

# Challenges in Urban Tunneling

By

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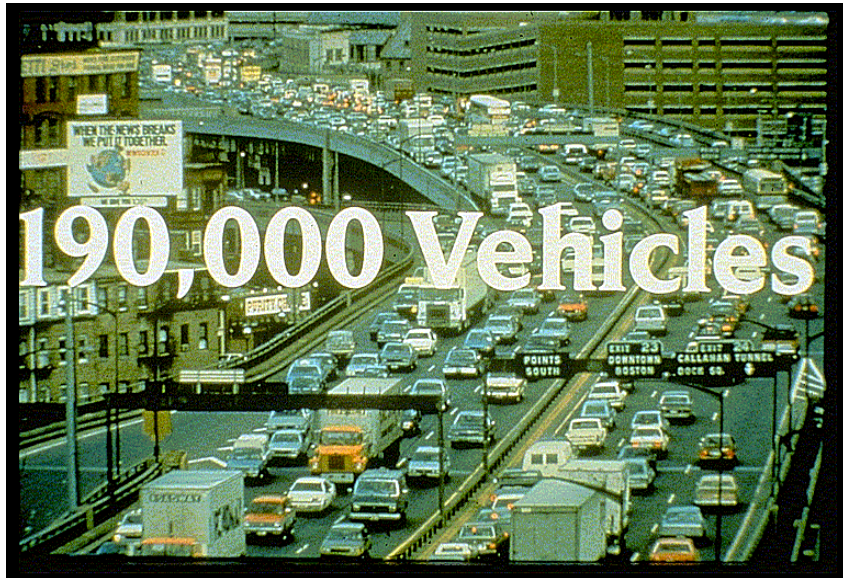


# Agenda

- **Tunneling as a solution for Urban Tunneling**
- **Urban Tunneling Problems**
- **Urban Tunneling Issues and Mitigation Measures**
- **Advantages of Urban Tunneling**
- **Disadvantages of Urban Tunneling**
- **Structural Rehabilitation of Tunnels**
- **Fire Life safety**
- **E & M Rehabilitation**
- **Conclusion**



