Bridge Security

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Chair--AASHTO Technical Committee on Bridge Security (T-1)

Bridge Engineering Course
University at Buffalo

Nov 16, 2009

Outline

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- Background
- Owner's Perspective
- Activities and Strategies
  - Vulnerability assessments
  - Mitigation
  - Design for Blast
- Recent Developments
  - T-1 Activities
  - New design approaches, Multi hazard

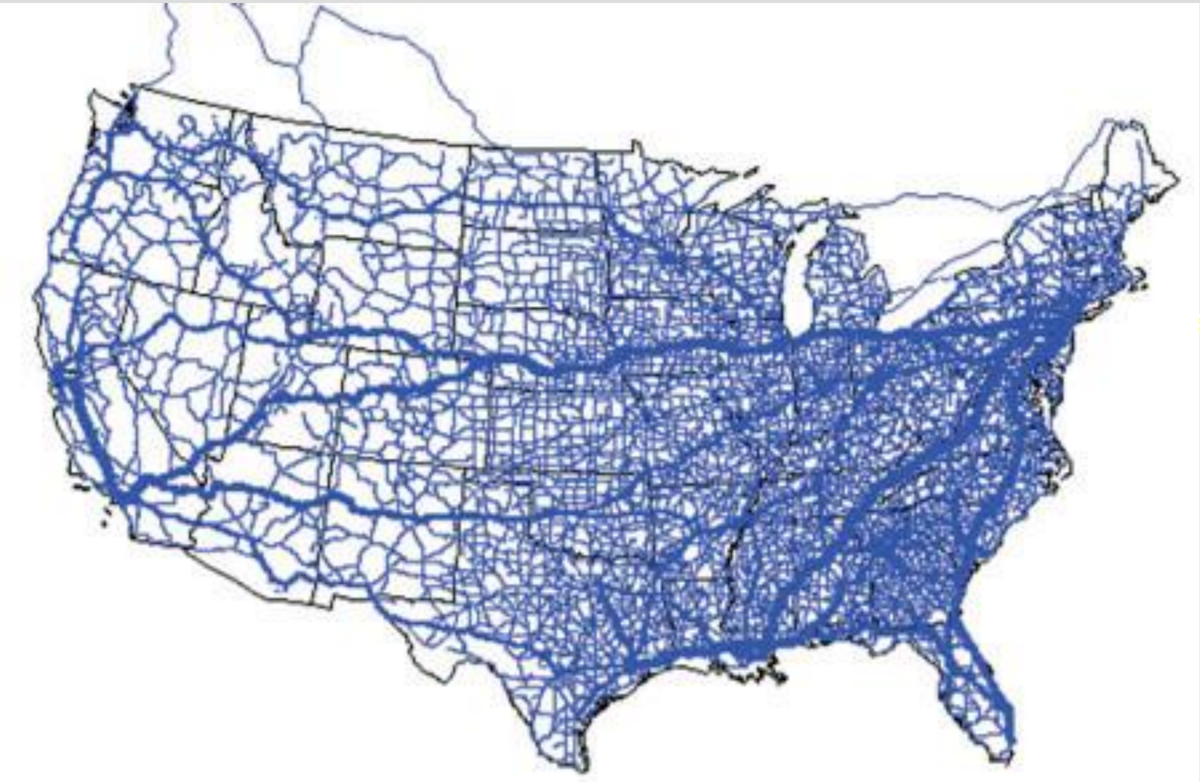
Acknowledgement to:

Federal Highway Admin.
US Army Corps of Engineers
Transportation Security Admin

Background

Transportation is Vital to Nation's Economy

- $5.4 billion/yr in freight shipped on roads
- 89% of all US freight by value shipped on roads
- 8.2 million Americans employed in surface transportation



Projected Truck Traffic Volumes on US Highway Network in 2020

Transportation System Has Vulnerabilities

- Most of system is robust
- Busy travel "bottlenecks" are targets
- 1,000 critical bridges

- *Potential $10 billion impact from losing critical bridge or tunnel*

Are Bridges and Tunnels Really Targets?

Terrorists Goals

- Make a high visibility statement
- Obtain publicity for their cause
- Destroy a landmark or critical asset
- Exert political pressure
- Advance a religious imperative
- Seek vengeance
- Create public fear and panic
- Maximize casualties
- Disrupt traffic and main or emergency routes

Source: Transportation Security Administration

Are Bridges and Tunnels Really Targets?

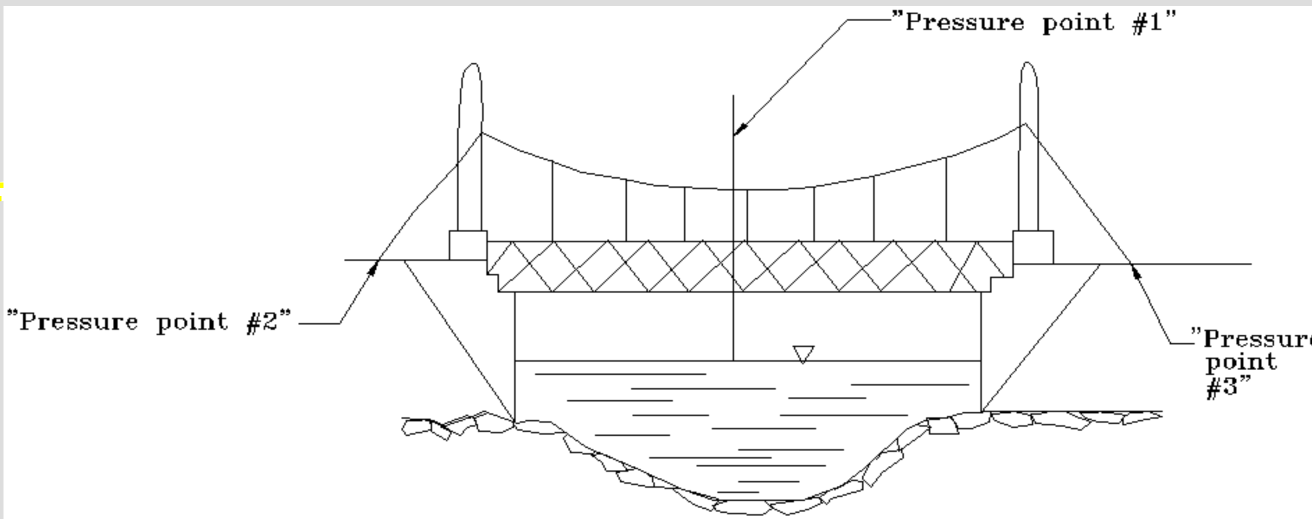
Bridges and tunnels are attractive terrorist targets due to:

- Economic importance to traffic and commerce
- Symbolism (i.e. Golden Gate Bridge, Lincoln Tunnel, etc.)
- Cost/time for replacement
- Public impact from an attack
- Relatively high vulnerability (susceptibility and structurally)

Source: Transportation Security Administration

Are Bridges and Tunnels Really Targets?

<u>Encyclopedia of Afghan Resistance</u>



"When you destroy large bridges by explosives, loading the middle part will destroy the netted area (the roadway), the explosives should be combined with others placed at the two pressure points. This will destroy the bridge." *

*Enclyclopedia of Afghan Resistance"

Intelligence Agencies Warn California of Bridge Threat

UC Berkley Engineering Professor claims Bay Bridge replacement "alarmingly vulnerable" to car bomb

Computer analysis shows that 200 pounds of explosives could cause catastrophic failure

FBI has "credible evidence" that terrorists are plotting a rush-hour attack on a bridge or bridges in California

www.nytimes.com
The New York Times ON THE WEB

Brooklyn Bridge Is Briefly Closed as New York Tightens Security

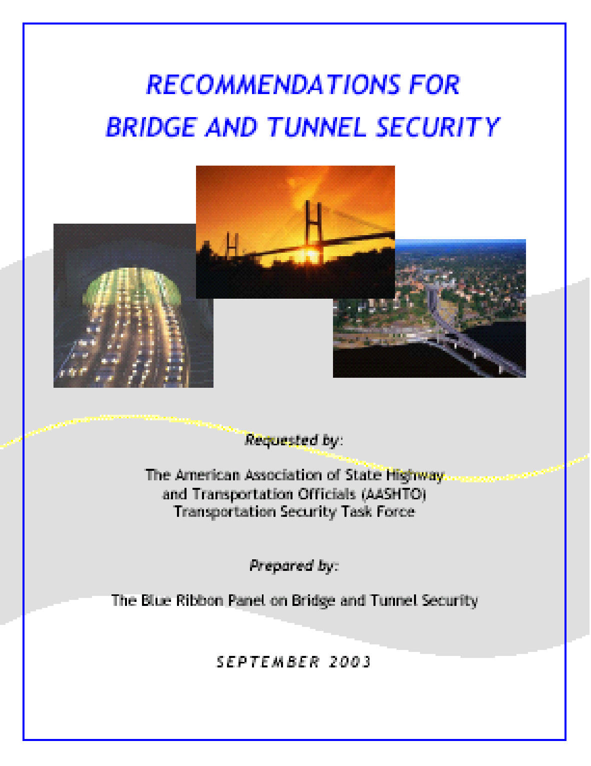
May 2002

The police began operating checkpoints at many of the city's major bridges and tunnels following a warning of vague and uncorroborated threats against both the Brooklyn bridge and the Statue of Liberty. Well into last night, officers were stopping any car or truck that they deemed suspicious, while police boats patrolled the waters under the Brooklyn and Manhattan Bridges and around Liberty Island. Police officials said that these checkpoints and patrols would continue indefinitely.

Bridges are subject to malicious attack

FHWA / AASHTO Blue Ribbon Panel
Overarching Recommendations

- Institutional
  - Interagency Coordination
  - outreach /communication strategies
  - clarification of Legal responsibility
- Fiscal
  - New funding
  - Funding Eligibility
- Technical
  - Engineered Solutions
  - Research and Development → Implementation


RECOMMENDATIONS FOR
BRIDGE AND TUNNEL SECURITY

Requested by:

The American Association of State Highway
and Transportation Officials (AASHTO)
Transportation Security Task Force

Prepared by:

The Blue Ribbon Panel on Bridge and Tunnel Security

SEPTEMBER 2003

AASHTO

organization of state transportation agencies

- Security is a key component of transportation safety
- Voice and resource for DOT’s to improve transportation security
  - All transportation modes
  - All aspects (operations, response, infrastructure….)

AASHTO Special Committee on Transportation Security and Emergency Management (SCOTSEM)

- Establish key role of transportation in homeland security
- Shape policy, legislation, funding, regulatory development
- Promote research
- Awareness, education, Tech. assistance

security.transportation.org

AASHTO Bridge
Technical Committee on Security: T-1

- Blue Ribbon Panel Recommendation
- Established by Hwy Subcommittee on Bridges and Structures (HSCOBS) in 2003
- Membership (2009)
  - 9 State DOT reps: (CA, GA, LA, MI, MO, NY, PA, VA, WA)
  - 2 FHWA reps.
  - 1 Authority (GGBA)

AASHTO T-1 Technical Committee

- Review / promote transportation security technical research
- Provide guidance to implement:
  - Design Specifications
  - Risk management methodologies
  - Strategies to improve safety / security
- Manage security sensitive information

What are Owner agencies doing about Bridge Security?

