Risk to Investment Chart

$25.0 $20.0 $15.0 $10.0 $5.0 $0.0

Absolute Risk Value

Capital Investment

TCO - Net Present Value

Event Consequences

$1,400 $1,200 $1,000 $800 $600 $400 $200 $0

Other Rcvry

Added Ent Cost

Eq Oc Cost

CapEx

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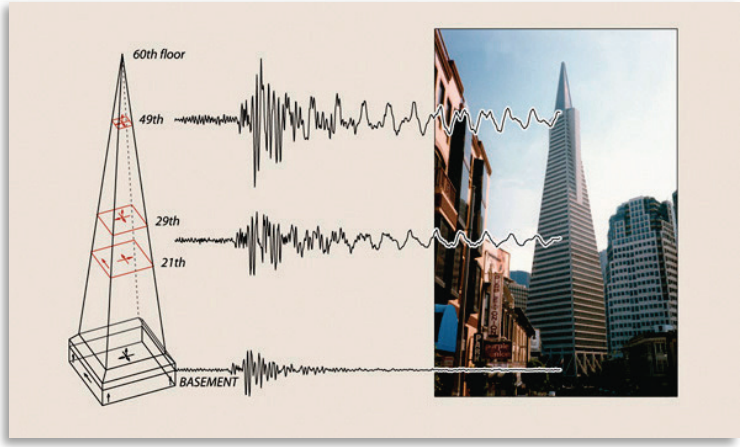
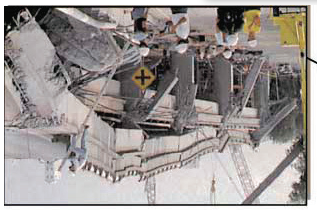
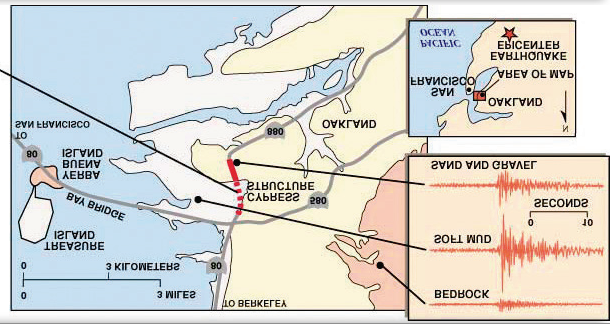
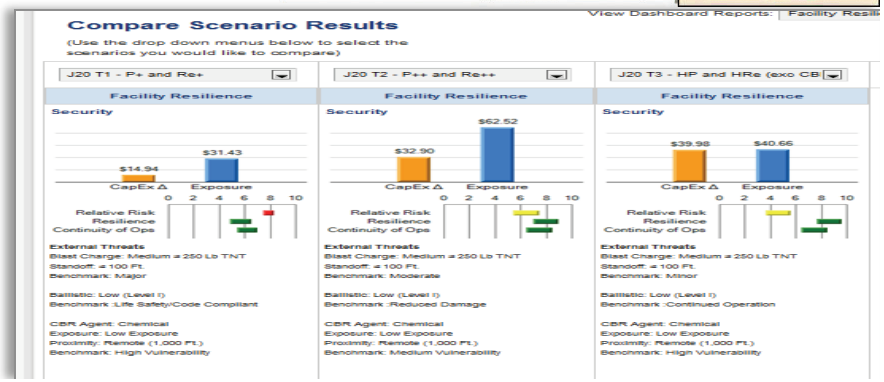
OPR and EQ Related Issues

- Demand levels for varying EQ intensities
- Range of seismic performance levels covers four categories: Baseline (code minimum) to High Performance (continued operations)
- Exposure estimated for each performance level (measured in $$$)
- Relative risk
- Resiliency measure
- Ranges of envelope system types considered as they relate to seismic demands and seismic performance
- Uncertainties of cost and performance estimates are covered
- Interactions with other hazards (blast, wind, fire, etc.) and attributes (architectural, environmental, energy, etc.) are built in









