7º Congreso Internacional de Ingeniería de Seguridad contra Incendios
7th International Congress on Fire Safety Engineering

The Marriage of a Bus Terminal, NFPA 130, Smoke Control and Wind

Armin Wolski, PE
Associate Principal
Arup, San Francisco

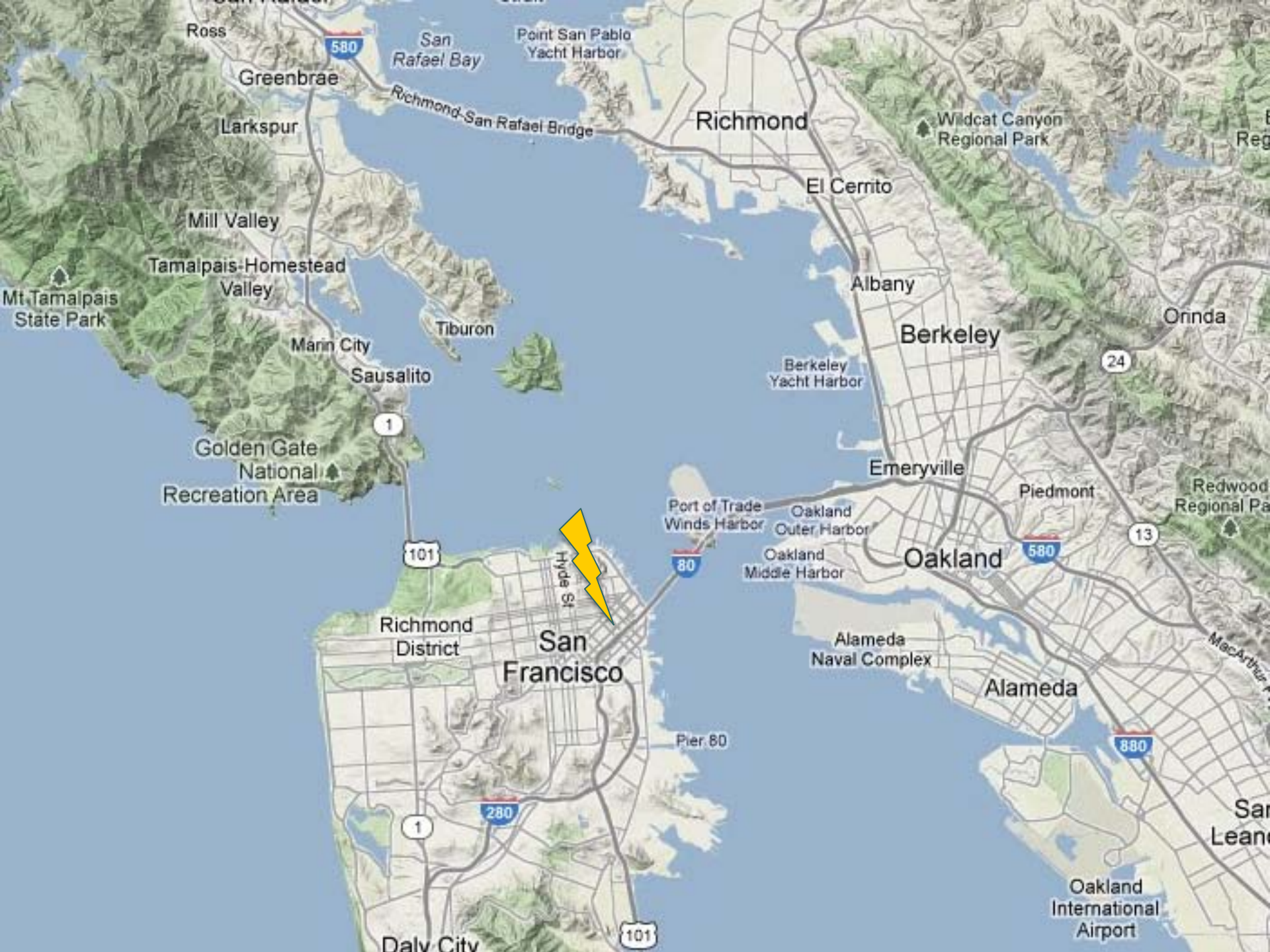
ARUP

Organizadores / Organizers

APICI Asociación de Profesionales de Ingeniería de Protección Contra Incendios
AFITI
ALAMYS
FUNDACIÓNMAPFRE

Madrid, 20 – 22 de Febrero de 2013
Centro de Convenciones Mapfre

Transbay Transit Center, San Francisco, CA, USA


Ross
580
San Rafael Bay
Point San Pablo Yacht Harbor
Greenbrae
Richmond-San Rafael Bridge
Richmond
Wildcat Canyon Regional Park
Larkspur
El Cerrito
Mill Valley
Tamalpais-Homestead Valley
Albany
Mt Tamalpais State Park
Tiburon
Berkeley
Orinda
Marin City
Berkeley Yacht Harbor
24
Sausalito
1
Golden Gate National Recreation Area
Emeryville
Piedmont
Redwood Regional Pa
Port of Trade Winds Harbor
Oakland Outer Harbor
13
101
80
Hyde St
Oakland Middle Harbor
Oakland
580
Richmond District
San Francisco
Alameda Naval Complex
MacArthur
Alameda
Pier 80
880
280
1
Oakland International Airport
Daly City
101

Neighborhood

Transbay Transit Center amongst SF Financial District

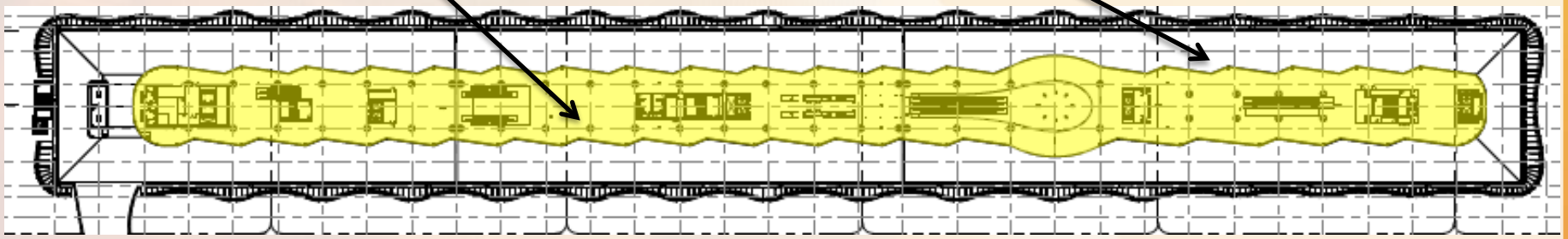

Park
Bus Deck
Grand Hall
Concourse
Train Platforms

Bus Deck Egress Strategy

- **Circa 18,000 square meter bus deck**
- **San Francisco Building Code approach:**
- **~1 person per m^2?**
  - **Required total exit stair width ~57m.**
  - **Escalators are not permitted exits.**

Passenger Area
8,000 square meters

Bus Circulation Area
10,000 square meters



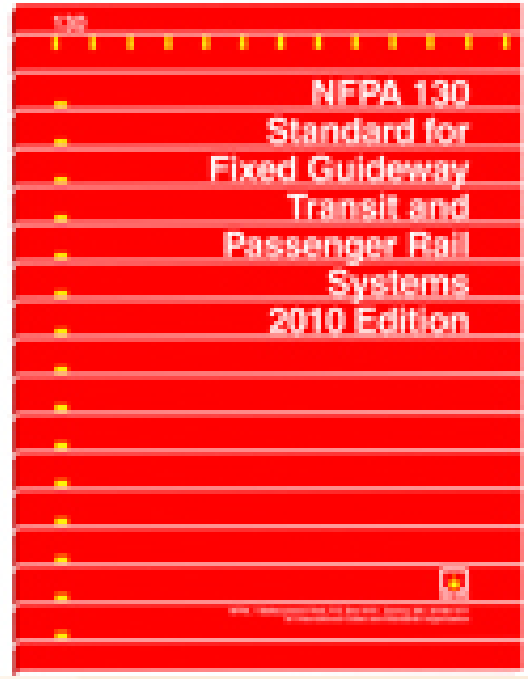
Bus Deck Egress Strategy

- Using NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems, apply to the Bus Deck
- NFPA 130 permits use of escalators, bases occupant number on transit schedule & exiting width on flow calculation
  - Exiting time should be no greater than 4 minutes
- NFPA 130 requires emergency smoke ventilation

Emergency Ventilations Systems and NFPA 130

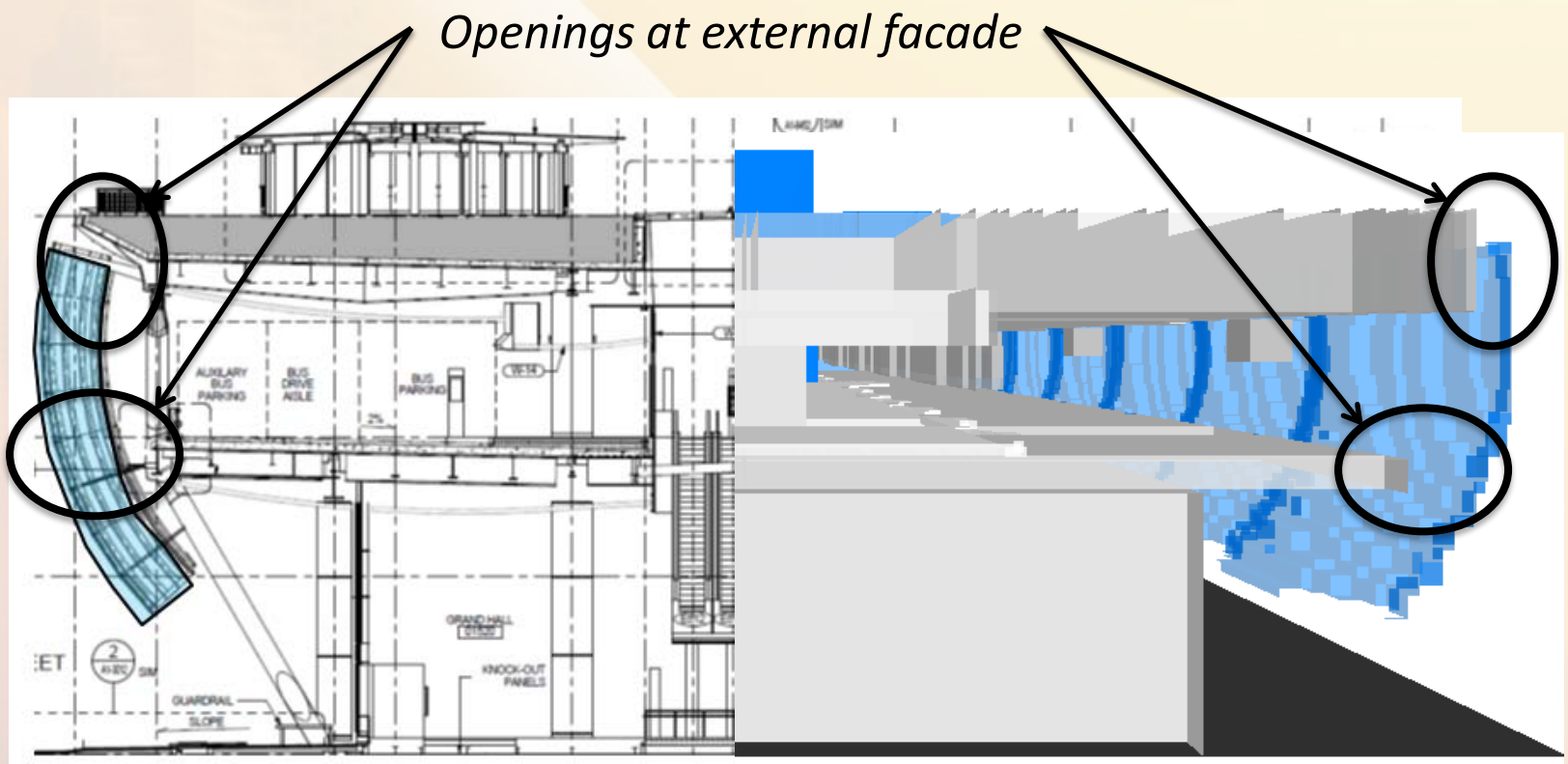
Emergency Ventilation System should:

- Provide tenable environment such that occupants can safely evacuate the building
- Limit exposure to fire and smoke for passengers, employees, and emergency personnel
- Provide assistance during fire fighting intervention and limit smoke spread



Emergency Ventilations Systems and NFPA 130

- ***An open station is not required to be provided with a <u>mechanical</u>*** emergency ventilation system.
- Can we characterize the bus deck as an ***open station***?

