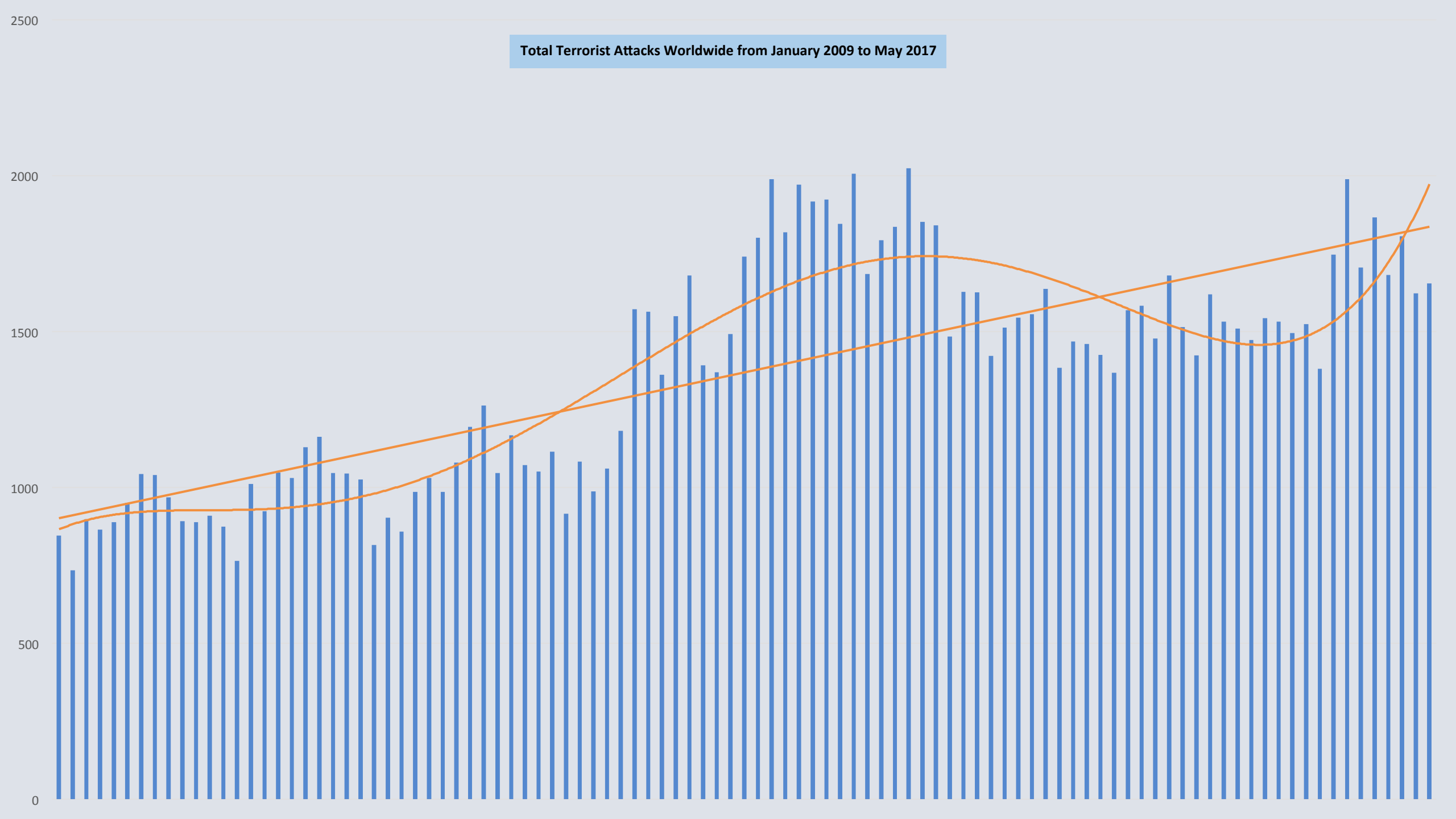


# Estimating Amputations and Blood Requirements for Civilian Mass Casualty Events

**Dr Dave Sloggett**

Alan Taylor Research Fellow  
Department of Mathematics  
University of Oxford

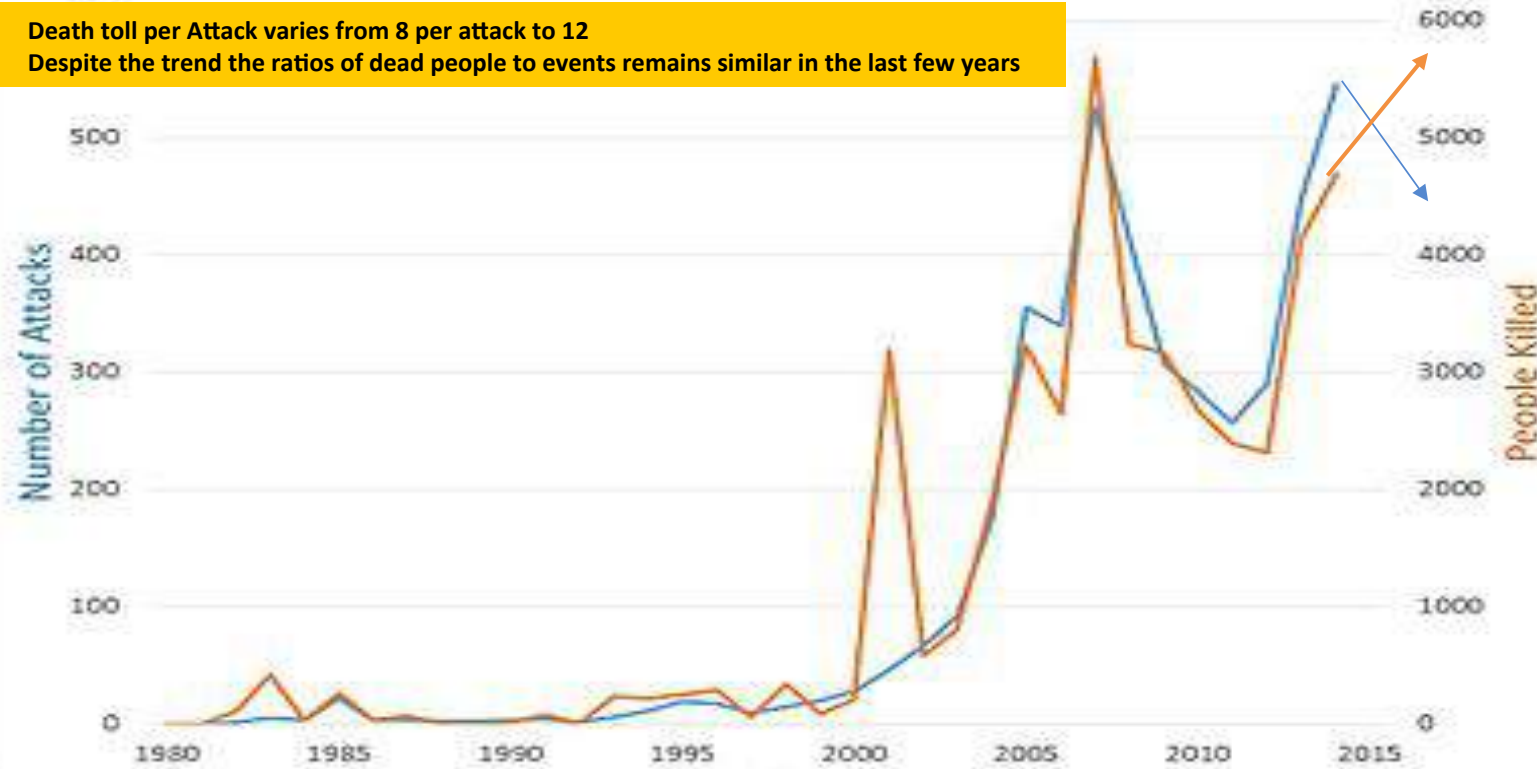
Total Terrorist Attacks Worldwide from January 2009 to May 2017





## Suicide Attacks Worldwide

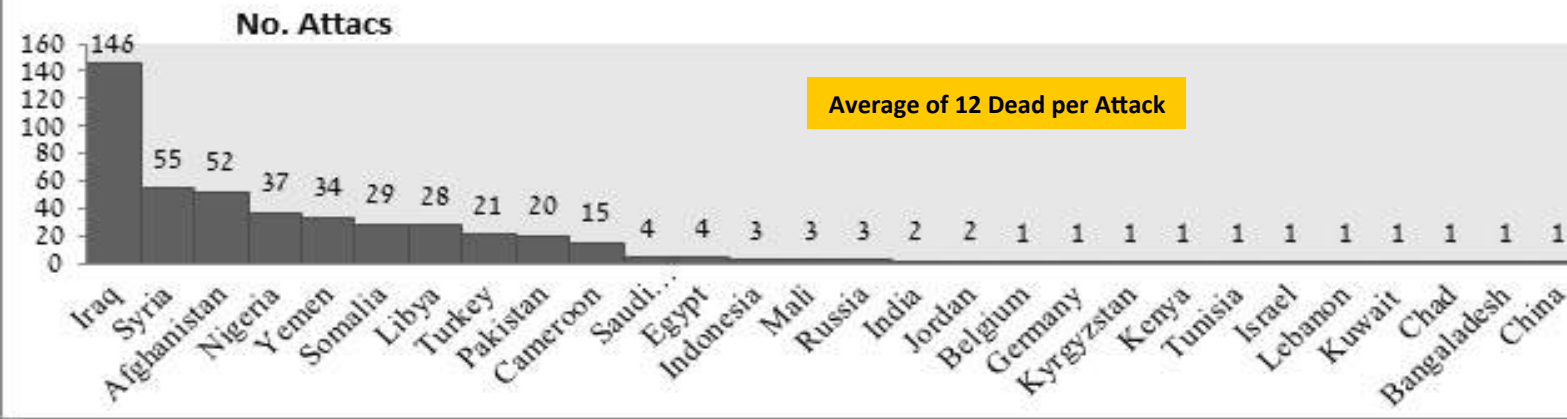
- Death toll per Attack varies from 8 per attack to 12
- Despite the trend the ratios of dead people to events remains similar in the last few years