Bridge Security Strategies

Strategies for “High Value” Bridges

- Comprehensive, multi-faceted
  - Surveillance
  - Access denial
  - Hardening

- **Suspension Bridge Suspender Rope Protection**

Structural Hardening for Cable Elements

- **Suspension Bridge Main Cable Protection**

State DOT Owner's Perspective

Bridge Security Issues

- Individual bridges and Bridge networks
- Safety
  - Structural failure prevention
  - Operations
- Mobility
  - response
- Bridges subject to explosions (blast)
  - Vulnerability?
  - Remedies?
  - priority?

Our bridges do get 'attacked'

Major Bridge Failure Events

- Multiple fatalities
- Long recovery times
- Very high recovery costs
- Significant adverse impacts on economy, mobility

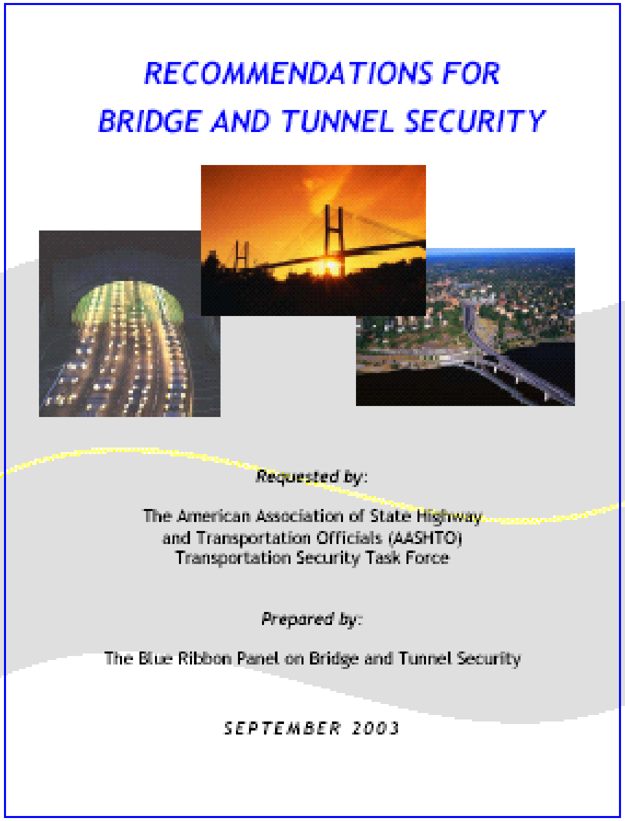
Bridge Security Strategies

Major Activities by State DOT's

- Vulnerability Assessments:
- Practical, Cost effective countermeasures
- Response Plans

Vunlerability Assessments

- Risk Assessment Method recommended by the BRP
- A step by step process to prioritize security improvements



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Risk Assessment Method

$$R = O \times V \times I$$

- R is the Risk factor
- O is the Occurrence factor
- V is the Vulnerability factor
- I is the Importance factor

The equation reflects an approach similar to that for assessing seismic and other natural or accidental hazards.

Risk Assessment Method

R = O x V x I

- Risk Factor: value used for comparison
- Threat specific
  - Must assess for any credible threat

Risk Assessment Method

$$\mathbf{R = O \times V \times I}$$

- Occurrence: reflects likelihood the bridge (or component) will be attacked
- Occurrence attributes: Attractiveness as a target, Security level against attack, Visibility as a target, Publicity if attacked, Prior threats or attacks
- Input comes from law enforcement and security experts

Risk Assessment Method

$$R = O \times V \times I$$

- Vulnerability: Reflects the degree of damage to the bridge, or component from an attack
- Vulnerability attributes: expected damage, expected downtime, expected number of casualties
- Input to value comes from engineering analysis and expertise

Risk Assessment Method

$$\mathbf{R = O \times V \times I}$$

- Importance: Reflects the consequence of its loss, independent of the hazard that might damage it.
- Importance attributes: historical value, evacuation route, regional economy, cost and time to replace, revenue loss, critical utilities, exposed population, military value
- Input to value comes from owners, operators, users, regional government

Steps to Prioritize Security Improvements

Six Steps From BRP Report "Design Process"

1) **Threat** → **R=OxVxI (consequence)**
Component → **R=OxVxI (consequence)**

2) **Accept or Mitigate? (owner decides)**

3) **Mitigate** → **Security control of access**
or
Mitigate → **Engineered solution – harden, etc.**

4) **Estimate cost of mitigation**

5) **Recalculate R=OxVxI (with revised O or V)**

6) **Reduced R → Cost/benefit → Prioritize Mitigation**

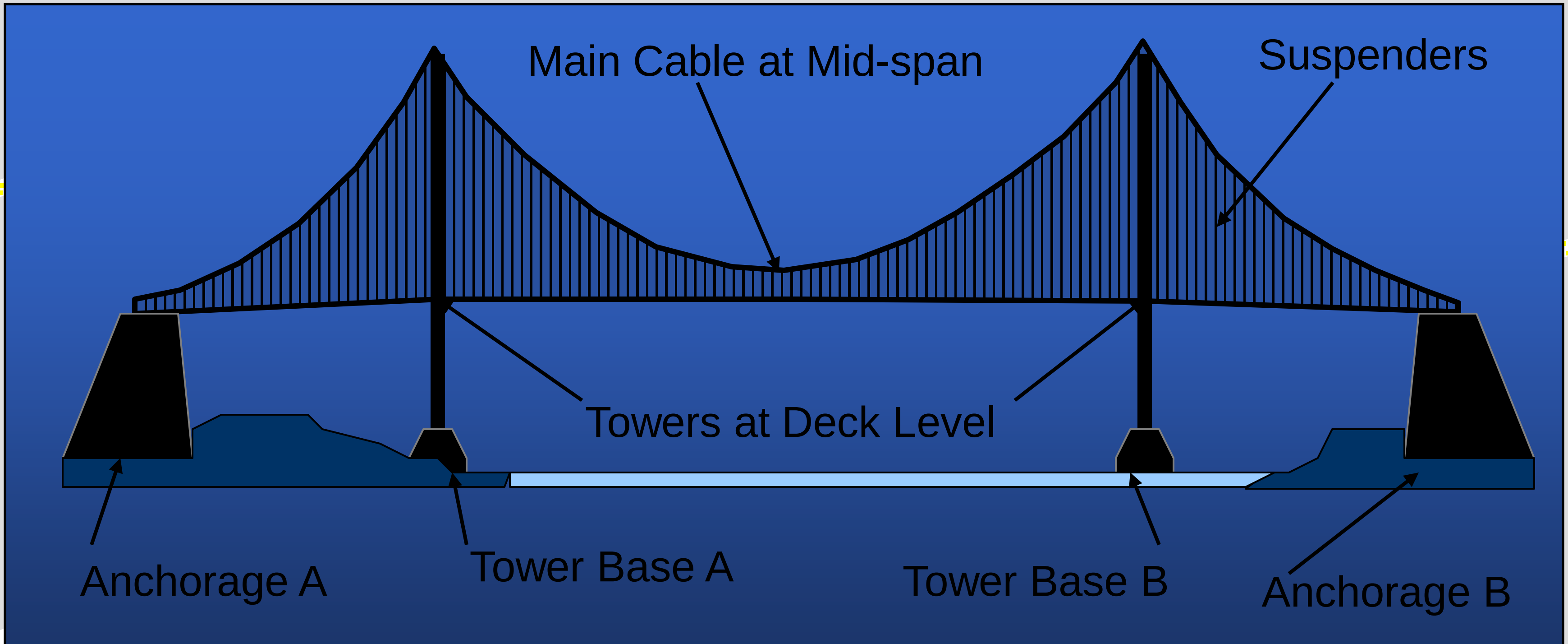
Steps to Prioritize Security Improvements

Define the Threats

- Precision demolition attack (strategically placed explosives, shape charges, cutting tools)
- Conventional Explosives (delivery by pedestrian, vehicle, water borne)
- Collision to structure (vehicle, water borne)
- Fire (fuel vehicle, fuel barge, incendiary device)

Steps to Prioritize Security Improvements

Critical/Vulnerable Components



(Example:Generic Bridge)

Steps to Prioritize Security Improvements

Threat Definition

i = 1 to 17

- **Suspension Bridge**
  - **Tower Base A**
    - Pedestrian
    - Water Borne
    - Land Borne
  - **Tower Base B**
    - Pedestrian
    - Water Borne
    - Land Borne
  - **Deck Level at Towers**
    - Pedestrian
    - Vehicle
  - **Anchorage A**
    - Pedestrian
    - Vehicle
  - **Anchorage B**
    - Pedestrian
    - Vehicle
  - **Main Cable Mid-span**
    - Pedestrian
    - Vehicle
  - **Suspenders**
    - Cable Pedestrian
    - Vehicle
    - Socket Pedestrian

Steps to Prioritize Security Improvements

Occurrence Value (Vulnerability Value Similar)

- <u>Computed for each threat</u>:

Suspension Bridge

Tower Base A

Land Borne

- Weighted sum of utility values:

$$OF_i = \sum_{j=1}^{5} x_j w_j$$

- Occurrence Attributes mapped to utility values
  - Access for attack
  - Security against attack
  - Visibility as a target
  - Publicity if attacked
  - Past threats/attacks

Steps to Prioritize Security Improvements

Importance Value

- Computed once for the facility
- Weighted sum of utility values:

$$IF = \sum_{j=1}^{9} x_j w_j$$

- Attributes mapped to utility values
  - Historical/symbolic importance
  - Replacement value
  - Use as evacuation route
  - Importance to regional economy
  - Importance to transportation network
  - Annual revenue
  - Attached utilities
  - Use as military route
  - Exposed population

Steps to Prioritize Security Improvements

$$\mathbf{R = O \times V \times I}$$

Bridge Facility Risk Score

$$= \sum_{i}^{n} [OF_i \times VF_i] \times IF$$

- OF_i or VF_i is a weighted factor summed over all the attributes of O and V for each critical component (*i*) in the bridge, or for I, the bridge as a whole
- The bridge facility score is a sum over all (n) critical bridge components (*i*)

Steps to Prioritize Security Mitigations

Methods to reduce threats (Occurrence):

- Establish Secure Perimeter
- Surveillance, Intrusion Detection & Enforcement
- Visible Security Presence
- Minimize Time on Target

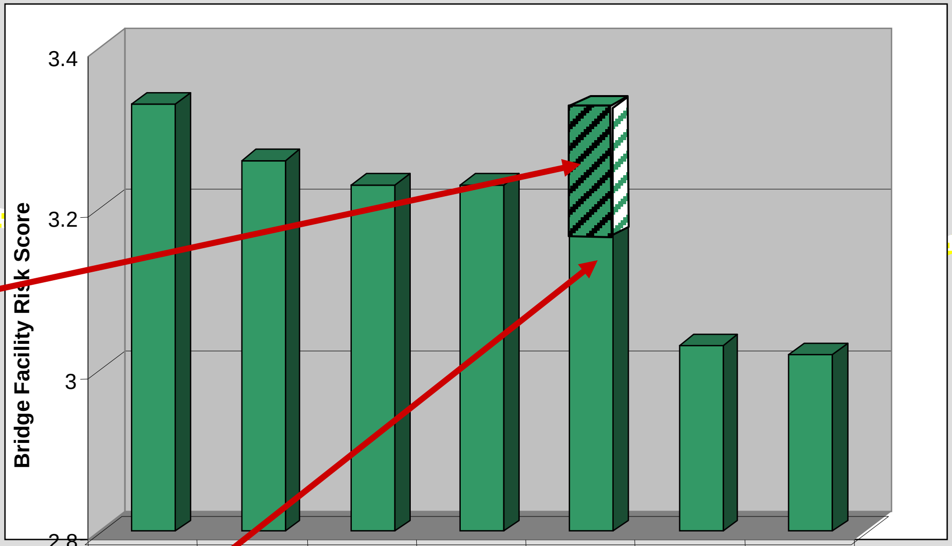
Steps to Prioritize Security Mitigations