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OPR Tool Website

PROJECT REQUIREMENTS REPORT

Project Information

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

Life Cycle Baseline Information

Use Period (TCO)	25 Years	Unit Cost		Occupancy Information	
		Energy Cost ($/KBtu)	$0.05	Census (GSF/Occupant)	150
Service Life (Years)		Service & Maintain Cost ($/GSF)	$0.25	Operation (Hours/Week)	40
Whole-building	50 Years	Annual Escalation Trend		Operation (Weeks/Year)	51
Exterior Wall	30 Years	Energy	5.0%	Indirect Project Cost	
Exterior Glazing	20 Years	Service & Maintain	5.0%	Construct	10%
Roof System	15 Years	Present Value Discount Rate	5.0%	Design, Test, Commission	12%

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

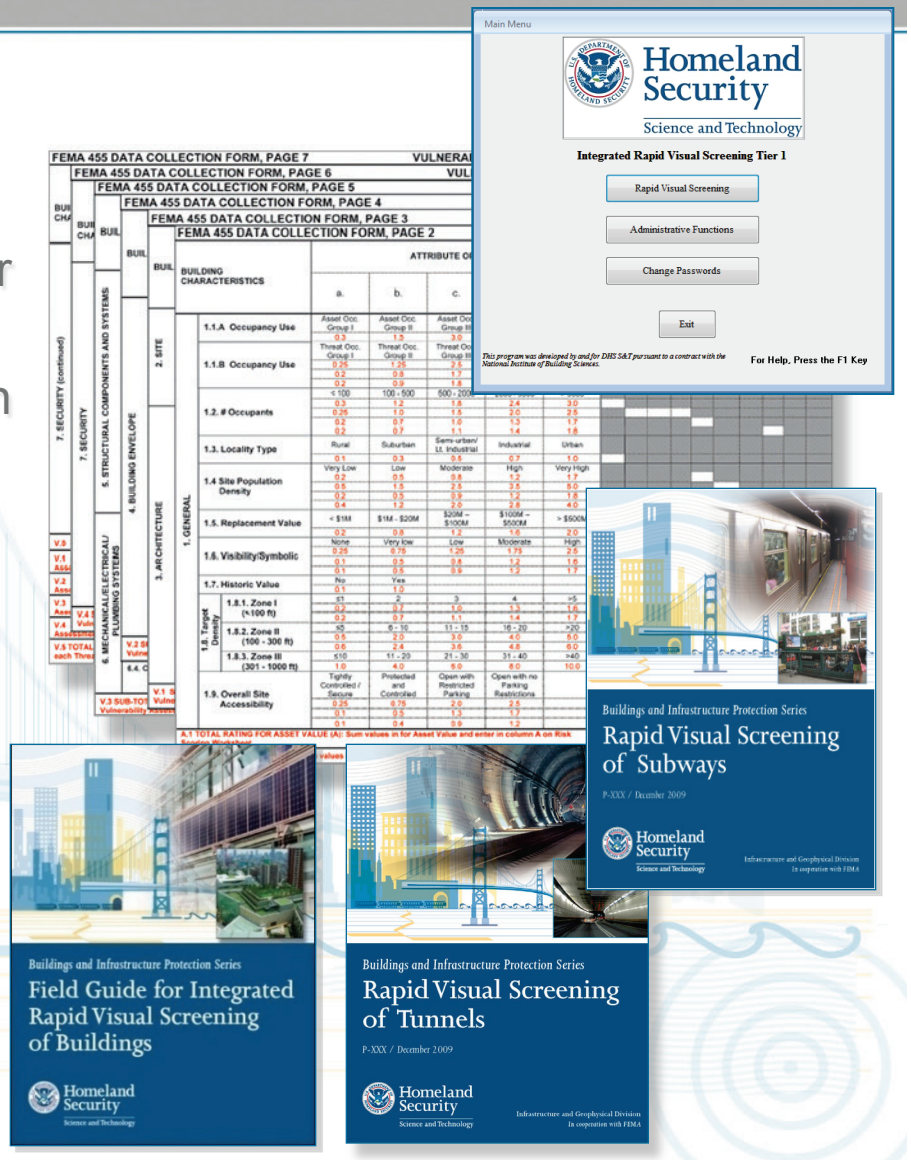
Basis of Earthquake Design: 10% probability of exceedance in 50 Years.