# Elevated Expressway Before Central Artery /Tunnel Project



Future Traffic Projections



Traffic before Central Artery



Long Parking Lot during evening  
rush hour before Central Artery

- Central Artery Tunnel - A Solution

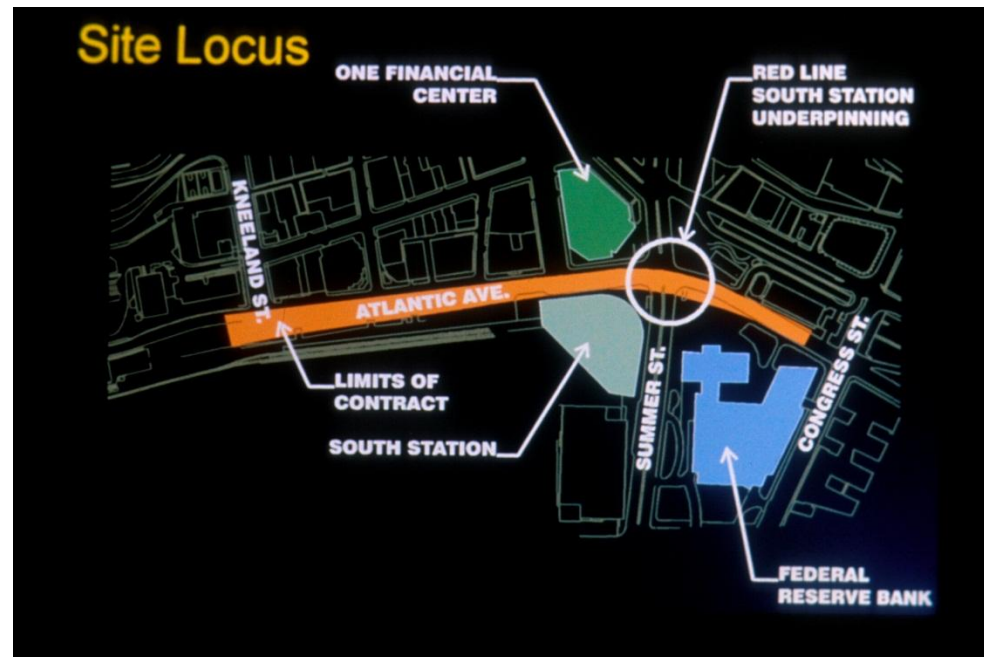




# Urban Tunneling

## Problems During Planning

- Public Perception
  - Not in my backyard
  - Loss of Revenue

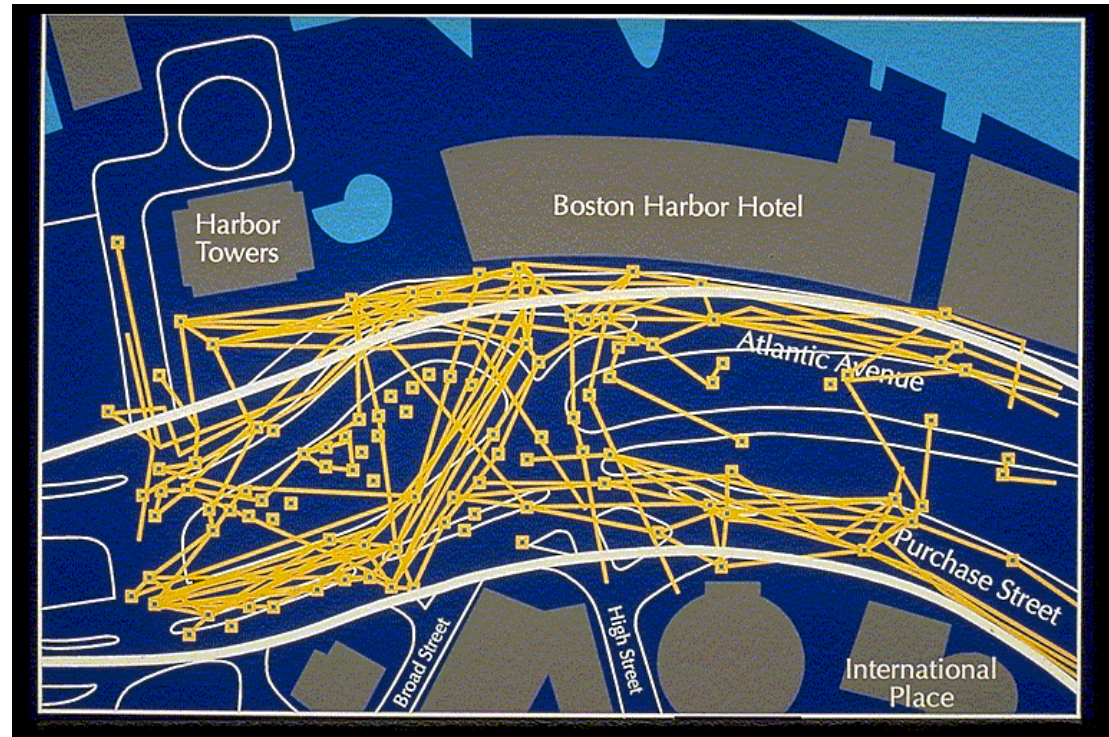


# Urban Tunneling

## Problems During Planning – Cont.

### Relocation of Utilities

- Disruption of services
- Short and long-term Access to properties



# Urban Tunneling

## Problems During Planning – Cont.

- Acquisition of Property
- Settlement of Foundations and Structures





# Urban Tunneling

## Problems During Planning – Cont.

### – Physical Obstructions





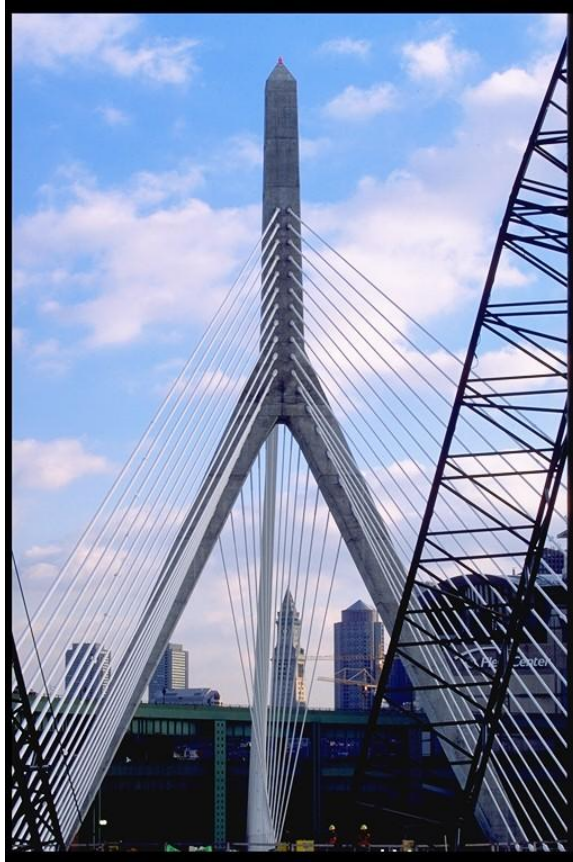
# Urban Tunneling

## Problems During Planning – Cont.

- Construction Noise, Vibration and Dust
- Increased Traffic on Major Roads
  - Construction traffic
  - Wear and tear of roadways
- Traffic Diversion
  - Increased traffic on arterial roads
  - Parking restrictions for local residents
- Aesthetics During Construction



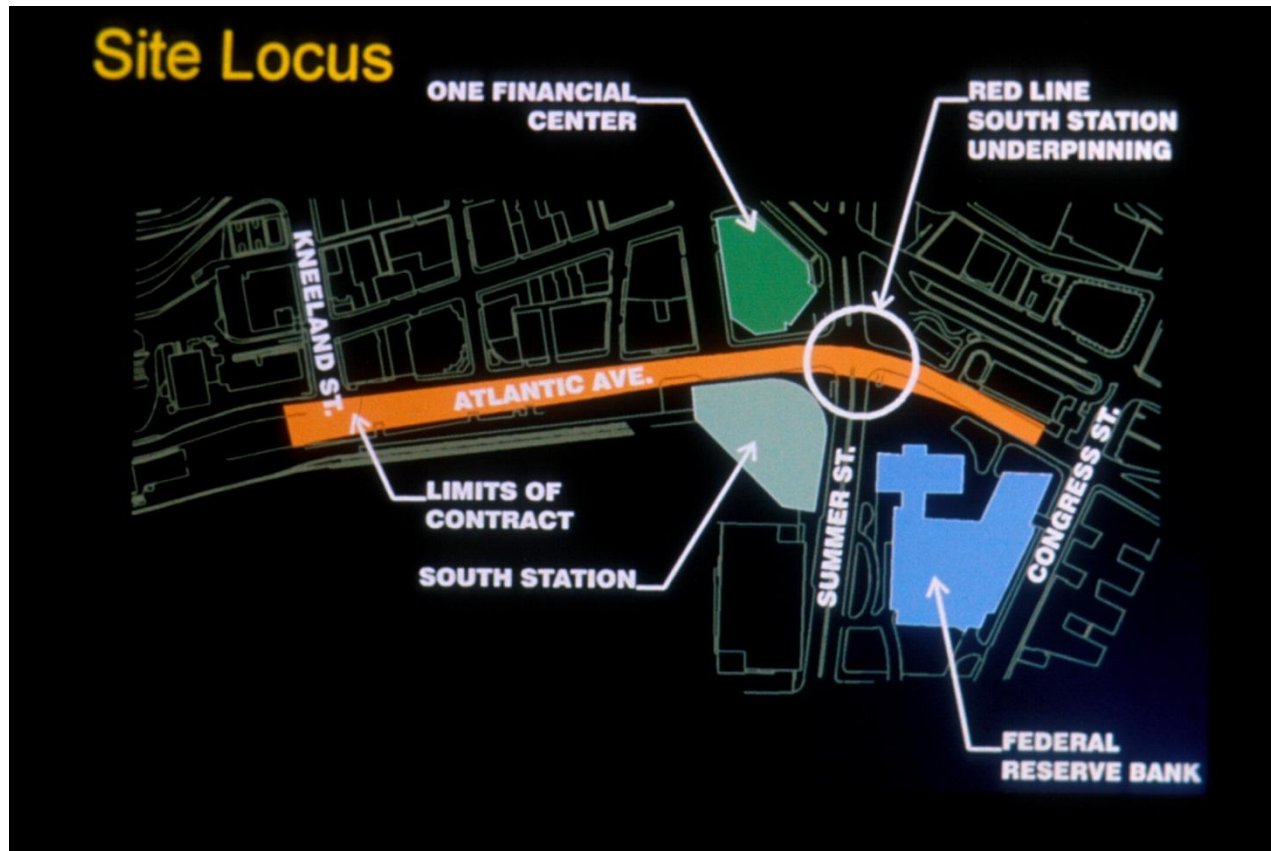
# Gateway to Central Artery from North



Bunker Hill Cable Stay Bridge

# Mitigation Measures

- Pro-active Community Outreach
- Work Very Closely with Property Owners





# Mitigation Measures (Cont.)

- Avoid Open-Cut Excavation Where Possible  
Use braced support of excavation,  
Monitor ground movements