Mitigating Consequences (Vulnerability):

- Create Standoff Distance
- Add design Redundancy
- Harden/Strengthen Structural Elements
- Develop An Accelerated Response And Recovery Plan

Steps to Prioritize Security Improvements

Post-Mitigation Risk Scores



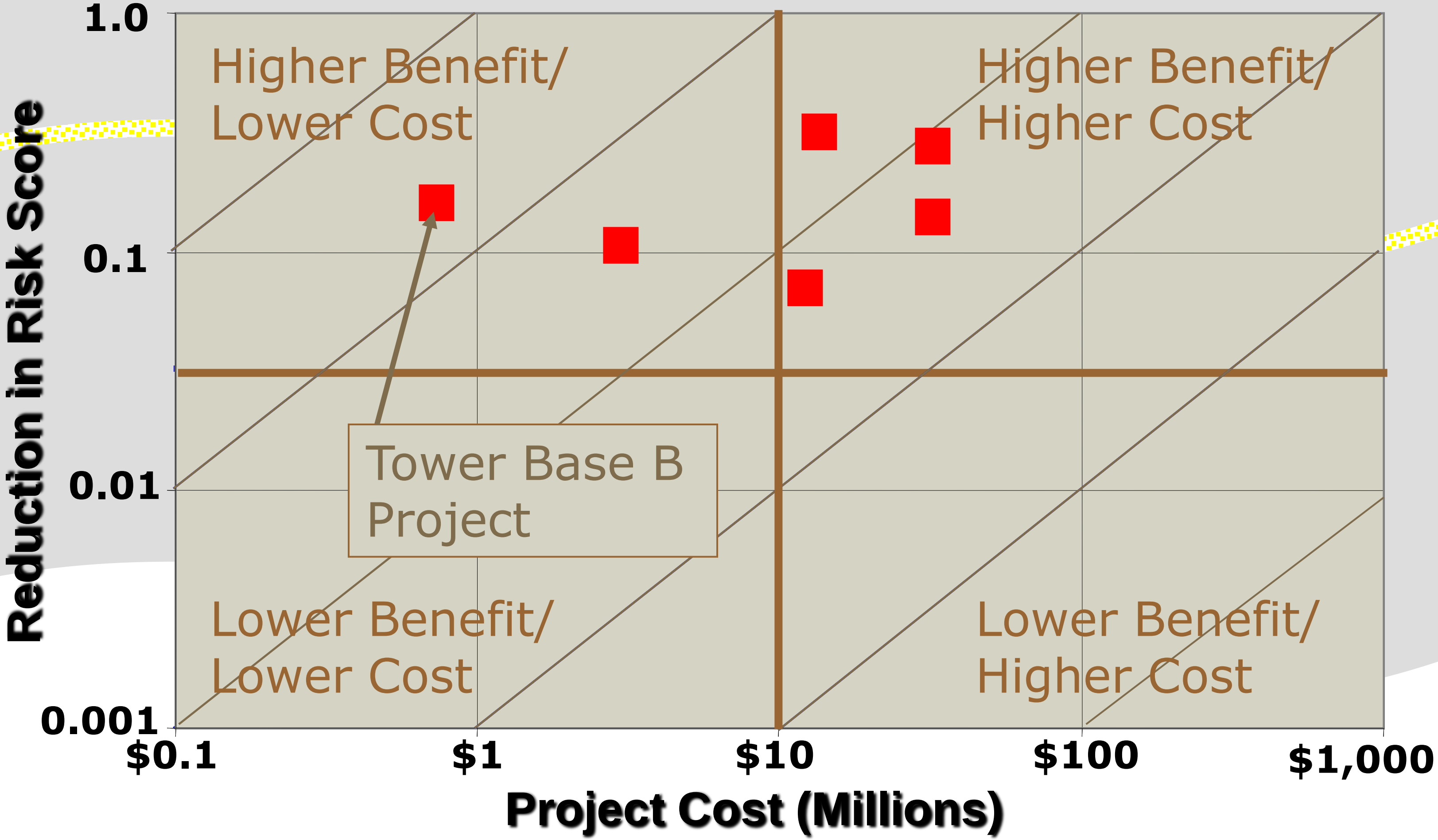
Tower Base B

0.16 Reduction in Risk Score for Tower Base B Mitigation Project

Mitigation Project	Cost ($1000)	Risk = OFxVFxIF
Tower Base B	750	3.17
Anchorage B	2,840	3.23
Anchorage A	2,840	3.23
Suspenders	12,360	3.26
Tower Base A	13,940	3.02
Deck Level at Towers	30,870	3.03

Steps to Prioritize Security Improvements

Benefit/Cost Comparison To Prioritize Projects



Bridge network vulnerability assessments

- R = O x V x I
- Inventory Screens
  - on Importance factors: AADT, detour length, functional Classification, replacement cost…
  - on Vulnerabilities to threats: bridge types, features crossed…
  - Develop priority list
- Mitigation analysis on higher priority bridges

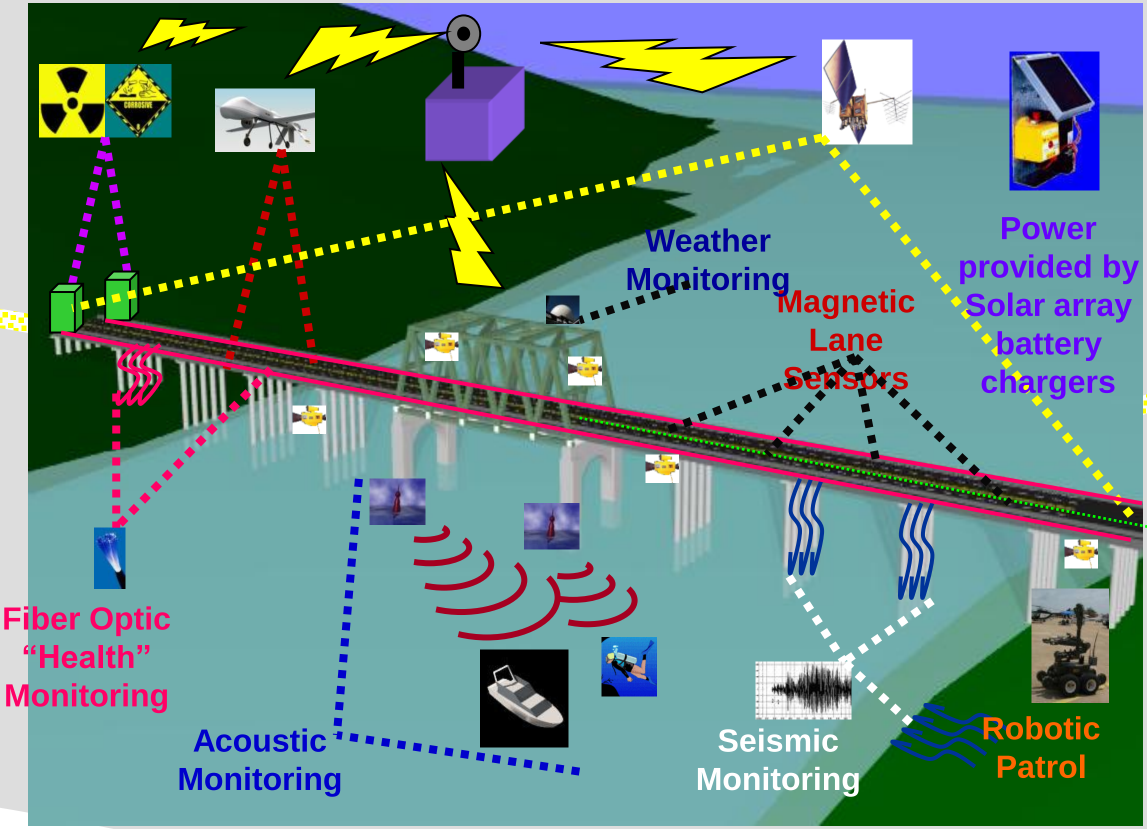
Vulnerability Assessment Objective is to Construct an Effective Defense

Four “D’s”

- ***Deter***
  - High visibility, make them know you’re watching
- ***Deny***
  - Physically limit access
- ***Detect***
  - Security, sensors, surveillance
- ***Defend***
  - Standoff, Structural Toughening

Critical Asset Protection

- **Deterrence & Detection:** E.g. alarms, CCTV, patrols, lighting
- **Defense:** E.g. barriers around approaches
- **(Re) Design:** E.g. protect key structural members from blast



"The smart bridge"

Practical Countermeasures for "Typical" Bridges

- Retrofits to increase redundancy.
- Limit approachability / standoff
- Increased pier protection for vehicle and vessel collision.
- Install crossovers for twin structures (network redundancy).
- Increased capacity and resiliency for new designs and rehabbed major structures

Vulnerability Assessment

Conclusions

- A model for assessing risk from natural disasters can be applied to risk from terrorist attacks
- No matter what mitigation measures are taken, risk from attack can never be eliminated ($R \neq 0$)