Chinese Suicide Bomber World War Two



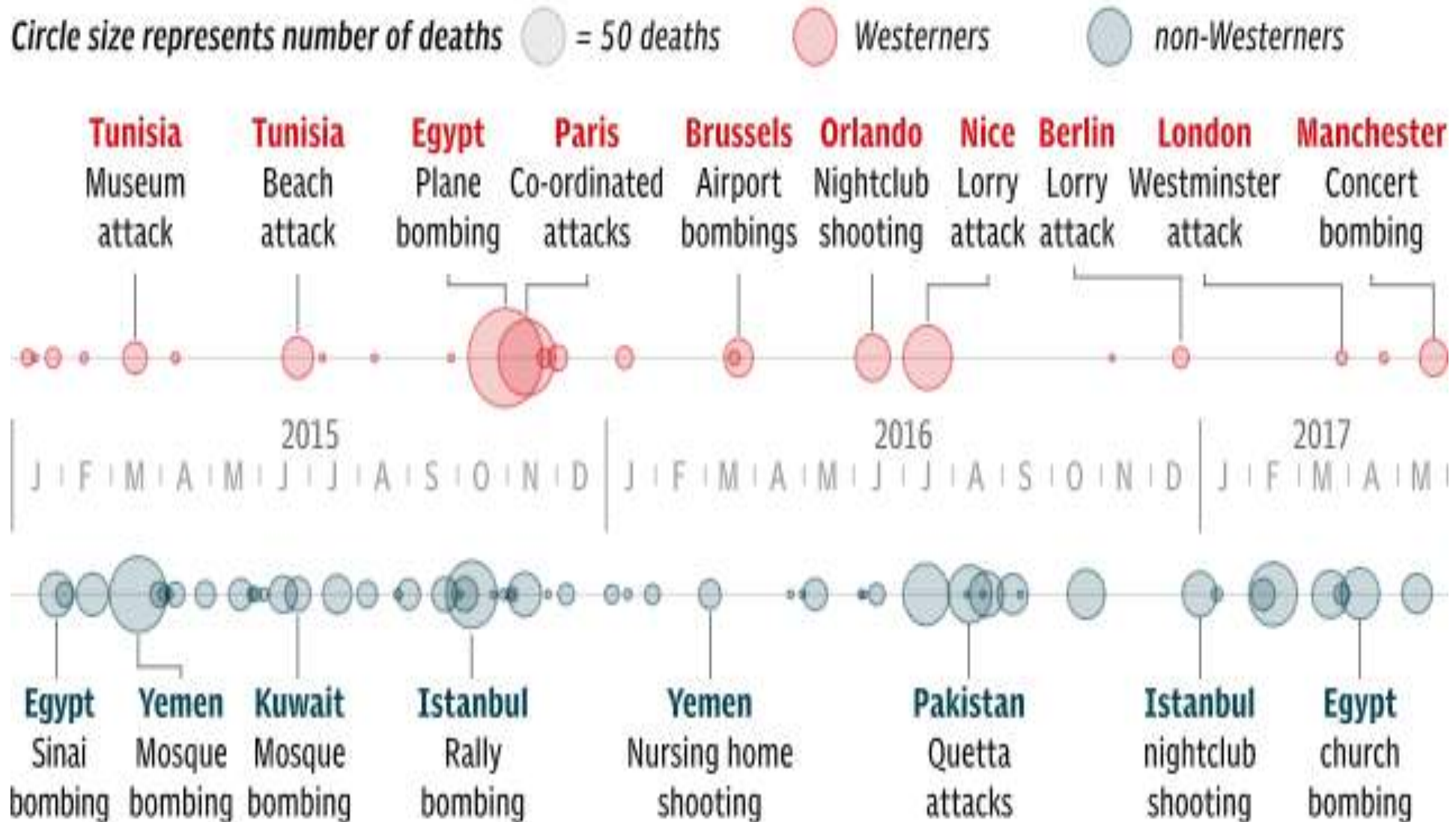
**In 2016, 469 suicide attacks carried out by 800 perpetrators in 28 countries caused the death of 5650 people.**



# Global Isil attacks

Attacks Isil have been responsible for since 2015 outside of Syria and Iraq

Far more non-Westerners Die in Attacks





Suicide Bombing: Average ratio of dead to wounded is 1:3 (2.9)



# Example Friedlander Waveform

## Pressure (kPa)

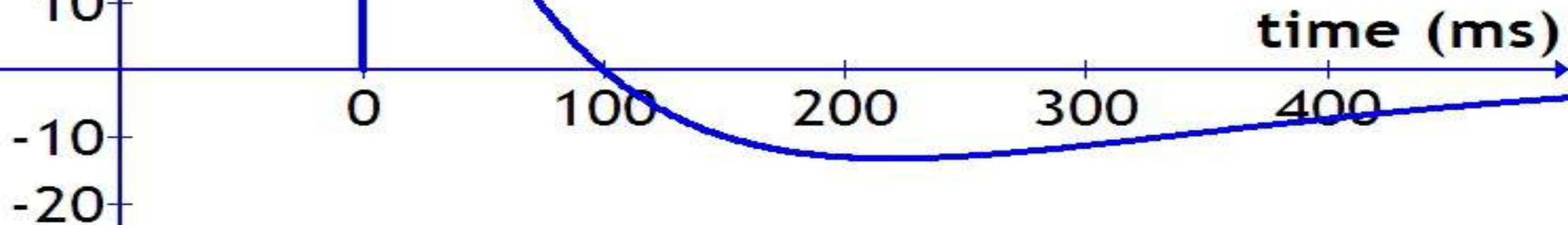
Research Material unclear on precise threshold for mortality from Blast Lung; dependent on a number of variables; at 100 psi there is a high probability of death

$$P = P_s(e^{-t/t^*})(1 - (t/t^*))$$

In this example,

$P_s = 70 \text{ kPa}$

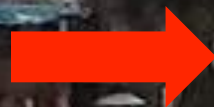
$t^* = 100 \text{ ms}$





Boston Bombing

Note area of flame











Density of the Crowd at the end of the race created the situation for multiple amputations; even though the explosive was gunpowder