# Mitigation Measures (Cont.)

- Ted William Tunnel

Immersed Tube Tunnel under Boston Harbor





# Mitigation Measures (Cont.)

## - Crossing Railroad Tracks



Ground Freezing

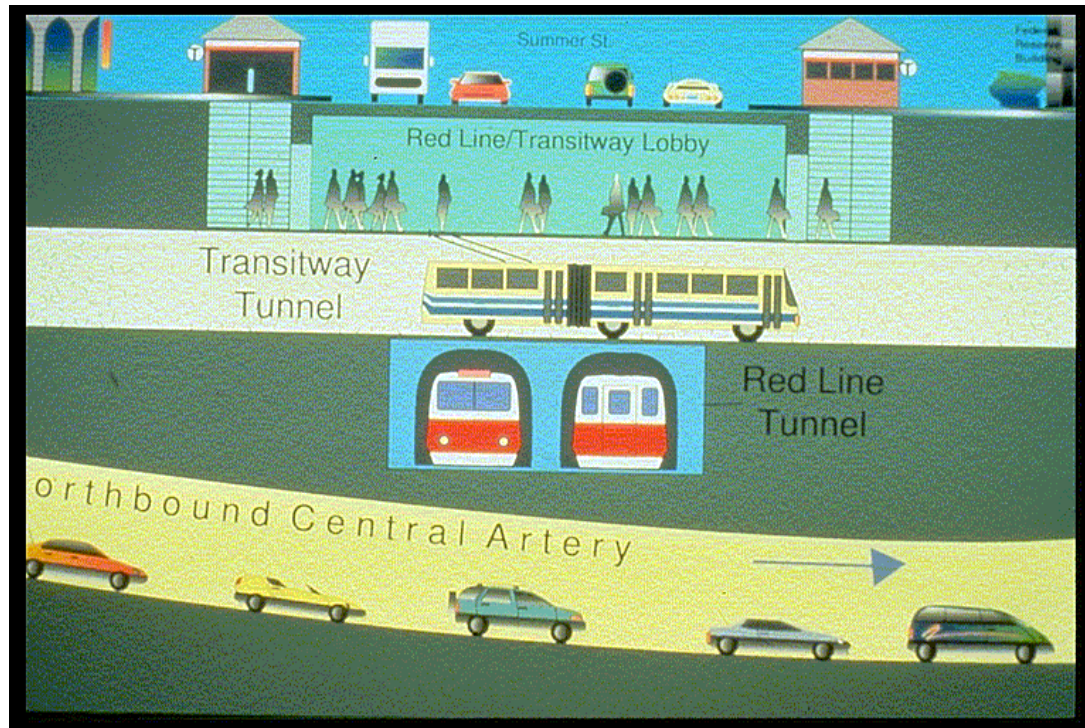


Existing RR Tracks to be Maintained



# Mitigation Measures (Cont.)

- Crossing an existing Tunnel at a Busy Intersection
  - Central Artery Tunnel below existing transit tunnel
  - Silver Line Tunnel above existing transit tunnel