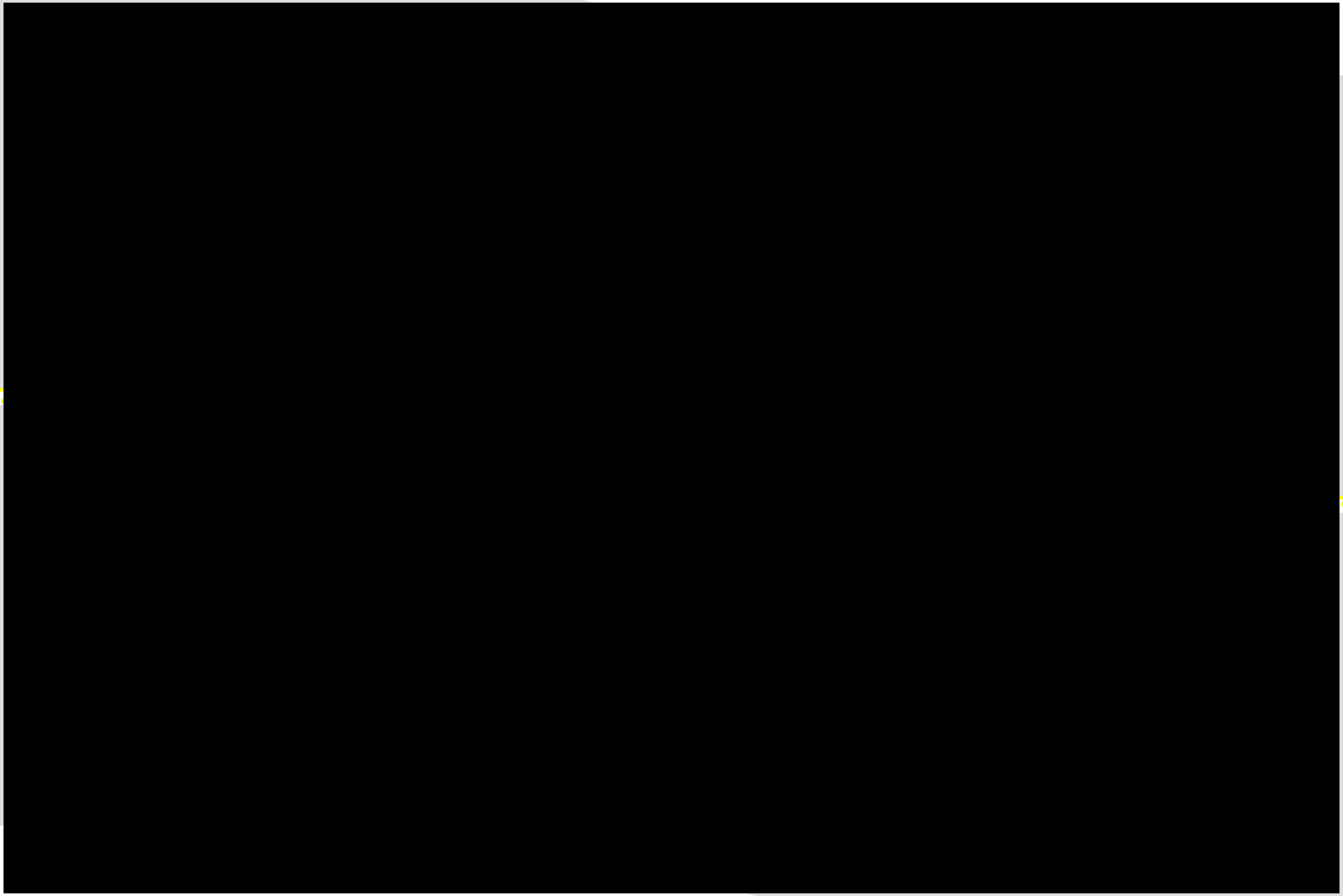
Vulnerability Assessment

Conclusions

- The amount of risk reduction from a mitigation project is a good measurement of benefit.
- Mitigation projects can be prioritized by comparing the cost and benefit (risk reduction) when available funds are limited.
- Engineered Solutions can cost-effectively reduce vulnerability.

Explosive Loadings

Vehicle Bomb Attack on Highway Overpass

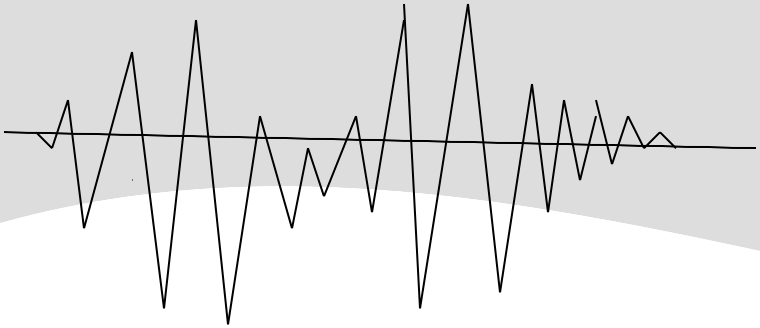


Design approach for bridges to resist blast

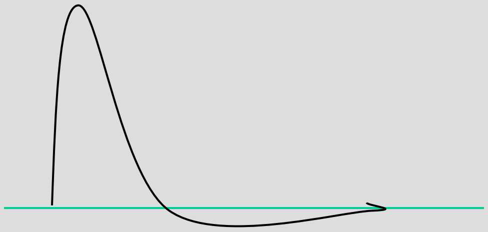
- Draw on knowledge and experience from seismic design and strengthening, i.e. how to sustain local damage without total collapse
- Use data, tools available from US Army Corps of Engineers
- Use information from building community re. blast and progressive collapse.

Earthquake vs. Explosion

- **Seismic Loading**
  - Long duration ground shaking



- **Blast Loading**
  - Short duration
  - High amplitude
  - Above ground pressure pulse



Earthquake vs. Explosion

Earthquake

Cyclic, Inertial Loading:

--Structural damping important

--Several modes may contribute

--Less mass helps

Explosion

Pulse Loading, proportional to exposed area:

--Damping not important

--one mode (shape) dominates

--Mass provides more resistance

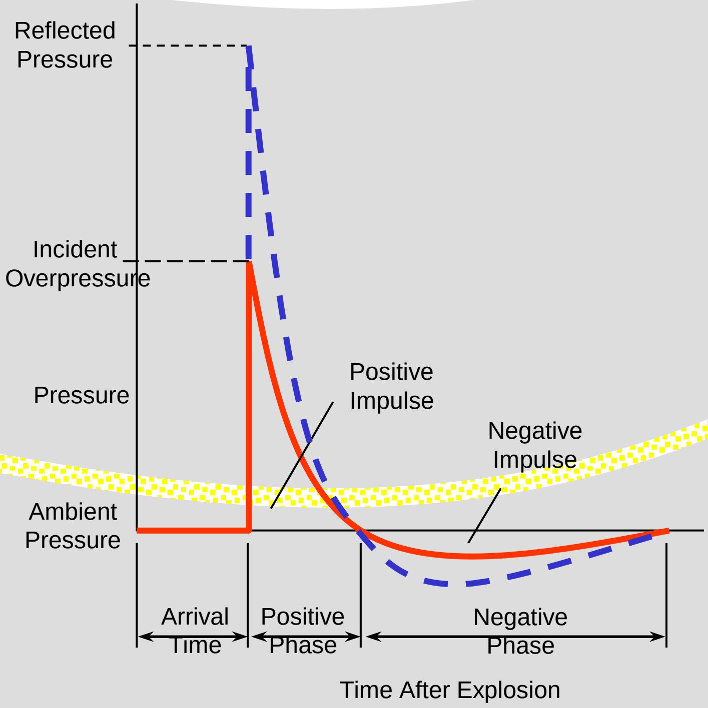
Both require Dynamic Analysis

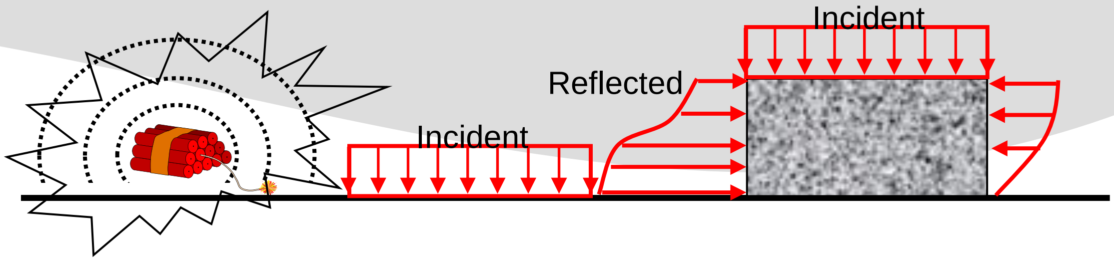
Blast Loading characteristics

Chemical Explosions: vehicle bombs, conventional weapons

- Air blast wave
- Relatively close ‘point source’
- Short wavelength rel. to structure
- Localized failure
- Combined with fragment loading
- Spall, breach may occur

Explosive Airblast Loadings



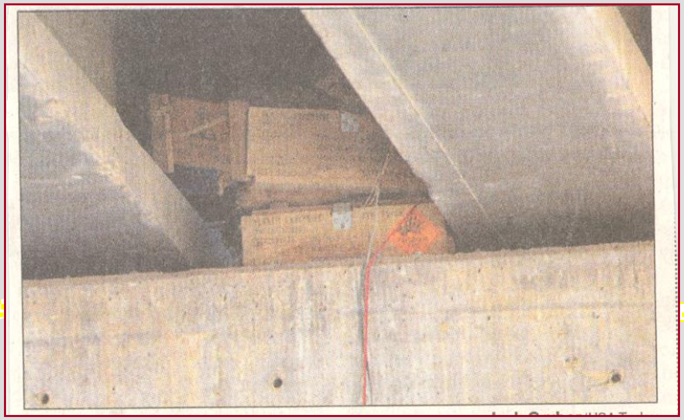


Explosive Effectiveness

- Explosive effectiveness depends upon:
  - Type
  - Amount (the more the better!)
  - Location
    - Internally placed
    - External contact (tamped)
    - External contact (untamped)
    - Standoff

- Decreasing Effectiveness
- Decreasing Time on Target

Understanding Explosive Effectiveness



SOME DIDN'T!

Note!

Understanding Explosive Effectiveness

Blast design procedure

- Define the design threat
- Compute blast loading on structural component
  - Dynamic (time history)
- Determine structural response
  - Nonlinear, dynamic
  - SDOF analysis for simple components
- Compare response to acceptable limits
  - Plastic rotation limits
  - Goal is Failure prevention

Explosive Types

Explosive	Density Mg/m3	Equivalent Mass for Pressure	Equivalent Mass for Impulse	Pressure Range MPa
ANFO (94/6 Ammonium Nitrate/Fuel Oil)	NA[1]	0.87	0.87[2]	0.03 to 6.90
Composition C-4	1.59	1.20 1.37	1.19 1.19	0.07 to 1.38 1.38 to 20.70
Gelatin Dynamite (50 percent strength)	NA[1]	0.80	0.80[2]	NA[1]
Gelatin Dynamite (20 percent strength)	NA[1]	0.70	0.70[2]	NA[1]
TNT	1.63	1.00	1.00	Standard