← Direction of travel



24 Critically Injured in the overall attacks

Survivors who gave testimony at inquests



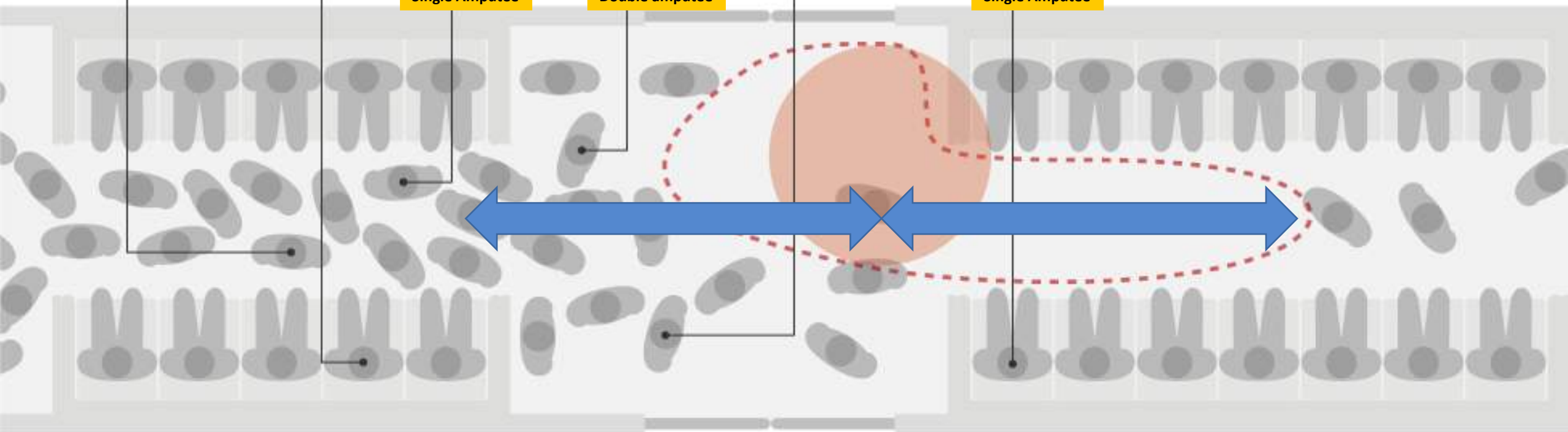
■ Blast area, location of bomber

○ Location of fatalities

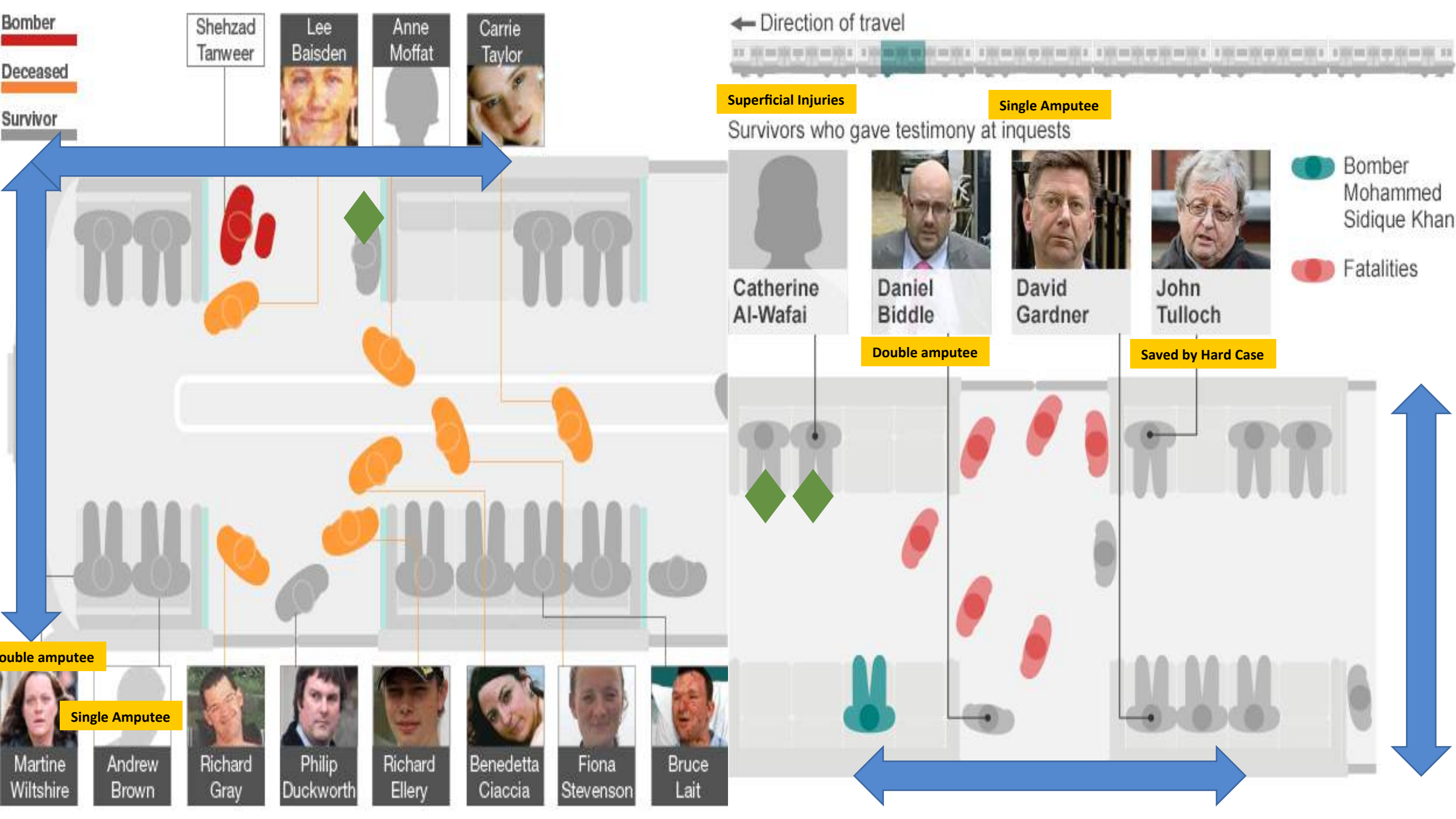
Single Amputee

Double amputee

Single Amputee







Note shape of initial blast



Turkey estimates ISIL has 300 'Sleeper Cells active in the country'

10<sup>th</sup> October 2015: Turkish Railway Station Attack; 108 dead; 246 wounded; twin bombing; note ratio of dead to wounded (2.28)



- Plot thrown together at the last minute
- After arrest of Salah Abdeslam; Paris attacker who dumped suicide vest
- Explosions 17 seconds apart; 16 dead, 150 injured, mainly severely
- No fire inside the terminal; fire precautions
- 20,000 evacuated from airport
- The Metro Attack occurs 1 hour later; parallels to 7/7
- Habrini Blown over by first bomb
- Taxi problem
- Field hospital evacuated three times; 80 people in the hospital
- Injured moved to hospitals over 100k away
- 40 responding hospitals
- 1400 controlled explosion on third device; 2,000 bags left in terminal