Artistic Rendering

# Mitigation Measures (Cont.)

- Traffic  
Maintenance

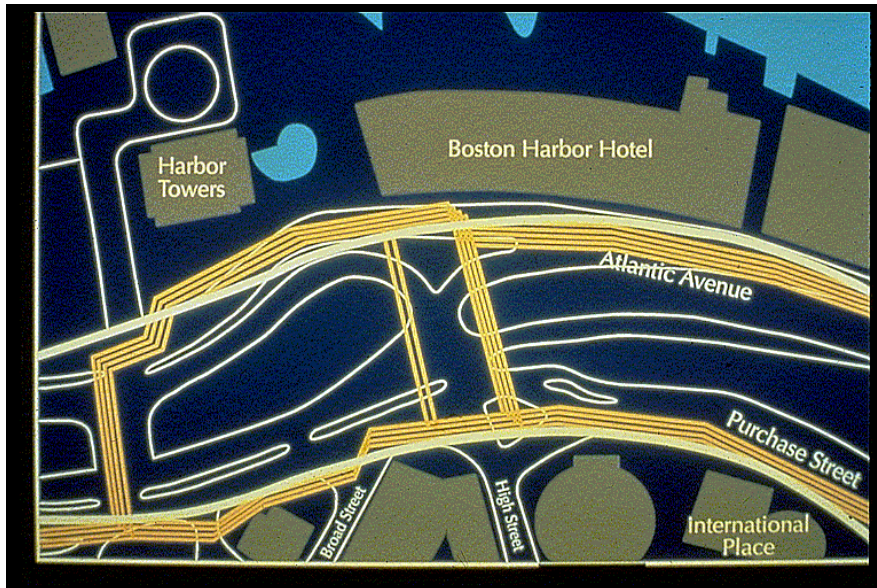


Underpinning Existing Expressway

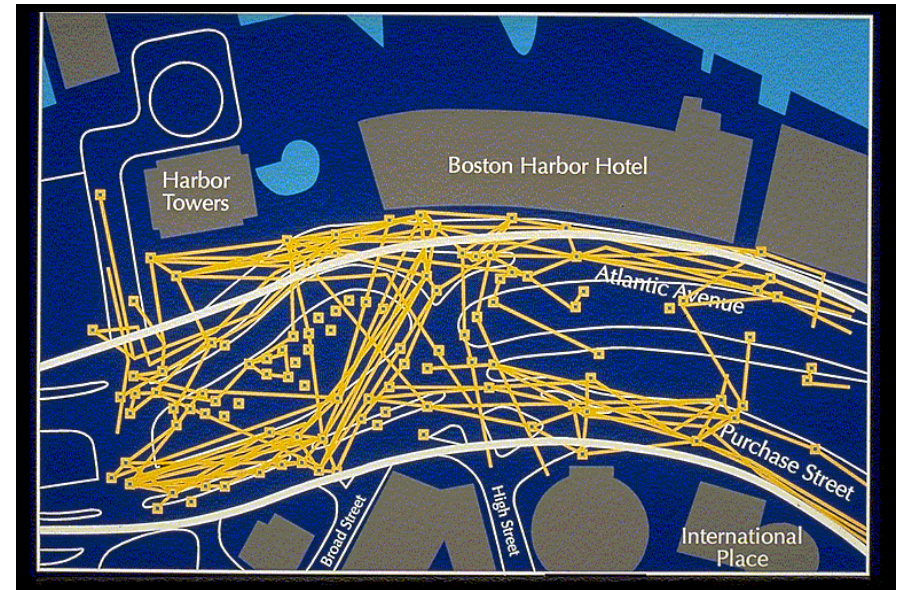


# Mitigation Measures (Cont.)

## - Utility Relocation



Proposed Utility Relocation – an example



Existing Utilities – an example



# Mitigation Measures (Cont.)

- Minimize construction duration
- Provide Environmental Controls

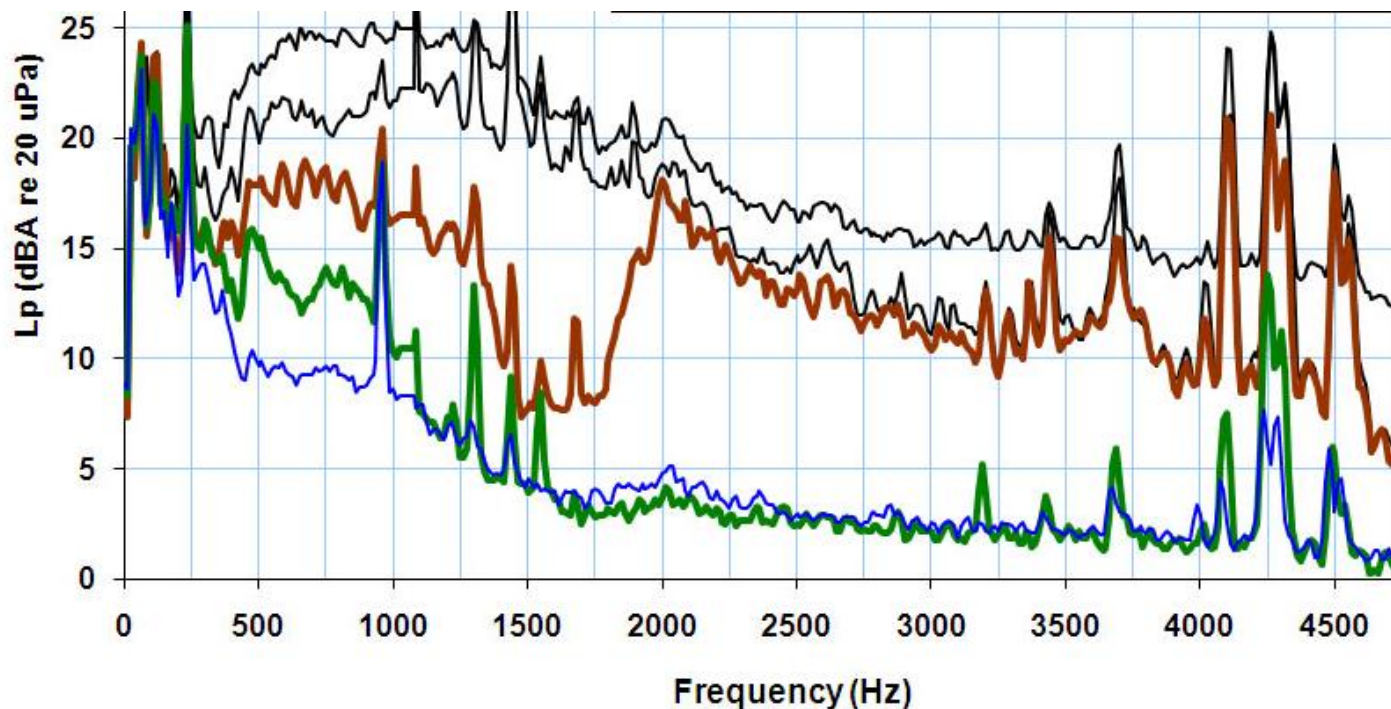
Noise dampers

Vibration monitors

Dust control by spraying water

Avoid after hour work

Adequate staging areas



# Advantages of Urban Tunneling

## – Advantages

- Design Service Life – 100-150 years
- Reduced travel time – increased productivity
- Reduced traffic fatalities
- Smooth traffic flow between North and South Boston
- Easy and convenient road connection to Logan International Airport

# Advantages of Urban Tunneling (Cont.)

## - Land Use



New Construction  
on top of Tunnel



Open Space



# Advantages of Urban Tunneling (Cont.)

- Land Use



Combined Structure  
Boston Continental Hotel & Vent Building

# Advantages of Urban Tunneling (Cont.)

- Reduced entries and exits from Expressway
- No new real estate required with additional lanes of traffic– existing ROW used
- Energy conservation – less fuel cost
- Reduced Noise and pollution
- Open Space
- Scope to construct on top based on land use planning

# Disadvantages of Urban Tunneling

- High initial cost
- Construction impact to adjacent properties
- Potential damage to high rise building foundations
- Noise/ventilation from vent buildings
- High maintenance cost due to power usage and ventilation
- High maintenance cost of E/M equipment



# Lessons Learned

- Never Use Temporary Support of Excavation as a part of the permanent structure. It has a potential for future leakage
- Test all Epoxy Resins for long-term usage
- Test all inserts