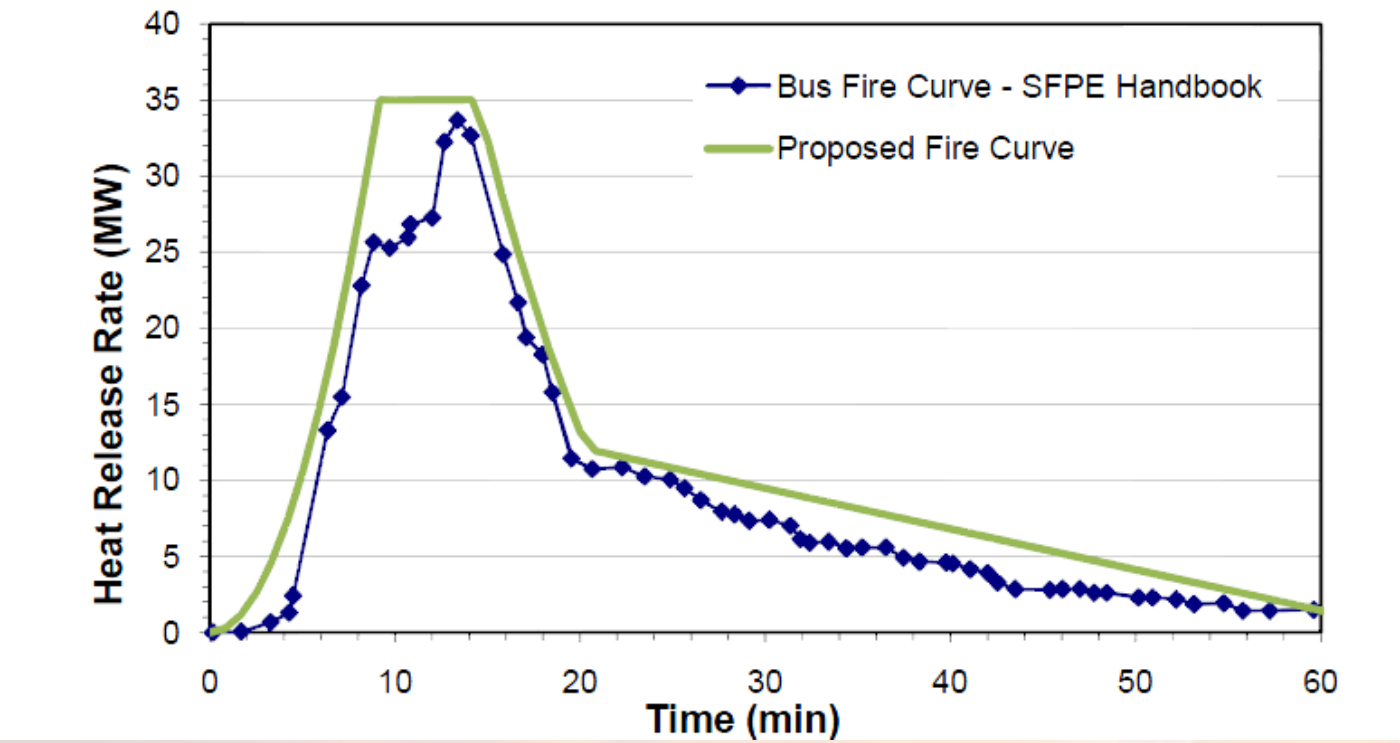


Methodology of the Analysis

1. Establish design basis fire
   - Fully involved bus fire, sprinklers
2. Investigate fire scenarios
   - Fire Locations
   - Impact of wind
3. Investigate protection systems
   - Fans/Downstands
   - Sprinkler System Effects
4. Investigate occupant safety and fire fighting impact
   - Governing Criteria for occupants: Minimum visibility 10m @ 2.5m above the finished floor

Design Basis Fire

- Single 35MW (peak) bus fire scenario used (from SFPE Handbook)
- Sprinklers activated to mitigate spread beyond
- Later bus fire tests available (Sweden) suggest lower peak heat release rates

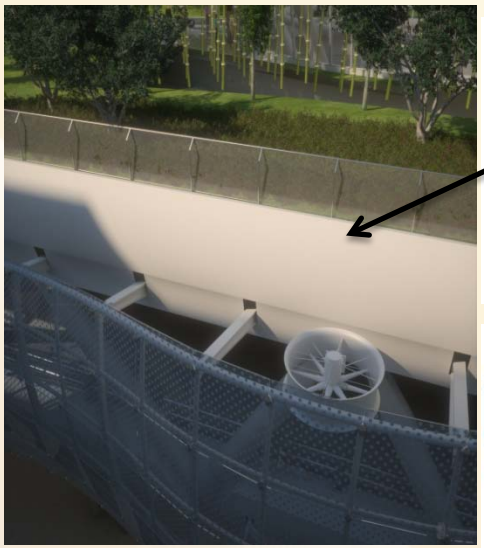


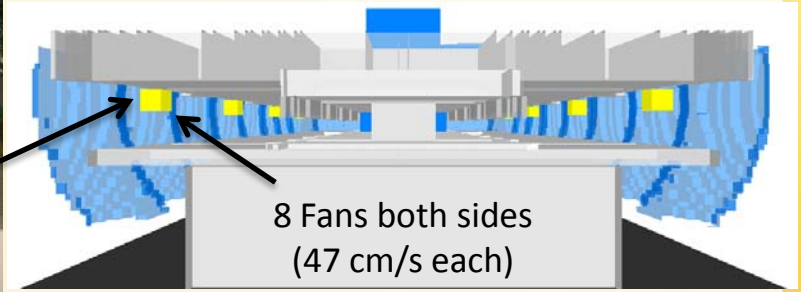
Design Basis Fire

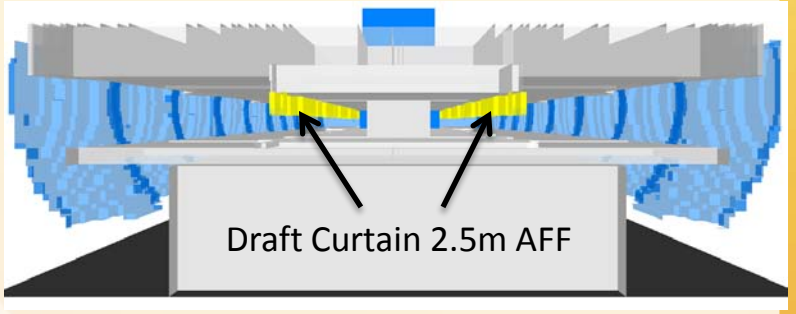
Property	Proposed
Soot Yield, y_s (g/g)	0.102
CO Yield, y_{CO} (g/g)	0.040
Heat of Combustion, ΔH_c (MJ/kg)	24.5
Mass Extinction Coefficient, K (m^2/kg)	7,600
Visibility Factor, K (m^{-1})	3 (light reflecting)

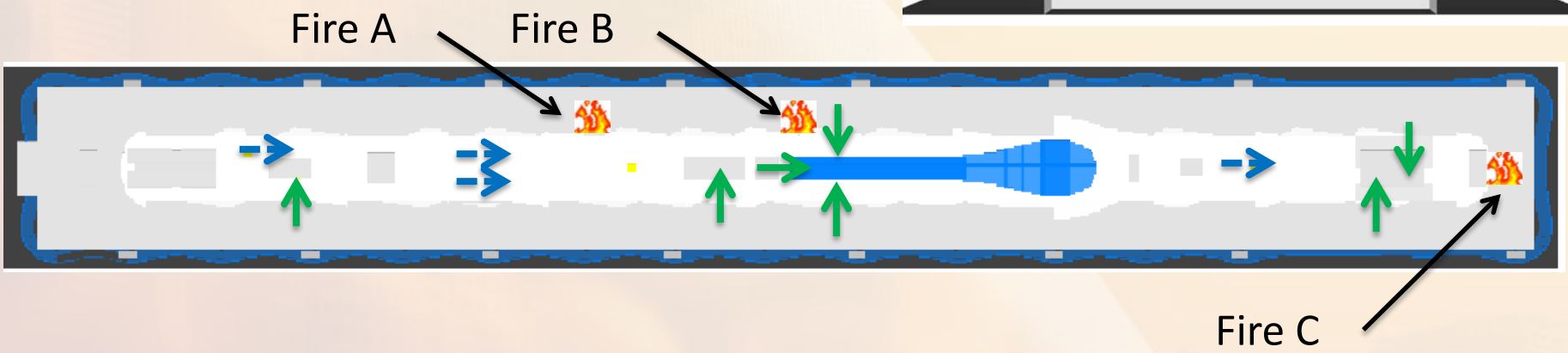
Methodology: No Wind

- 3 different fire locations study
- Fire location A is most onerous
- Investigate several design features







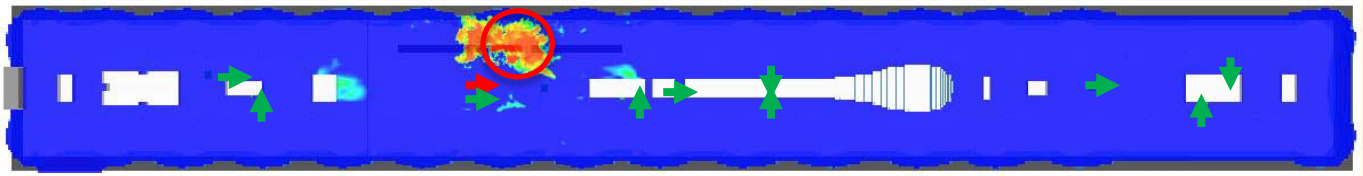
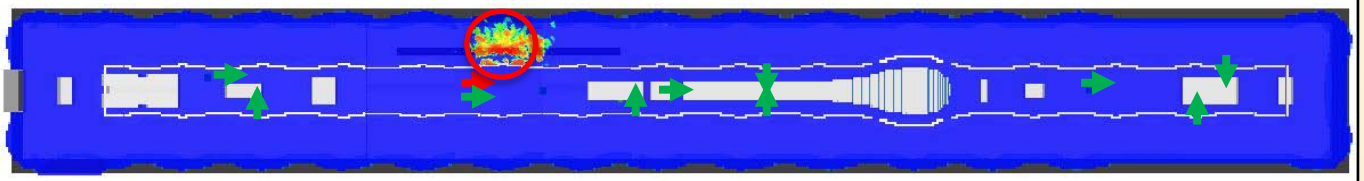
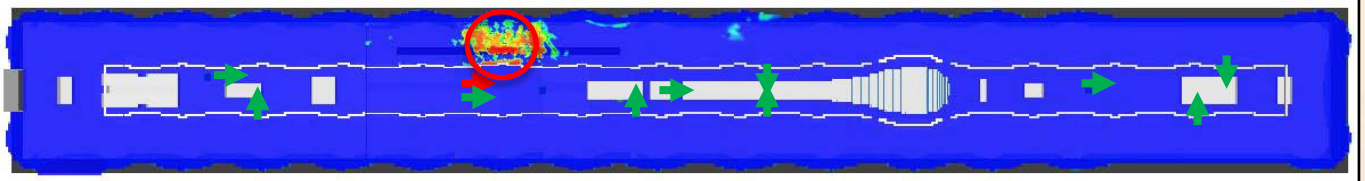