Not so smart Terrorists/ Authorities



The Terrorists

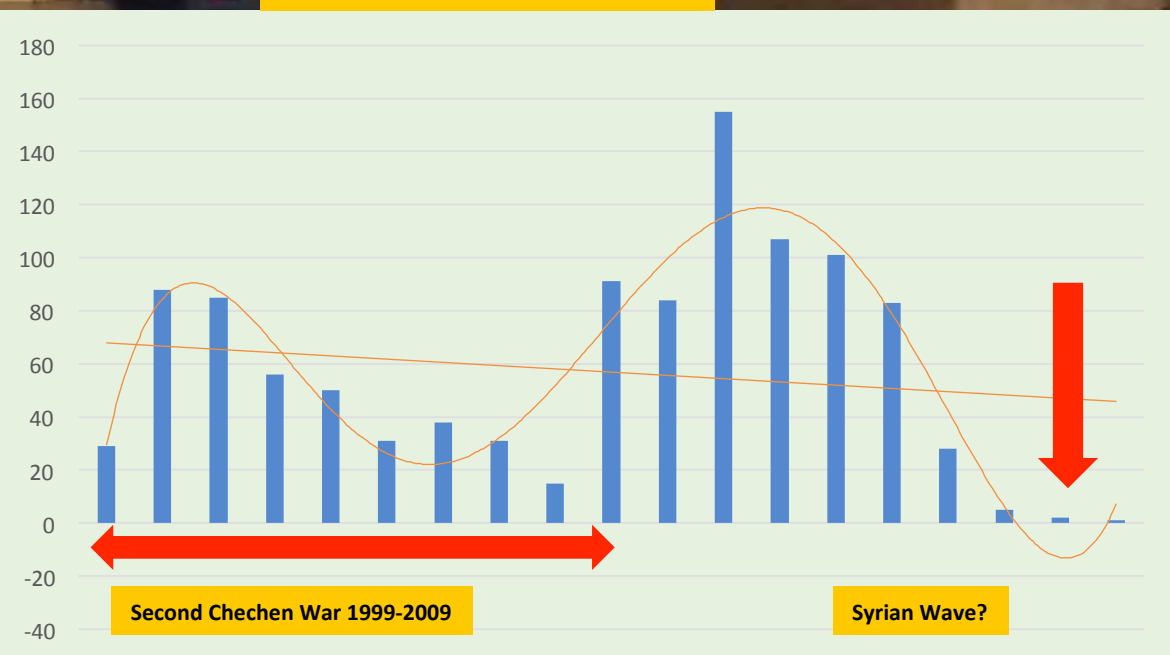


Two terrorists killed in shoot-out in Moscow

Reaction to Russian Military Operations in Syria

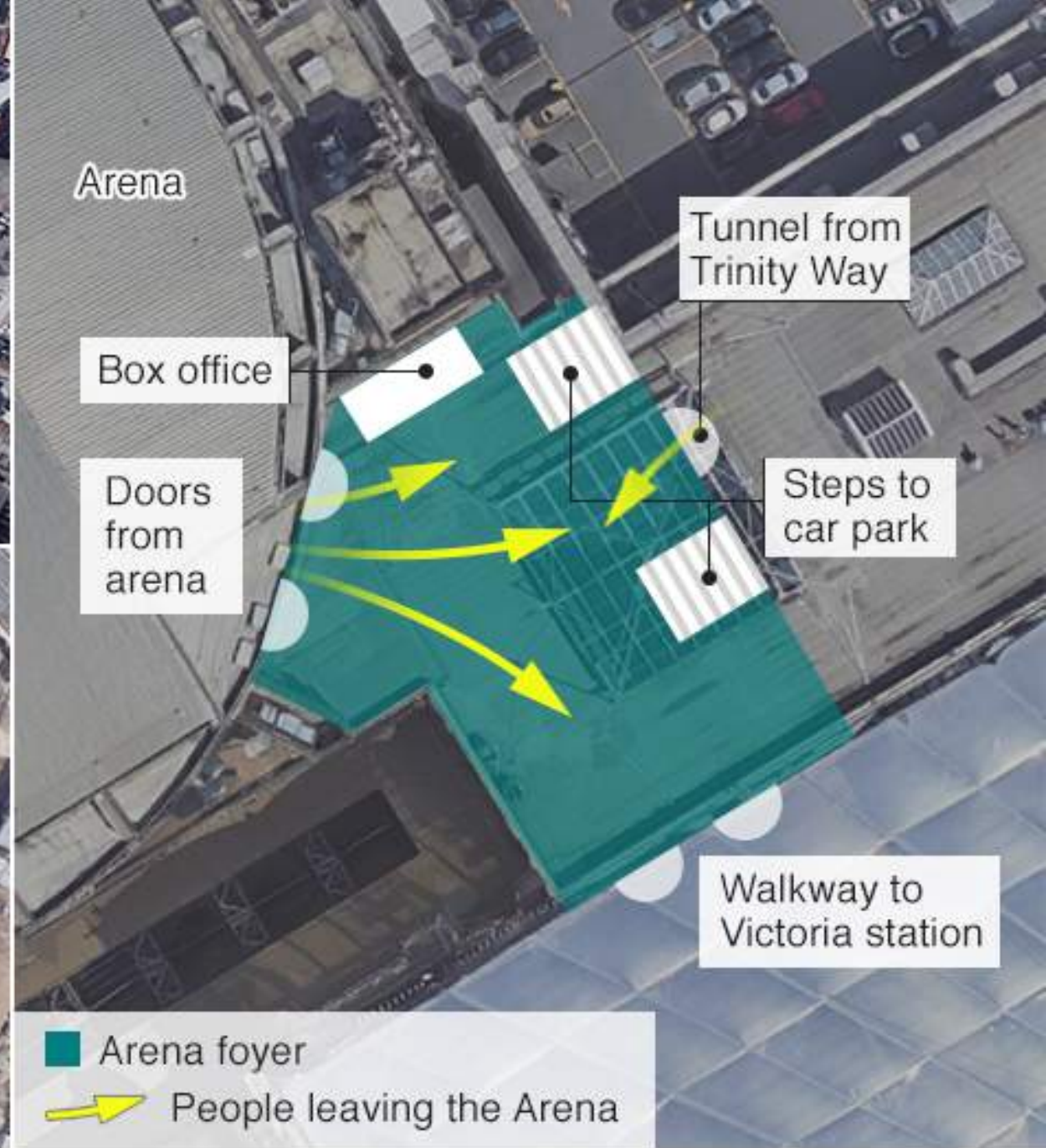
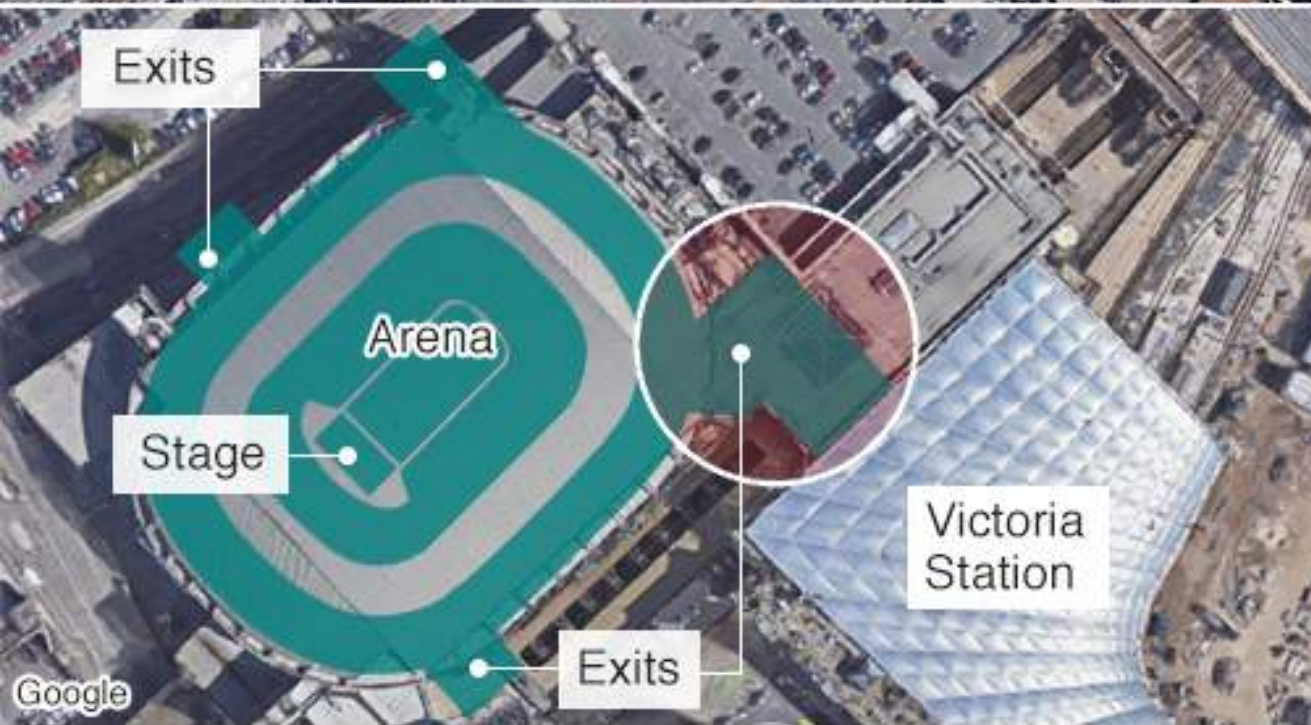
7 Dead immediately; 8 died in hospital; 64 injured; 300 grams of TATP; second device found in Fire Extinguisher  
Past Russian suicide bombings involved 1.5kg to 2 kg worn by women as belts; 40 Dead/ 102 injured

Terror Bombings in Russia 1999-2017



Russia has since arrested nine people they claim are involved





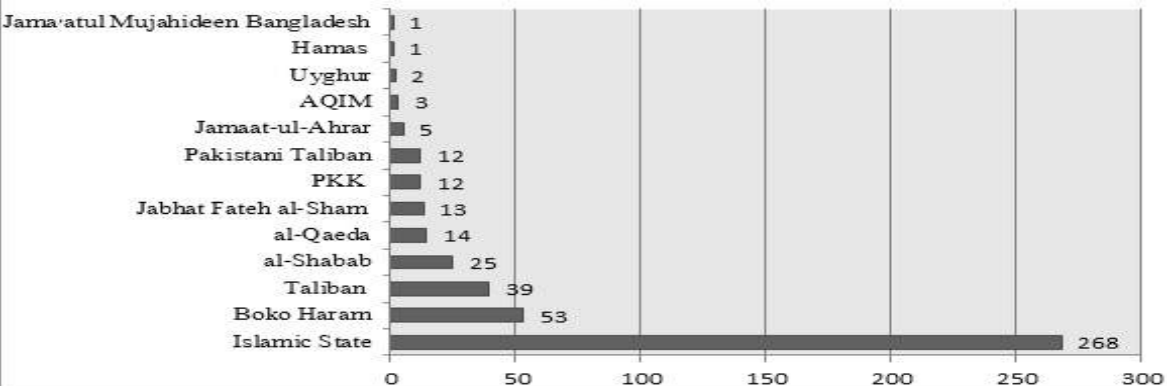








**The Islamic State was responsible for 70% of the attacks in 2016.**



- Shrapnel is responsible for around 90% of the casualties
- Most dangerous are steel balls 3mm to 7 mm in diameter
- Vest can weigh between 5 and 20 kg
- 10kg TAPT explosion will cause a 20 psi at 5 metres/ 13.24 psi at 7.5 metres
- 10kg TAPT explosion will create a td=29ms at 5 metres/ 4.57 ms at 7.5 metres







# MANCHESTER ARENA

At 10 metres the overpressure would have been 5.75 psi and the pulse duration 5.21 ms [15kg TAPT]

## BOX OFFICE

Canalising Effect of the Wall Structure

Some shaping of the blast wave by the fabric of the centre

At point of detonation which way was the bomber looking? What effect did the water in his body have?

## Arena doors

Younger Victims

Average kill radius: 10.28 metres

Victims

## MEZZANINE

A Younger Person

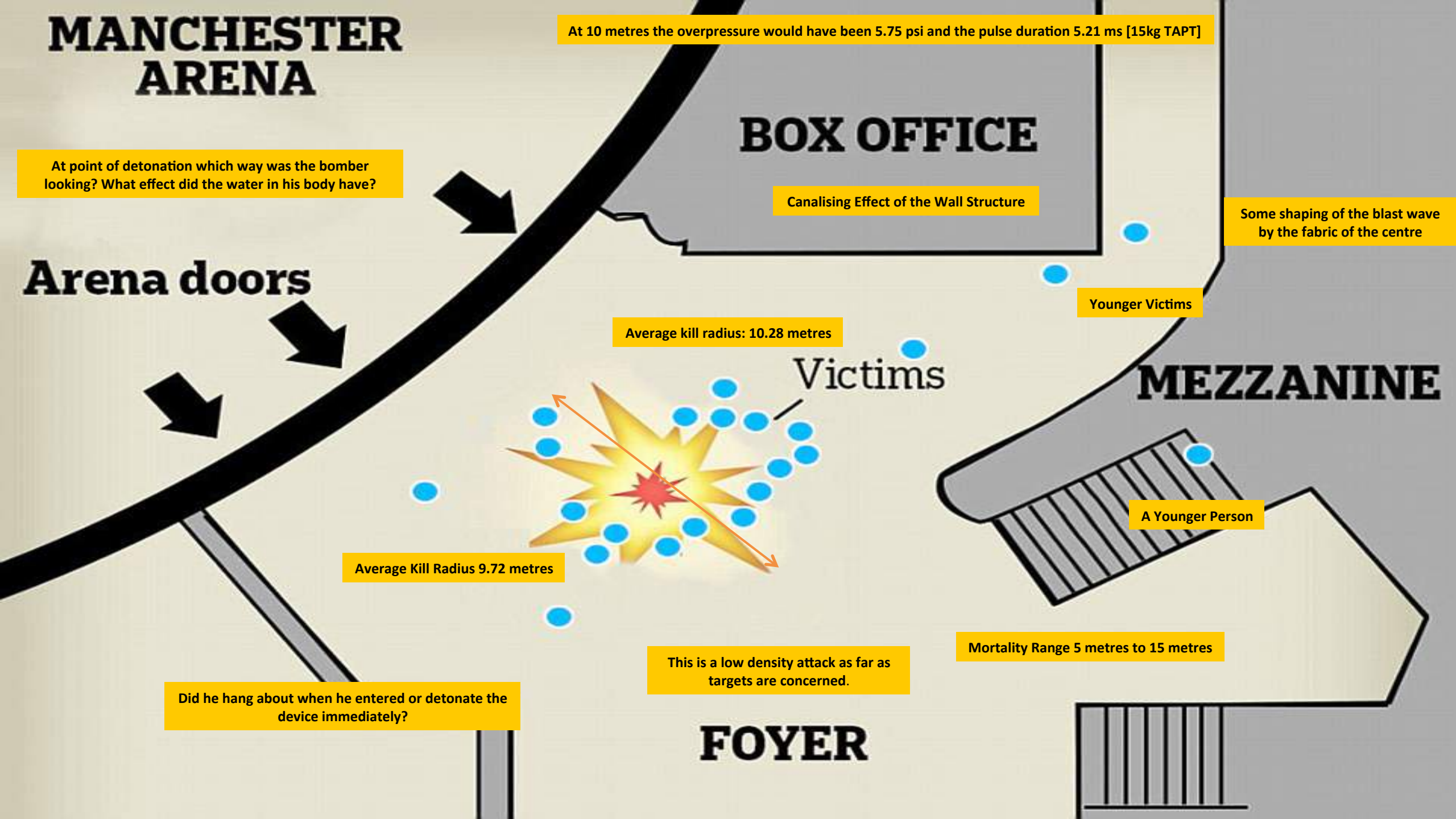
Average Kill Radius 9.72 metres

Mortality Range 5 metres to 15 metres

This is a low density attack as far as targets are concerned.