[1] NA – Data not available [2] Value is estimated

Terrorist Choice

Common Military

Easy Purchase

Relative Equivalence (RE) Factors

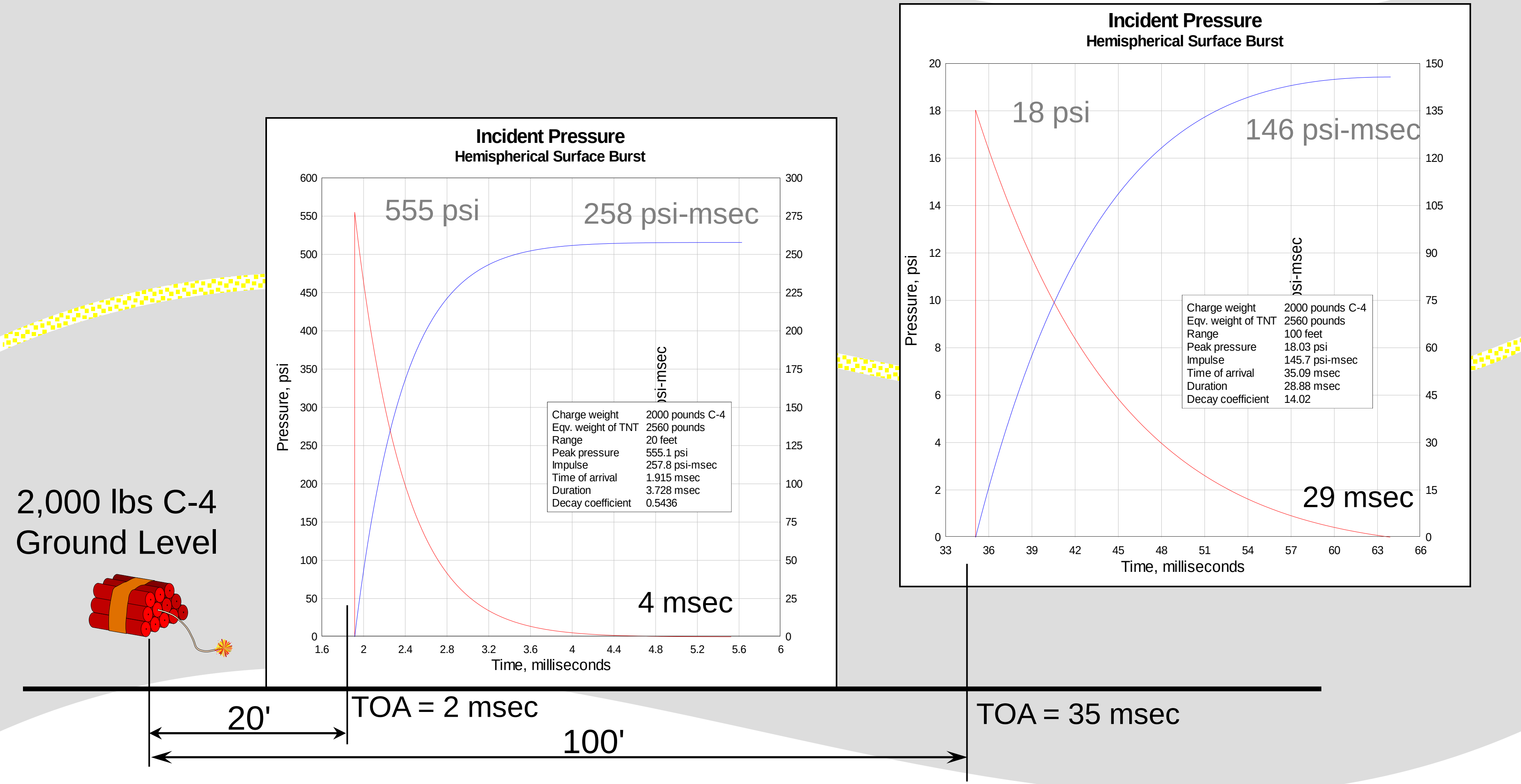
Define the Threat

- Defined by designer and/or owner agency
- No specifications

ATF	VEHICLE DESCRIPTION	MAXIMUM EXPLOSIVES CAPACITY	LETHAL AIR BLAST RANGE	MINIMUM EVACUATION DISTANCE	FALLING GLASS HAZARD
	COMPACT SEDAN	500 Pounds 227 Kilos *(In Trunk)*	100 Feet 30 Meters	1,500 Feet 457 Meters	1,250 Feet 381 Meters
	FULL SIZE SEDAN	1,000 Pounds 455 Kilos *(In Trunk)*	125 Feet 38 Meters	1,750 Feet 534 Meters	1,750 Feet 534 Meters
	PASSENGER VAN OR CARGO VAN	4,000 Pounds 1,818 Kilos	200 Feet 61 Meters	2,750 Feet 838 Meters	2,750 Feet 838 Meters
	SMALL BOX VAN *(14 FT BOX)*	10,000 Pounds 4,545 Kilos	300 Feet 91 Meters	3,750 Feet 1,143 Meters	3,750 Feet 1,143 Meters
	BOX VAN OR WATER/FUEL TRUCK	30,000 Pounds 13,636 Kilos	450 Feet 137 Meters	6,500 Feet 1,982 Meters	6,500 Feet 1,982 Meters
	SEMI-TRAILER	60,000 Pounds 27,273 Kilos	600 Feet 183 Meters	7,000 Feet 2,134 Meters	7,000 Feet 2,134 Meters

Explosive Airblast Loadings

Pressure Decay with Distance



Standoff: distance from charge to target

- Scaled Standoff: Indicator of blast intensity

$$Z = \frac{R}{W^{1/3}}$$

Z = scaled standoff (ft. / lb.$^{1/3}$)

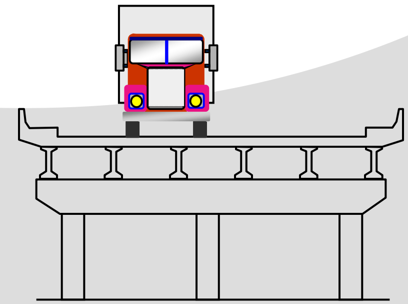
R = standoff distance (ft.)

W= charge weight (Lb. TNT equiv.)

--Z values are used to categorize levels of intensity and can be used to estimate protection requirements.

Bridge Specific Blast Loading Program

USACOE: Bridge Explosive Loading (*BEL*) Code

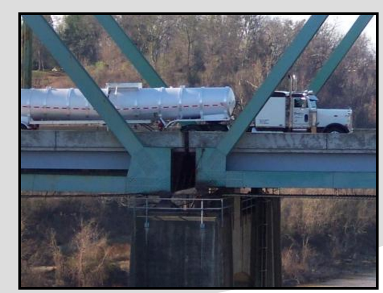


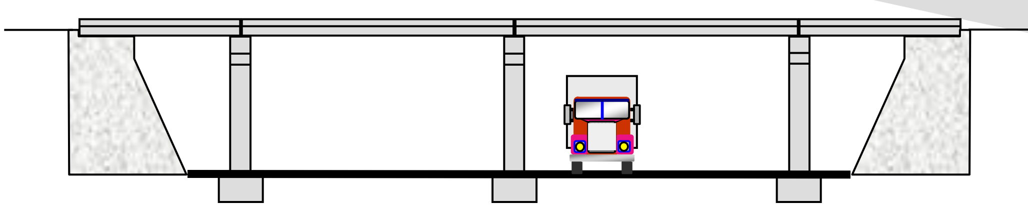
Features:

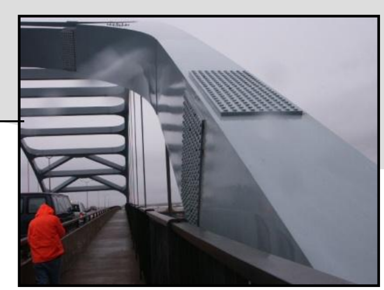
- Utilizes blast algorithms from:
  - ConWep: Low resolution.
  - BlastX: Medium resolution. Better facilitates FEA loadings.

- Includes ConWep breaching and ground cratering algorithms.

- Consider 3 types of loadings:
  - Loadings on Decks
  - Loadings on Vertical Surfaces Adjacent to Decks:
    - Suspension/Cable-stayed towers
    - Axial members (through trusses and arches)
  - Loadings on Columns