Closed exit to ground, below

Open exit to ground, below

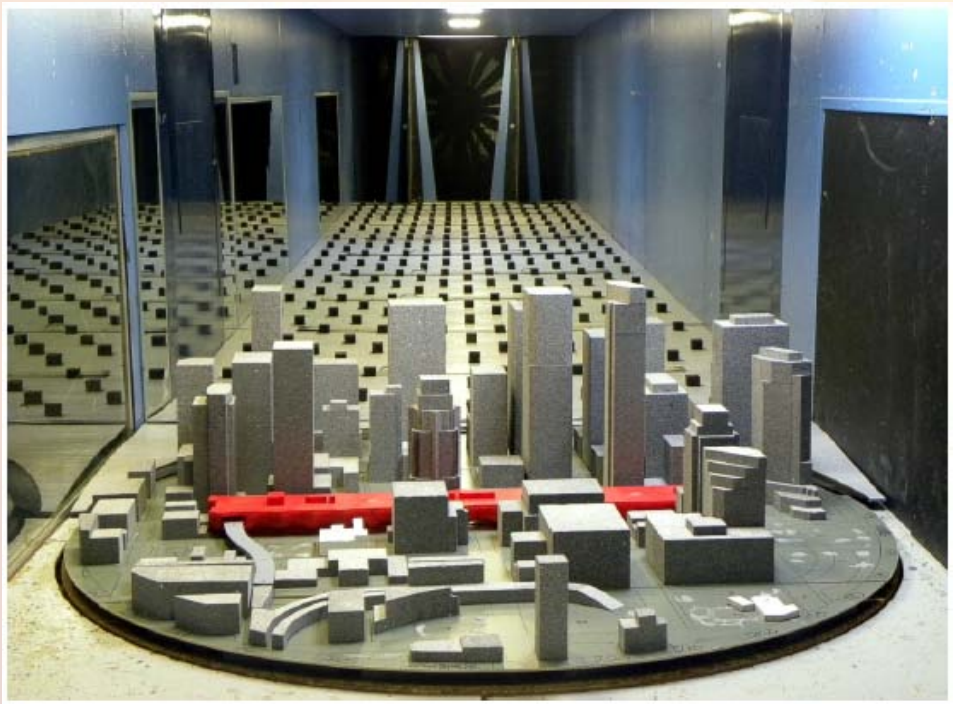
Methodology: No Wind

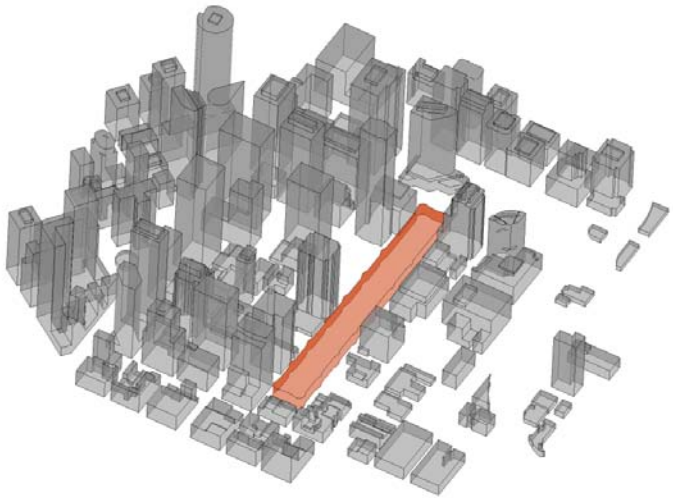
- Fire Location A at Bus Fire Peak (12min, 35MW)

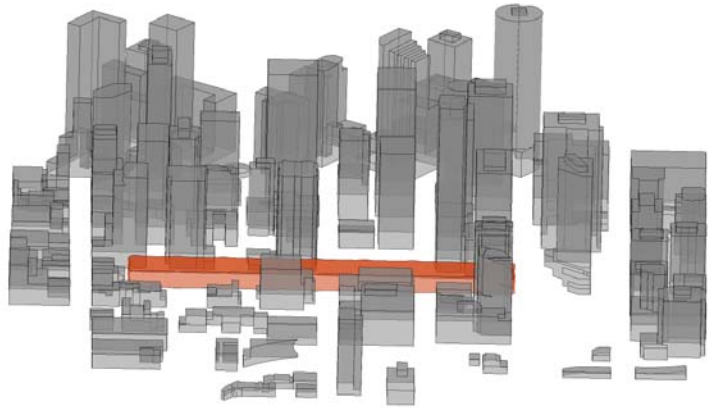
No Fans	
Draft Curtains No Fans	
Draft Curtains & Fans	

Methodology for Incorporating Wind

$$C_p = \frac{Computed/Measured\ Pressure}{{}^1/_2\,\rho V^2}$$

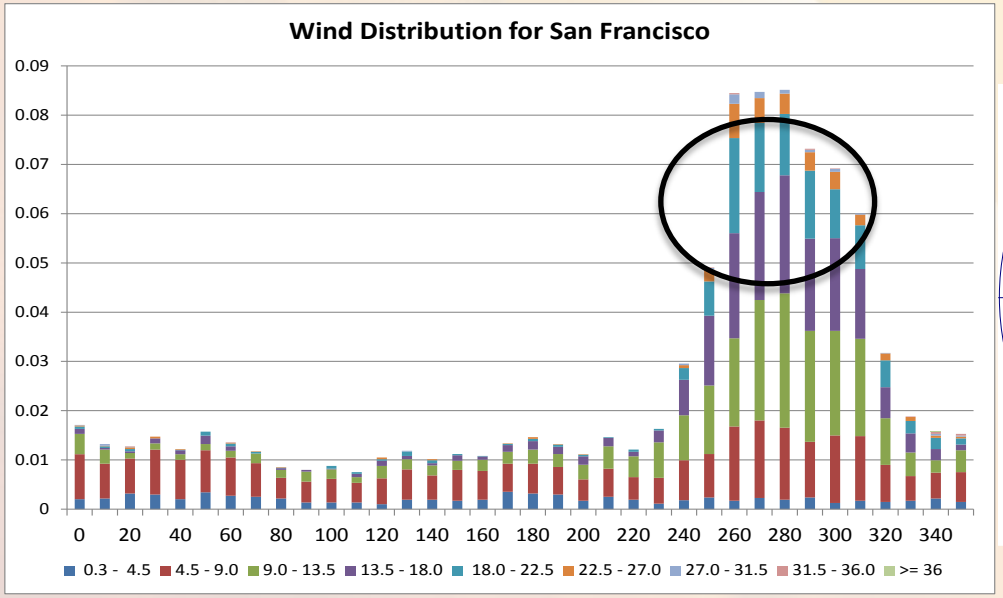


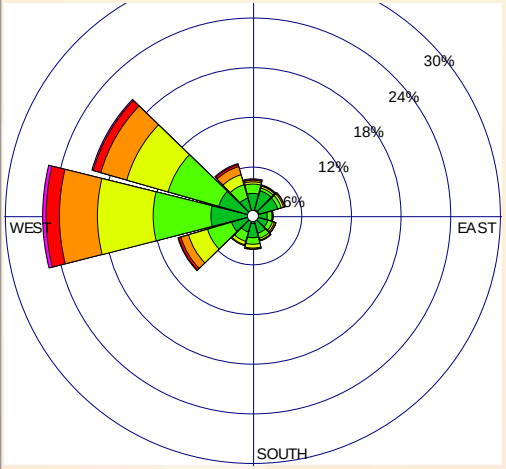




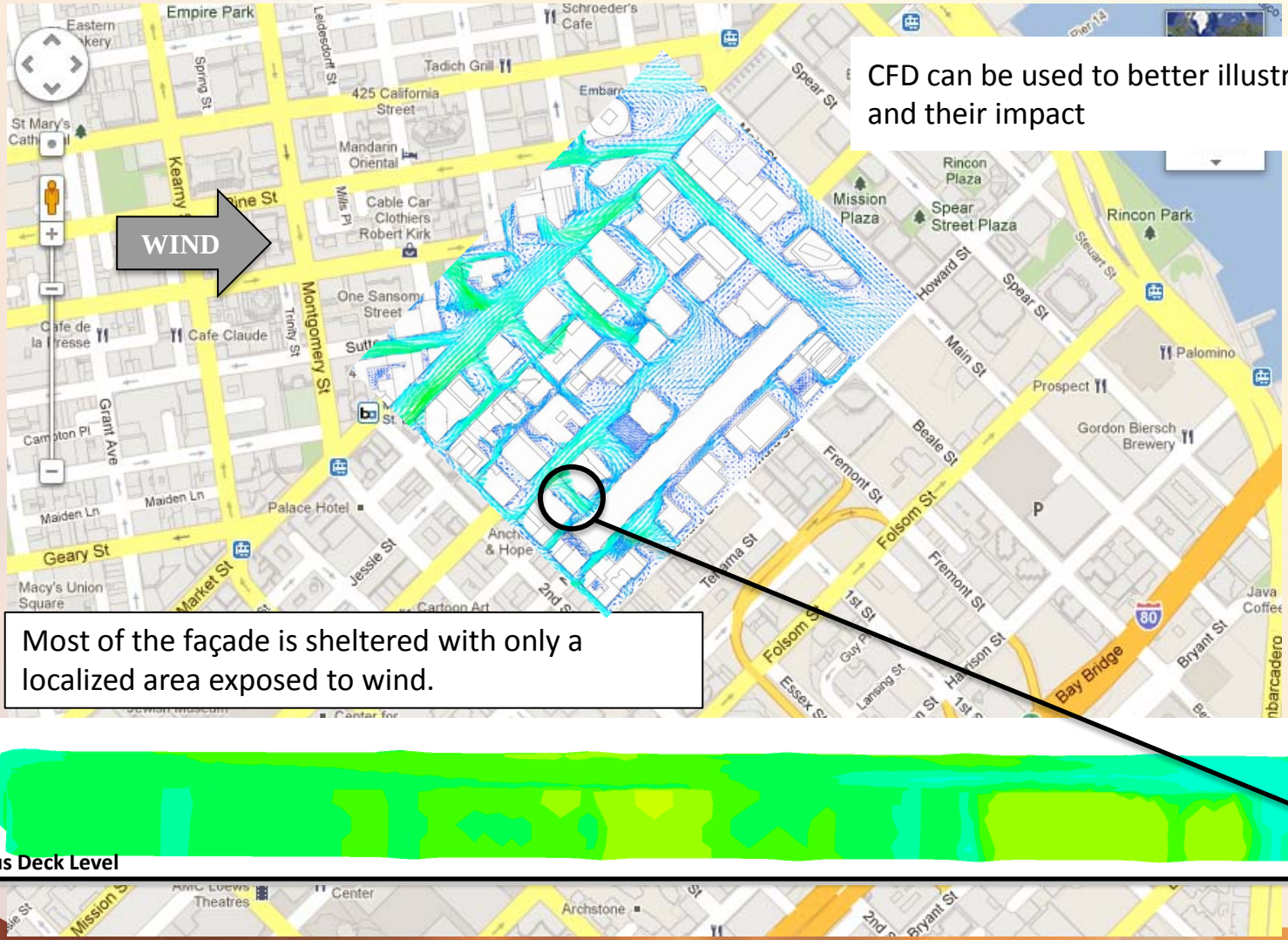
Methodology for Incorporating Wind

1. Review the wind tunnel results for 8 wind directions (N, NE, E, SE, S, SW, W, NW) onto the TTC station to identify worst case wind directions at 1% winds.
2. Model steady-state fires in locations where wind exerts biggest positive/negative pressures to identify worst fire & wind condition.
3. Model worst combination fire & wind conditions transiently using FDS.





Methodology for Incorporating Wind



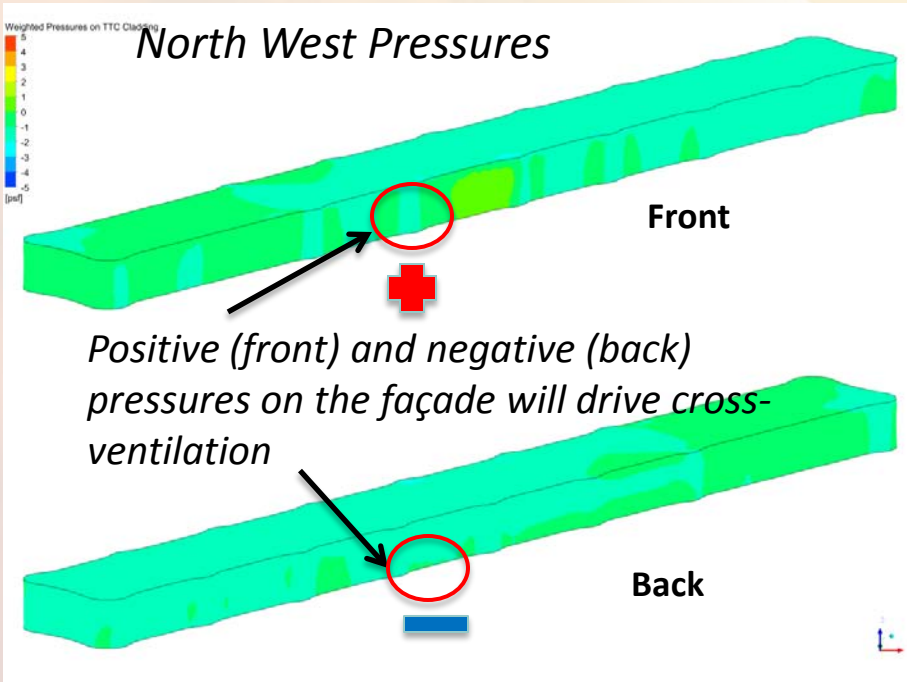
CFD can be used to better illustrate local winds and their impact

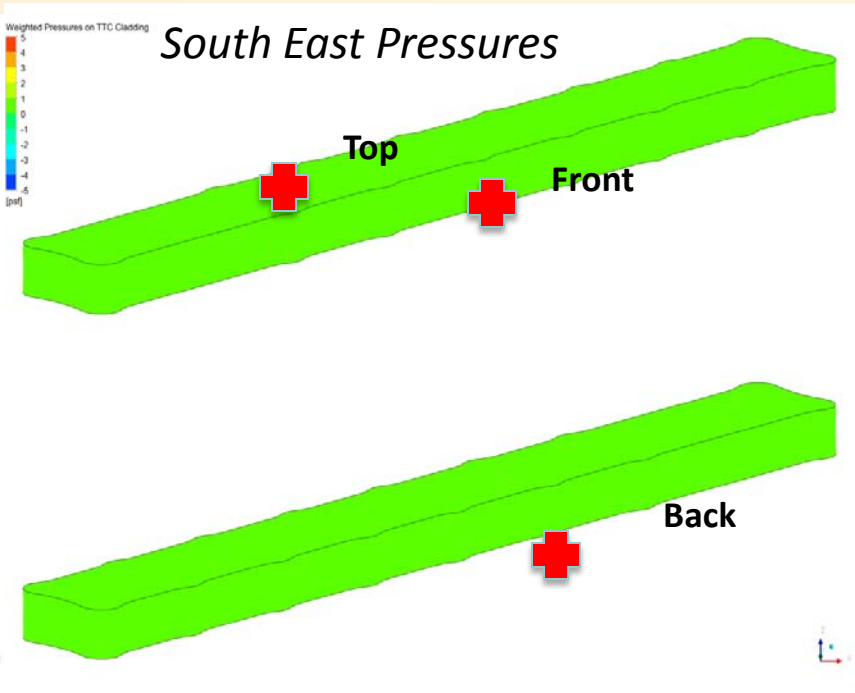
Most of the façade is sheltered with only a localized area exposed to wind.