Did he hang about when he entered or detonate the device immediately?

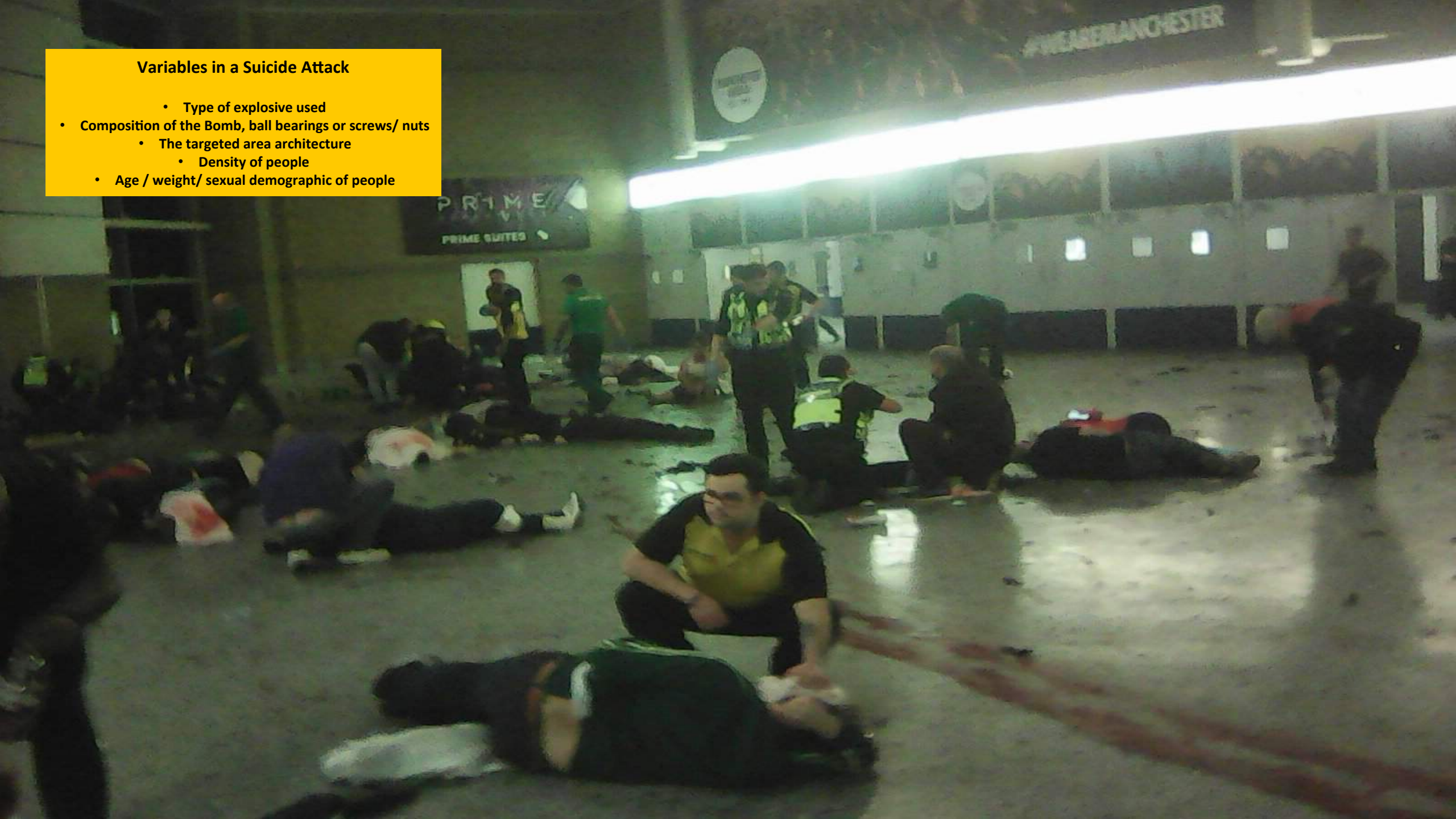
## FOYER





## Variables in a Suicide Attack

- Type of explosive used
- Composition of the Bomb, ball bearings or screws/ nuts
  - The targeted area architecture
    - Density of people
- Age / weight/ sexual demographic of people