# Structural Tunnel Rehabilitation

## Typical Problems



Tunnel Leakage



Concrete cover Spalling and  
Reinforcement Corrosion

- Structurally Repaired Tunnel



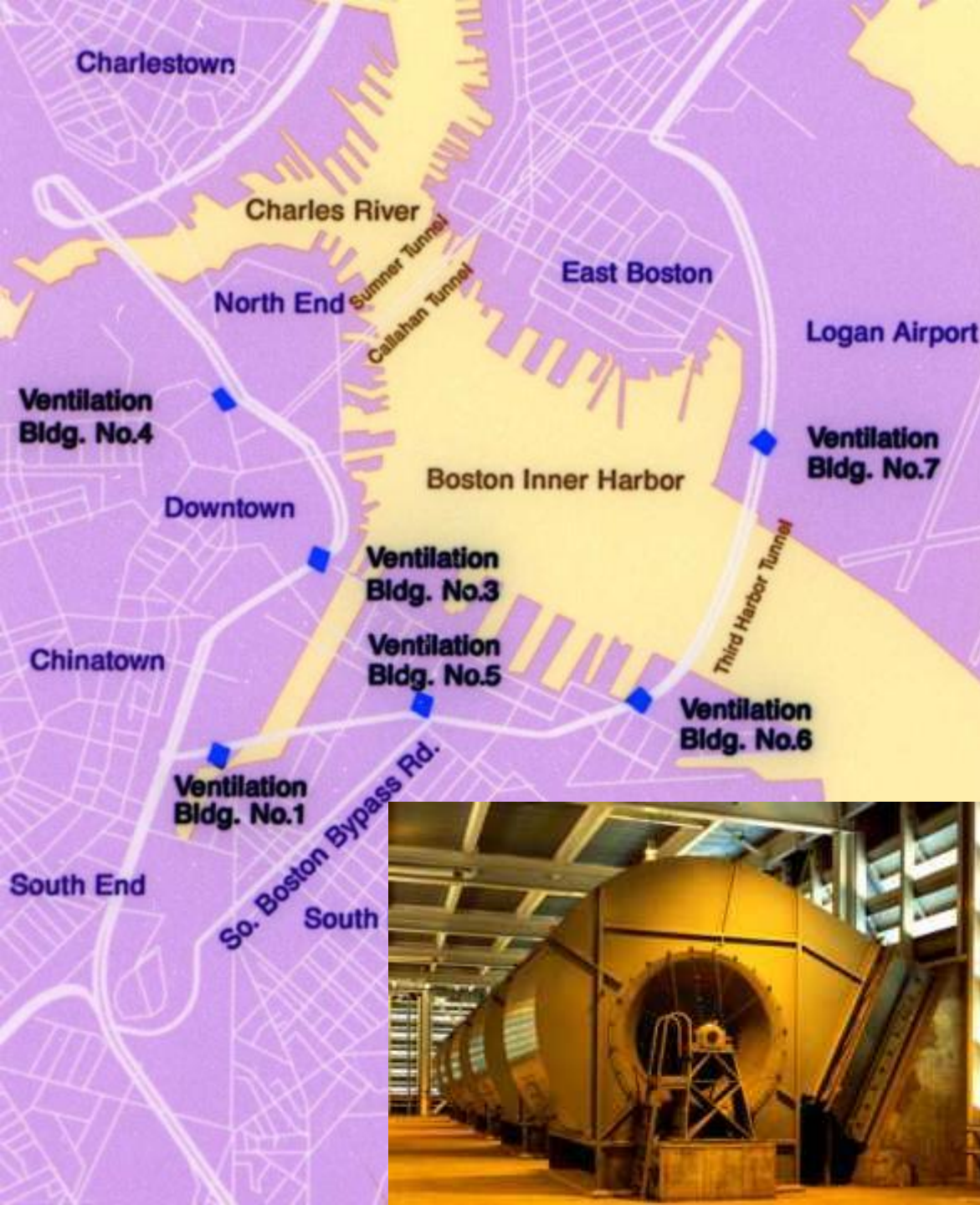


# Jacobs Tunnel Rehab Projects

- Current Projects
  - Massachusetts Bay Transit Authority Tunnels
  - FHWA Yosemite National Park Tunnels
  - Nevada Carlin Tunnel, I-70
- Past Tunnel Experience
  - Chesapeake Bay Bridge Tunnel
  - Hampton Roads Bridge Tunnel
  - Downtown Tunnel VA
  - Baltimore Metro Subway Tunnel, MD
  - Brookline Battery & Queens Midtown Tunnel, NY
  - Sumner and Callahan Tunnels, Boston
  - Eisenhower/ Johnson Memorial Tunnel, CO
  - Howard Street CSX Tunnel, MD
  - Bergen Tunnel, NY
  - Brush Tunnel, MD
  - PATH Tunnels, NY

Fire Life Safety

E & M Rehabilitation



VB #1



VB #4



VB #7





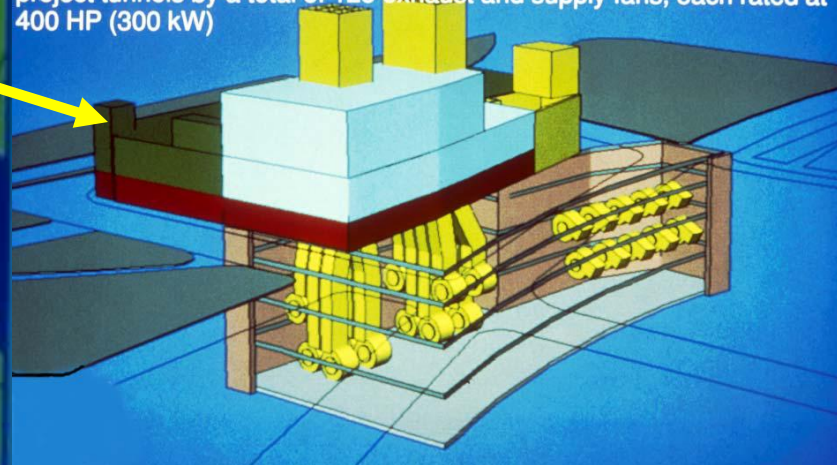


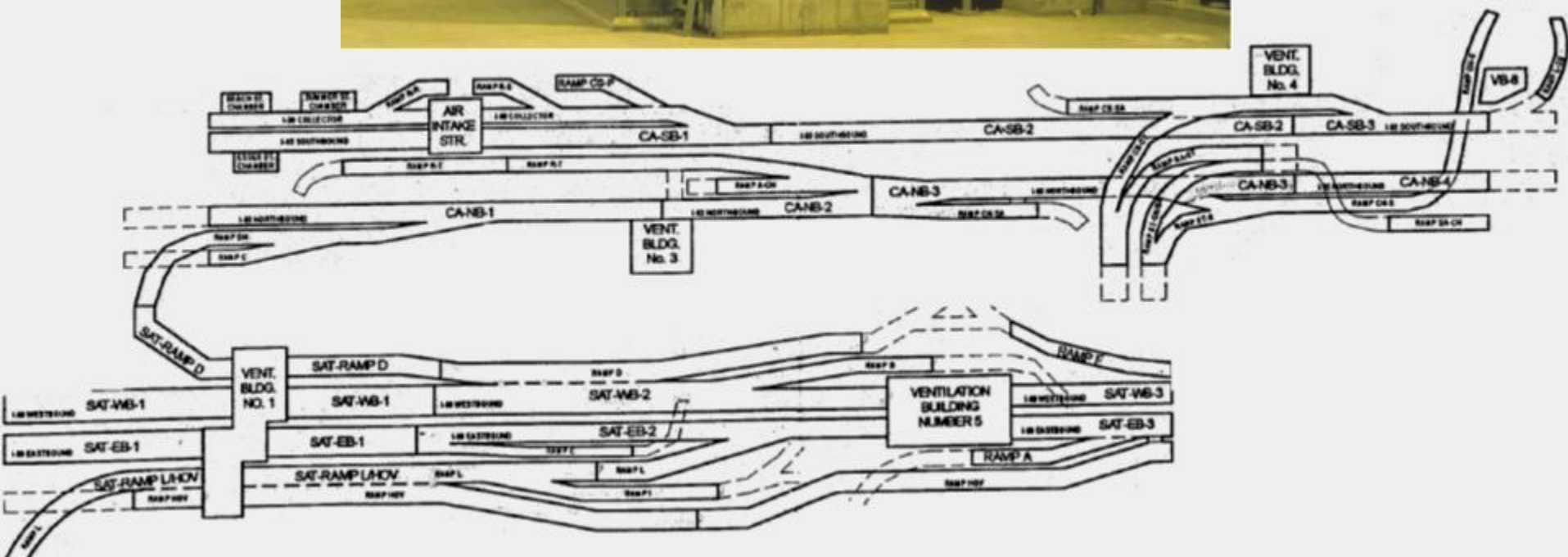




# VENTILATION BUILDING LOCATIONS

One million cubic meters of air per minute will be moved throughout the project tunnels by a total of 125 exhaust and supply fans, each rated at 400 HP (300 kW)