Performance Standard(s)

IBC-2009
ASCE 7-05
ASCE 41-06
NEHRP Recommended Provisions for Seismic Regulations
FEMA E-74
ASTM E 2026

IRVS Buildings, Subways, and Tunnels

- A rapid (3 hours instead of 3 days) but comprehensive group of assessment tools
- Designed to assess risk and resilience for buildings, mass transit, and tunnels
- Evaluates risk related to all hazards, such as explosives; chemical, biological, and radiological events; and earthquakes, floods, high winds, and fires
- Expected to save millions of dollars to federal, state, local governments, and private sector
- Computes risk and resilience providing scores and ratings



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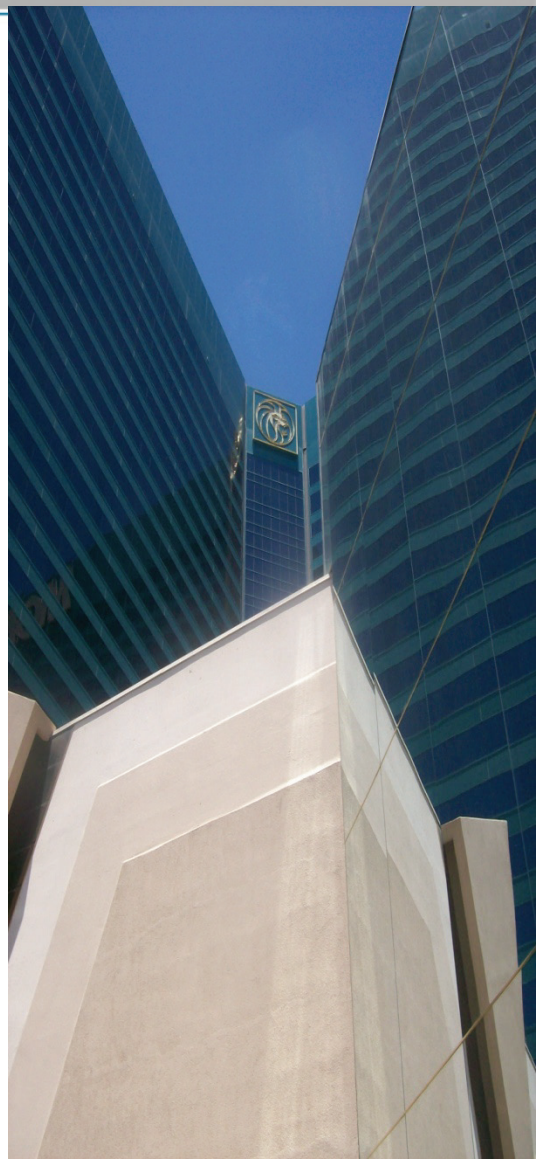
IRVS Dictionaries

Consequences	Threat/Hazard	Vulnerability	
Buildings			
• Locality Type • Number of Occupants • Replacement Value • On Historic Registry • Business Continuity • Physical Loss Impact	• Occupancy Use • Number of Occupants • Site Population Density • Visibility/Symbolic Value • Target Density • Overall Site Accessibility • Target Potential	• Site • Architecture • Building Envelope • Structural Components and Systems • Mechanical/Electrical/ Plumbing (MEP) Systems • Security	
Mass Transit Stations			
• Number of Tracks • Number of Station Levels • Impact of Physical Loss • Number of Riders per day • Commercial, and Industrial Facilities • Adjacent Stations • Adjacent Critical Infrastructure • Social Effect of Loss • Replacement Value • Operational Redundancy • Function Criticality	• Visibility • Historic Nature/Landmark Status • Number of Riders per day • Previous Threats • Accessibility • Elevation • Site Locality • Adjacent Critical Infrastructure • Function Criticality • Storage Use	• Site • Architectural • Structural • Ventilation (including HVAC) • Fire Systems • Operations (including power supply, lighting, etc.) • Non-Structural	
Tunnels			
• Impact of Physical Loss • Number of Vehicles/Trains per Day • Nearby Commercial Facilities • Adjacent Critical Infrastructure • Social Effect of Loss • Replacement Value • Operational Redundancy • Function Criticality	• Visibility • Historic Nature • Number of Vehicles/Trains per day • Previous Threats • Accessibility • Elevation • Site Locality • Adjacent Critical Infrastructure • Function Criticality	• Site • Architectural • Structural • Ventilation (including HVAC) • Fire Systems • Operations (including power supply, lighting, etc.) • Non-Structural • Physical Security	

