Fragmentation Safety Risks and Safety Distances for Field Storage of Large Calibre Munitions

Mark G. Stewart
Distinguished Professor of Civil Engineering
Director, Centre for Built Infrastructure Resilience
University of Technology Sydney
Australia

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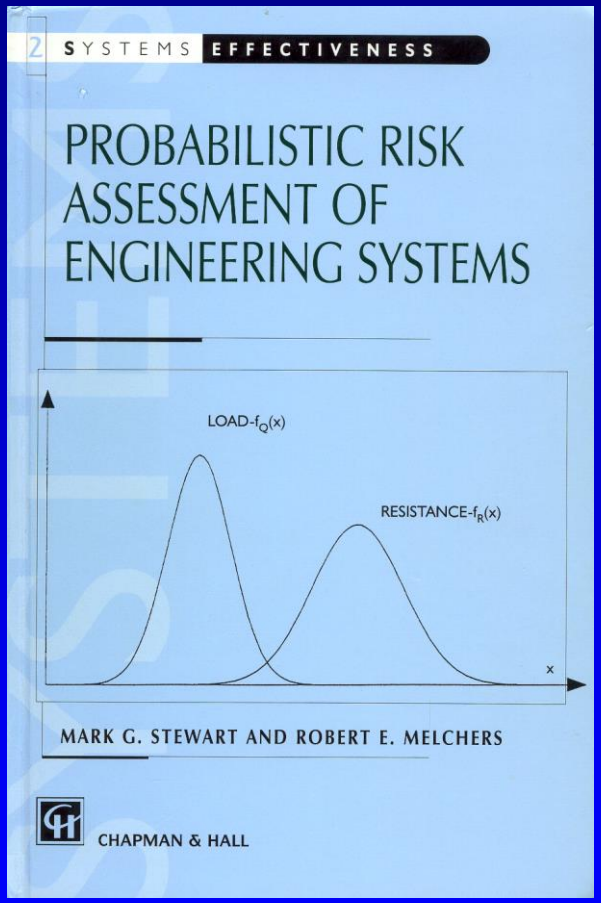
Scope of Talk

- Who am I?
- Safety Distances (Quantity Distance)
  - What is a safe distance from 155 mm projectiles?
  - Probabilistic assessment
    - variability and uncertainty analysis of fragment trajectory
  - Single projectile
  - Pallet - stack of 8 x 155 mm projectiles
- How does a transverse / barricade affect:
  - safety distance
  - fatality risk reduction

Hypothetical

Probabilistic Risk Assessment

- Assess safety of:
  - Buildings
  - Bridges
  - Pipelines
  - Dams
  - Shipping
  - LPG storage tanks
  - Nuclear facilities
  - Aircraft
  - Wharves
  - Medical procedures
  - Terrorism
  - EO



Low Probability – High Consequence Events
EXTREME EVENTS

(Defence) Research @ UTS

- What is variability of explosive blast loads, fragmentation & ballistics ?
- What is the vulnerability of people and infrastructure ?
- What is the risk of damage or casualties?
- What is an optimal decision based on risks vs. costs ?
  - e.g. selection of weapon type and delivery
  - explosive safety distance of EO storage
  - minimum safe distance for joint fires
  - force protection

Risk-based Decision-Making
includes uncertainty & variability of hazard, vulnerability, loss
e.g. is a safety risk less than acceptable level ?

Fragmentation Safety Hazards

- Given an accidental detonation of high-explosive munitions:
  - What fatalities and injuries may occur?
- The current research considers typical metal-cased munitions:
  - However, it is also 100% applicable to Improvised Explosive Devices (IEDs) to predict the likelihood and extent of mass casualties from terrorist attacks.
- The risk-based analysis can be used to assess **safe evacuation distances** for people exposed to an explosive hazard.

Safety Distances or Quantity Distance

- Guidance from:
  - LWP-CA (ENGR) 4-3-2 *Australian ARMY Land Warfare Procedures – Combat Arms (Engineers)*
  - DDESB TP-14 *Approved methods and algorithms for DoD risk-based explosives siting*.
  - NATO AASTP-1 *Guidelines for the storage of military ammunition and explosives*
- Hazardous fragment:
  - >79 J kinetic energy
- Safety Distance
  - no more than one hazardous fragment (79 J) per 56 m^2
  - = 0.0179 fragments/m^2

Numerical Example

- The proposed method is demonstrated by a **numerical example**

- Hazards risks for an individual in a standing position exposed to the detonation of:
  - single 155 mm projectile
  - stack of 8 x 155 mm projectiles

The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement.