# 16 ducts sections modeled

Over 500 geometric variations analyzed

Changes constrained by duct construction

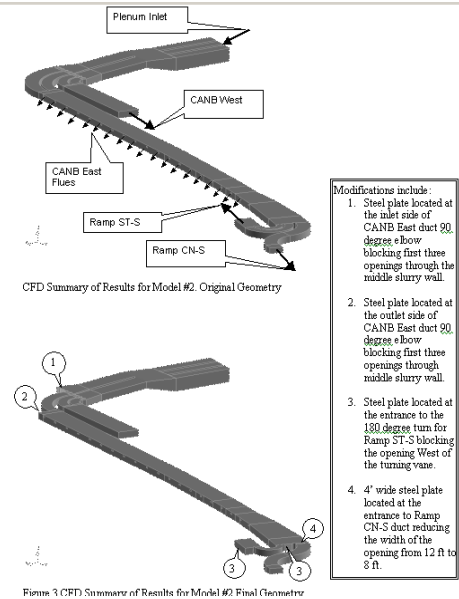
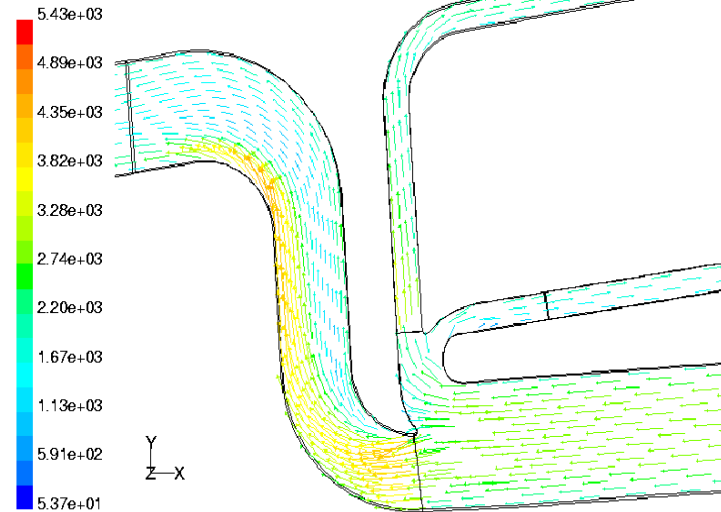
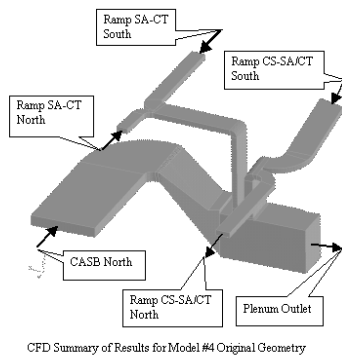


Figure 3 CFD Summary of Results for Model #2 Final Geometry

Boston Central Artery Vent Bldg. 5 Model 14J

Jacobs/Sverdrup Civil, Inc.



CFD Summary of Results for Model #4 Original Geometry

- Modifications:
1. CS-SA/CT Riser - eliminate 45 degree chamfer at bottom of riser via the addition of cellular deck material (2 places).
  2. CS-SA/CT Riser - add triangular baffles on both sides of the base of the 6"x23" duct riser.
  3. CS-SA/CT South Leg - Change opening from 12'-9"x3'-6" to 8'-0"x3'-6".
  4. CS-SA/CT South Leg - Change inside radius from 7.8' to 14.9'. Change outside radius from 25.8' to 14.9'.
  5. CS-SA/CT North Leg - Change opening from 7'-3"x3'-6" to 5'-0"x2'-6".
  6. CS-SA/CT North Leg - Change outside smooth elbow radius to sharp 90 degree bend.
  7. CS-SA/CT North Leg - Change inside smooth radius to sharp 90 degree bend.
  8. SA-CT Riser - eliminate 45 degree chamfer at bottom of riser.
  9. SA-CT North leg - Construct orifice opening in duct at inside edge of 90 degree bend.
  10. SA-CT North leg - Change inside smooth radius elbow to sharp 90 degree bend.
  11. SA-CT North leg - Change outside smooth radius to sharp 90 degree bend.
  12. SA-CT South leg -

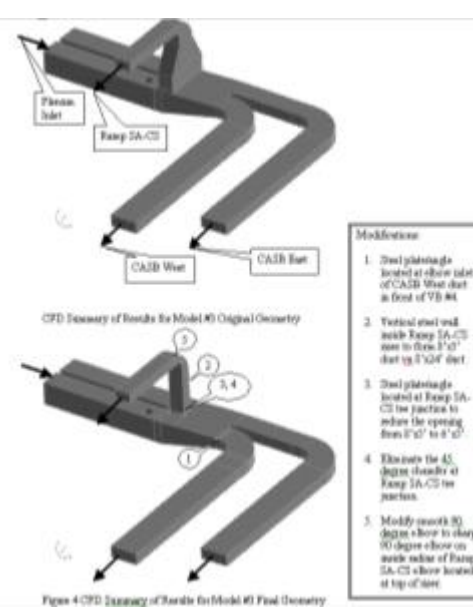


Figure 4 CFD Summary of Results for Model #4 Final Geometry

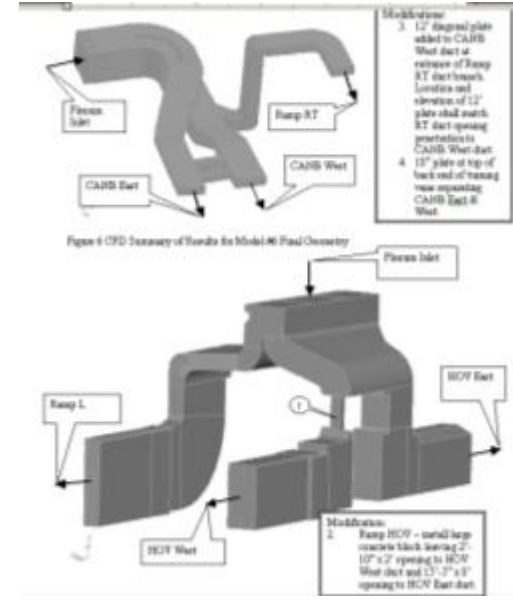


Figure 4 CFD Summary of Results for Model #4 Final Geometry





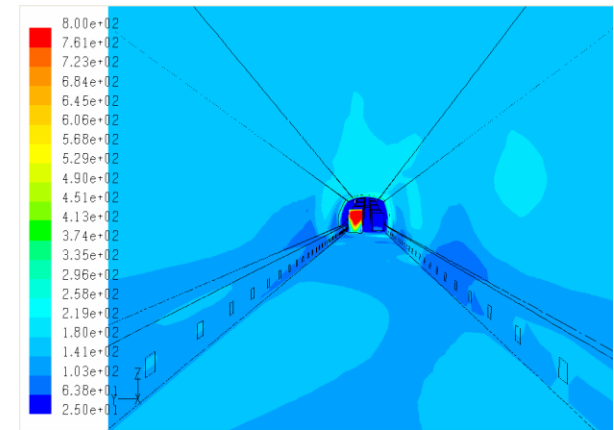
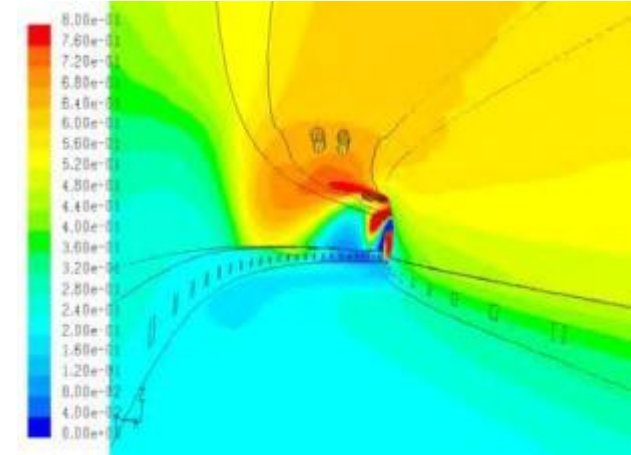