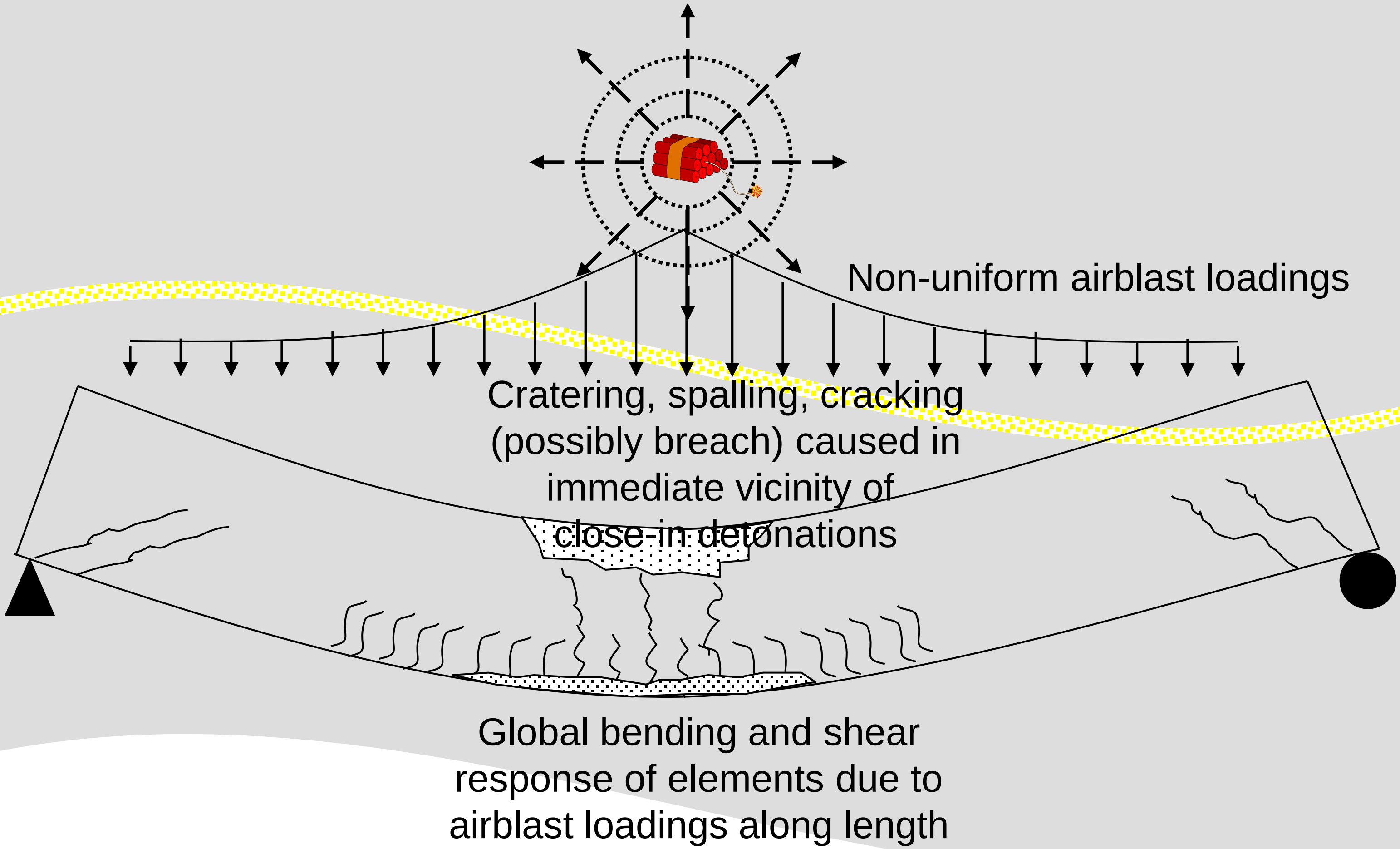






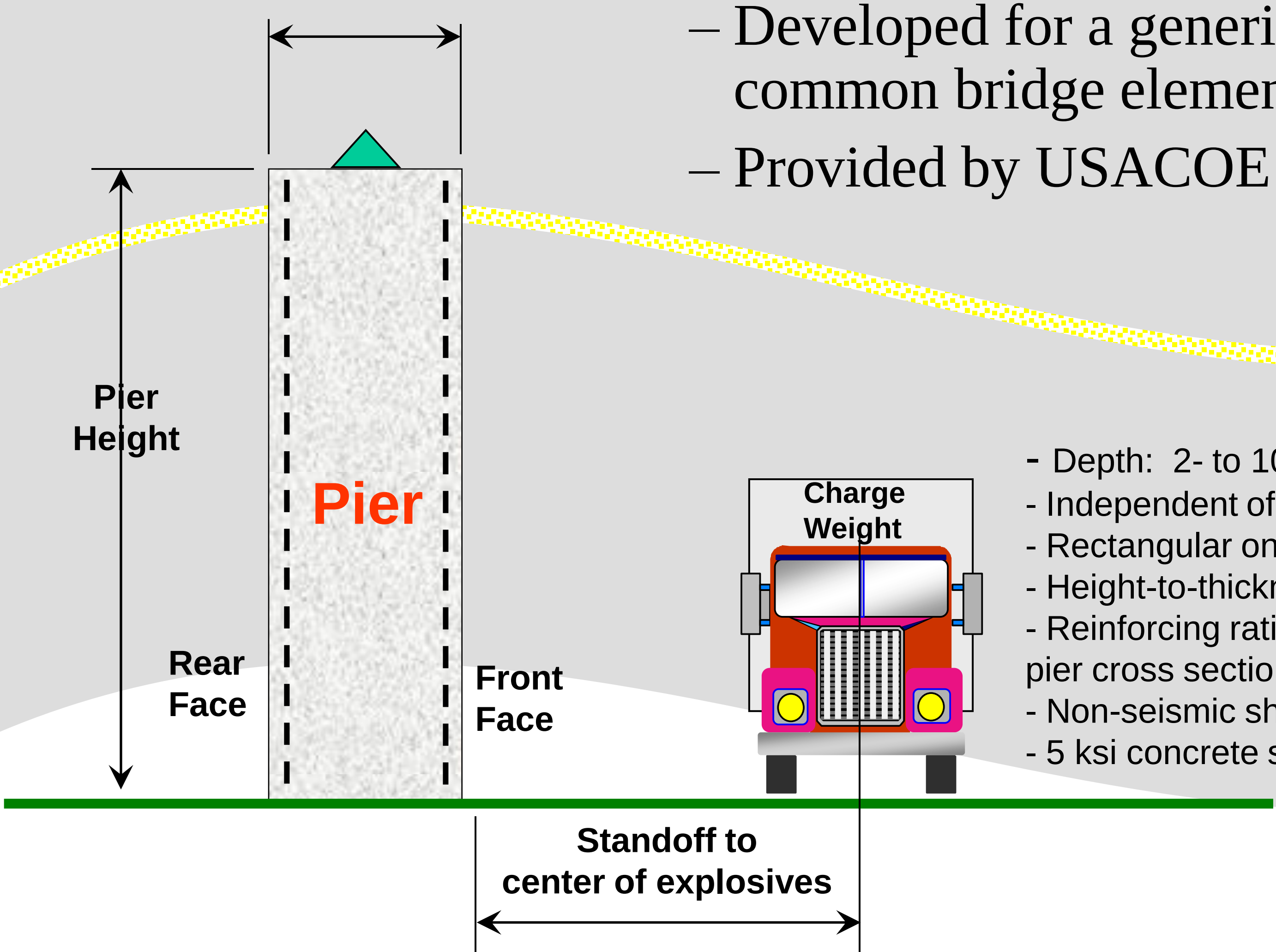
USACOE

Explosive Damage Mechanisms
Concrete Exposed to Standoff Explosives



Standardized Blast Response Curves for Bridges

- simple design aids to help engineers design bridges for blast loadings
- Developed for a generic set of common bridge elements
- Provided by USACOE



- Depth: 2- to 10 feet
- Independent of width
- Rectangular only
- Height-to-thickness (L/D) ratios: 3 to 18
- Reinforcing ratios: 0.4- to 2 percent of pier cross sectional area
- Non-seismic shear reinforcing
- 5 ksi concrete strength, 60 ksi steel

Standardized Blast Response Curves for Bridges

Reinforced Concrete Bridge Piers

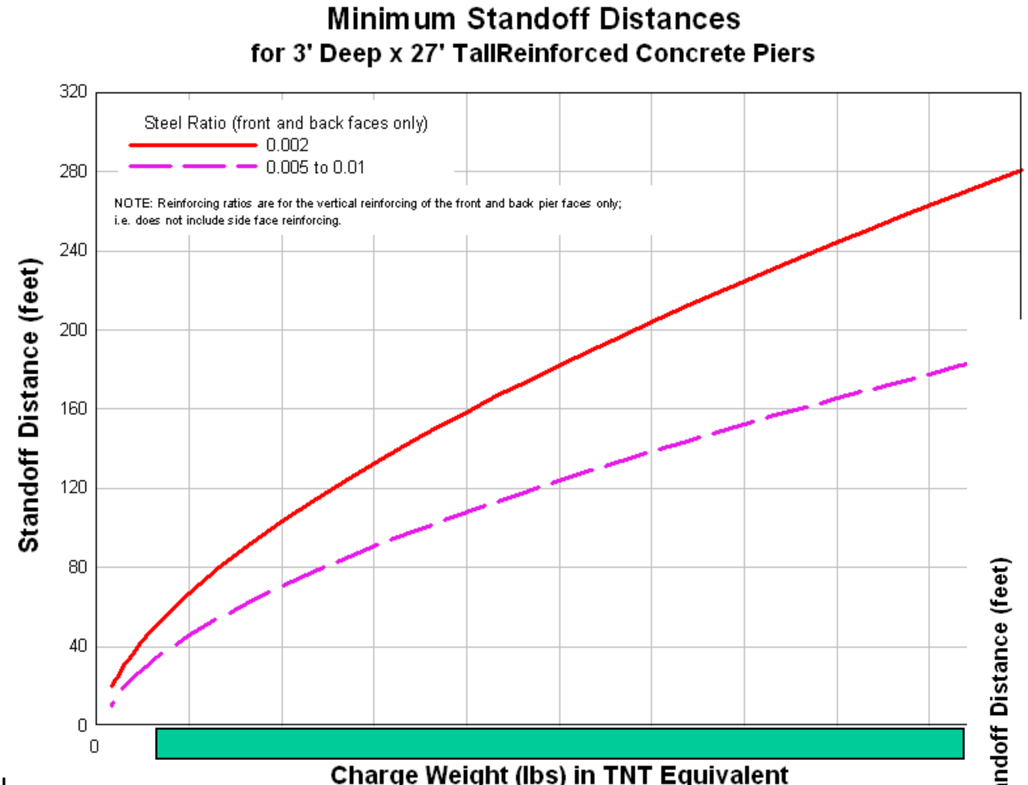


Figure A-5

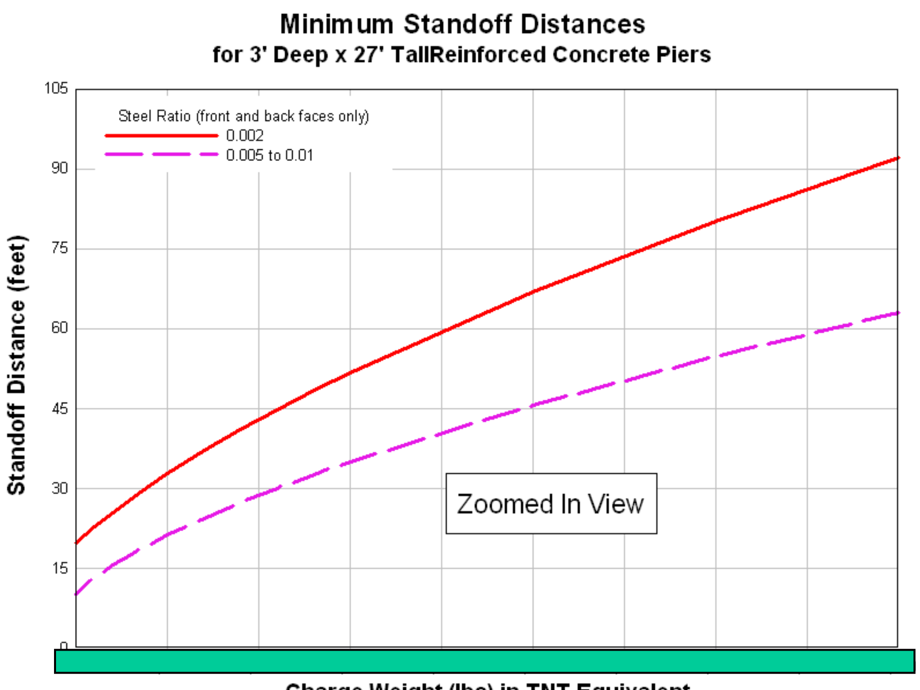


Figure A-5a

Standardized Blast Response Curves for Bridges

Suspension Towers

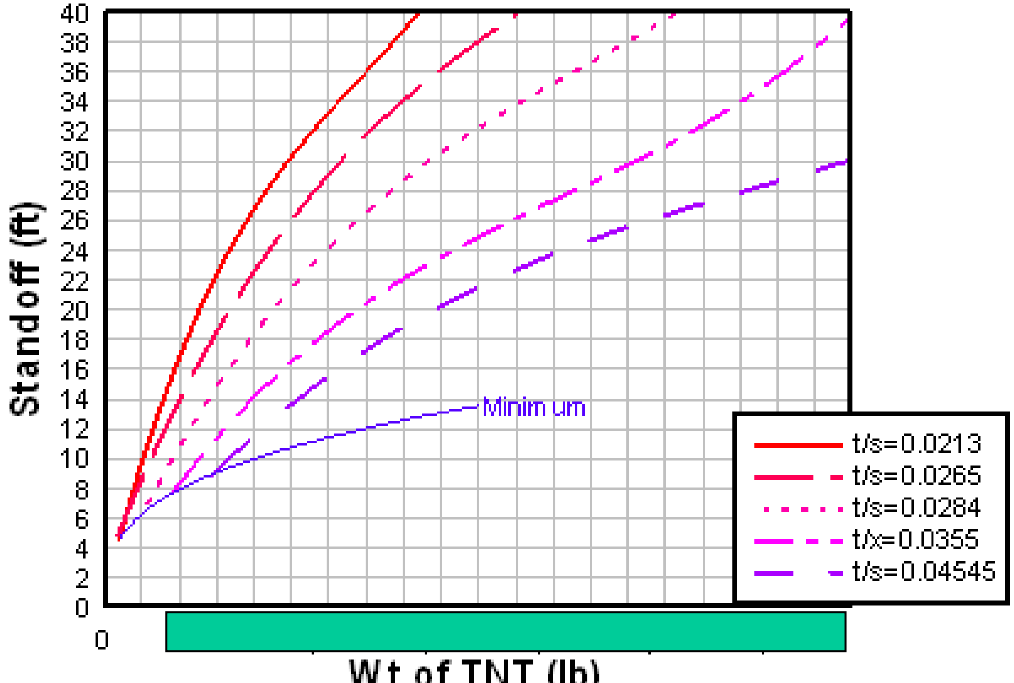


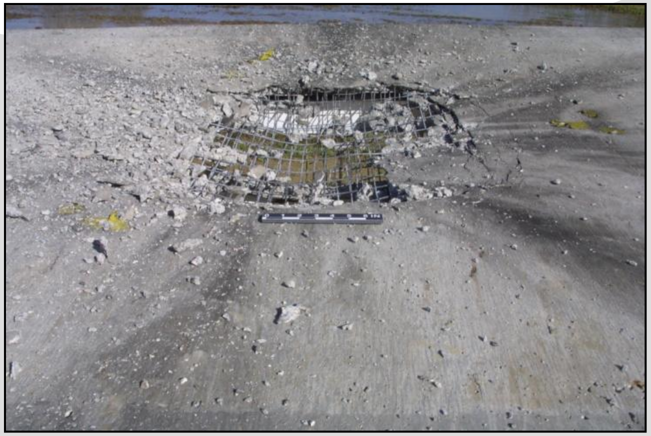
Figure A-1. Standoff for various weights of TNT for steel plates with 2-way support