Fragmentation Safety Hazards

- Probabilistic assessment includes:
  - Fragment generation
    - Fragment mass distribution
    - Shape of fragments
  - Trajectories
    - initial velocity
    - launch angle
    - drag coefficient
  - Human vulnerability

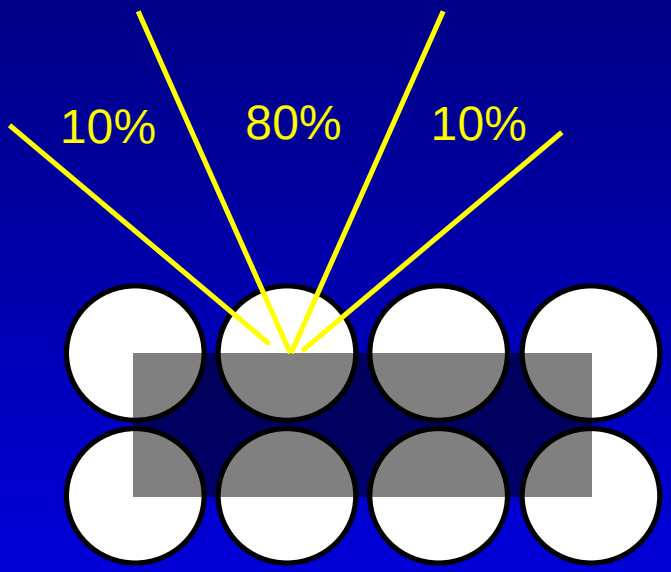
Uncertainty
+
Variability

- Monte-Carlo computer simulation
  - Trajectory of each fragment is modelled

Statistical Parameters

Parameter	mean	95% confidence interval	Probability Distribution
Initial velocity			Normal
single projectile	1100 m/s	±330 m/s	Normal
stack	1800 m/s	±700 m/s	Normal
Stack effects model uncertainty	1.0	±40%	Normal
Drag coefficient	0.95	±0.38	Lognormal
Shape factor	4740 kg/m^3	±1900 kg/m^3	Normal
Launch Angles	-	-	Uniform