Bus Deck Level

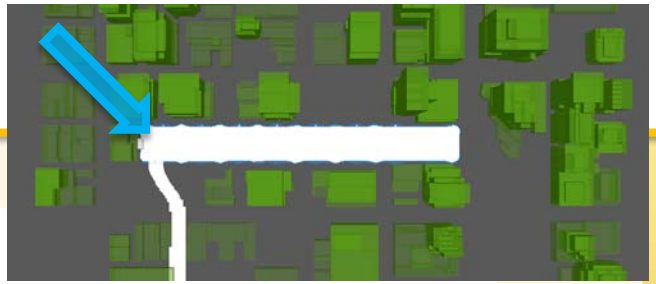
Methodology for Incorporating Wind

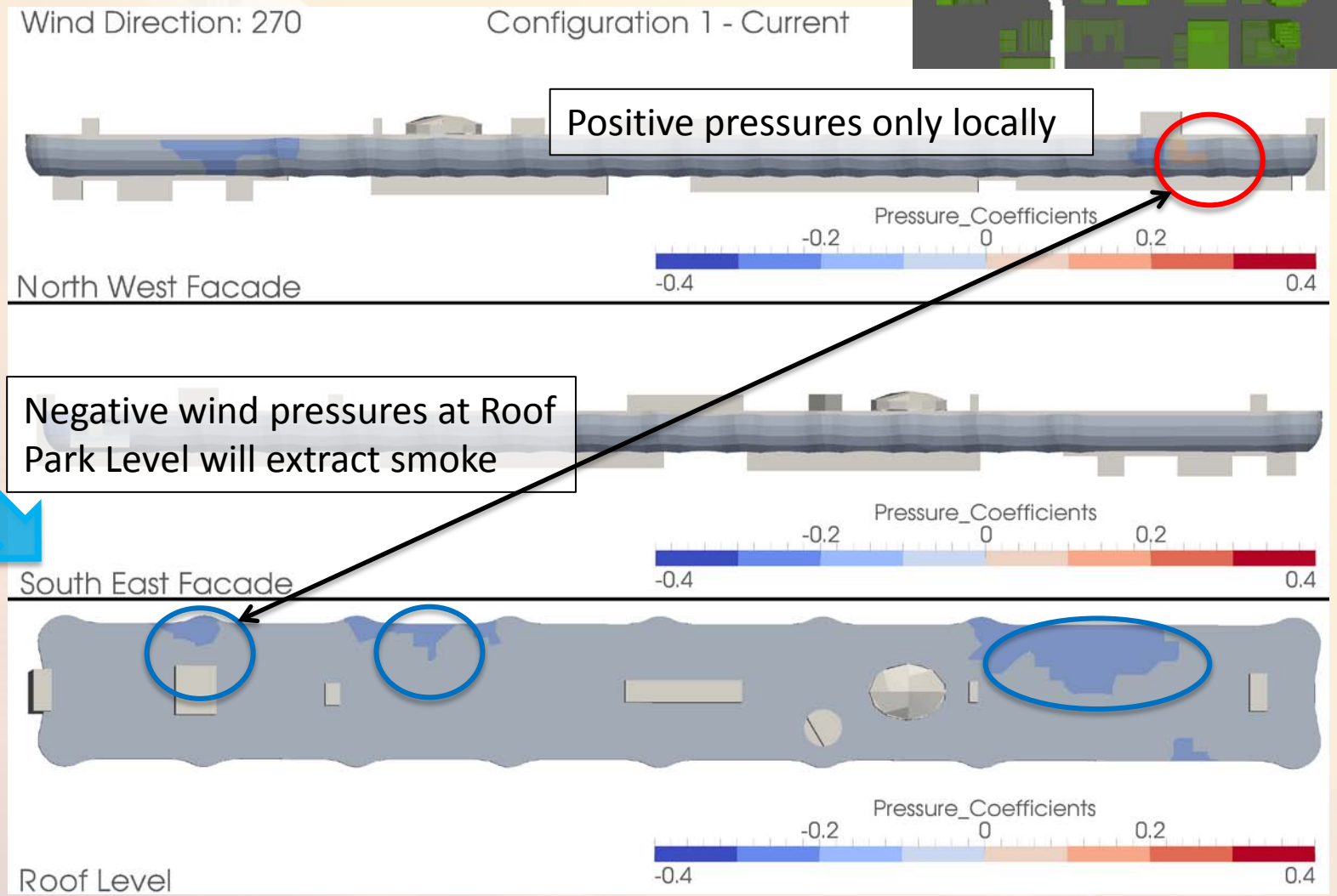
- Investigate the façade pressures from 8 directions. **The worst wind directions would be when**:
  - Smoke is prevented from escaping the bus deck level (largest external positive pressures)
  - Smoke is spread across the bus deck level (largest pressure differential between the front and back of the TTC envelope)





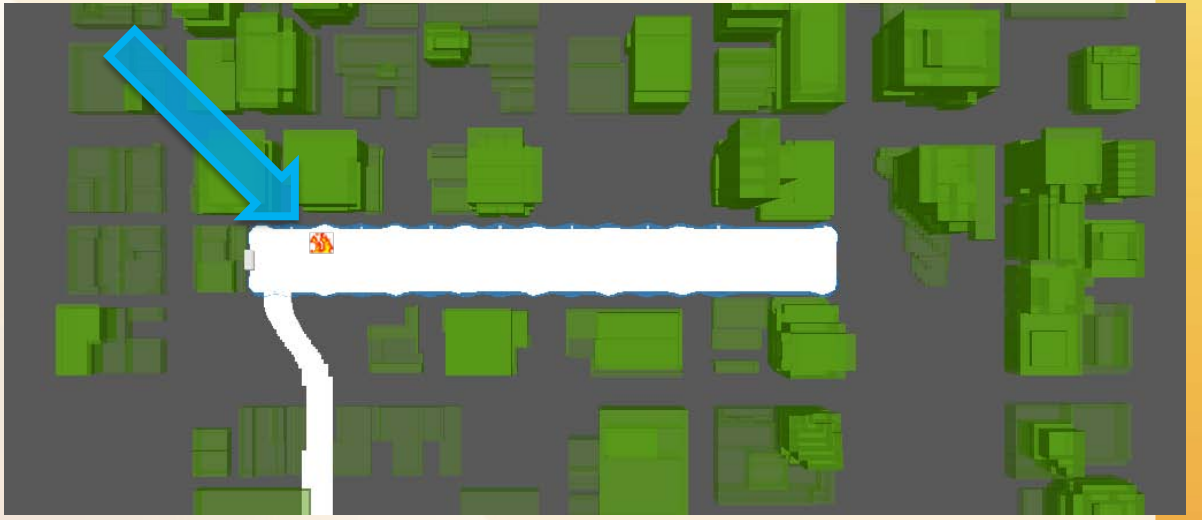
Worst Case Wind Directions



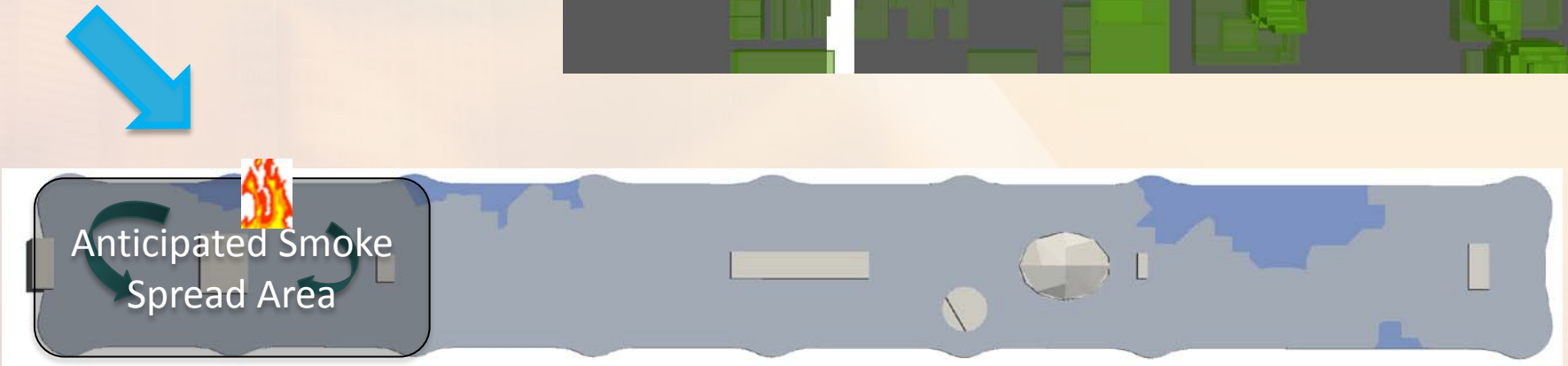


Wind and Fire Direction – 270º Wind

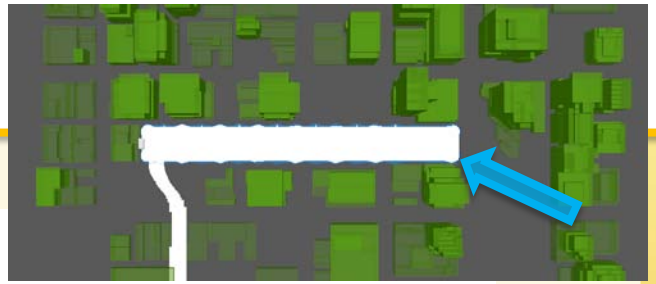
- Anticipated wind pattern & associated worst case fire location