IRVS Analytical Background

- **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 x T x V**
- **Resilience:** computes robustness (R1), resourcefulness (R2), and recovery (R3) using information, such as hardening, training, and redundancies. Resilience is calculated as follows: **Resilience = R1 x R2 x R3**



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IRVS and EQ Related Issues

- Two specific seismic scenarios are considered:
  - Ground shaking
  - Ground failure
- Consider important factors that affect seismic threats and building vulnerabilities:
  - Seismic zone, soil/foundations, building types, irregularities, seismic anchoring, etc.
- Consider potential interactions between seismic vulnerabilities and vulnerabilities to other hazards (blast, wind, fire)
- Consider a fire scenario resulting from seismic event

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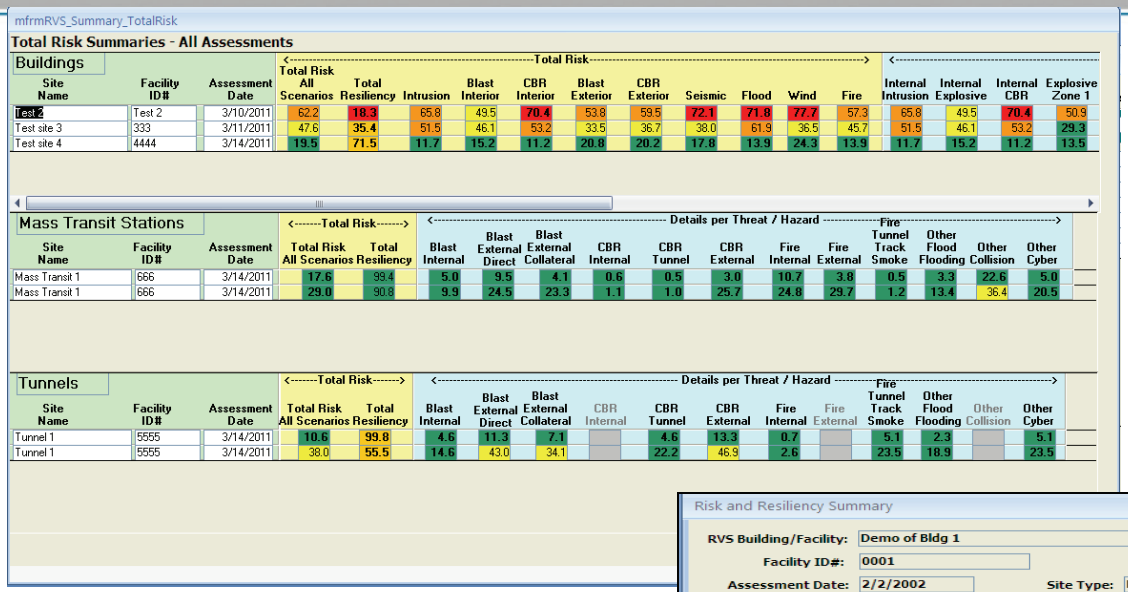
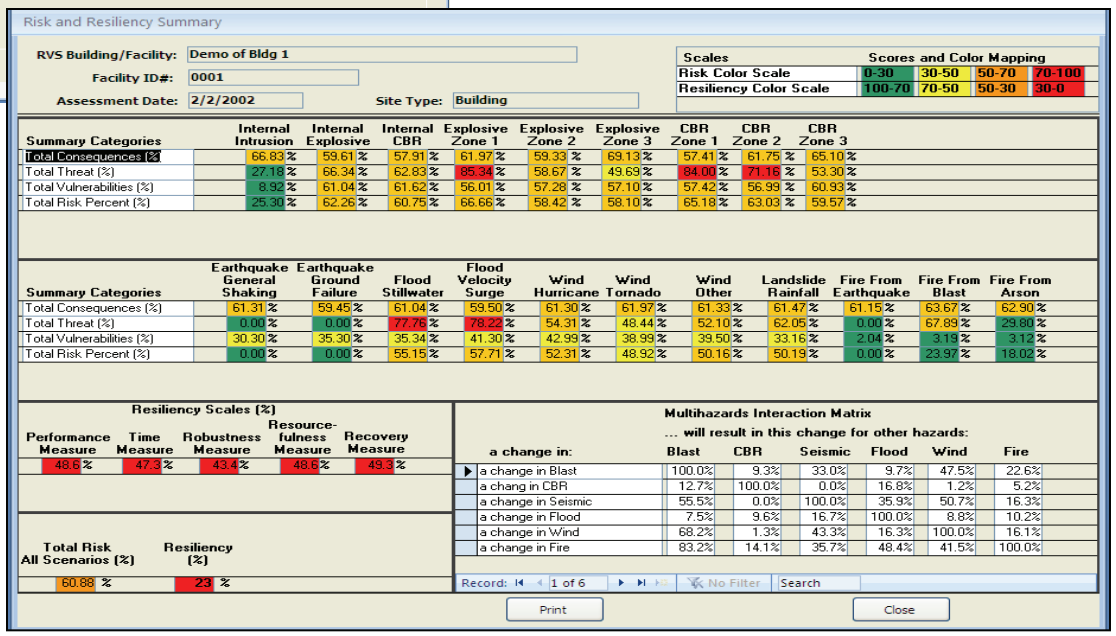
IRVS Tool - Scores