Fragment Launch Angles



Total fragments on long side
= equivalent to a single shell

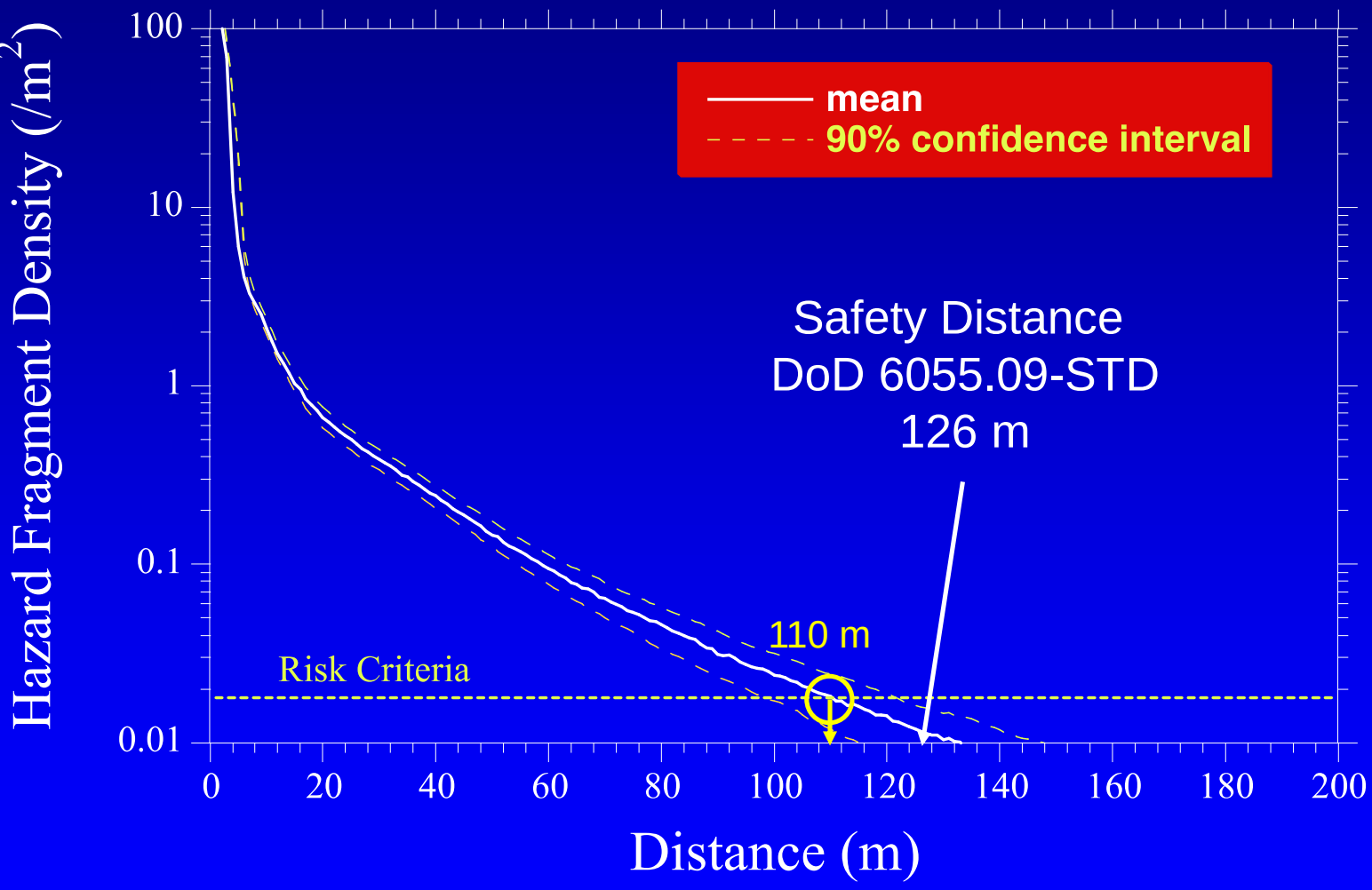
Polar launch angle: (elevation)	-20° – +20°	80% fragments
	+20° – +80°	20% fragments
Azimuthal angle:	70° – 110°	80% fragments
	45° – 70° & 110° – 135°	20% fragments

Test data:

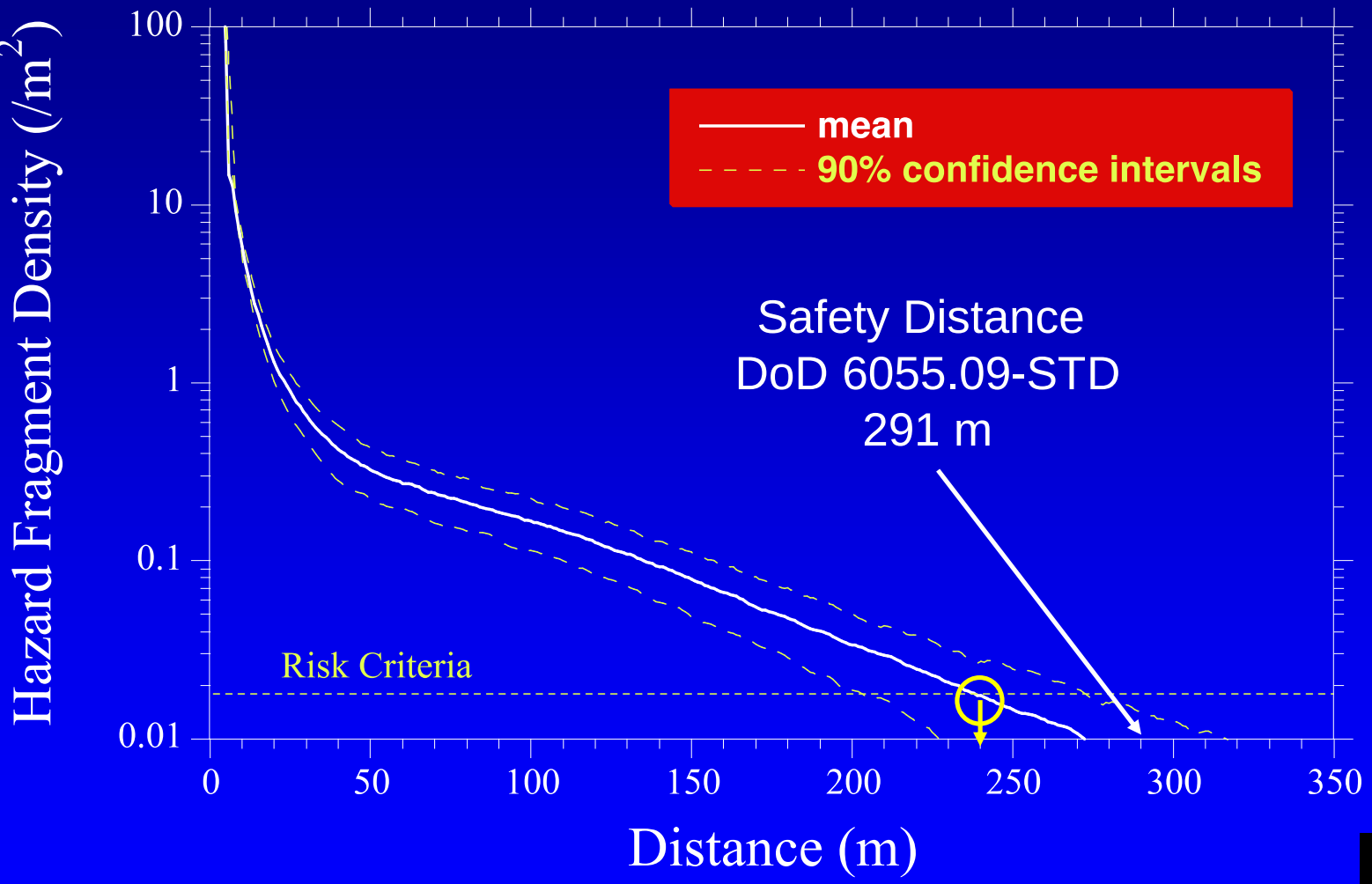
Powell, J. G. Smith, W. D. McCleskey, F. (1981). *Fragment Hazard Investigation Program: Natural Communication Detonation of 155 mm Projectiles*. Naval Surface Weapons Center, Dahlgren, VA, USA.

Crull, M. M., Hamilton, S. D. (2012). *Methodologies for calculating primary fragment characteristics*. Department of Defense Explosives Safety Board (DDESB), Technical Paper 16, Alexandria, VA, USA.

Single Shell

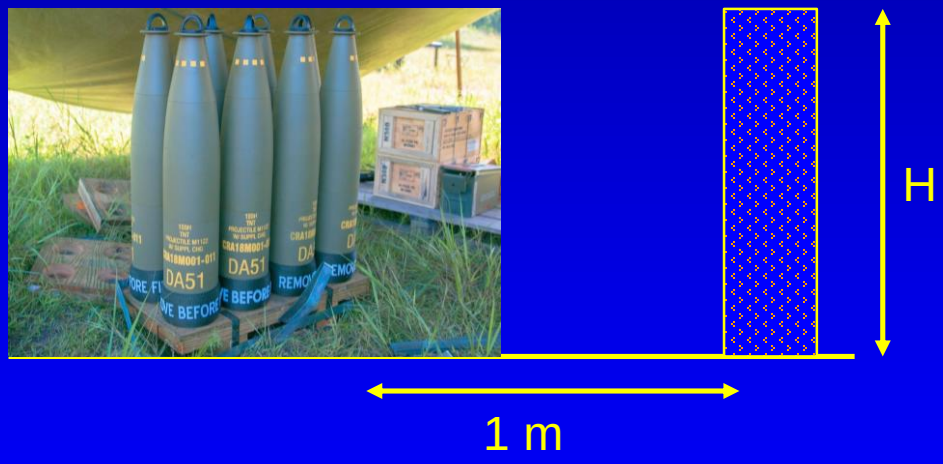


Pallet


Hazard Fragment Density (/m^2)
100
10
1
0.1
0.01
0
50
100
150
200
250
300
350
Distance (m)
mean
90% confidence intervals
Safety Distance
DoD 6055.09-STD
291 m
Risk Criteria