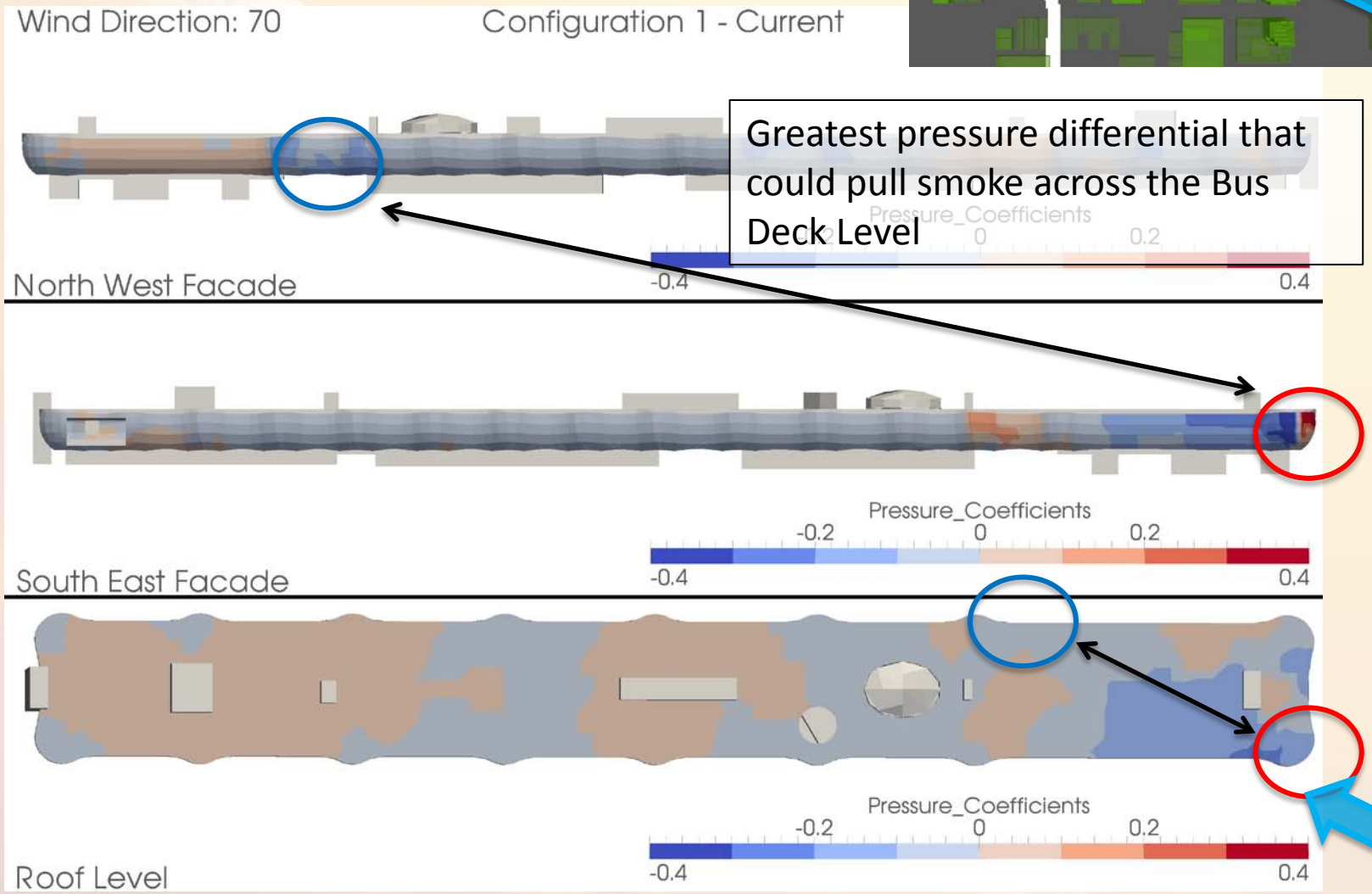


Wind Direction



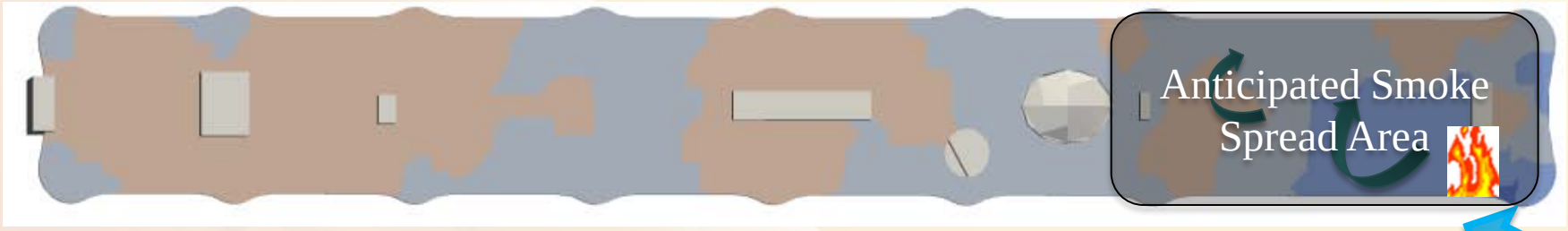
Worst Case Wind Directions





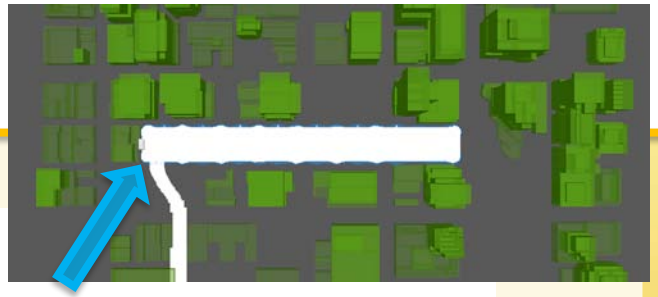
Wind and Fire – 70º Wind

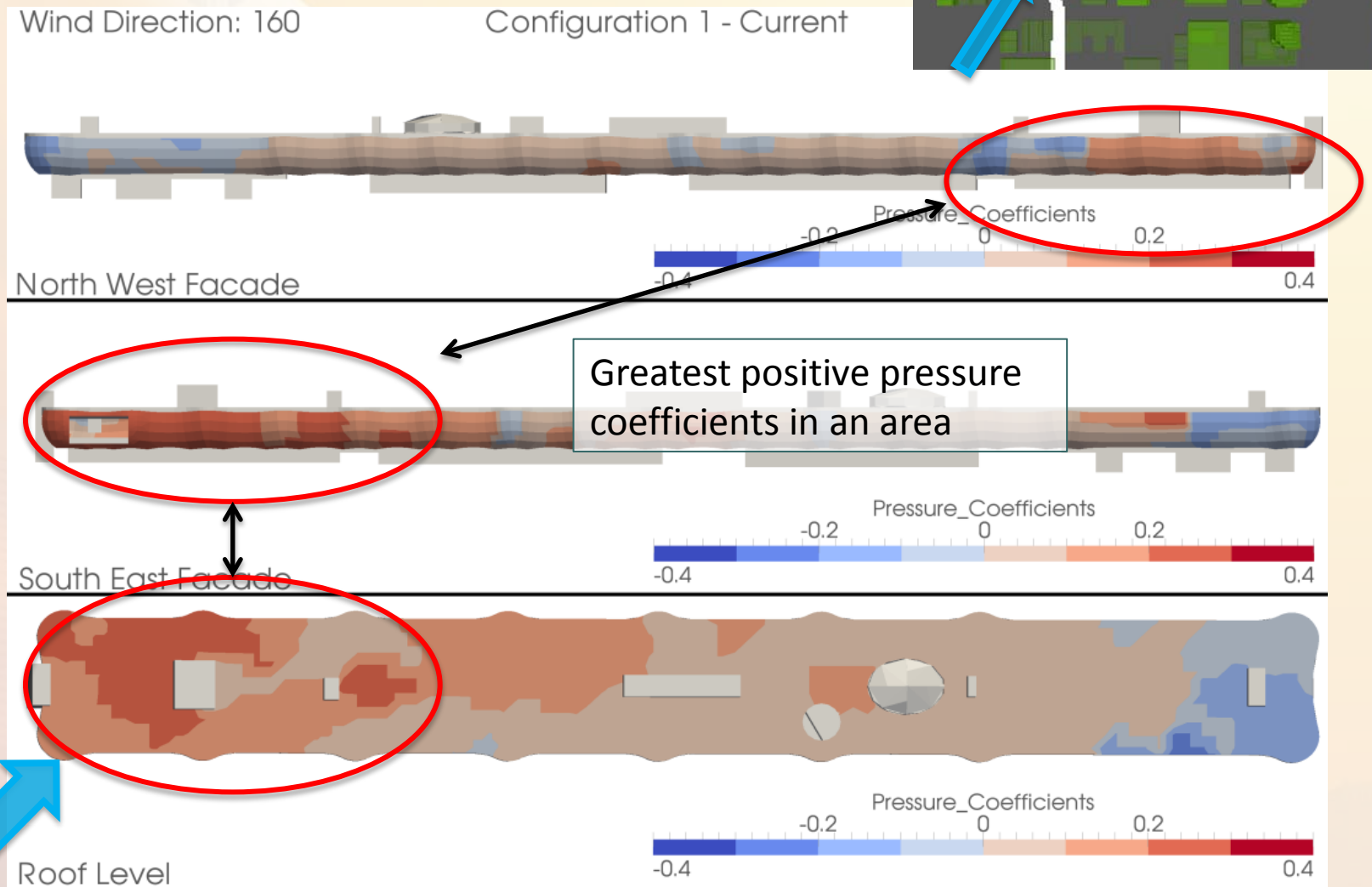
- Anticipated wind pattern & associated worst case fire location