Mix of 50% adults and 50% teenager/ children





# MANCHESTER ARENA

BOX OFFICE

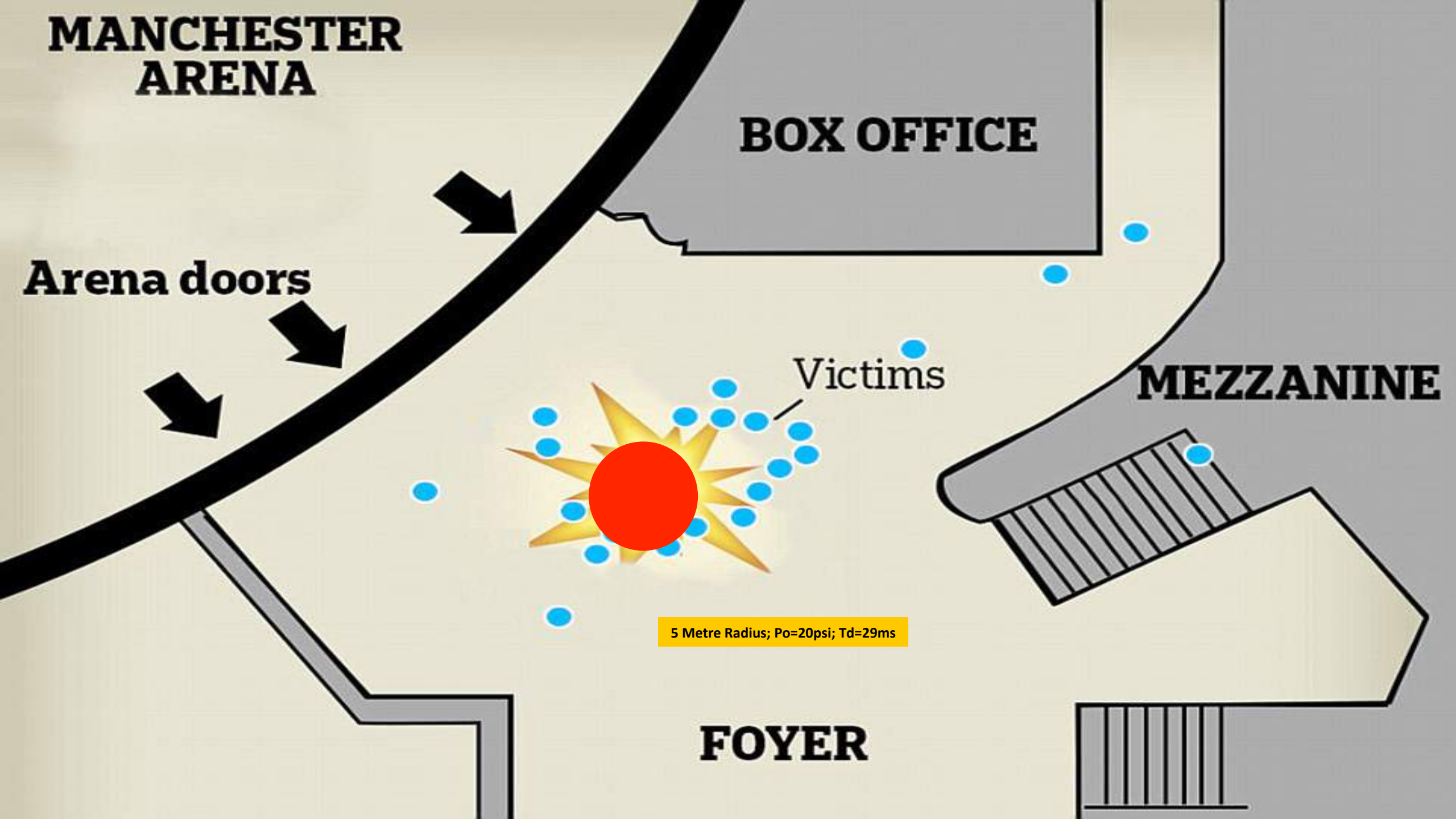
Arena doors

Victims

MEZZANINE

5 Metre Radius;  $P_o=20\text{psi}$ ;  $T_d=29\text{ms}$

FOYER





# MANCHESTER ARENA

BOX OFFICE

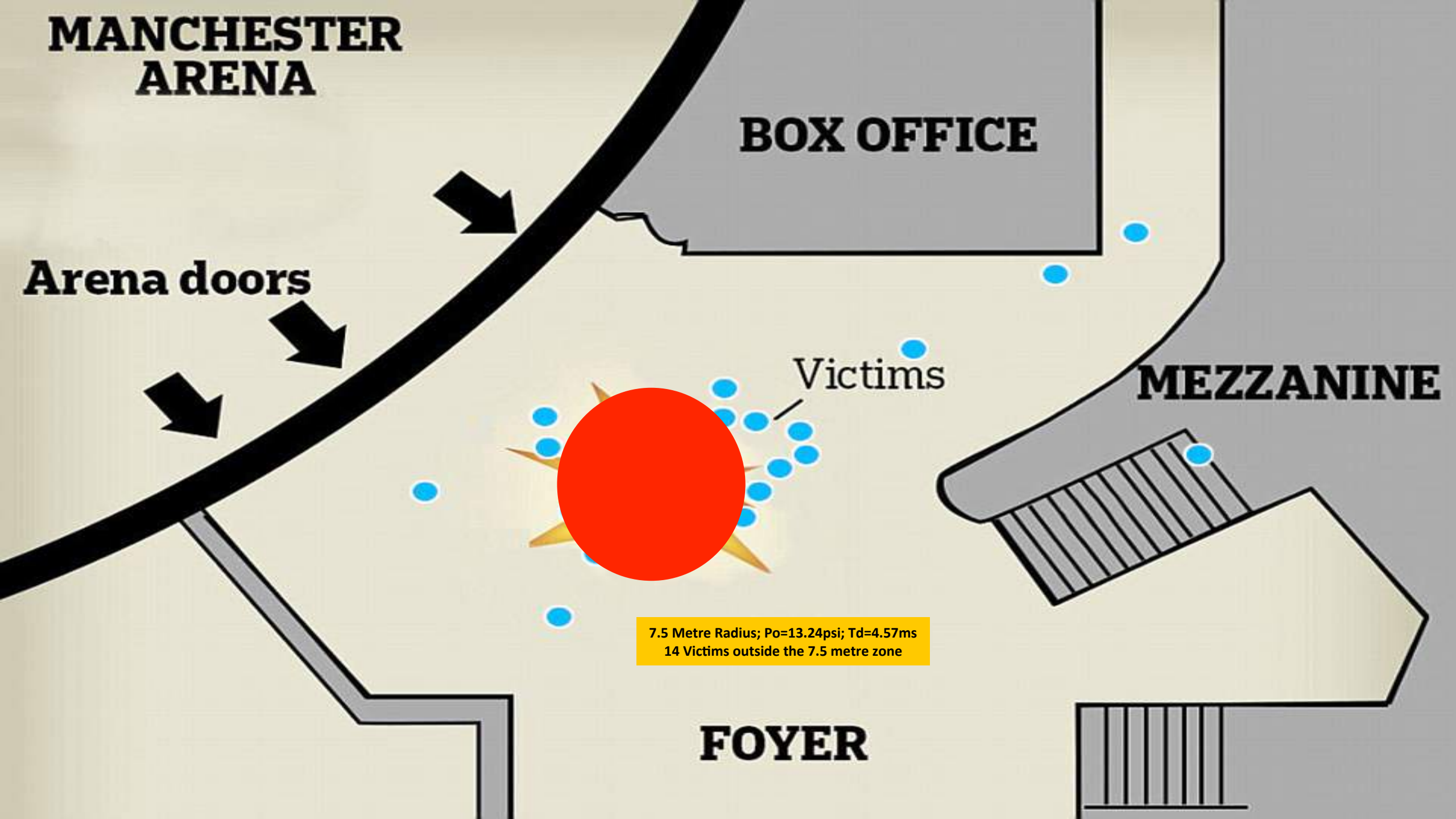
Arena doors

Victims

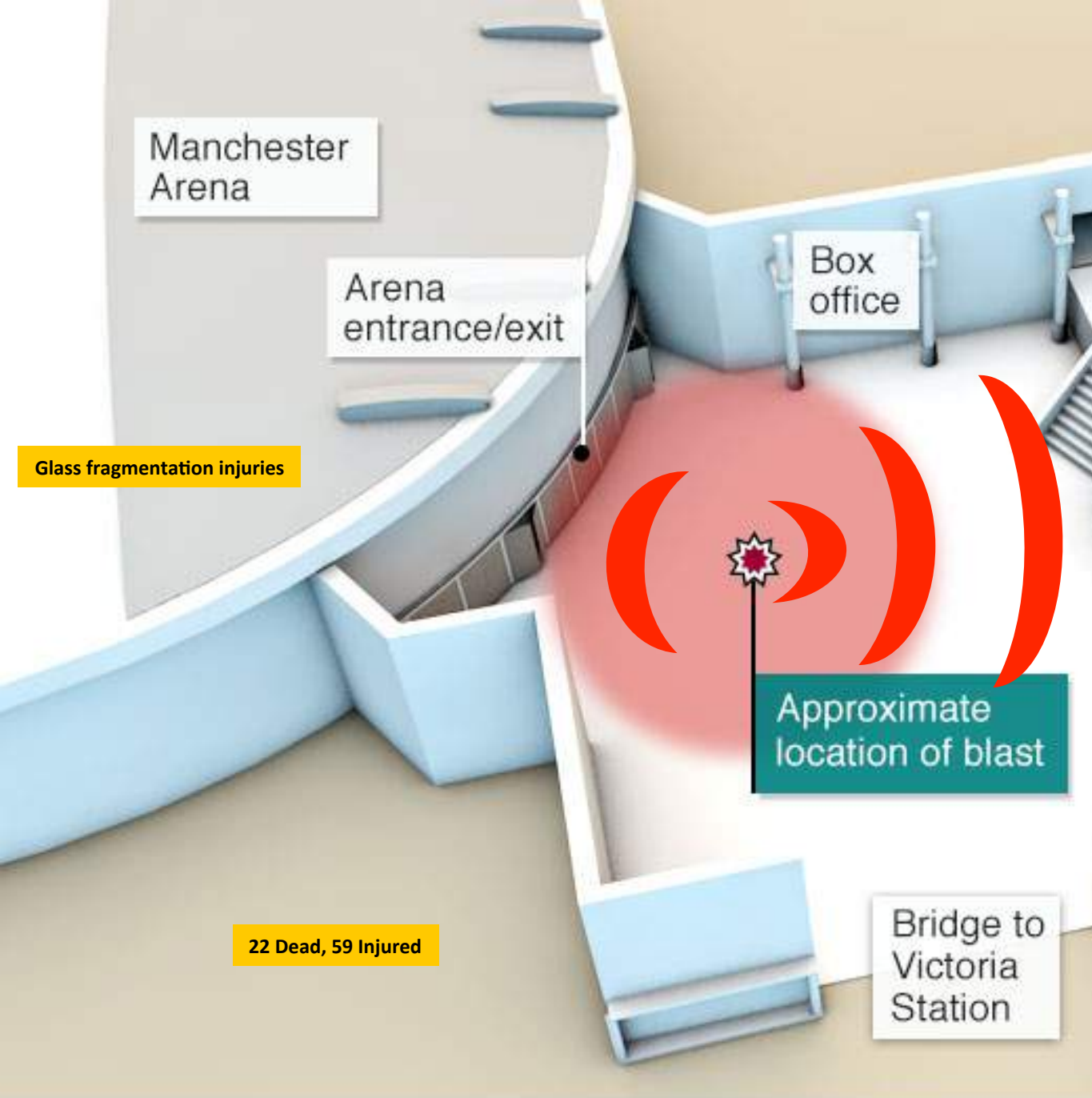
MEZZANINE

7.5 Metre Radius; Po=13.24psi; Td=4.57ms  
14 Victims outside the 7.5 metre zone

FOYER



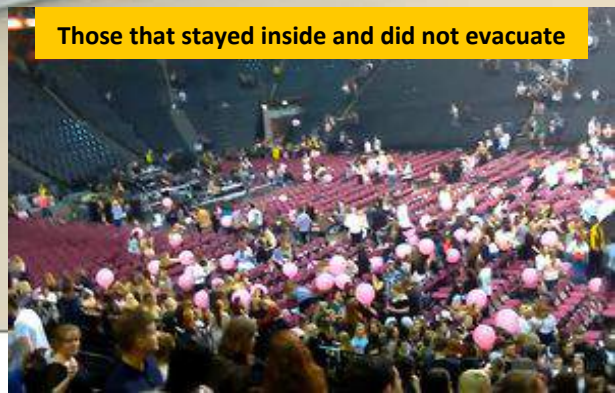




Radius from Initial Blast (metres)	Surface Area of Semi-Hemisphere of Blast Wave (Square Metres)	Number of Fragments Hitting a Human Being at Ground Level	Probability of being hit
1.0	3.141	15.9	1
2.0	12.57	3	1
2.5	19.69	1.3	1
3.0	28.27	<1	0.7
5.0	78.54	<1	0.1

### Synopsis based upon formulaic analysis; first order effects model

- 10kg TATP Explosion; augmented by 100 screw nuts (0.5 inch) weight 2kg.
- 20 Remain in critical care
- Size of explosives limited to conceal them in backpack; most not be obvious
- Shock wave moves at 5.3km per second
- Anyone within 3.0 metres of the blast sustains > 60 psi overpressure; amputations
- First person dead is 5 metres away; Coroners investigation
- Analysis is complicated by enclosed area which reduces the survival rate to overpressure
- Initial Survival zone starts at 5metres; limbs at risk; none lost in Manchester;
- Three victims close to bomber died almost instantaneously; blast lung effects; primary blast injury
- Sixteen bled out due to secondary injuries; Three due to tertiary injuries (Impact)



Those that stayed inside and did not evacuate

A suicide bomber would find it hard to make a shaped charge that focused the energy of the explosion