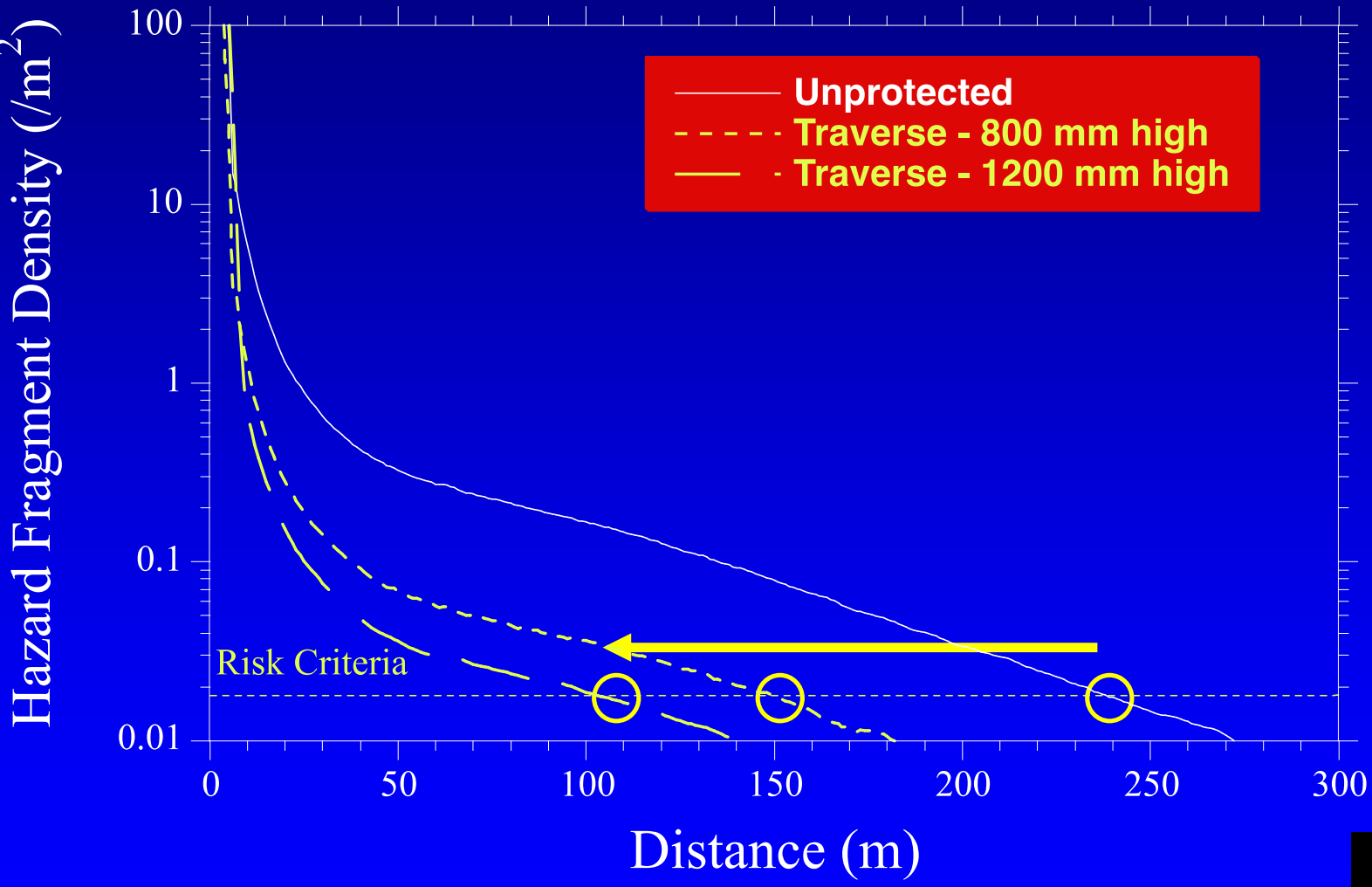
Effectiveness of a Traverse (or Barricade)