Wind Direction

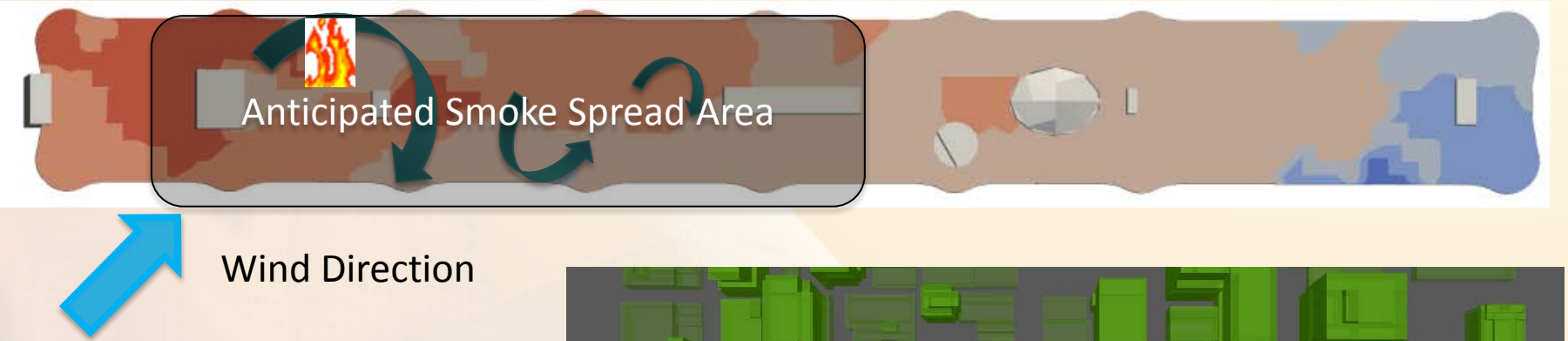
Worst Wind Directions

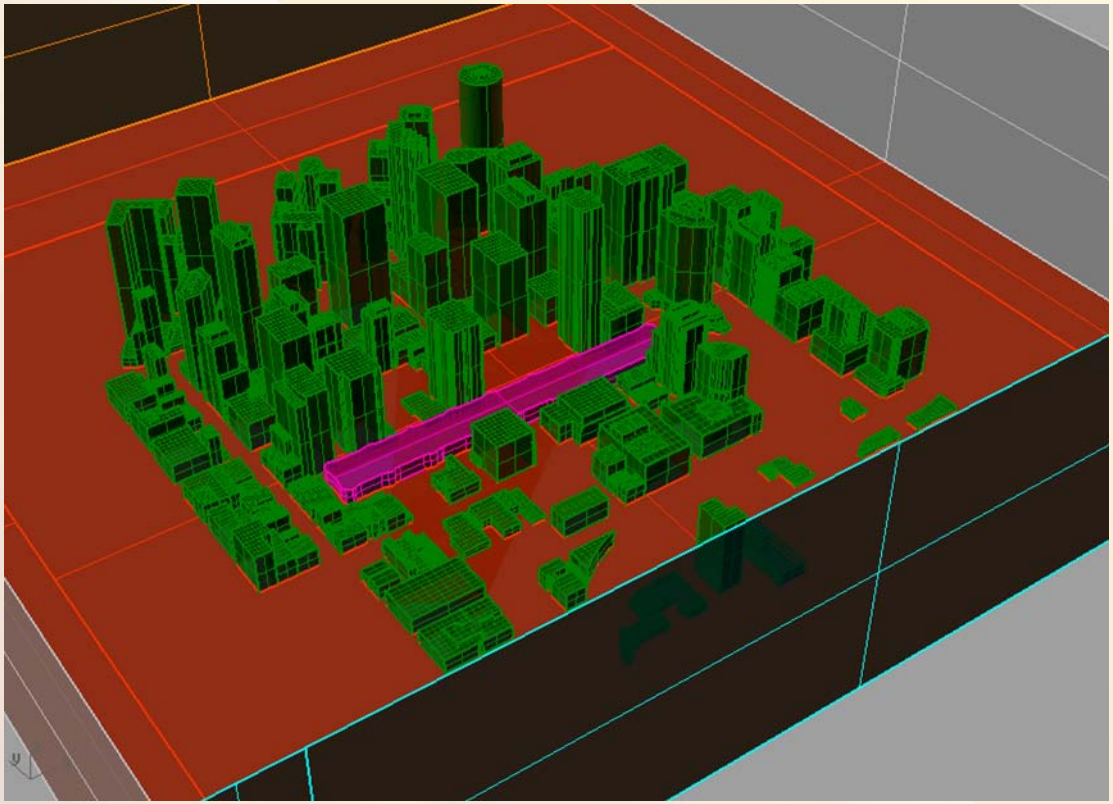




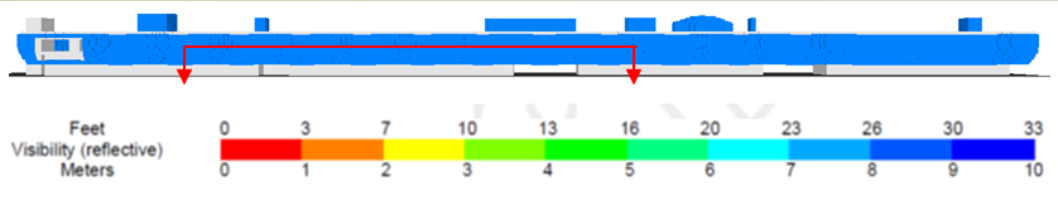
Wind and Fire – 160º Wind

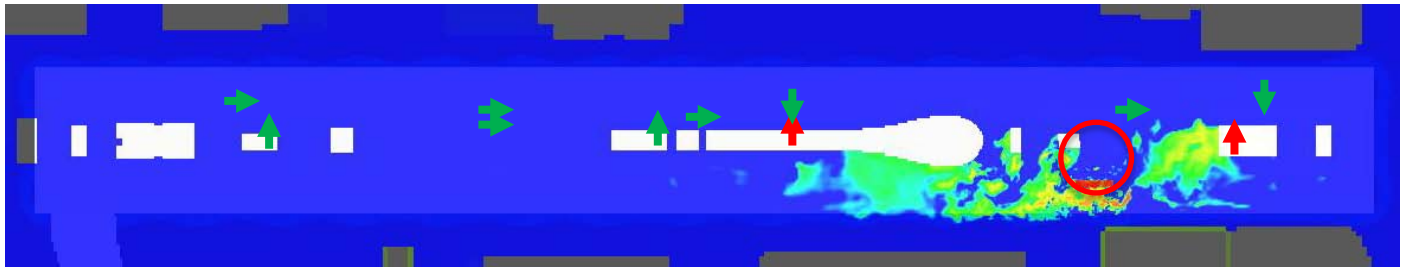
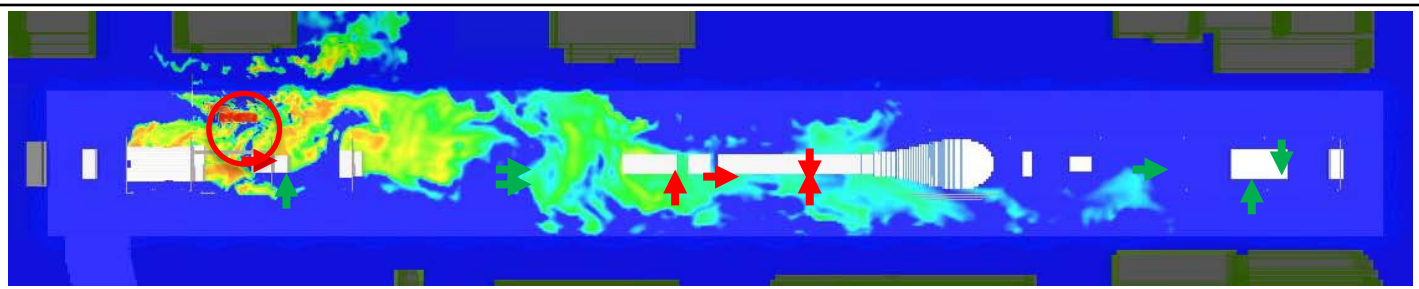
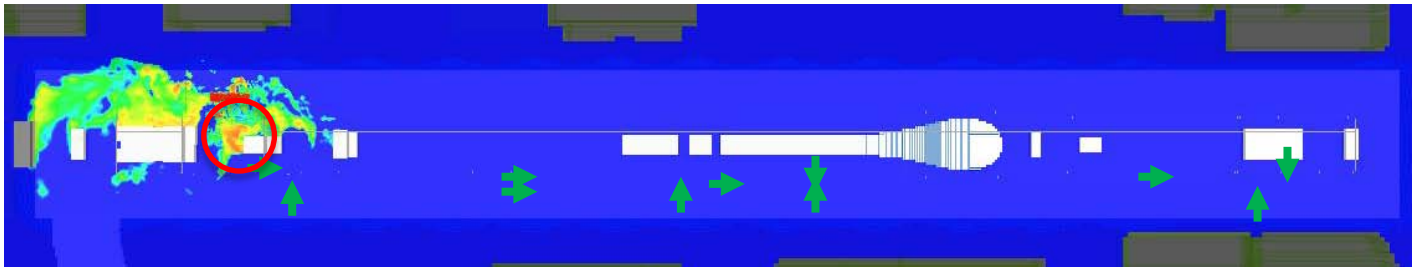
- Anticipated wind pattern & associated worst case fire location





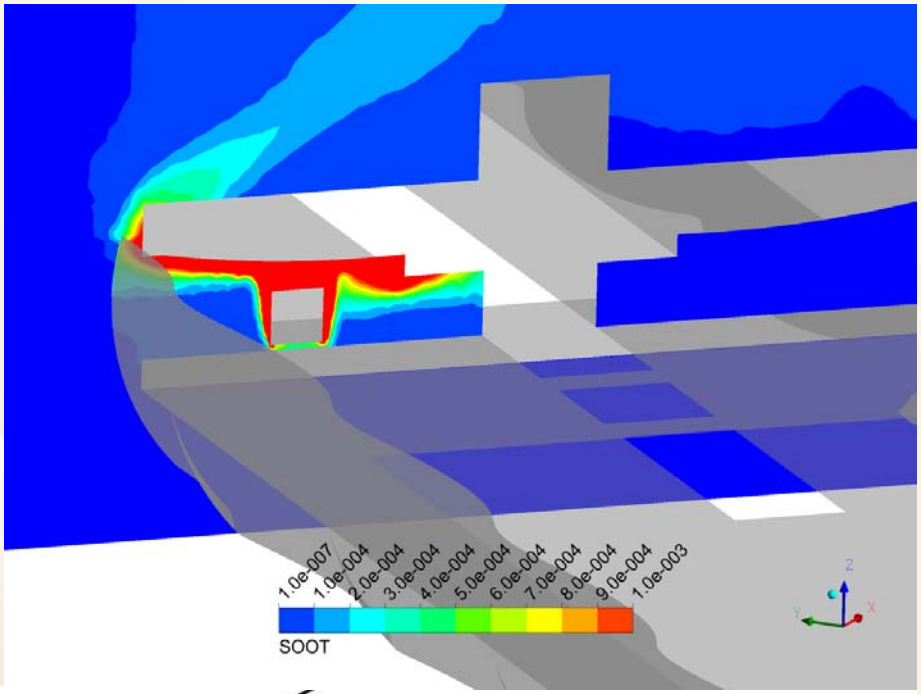
Worst Case Wind Directions /Worst locations at Peak Fire

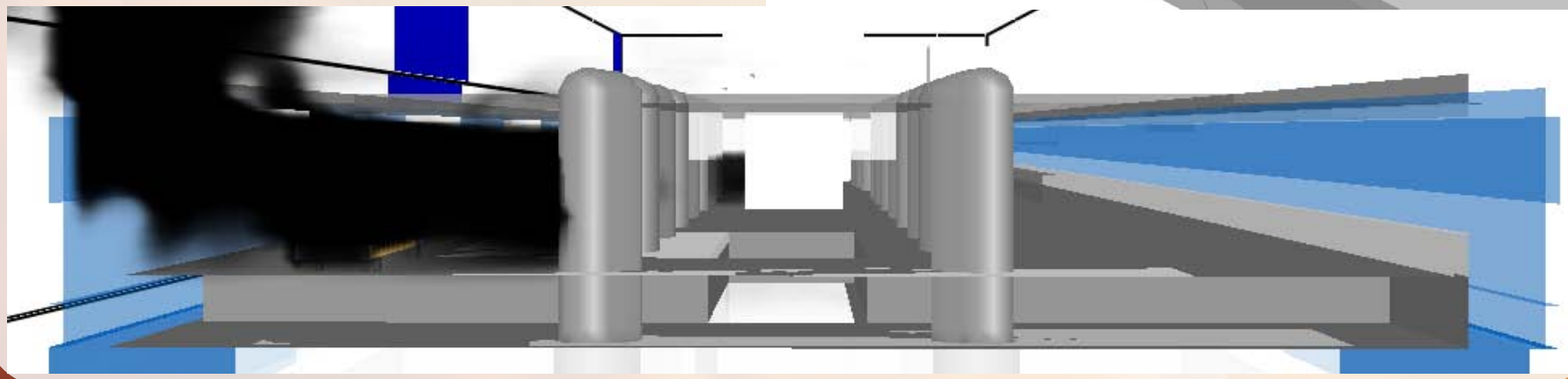


70º (11.7 m/s)	
160º (11.7 m/s) Governing Case!	
270º (20.7 m/s)	

Fire Dynamics Simulator (FDS)

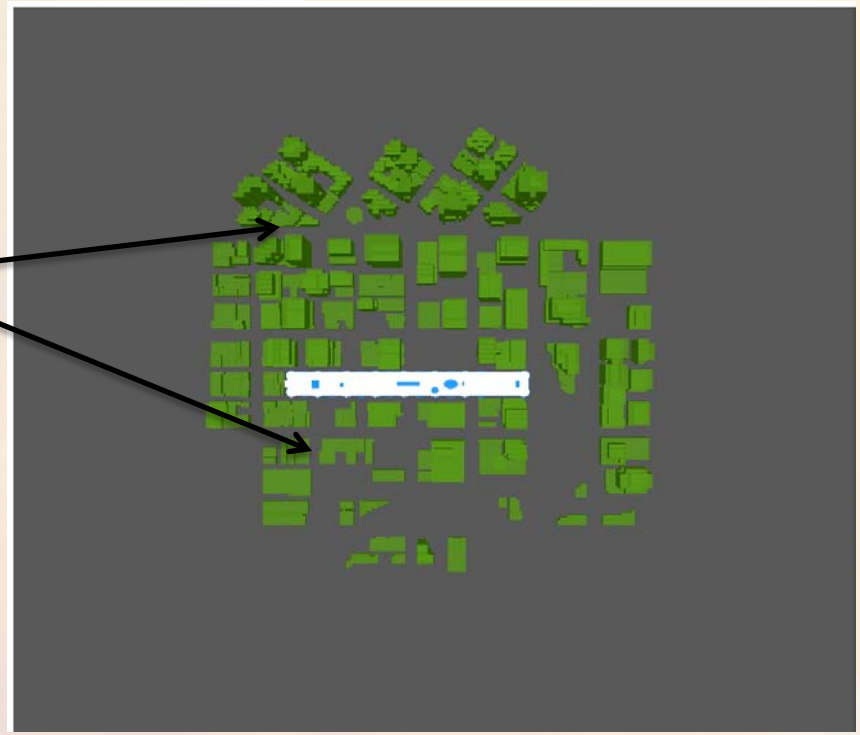
- Model worst wind directions/speeds condition at the worst case fire locations transiently with growing fire