Foyer Area is approximately 40 metres square






A Model for the Bergen World Cycling Championships



## World Cycling Championship Model of Likely Casualty Count – Crowd and Cyclists

- 10 kg TAPT Bomb; plus fragmentation; back-pack worn/ not a belt or an internal device carried in a body cavity
  - Assume crowd 5 deep at finish; packing density 0.24 square metres/ person
  - Initial kill radius from PBI Blast Lung 2 metres = 52 dead if Peloton Passing
- Between 2-3 metres 66 adults at risk of amputation of one limb; due to density of people likely figure is 40 with single amputations
  - This would require 800 PRBC & FFP, 160 Platelets, 16 litres of Colloids, Cryoprecipitate 240 units, 240 Litres Crystalloids
    - > 3 metres risk of amputations reduced, > 4 metres reduced significantly
      - 63 Cyclists at risk in the Peloton < 5 metre blast range
  - > 5 metres survival rate improves from Blast Lung; fragmentation injuries dominate
    - Total cyclists and crowd at risk from a single suicide bomber is circa 250-300
      1. Assumes that majority of crowd are adults
      2. Seating in stands are set back from main crowd line by over 5 metres



Observation: Stand the crowd back by 2 metres from the cyclists to improve survivability rate of the cyclists to a blast

- Comprehensive Bag Search for entry to stands
- Regular sweeps by security personal in vulnerable areas
- No let up until races are complete and crowd has dispersed
- Avoid single locations for dispersal

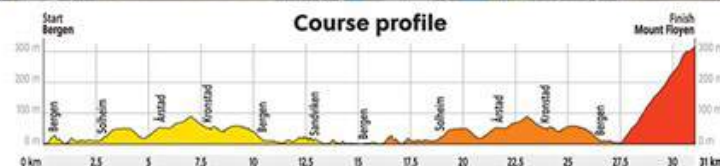
Crowd 5 Deep; walking area at back of crowd relatively unpopulated; stands further back



**Individual Time Trial**  
 Women Juniors : 1 short lap, 16.1 km  
 Women Elite : 1 long lap, 21.1 km  
 Men Juniors : 1 long lap, 21.1 km  
 Men Under 23 : 1 long lap + 1 short lap, 37.2 km



**Individual Time Trial Men Elite**  
 2 laps + finish Mount Floyen, 31 km





## Variables with a Knife Attack

- Number of attackers
- Success rate in hitting major circulation systems or organs
  - Lethality of the first strike
- Speed of dispersal of crowd; finding people in an enclosed area
  - How pliant is the target; do they fight back
- Immediacy of Response and measures taken to stop bleeding

Since 2013 there have been > 44 attacks where an edged weapon has been used



TARGETS

CHOOSING  
THE RIGHT WEAPON

Stabbing Spree in Minnesota 18<sup>th</sup> September 2016; nine injured

Dressed in a private security uniform





**Another EAD unit nicknamed 'The Thunder' is believed to have landed by helicopter on London Bridge**

The crowd is walking into Borough Market shopping at retailers. From left: Florio Market, from the Bread Ahead bakery, has a cake in one of them, holding his hand.

**A black robot** attacks motorists into The Glades Tavern, Wilmslow says he stood still, he almost lost his nerve before slaking people in the stomach and legs shouting 'Black Power, Black Power' - 'Arise for God is good'

**The Hilbert country past Or Market Porter gets seconds from their own dishes**



A few steps further outside The Whitehouse gate, eight armed officers confront the fanatics, who are dressed in black suicide bomb suits. Despite believing they might be blown up, the officers desperately try to separate the terrorists from the crowds, ordering the three to get down - before telling them it's a hell of a quiet.



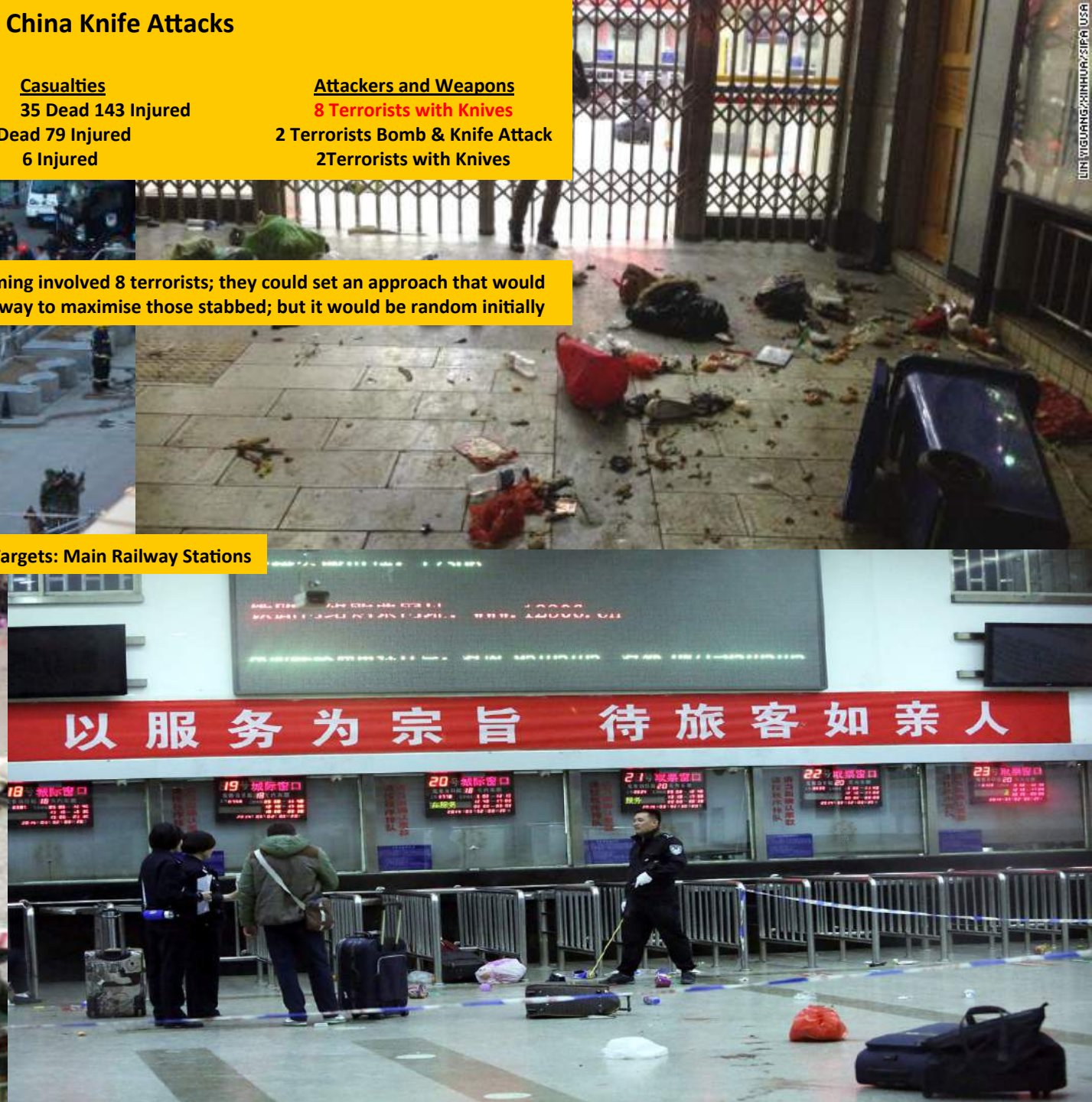




China Knife Attacks		
Date	Casualties	Attackers and Weapons
1st March 2014 21:20:	35 Dead 143 Injured	8 Terrorists with Knives
1st May 2014 1910:	3 Dead 79 Injured	2 Terrorists Bomb & Knife Attack
6th May 2014 1130:	6 Injured	2 Terrorists with Knives

Comment: 1st March attack at Kunming involved 8 terrorists; they could set an approach that would set an ambush for people running away to maximise those stabbed; but it would be random initially

Targets: Main Railway Stations





Knife Attacks are Easier to Plan; draws in a wider cadre; lowers entry barriers

- First all women terrorist attack plot
- Rizlaine Boular; 21
- Mother (Mina Dich); 43 & Daughter Plot
- Plus Khawla Barghouti; 20
- 'English Tea Party' Plot
- Days after the attack by Khalid Masood







# JUST TERROR TACTICS









HOSTAGE-TAKING

As the Crusaders continue to wage their vicious campaign on the lands of Islam in the wilayat of Iraq, Sham, Khurasan, Sinai and elsewhere, they are constantly reminded of the painful reality that this honorable ummah has men – heroes who gallantly demonstrate with their operations against them that their howitzers, Tomahawks, white phosphorus bombs, and MOABs, which they rain over the heads of the Muslims and their homes, will be met with blades that plunge into their bodies, vehicles that unexpectedly mount their busy sidewalks, smashing into crowds,