Comprehensive scores for mass transit, tunnels, and buildings

Scores for a single building based on 20 hazard scenarios



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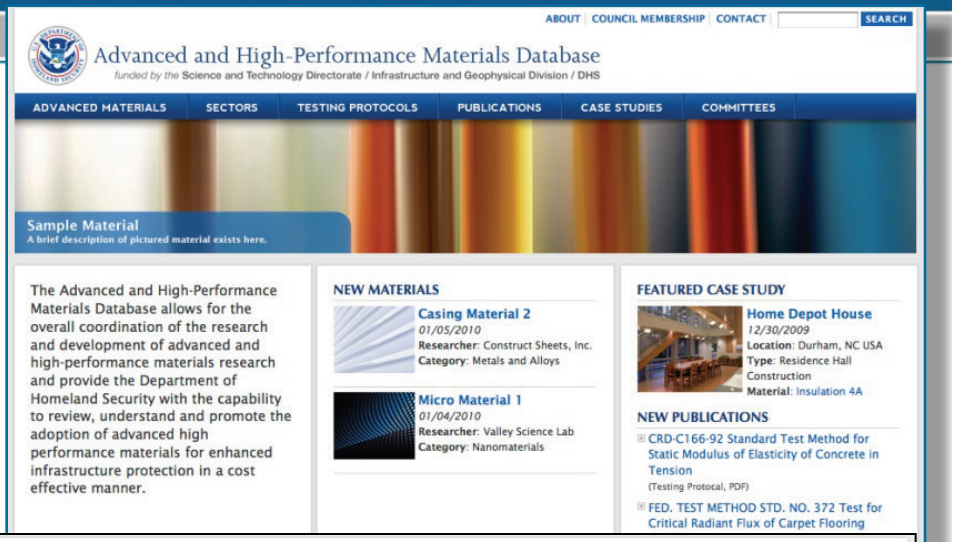
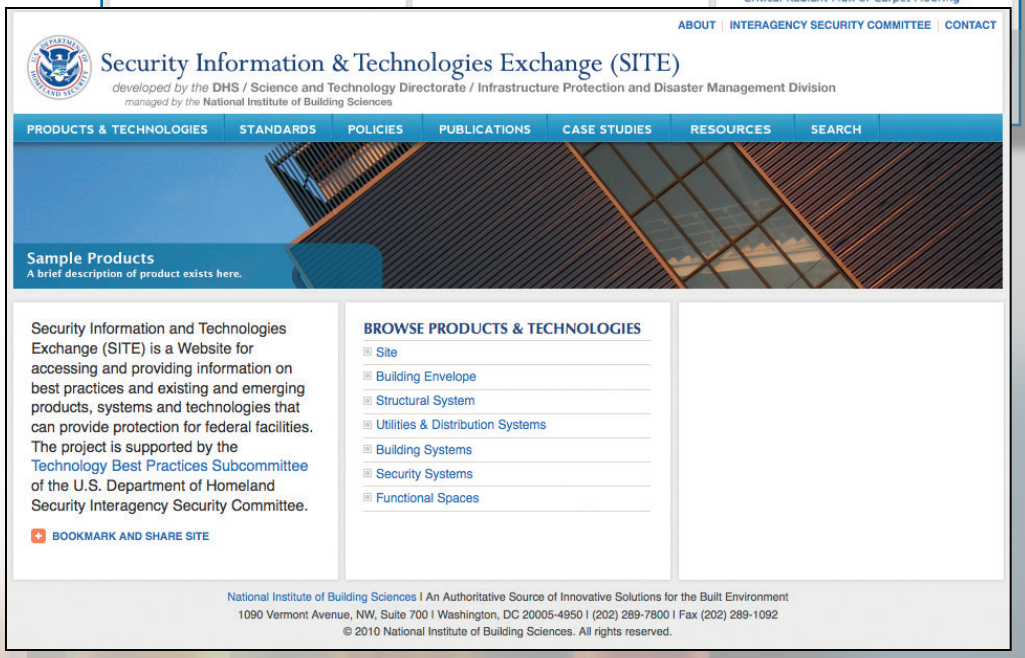
HP Materials Databases