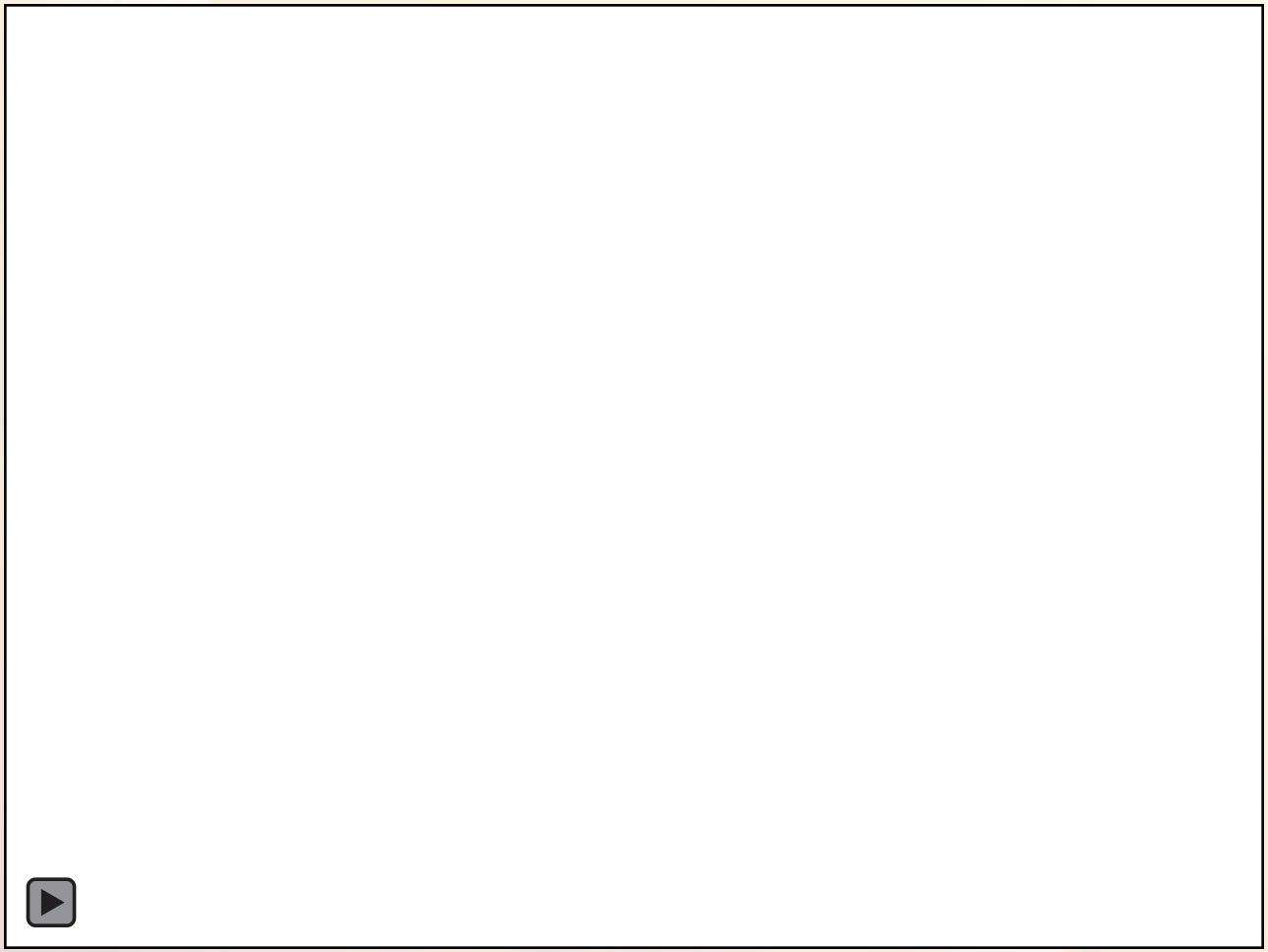


FDS Modeling Input

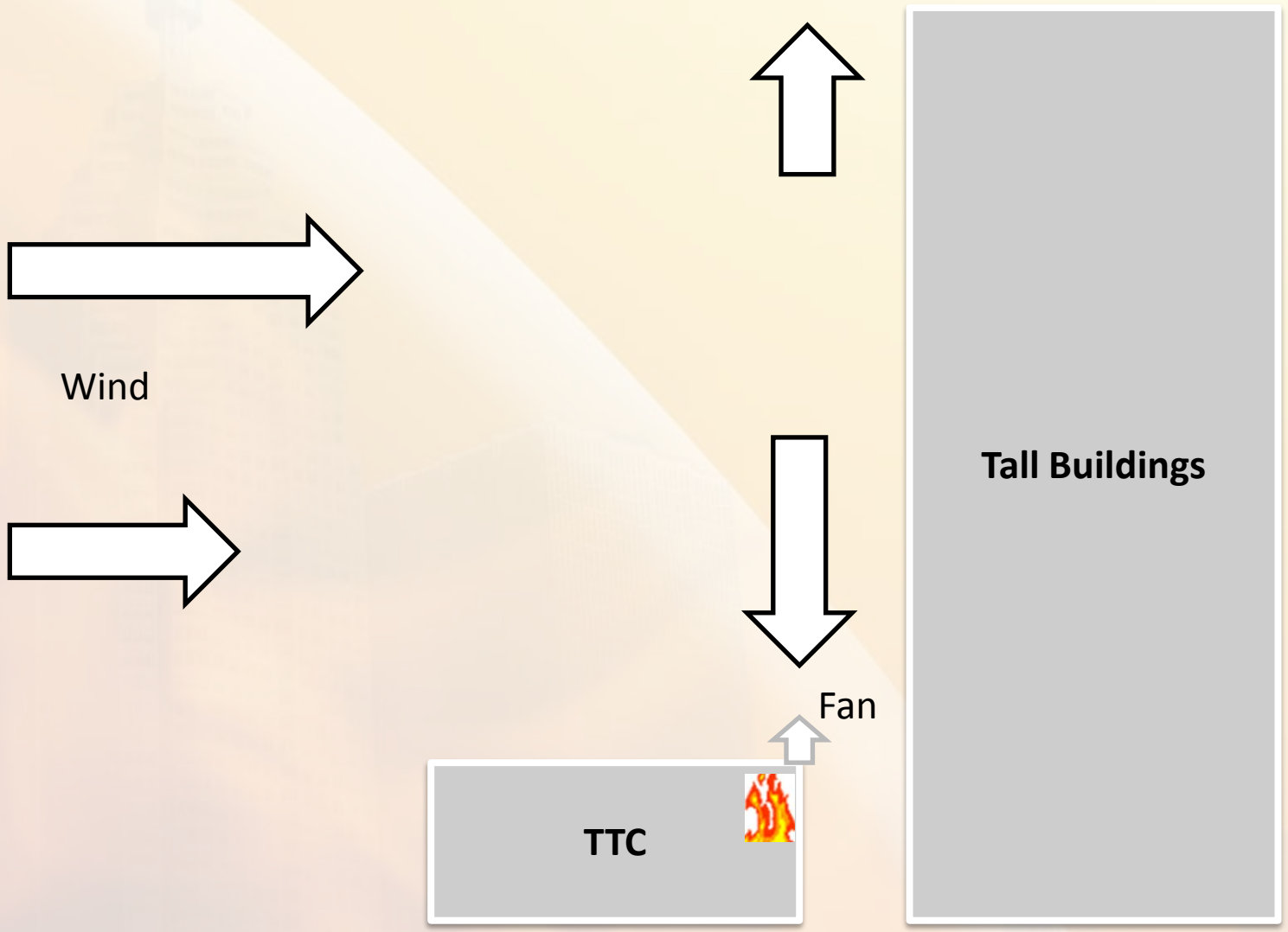
- Incorporate surrounding building effects
- Sprinklers “on” but no fire suppression effects
- Check with fans/without fans, with draft curtains, without draft curtains



Visibility During Growing Fire, Wind from 160 degrees

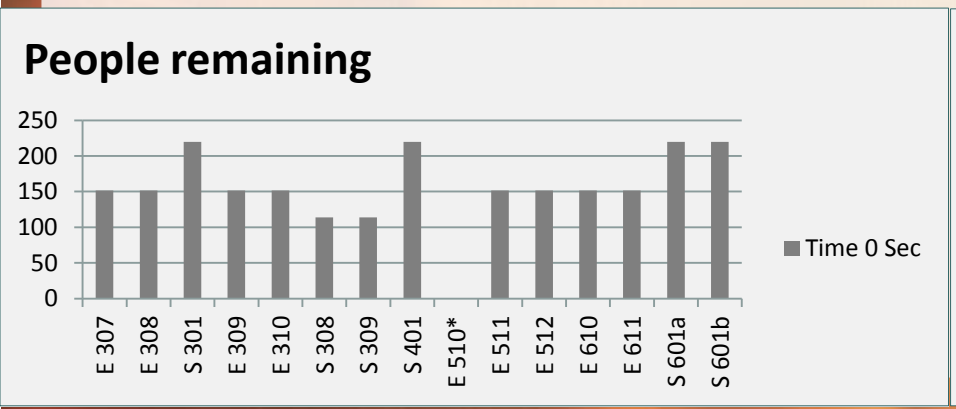


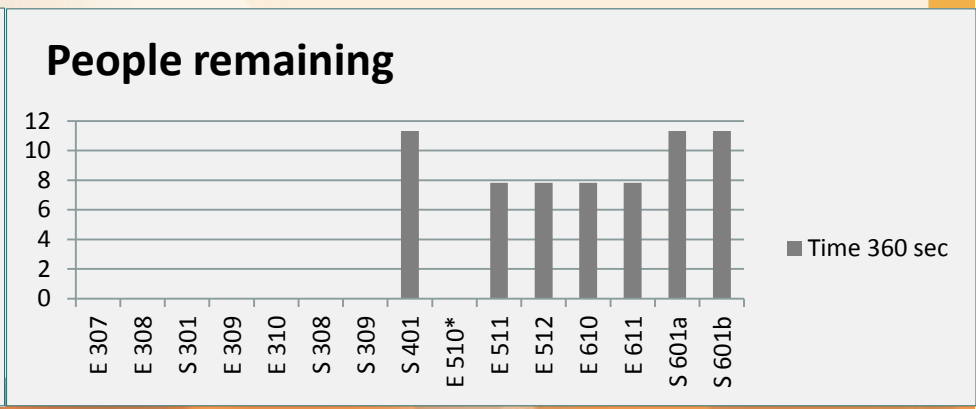
Effects of 160 degree Wind – Why is it the worst?



Example: Transient Egress Calculation NFPA 130

	Exit Label	E 307	E 308	S 301	E 309	E 310	S 308	S 309	S 401	E 510*	E 511	E 512	E 610	E 611	S 601a	S 601b	SUMS
	Governing Width (in)	40	40	36	40	40	30	30	36	0	40	40	40	40	36	36	524
	Exit Capacity (pp/min)	56.4	56.4	81.7	56.4	56.4	42.3	42.3	81.7	0	56.4	56.4	56.4	56.4	81.7	81.7	862.6
Fire Time (minutes)	Time (min) / Operation	E 307	E 308	S 301	E 309	E 310	S 308	S 309	S 401	E 510*	E 511	E 512	E 610	E 611	S 601a	S 601b	People
3.00	0.00	152	152	220	152	152	114	114	220	0	152	152	152	152	220	220	2,319
3.50	0.50	123	123	179	123	123	93	93	179	0	123	123	123	123	179	179	1,888
4.00	1.00	95	95	138	95	95	71	71	138	0	95	95	95	95	138	138	1,456
4.50	1.50	67	67	97	67	67	50	50	97	0	67	67	67	67	97	97	1,025
5.00	2.00	46	46	0	46	46	34	34	66	0	46	46	46	46	66	66	635
5.50	2.50	0	0	0	25	25	19	19	37	0	25	25	25	25	37	37	301
6.00	3.00	0	0	0	0	0	0	0	11	0	8	8	8	8	11	11	65
6.50	3.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
7.00	4.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-



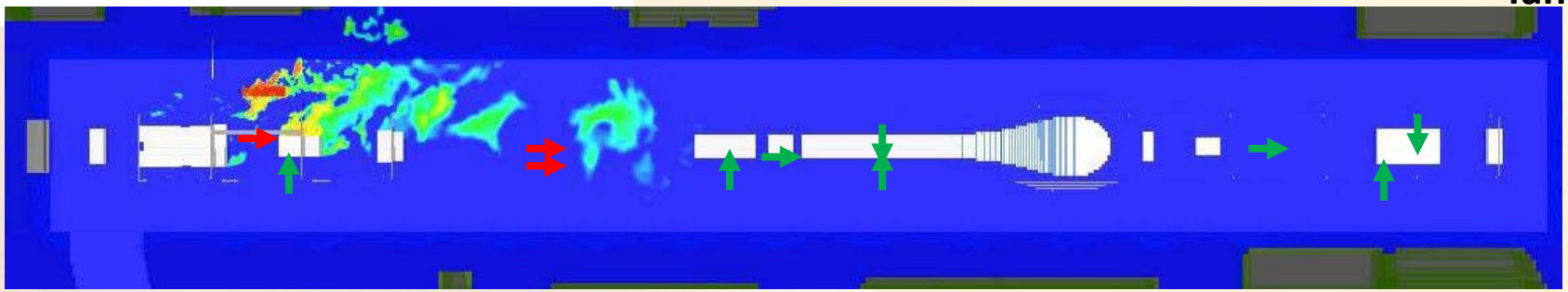


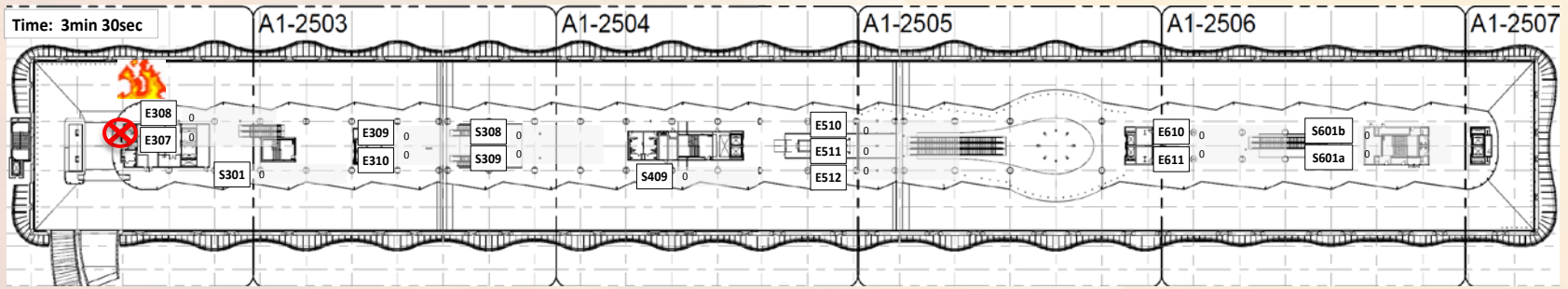
Transient: Governing Case 160º Wind, 11.7 m/s