# Potential Issues

- Noise
- Vibration
- Pollutants
- Smoke
- Fire rating of building construction
- Security



# ***Facilities Control***

## *Ventilation*

- *7 Ventilation Buildings*
- *30 MW Total Installed Power*

## *Fire Protection*

- *130 Standpipe Zones*

## *Drainage*

- *7 Tunnel Pump Stations*
- *21 Storm Water Pump Stations*







# Sumner & Callahan Tunnels

- ☐ Six-year Maintenance, Repair & Renovation Program
- ☐ Beneath Boston Harbor
- ☐ Condition Inspection & Reporting
- ☐ Structural, Mechanical, Electrical & Systems Condition
- ☐ Design of Replacement Ventilation & Electrical Systems



# Urban Tunnels Rehabilitations

## Seattle, WA

- ☐ I-90 Mount Baker and Mercer Island Tunnels

## New York, NY

- ☐ NY City Tunnels – Park Avenue; First Avenue, Battery Park Underpass
- ☐ Holland Tunnel
- ☐ Brooklyn-Battery Tunnel

## Boston

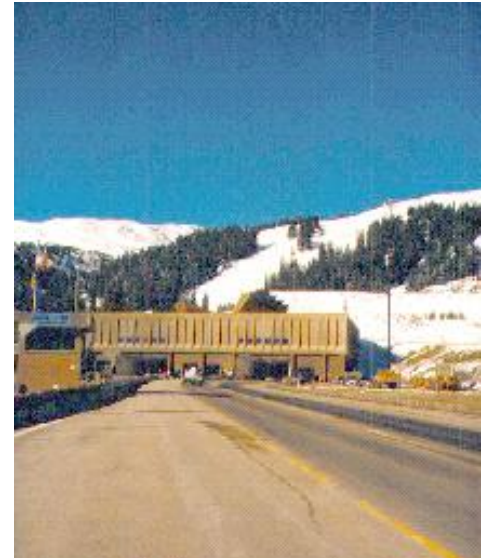
- ☐ Sumner/Callahan Tunnel

## Washington, DC

- ☐ Air Rights Tunnel
- ☐ Mall Tunnel
- ☐ Rosslyn Tunnel

## Baltimore

- ☐ Fort MacHenry Tunnel





# Other Tunnels Rehabilitation Projects

- ☐ Detroit - Windsor Tunnel
- ☐ Eisenhower – Johnson Memorial Tunnel
- ☐ Jack Lynch Tunnel
- ☐ Dartford Tunnel
- ☐ Chesapeake Bay Bridge Tunnel

## VDOT TUNNELS:

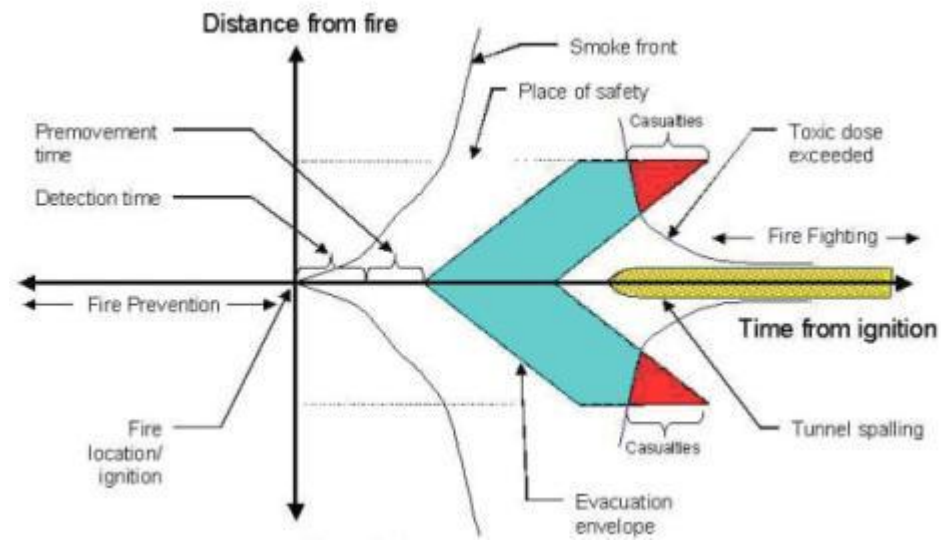
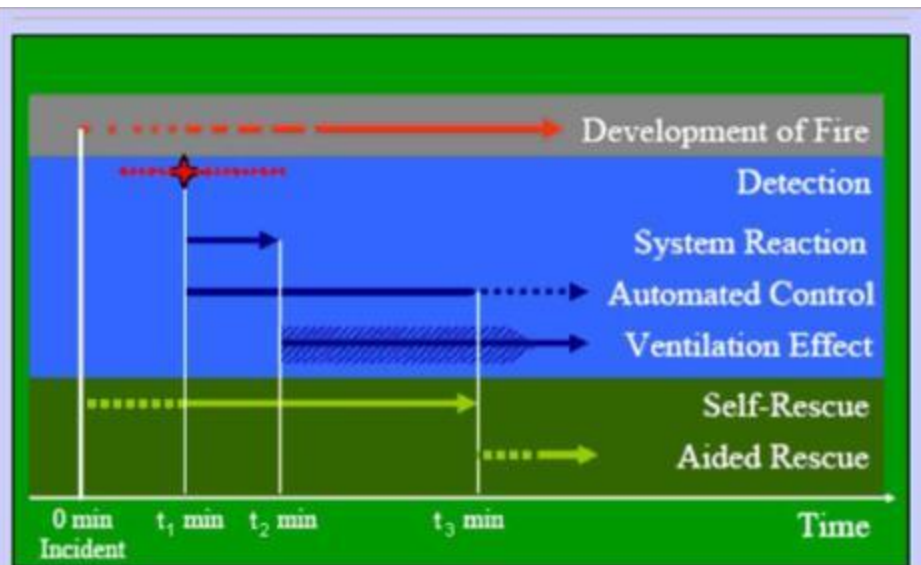
- ☐ Hampton Roads Tunnel
- ☐ Monitor Merrimac Memorial Tunnel
- ☐ Big Walker Tunnel
- ☐ Elizabeth River Tunnel
- ☐ Midtown Tunnel
- ☐ Downtown Tunnel
- ☐ I-564 Tunnel