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

- **SITE**, a web-based database for security products meeting ISC, VA, and DOD requirements





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BIPS Publications

Publications

- Aging Infrastructure
- IRVS Manuals
- Update of FEMA 426
- Update of FEMA 428
- Preventing Structures from Collapsing
- Designing for a Resilient America
- Security, Energy, and the Environment

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EQ Framework Used in the IVRS and OPR

- IBC-2009, "2009 International Building Code"
- ASCE 7-05, "Minimum Design Loads for Buildings and Other Structures"
- ASCE 41-06, "Seismic Rehabilitation of Existing Buildings"
- NEHRP Recommended Provisions for Seismic Regulations
- FEMA E-74, "Reducing the Risks of Nonstructural Earthquake Damage"
- ASTME2026, "Standard Guide for Seismic Risk Assessment of Buildings"

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High Performance Concrete

- Working with the Association of Cement and Concrete to identify and advance effective methods of promoting the construction and commercialization of reliable UHPC materials in the U.S. construction market
- Working with ERDC, ORNL, Sandia, Georgia Tech, MIT, UConn in advancing the performance of UHPC
- Final product is expected to exhibit major performance in:
  - Ultra high strength, ductility, flexibility and toughness, impact resistance, dimensional stability Ability to construct thin sections and complex structural forms
  - Durability - increased usage life
  - Impermeability – freeze/thaw resistance, corrosion resistance, abrasion resistance, and aggressive environment and chemical resistance