- Egress time: 4 minutes
- With alarm delay time, station is evacuated 6min 15sec after start of fire

Smoke spread/Visibility at 6min 15sec

No curtains & no fans

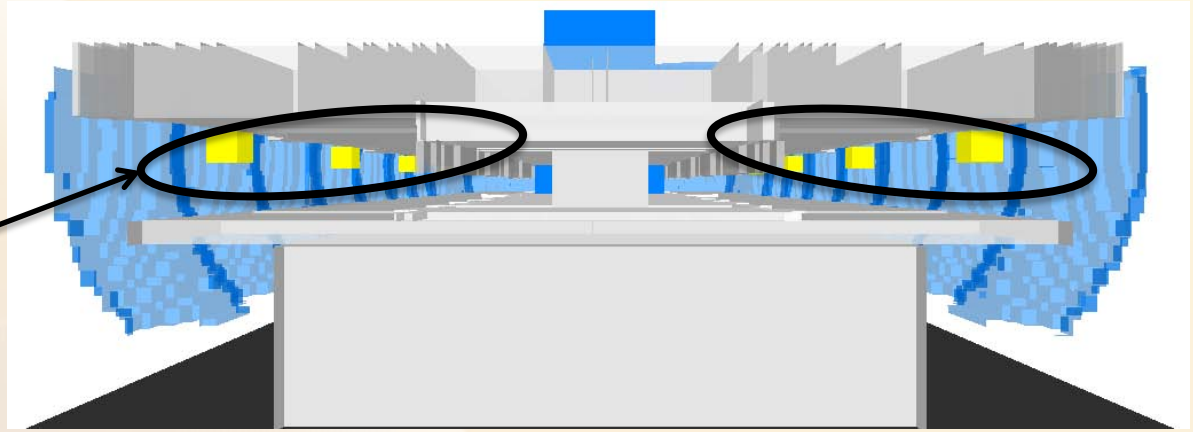


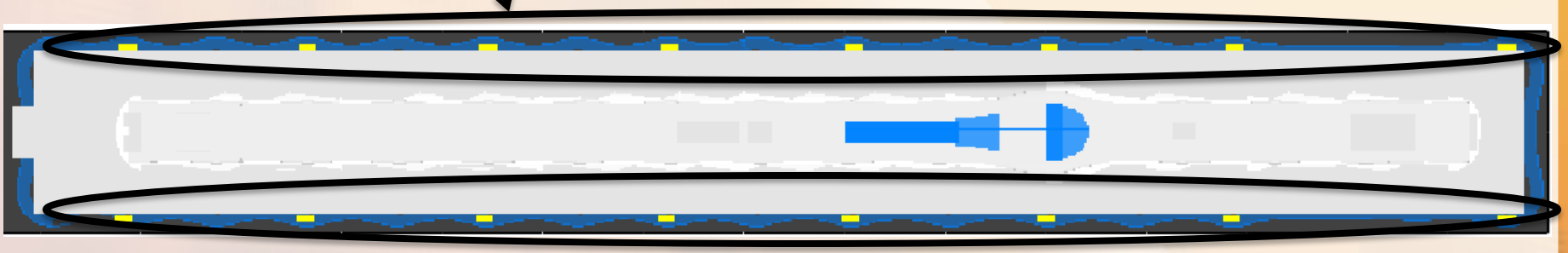


Explore Effects of Mechanical Fan System

- Mechanical Layout
  - Activation on fire side only
  - Incorporated into sequence of operation

(8) 47 cm/s
fans (each side)

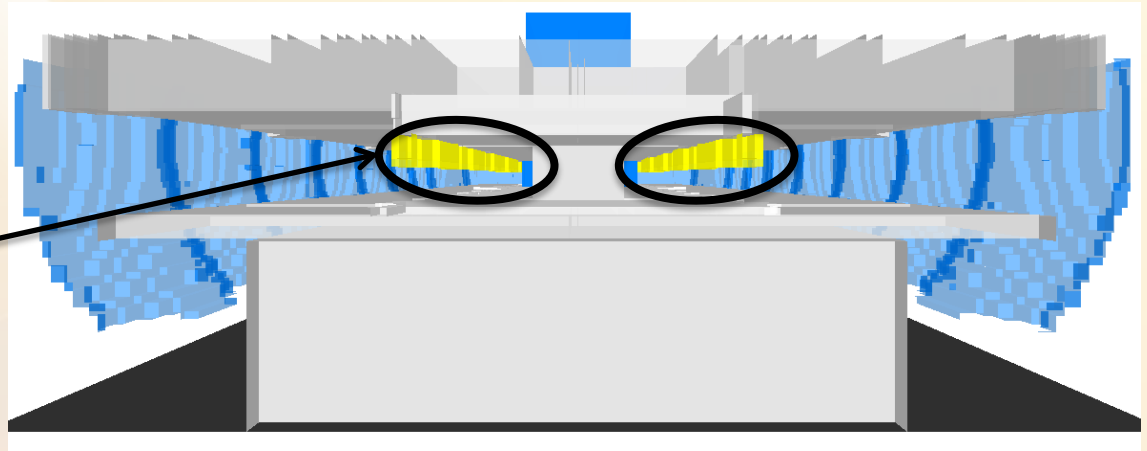


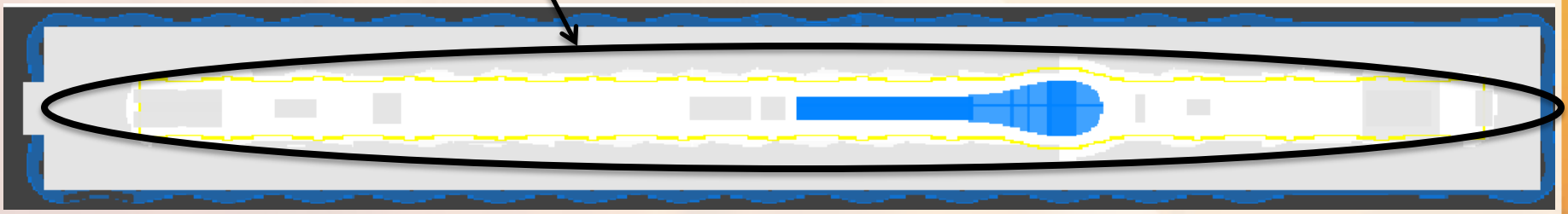


Explore Effects of Downstand/Draft Curtain

- Draft Curtain Location
  - 2.5m AFF

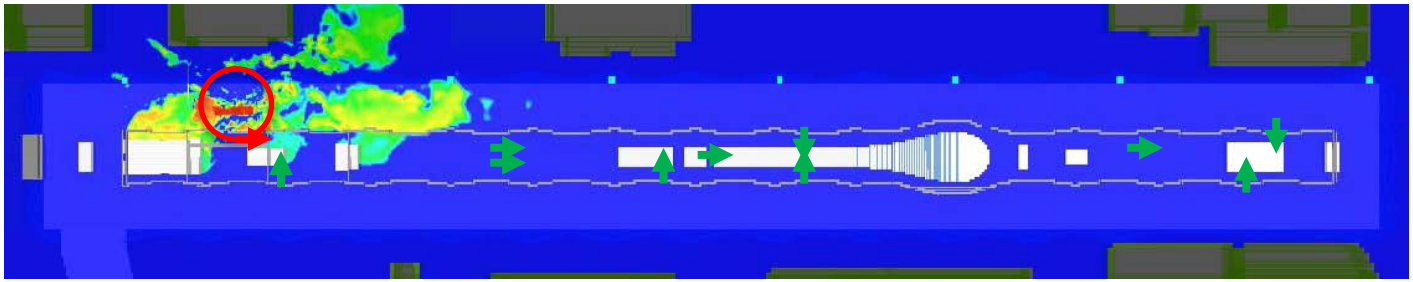
Draft curtain at
Bus Deck ceiling



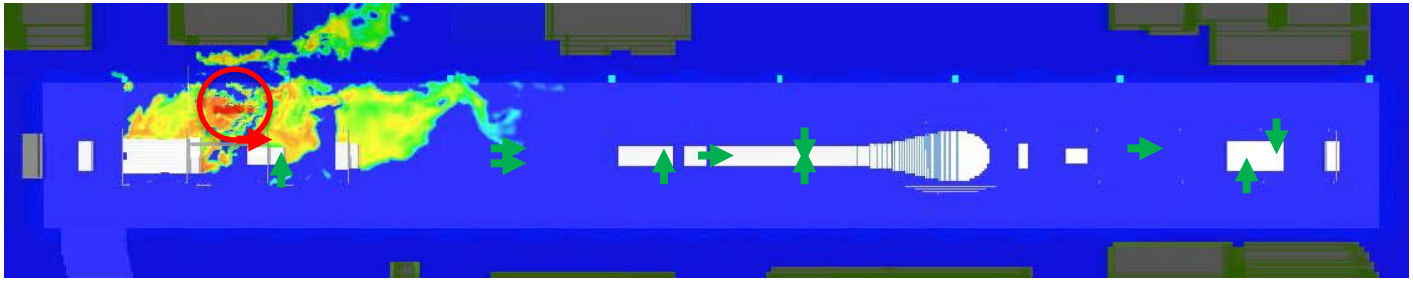


Explore Effects of Fans and Curtains 160º, 11.7 m/s

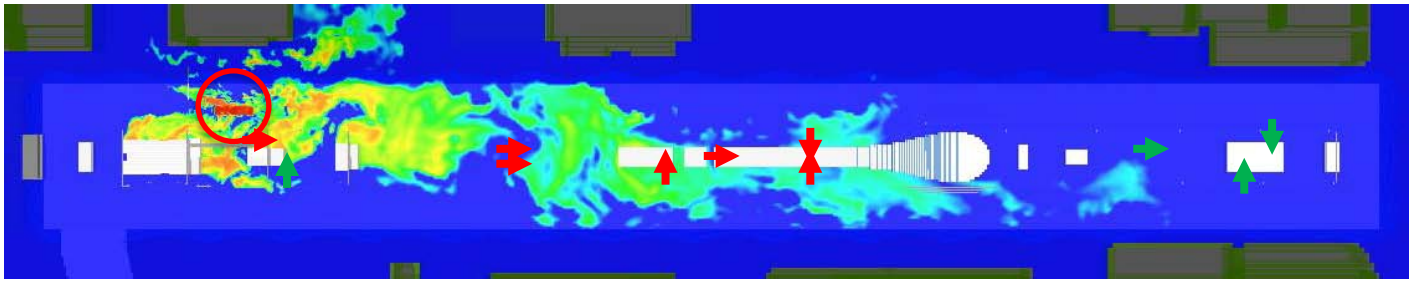
- Visibility Conditions at Peak Fire



- Fans & Draft Curtain
- Egress time: 4 minute



- Fans only
- Egress time: 4 minutes



- No System
- Egress time: 4 minutes

Other tenability criteria checked

1. Heat Exposure
   - Radiant heat < 2.5 kW/m^2
   - Temperature in egress pathways < 60°C
2. Other fire gasses such as carbon monoxide, etc per SFPE

Lessons

- For transit occupancies with uses similar to fixed guideway transit occupancies, *NFPA 130 can offer an alternate approach for occupant safety*.
- Transit facilities partially open to the outside should consider analyses to *check for the need for mechanical smoke exhaust systems.*
- *Smoke venting* by passive means *can be affected* significantly *by local wind patterns.*
- There is a need to establish *an industry standard for accommodating wind effects* for smoke control systems.
- *Clarifying performance criteria* for emergency ventilation systems for stations (in NFPA 130) would be useful.

Muchas Gracias.

Gracias por su atención
Thanks for your attention

ARUP

Armin Wolski, PE
Associate Principal
Arup, San Francisco

Organizadores / Organizers

APICI Asociación de Profesionales de Ingeniería de Protección Contra Incendios
AFITI
ALAMYS
FUNDACIÓNMAPFRE

Madrid, 20 – 22 de Febrero de 2013
Centro de Convenciones Mapfre

Effect of Draft Curtains