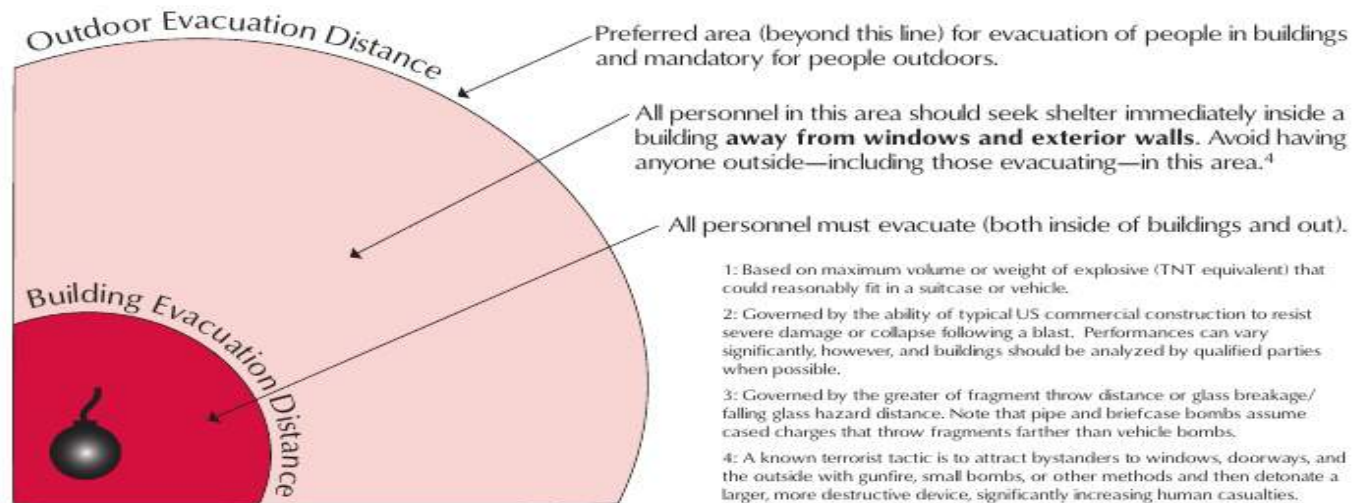
crushing bones, and severing limbs, and bullets that pierce their filthy bodies while they are in the midst of their foul enjoyment. The likes of Khalid Masood in the UK, Man Haron Monis, Numan Haider, and Farhad Khalil Mohammad Jabbar in Australia, Michael Zehaf-Bibeau, and Martin Couture-Rouleau in Canada, Zale Thompson, 'Abdur-Razzaq 'Ali Artan, Elton Simpson, Nadir Soofi, Faisal Mohammad, Syed Rizwan Farook, and his wife Tashfeen Malik in the US, Bertrand Nzohabonayo, Larossi Abdalla, Mohamed Lahouaiej-Bouhlel, Abu Jarir al-Hanafi, and Ibn



## Bomb Threat Stand-Off Distances

Threat Description	Explosives Capacity <sup>1</sup> (TNT Equivalent)	Building Evacuation Distance <sup>2</sup>	Outdoor Evacuation Distance <sup>3</sup>
 Pipe Bomb	5 LBS/ 2.3 KG	70 FT/ 21 M	850 FT/ 259 M
 Briefcase/ Suitcase Bomb	50 LBS/ 23 KG	150 FT/ 46 M	1,850 FT/ 564 M
 Compact Sedan	500 LBS/ 227 KG	320 FT/ 98 M	1,500 FT/ 457 M
 Sedan	1,000 LBS/ 454 KG	400 FT/ 122 M	1,750 FT/ 533 M
 Passenger/ Cargo Van	4,000 LBS/ 1,814 KG	600 FT/ 183 M	2,750 FT/ 838 M
 Small Moving Van/ Delivery Truck	10,000 LBS/ 4,536 KG	860 FT/ 262 M	3,750 FT/ 1,143 M
 Moving Van/ Water Truck	30,000 LBS/ 13,608 KG	1,240 FT/ 378 M	6,500 FT/ 1,981 M
 Semi-Trailer	60,000 LBS/ 27,216 KG	1,500 FT/ 457 M	7,000 FT/ 2,134 M

This table is for general emergency planning only. A given building's vulnerability to explosions depends on its construction and composition. The data in these tables may not accurately reflect these variables. Some risk will remain for any persons closer than the Outdoor Evacuation Distance.



## Material and methods



## Material and methods

- 5 patients – males
  - ⇒ Average age 28 years (vary from 25 to 36)
- TNT equivalent of the explosive – average 3,2 (from 0,4 to 7)
  - ⇒ 4 cases – high order explosive
  - ⇒ 1 case – improvised explosive device
- ISS of the injured – average 19,4 (from 12 to 29)
- The fragments affect the abdomen in 2 cases
  - ⇒ Transitory injury of the rectum
  - ⇒ Liver rupture



## War wounds - *Red Cross Wound Score*

- ❑ Evaluate six parameters – **E** (entry of wound – cm), **X** (exit of wound), **C** (cavity), **F** (fracture), **VS** (vital structure), **M** (metallic body)
- ❑ Grading of wounds according to severity
  - ⇒ G1 – E+X less than 10 cm and C0, F0 or F1
  - ⇒ G2 – E+X less than 10 cm and C1 or F2
  - ⇒ G3 – E+X more than 10 cm and C1 or F2
- ❑ Typing of wounds depending on injured tissues – **ST** (soft tissue), **F** (fracture), **V** (vital structure), **VF** (fractures involving vital structures)



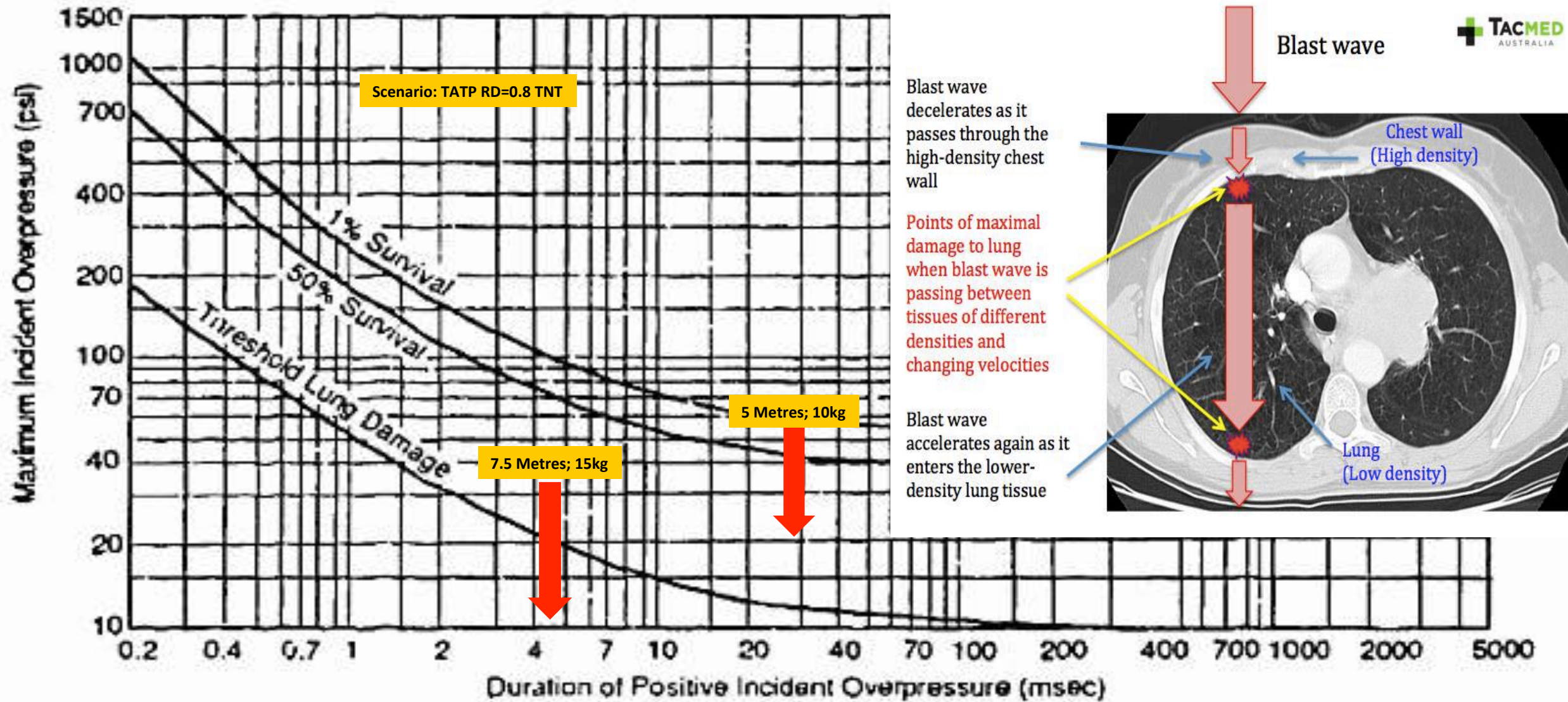
# Wound classification

	Grade 1	Grade 2	Grade 3
Type ST	1 ST Small, simple wound	2 ST Medium soft-tissue wound	3 ST Large soft-tissue wound
Type F	1 F Simple fracture	2 F Important fracture	3 F Massive comminution
Type V	1 V Small wound threatening life	2 V Medium wound threatening life	3 V Large wound threatening life
Type VF	1 VF Small wound threatening limb and/or life	2 VF Important wound threatening life and/or limb	3 VF Large wound threatening life and/or limb



N	Wound	E	X	C	F	V	M	Severity	Classification	IS S
1	1- pelvis, abdomen	12	25	C1	F2	VA	M0	G3	VF3 large wound threatening live	27
	2- tight	2	0	C0	F1	V0	M1	G1	F1 simple fracture	
2	1- face	2	0	CO	F1	V0	M1	G1	F1 simple fracture	17
	2- tight	5	0	C1	F0	VH	M1	G2	ST2 medium soft tissue wound	
3	1- abdominal wall	4	0	C1	F0	V0	M1	G2	ST2 medium soft tissue wound	12
	2- tight	5	0	C1	F0	VH	M1	G2	V2 medium wound threatening live	
4	1- forearm	12	0?	C1	F2	VH	M0	G3	VF3 large wound threatening live	29
	2- shank	5	0	C1	F0	V0	M1	G2	ST2 medium soft tissue wound	
5	1- face	3	0	C0	F0	V0	M1	G1	ST1 simple wound	12
	2- shank	6	0	C1	F0	V0	M1	G2	ST2 medium soft tissue wound	





**Survival curves predicted for a 70 kg man, applicable to free-stream situations where the long axis of the body is perpendicular to the direction of propagation of the blast wave**