- Traverse:
  - H= 800 mm (height of stack)
  - H=1200 mm



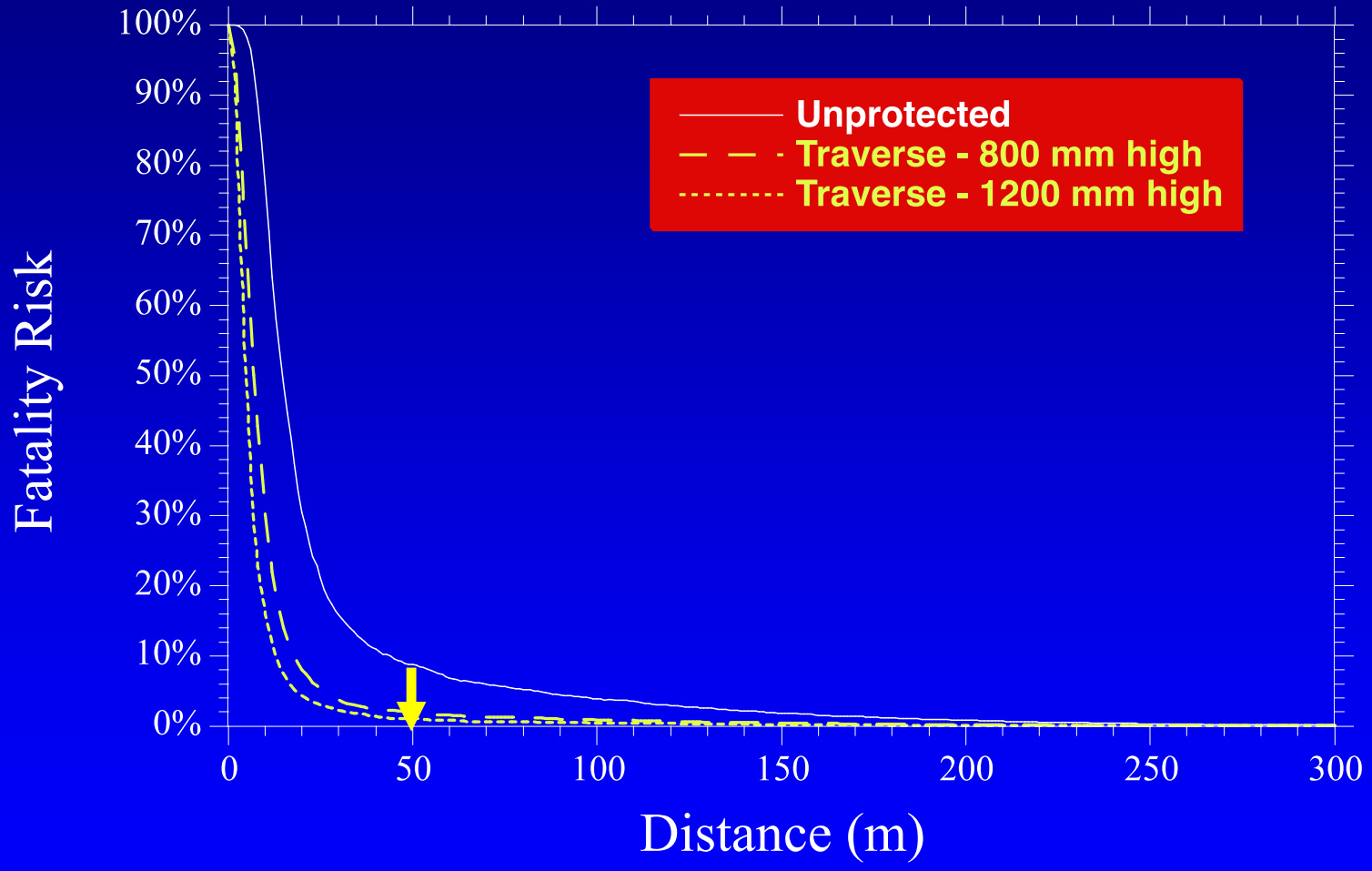
Probabilistic risk analysis allows for
risk mitigation scenarios to be tried and modelled
to test their effectiveness

Traverse Effectiveness



40-60% reduction in Safety Distances

Fatality Risks



80-90% risk reduction @ 50 m

Thank you

mark.stewart@uts.edu.au
Centre for Built Infrastructure Resilience
University of Technology Sydney
Australia

Australian Government
Australian Research Council