Steel Members: Flexure and Buckling

~ 1/5 Scale

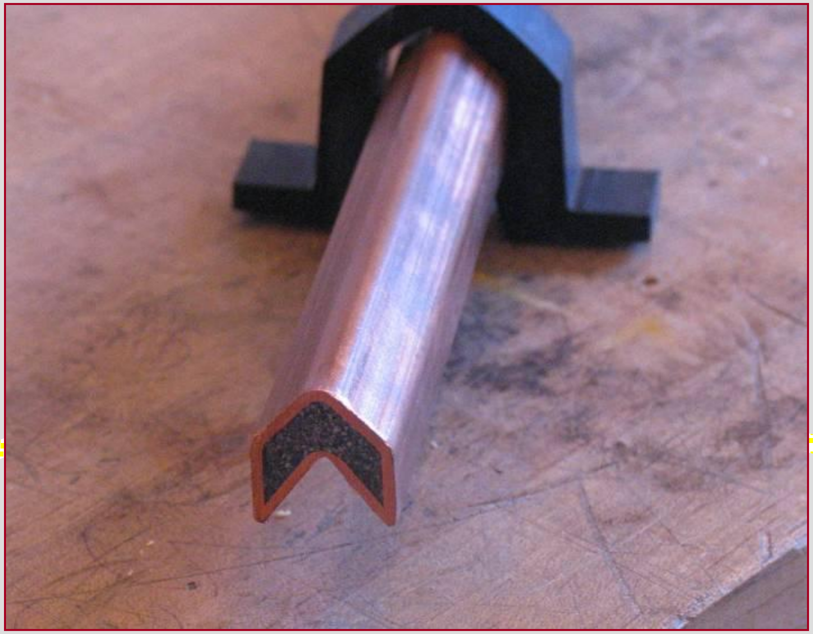
7 lbs C-4 @ 1.15’

1000 lbs @ 6’



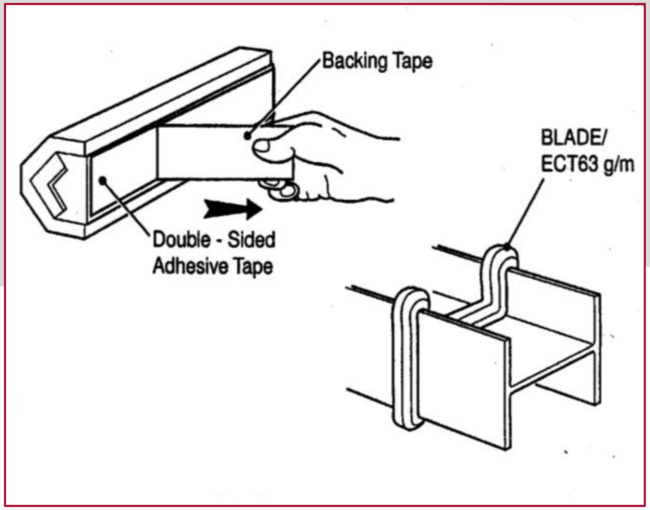
Precision explosives

Shaped Charges

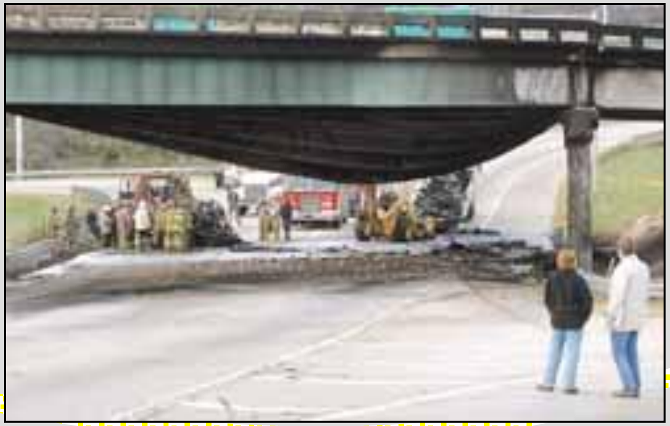


--Linear

Conical--



Other Threats to Bridges
Let's Not Forget These

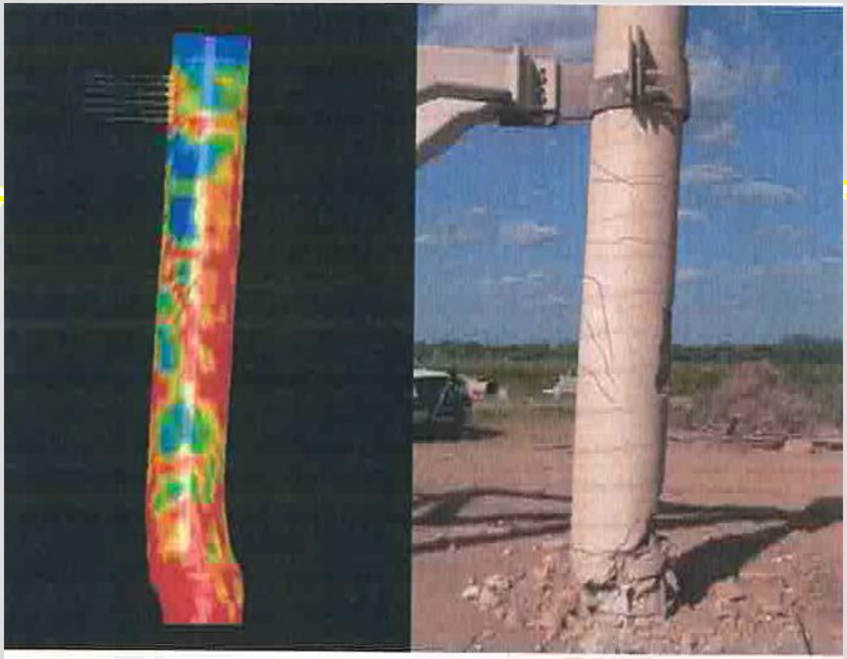


Fire

Impact

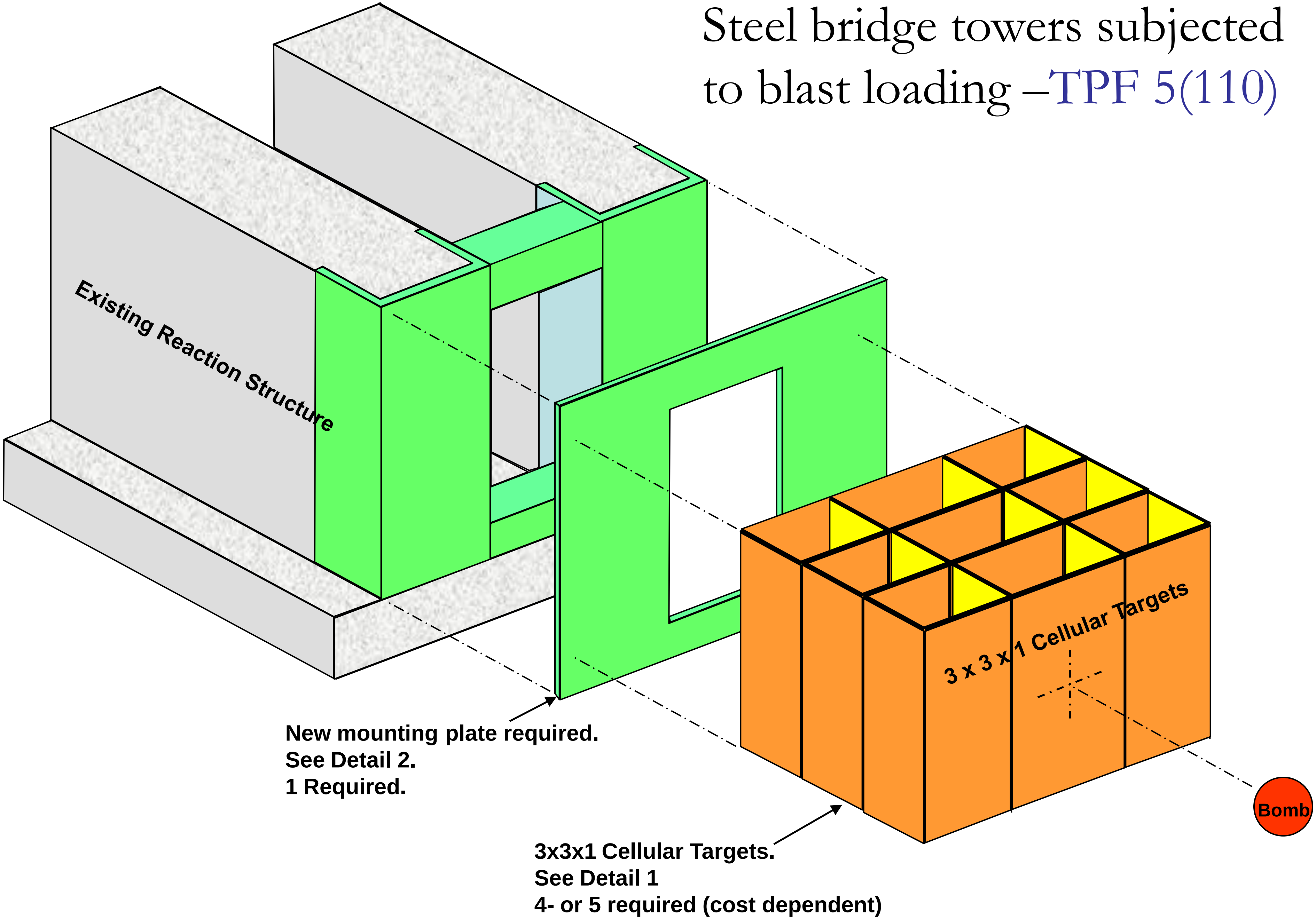
Bridge Design / Analysis for Security
Recent Developements

Recent Research on Blast Design for Bridges



- Steel bridge towers subjected to blast loading – TPF 5(110)
- Blast / Impact Resistant Highway Bridges—Effective Design and Detailing--NCHRP 12-72
- Full Scale test of Pretensioned girders subject to blast.-- TPF-5(115)
- Highway bridge design to resist fires--NCHRP 12-85

Steel bridge towers subjected to blast loading –TPF 5(110)



Steel towers subject to blast

LRFD Bridge Design Specifications

- Developed under NCHRP 12-72 (Task 4)
- Adopted into LRFD Code in 2007
- Consider Security in Bridge Design
  - General guidance and commentary
  - Optional provisions for blast, vessel collision
  - References

AASHTO T-1

Bridge Design Provisions

- **Security Design Guide** (under development)
  - AASHTO Guide Specification
  - Development oversight by T-1
  - NCHRP 12-72 for initial guide
    - *Task 4: General guidance*
    - *Task 8- Blast design provisions for substructures*
  - Focus on methodology, not spec. requirements

Multi-Hazard Design / Performance Based Design

Systematically consider all or a combination of man-made or natural, extreme and progressive hazards with a balance and optimization of demands.

- Complementary designs / seismic retrofits
- Redundancy, resiliency
- Resistance to progressive collapse
- Risk based approaches

Identified Needs in Multi-hazard Analysis and Design

- Multi-hazard failure modes and their interactions
  - Characterization of effectiveness of a bridge system and its components under these failure modes.
  - Assure or control that mitigation of one hazard will not attenuate the bridge in other hazards.
- Multi-hazard considerations
  - Risk-based analysis and framework
  - Before and after event effects.
  - Prioritization
  - Varied recurrence intervals—consider one year reference period or annual probability of failure

Emergency Management

- DOTs have "<u>all hazards</u>" plans in place – not just for terrorism
- DOTs often have vital support roles in major incidents – e.g. hurricane evacuation, or earthquakes
- DOTs field personnel may sometimes be "first responders"

DOTs' Emergency Management Expertise

Traveler Information:

- Hwy Advisory Radio, 511, Variable Message Signs, etc.