# Urban Tunnel Rehabilitation Issues

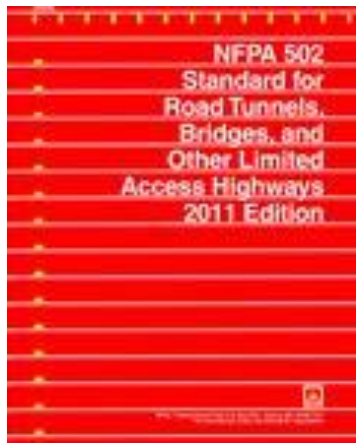
## Fire Emergency

1. Safety of Occupants
2. Safety of First Responders
3. Structural Safety
4. Safety of Surrounding Urban Area



# 1. Safety of Occupants

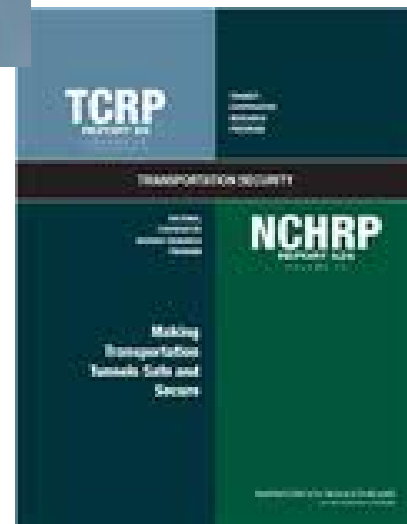
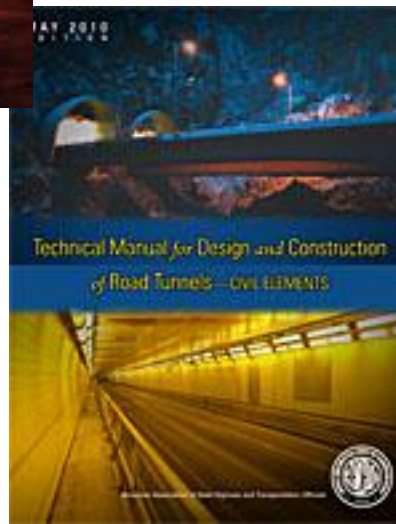
- Unpredicted behavior of tunnel users – human factor
- New Standards – new data
- Traffic Congestion in Urban Areas and difficulties with Traffic management, especially during city events





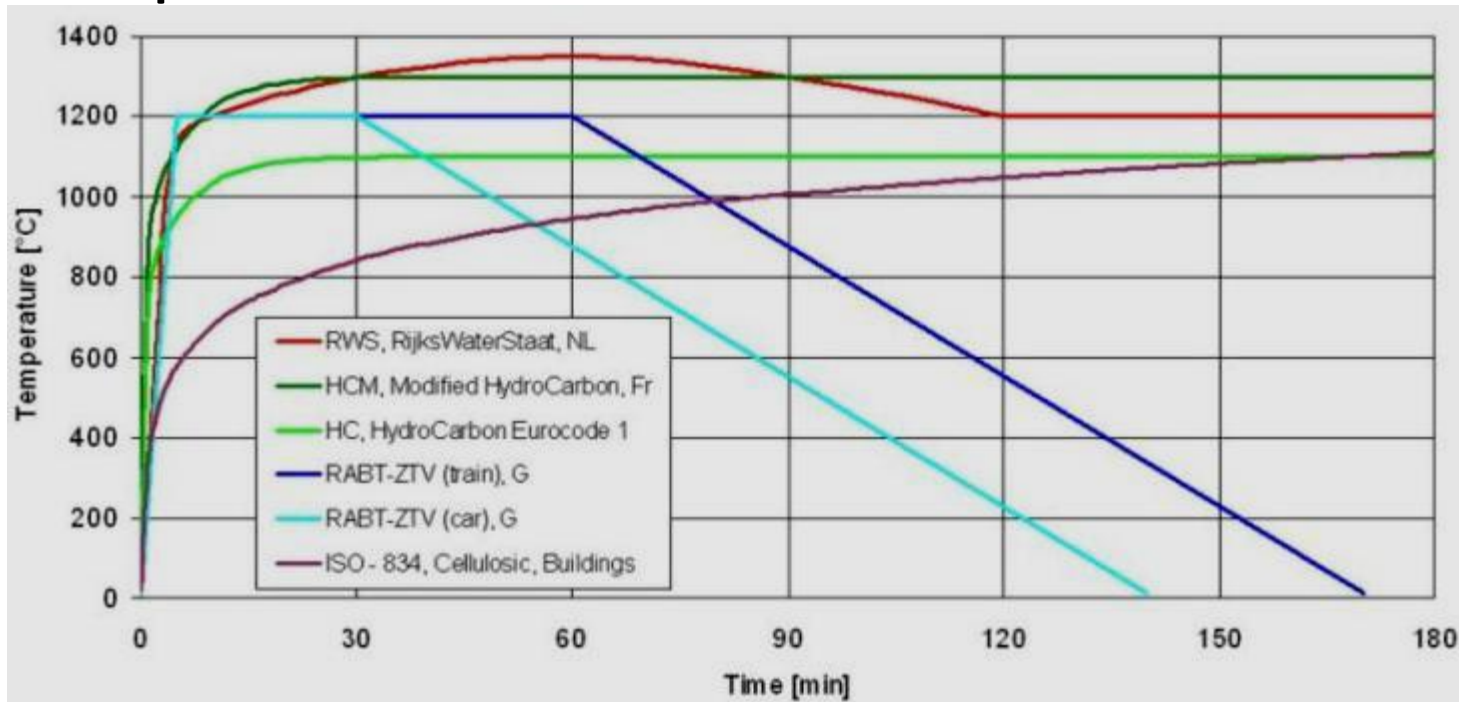
## 2. Safety of First Responders

- Traffic Congestion and increased response time



# 3. Structural Safety

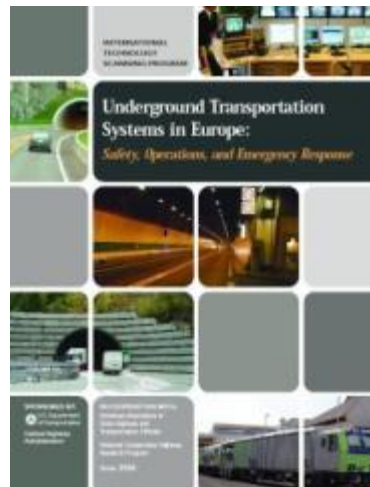
- Overbuilds and structures above
- RWS or similar curve
- Response Time



# 4. Safety of Surrounding Urban Area

- Smoke
- Noise
- Pollutions
- Vibration

Cause of Fire	Peak Fire Heat Release Rate, 10 <sup>6</sup> Btu/h (MW)
Passenger Car	17 to 34 (5 to 10)
Multiple Passenger Cars (2 to 4 vehicles)	34 to 68 (10 to 20)
Bus	68 to 102 (20 to 30)
Heavy Goods Truck	239 to 682 (70 to 200)
Tanker <sup>3</sup>	682 to 1,023 (200 to 300)





# Conclusion

- Tunneling is the solution for Urban Traffic issues
- Tunneling is the solution for air quality in major metropolis
- Tunneling is the solution for future urban development
- Tunneling though expensive but it the solution for longevity of infrastructure – 100 plus years
- New tunneling methods allow for reduction of cost and mitigate environmental issues
- Tunneling require regular operation, maintenance and periodic rehabilitation
- Rehabilitation is complicated in urban environment requiring highly skilled and experienced engineers. Jacobs has a track record of accomplishing best results tunnels