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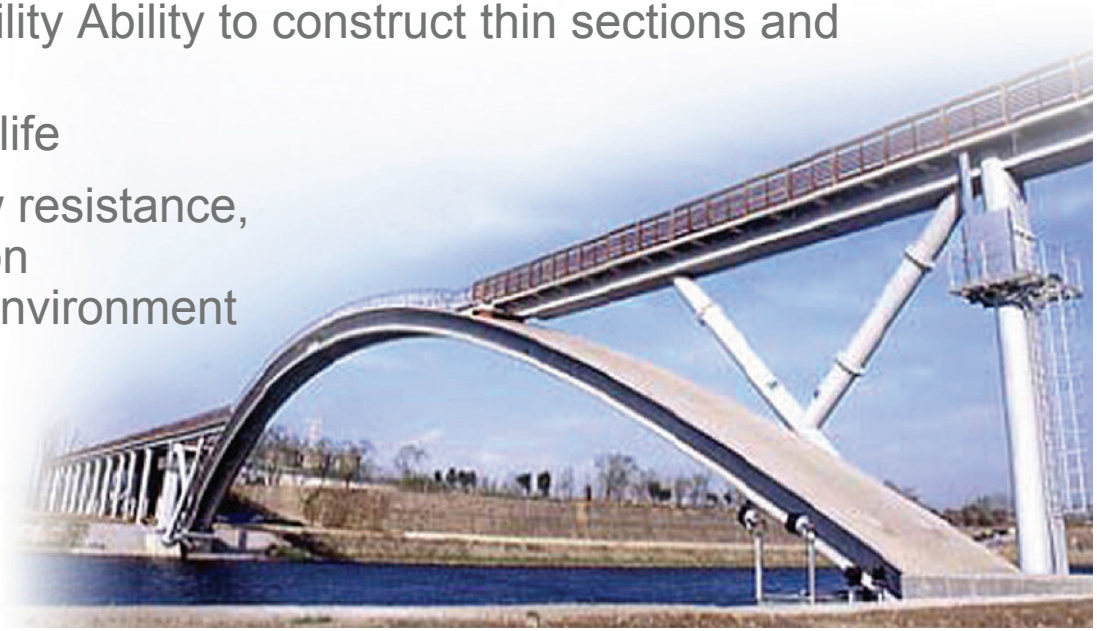
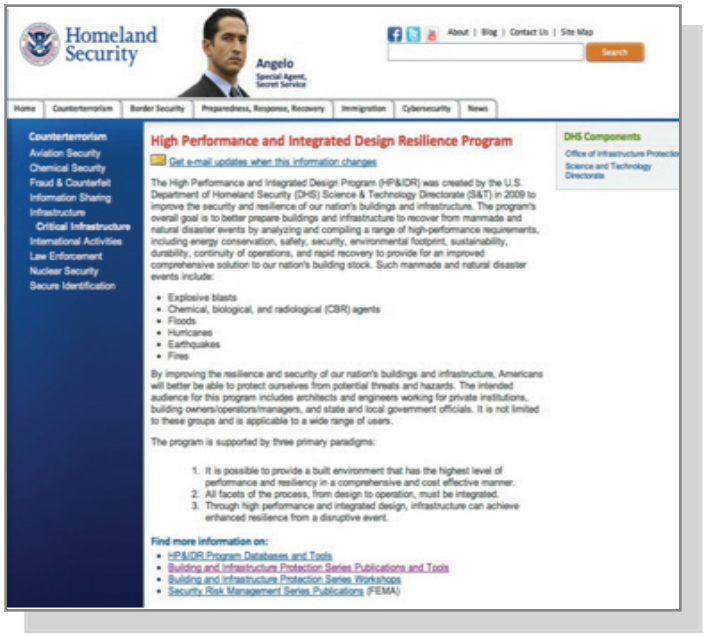


Building Stabilization Project

- An overall strategy that serves for the stabilization of buildings after an IED attack including
- To enhance the protection of first responders during search and rescue operations from events such as an explosives, wind, flood, fire, or general building collapse
- Major deliverables include monitoring and sensing techniques; **post disaster analysis tool (PDAT)**; field guide for shoring techniques; and BIM First Responders Standard
- In terms of seismic, the PDAT useful information for first responders, such as building types, potential failure modes, instability issues, fire potential, soil conditions, etc.

HP Resilience Website

Main Link:
http://www.dhs.gov/files/programs/high-performance-integrated-design-program.shtm



- **It currently holds:**
  - 4 demos, 2 software tools
  - 7 DHS S&T IDD publications and 20 Risk Management Series publications
  - 7 groundbreaking workshops

The website will be complete by the end of 2011

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Questions?

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http://www.dhs.gov/files/programs/high-performance-integrated-design-program.shtm