Facilities, Personnel, Equipment:

- Trucks, aircraft, communications networks, garages, etc.

Traffic Management:

- Sensors, cameras, ramp monitoring, etc.

Reconstruction Capabilities:

- Equipment, and contacting expertise

Bridge Security Strategies

Emergency Response Planning

- Plan detours
- Coordinate communications and response preparation.
- Emergency Response drills.
- Emergency laptops available preloaded with critical data.
- Ensure availability of emergency signs

Bridge Security Strategies

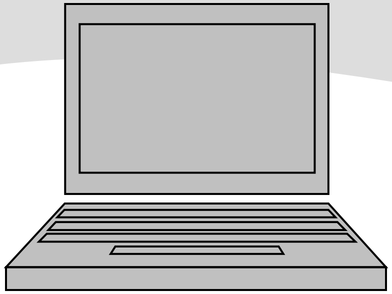
Emergency Response Planning

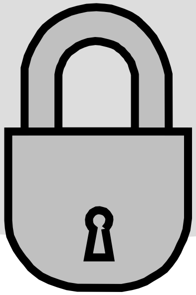
- expedited Awards / Supplemental Contracts
- Standby emergency contracts
- Rapid bridge replacements

Security Sensitive Information

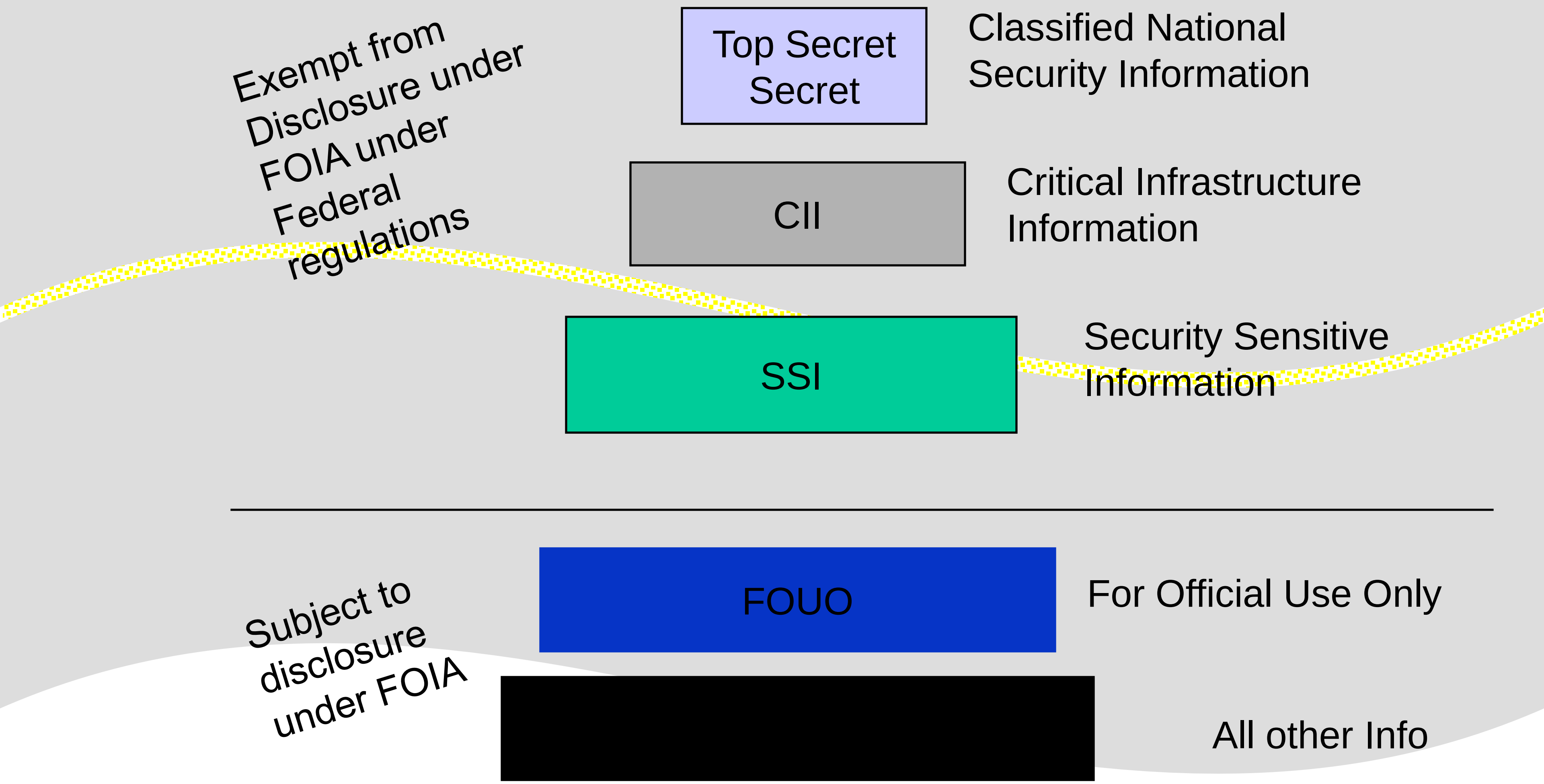
Security Sensitive Information is defined as:

"…sensitive, but unclassified information developed in the conduct of security or research and development activities, the unauthorized disclosure of which would be detrimental to transportation security."





Security Sensitive Information



Security Sensitive Information

Discerning SSI from other information

- Information useful in selecting a target for attack
- Information useful in planning/executing an attack

Security Sensitive Information

Examples of SSI?

- Threat information
- Vulnerability Assessments (systems, vehicles, facilities) and their results
  - Countermeasure options/actions
  - Security plans and schedules
- R&D results – failures more that successes
- Technical specifications/operating systems

Security Sensitive Information Observation

– There is good agreement on how to handle SSI
– There is less agreement as to what should be classified as SSI

Summary
Prioritizing Bridge Security Strategies

- First Priority
  - Develop an Accelerated Response and Recovery Plan
- Second Priority
  - Deter, Deny, and Detect
- Third Priority
  - Defend with Standoff
- Fourth Priority
  - Defend with Structural Toughening

PDH questions

Using the R = O x V x I methodology for Risk Assessments against malicious attacks, engineering analysis and expertise is used to determine:

a) Occurrence factor
b) Vulnerability factor
c) Importance factor
d) All three factors

In what manner are Earthquake analysis and Blast analysis similar?

a) Both involve pulse loadings

b) Both involve long duration cyclic loadings

c) For both, structural damping is important to consider

d) Both require dynamic analysis

True or False: The incident pressure of a blast wave is the pressure on a surface that is parallel to the direction of propagation.

Ans. TRUE

For blast analysis, adequacy of the structure response is generally determined by comparing the response to the:

a) Yield stress

b) Limiting plastic rotations

c) Factored loads

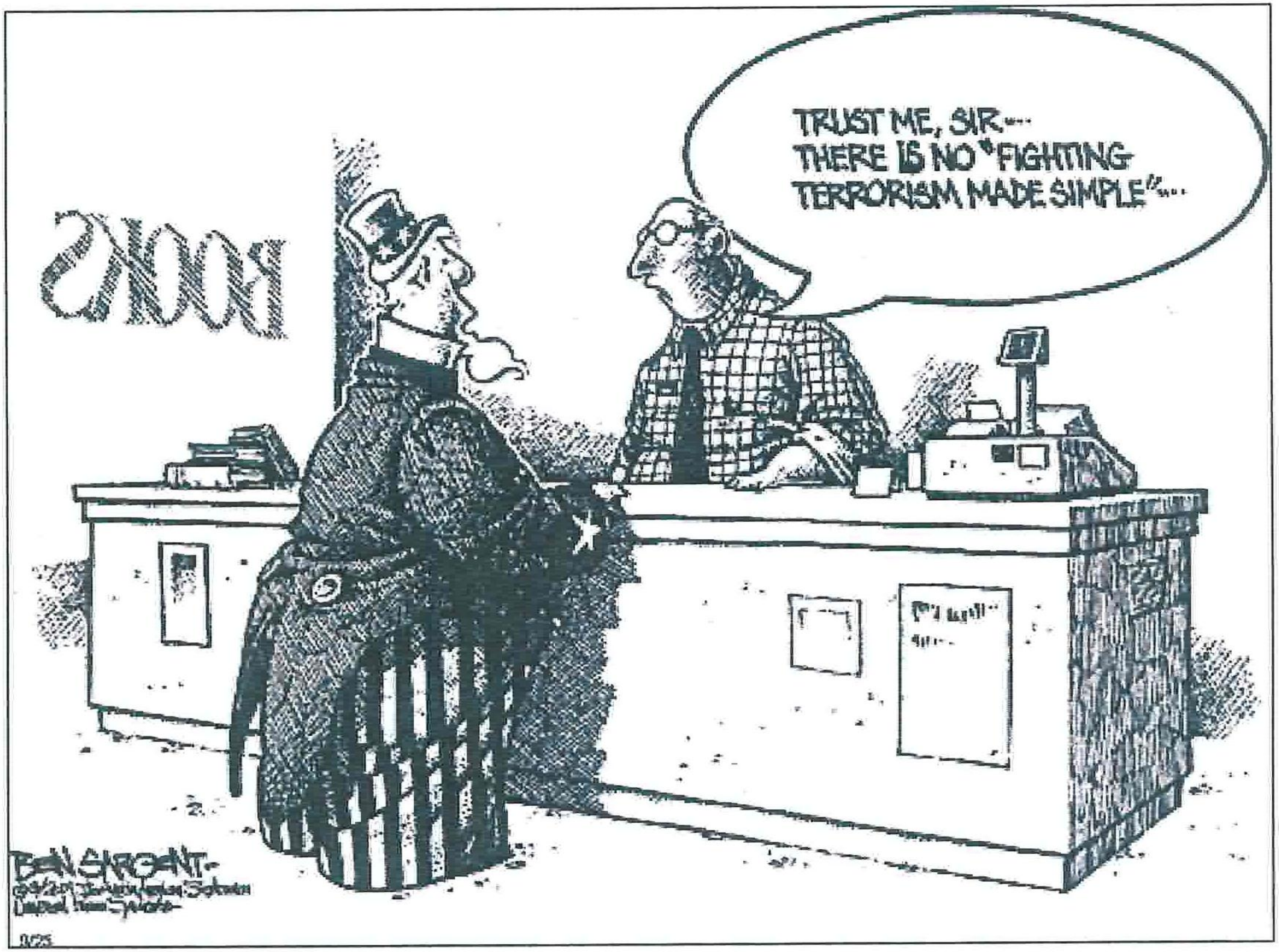
True or False: When using scaled standoff to categorize the intensity of a blast on a structure, scaled standoff is doubled by reducing the charge weight by half.

Ans: FALSE

True or False: Security Sensitive information is exempt from Freedom of Information Act (FOIA) requests.

Ans: TRUE

Questions?



NEW YORK STATE DEPARTMENT OF TRANSPORTATION