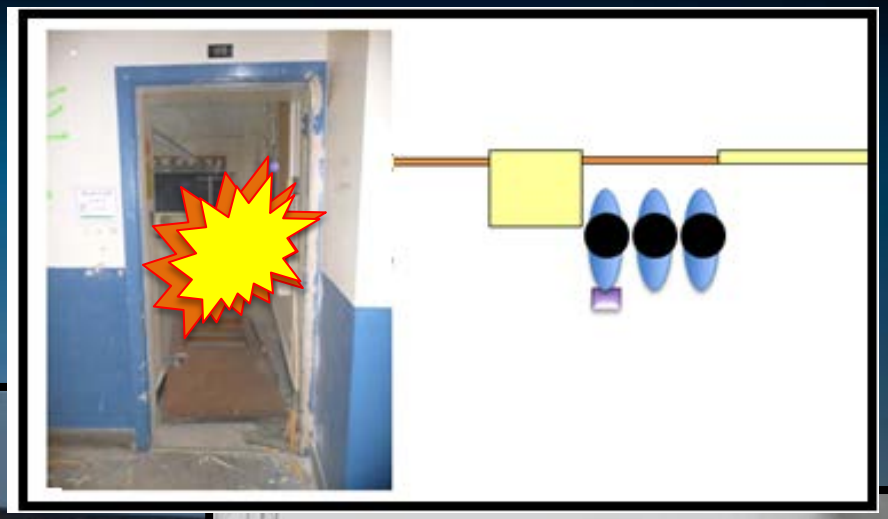
MED-ENG



IMPROVING SAFETY THROUGH USE OF PERSONAL BLAST DOSIMETER IN EXPLOSIVE BREACHING OPERATIONS

Aris Makris, VP R&D, Chief Technology Officer

BLAST EXPOSURE TO LOW LEVEL BLAST

- Most blast injury thresholds based on single event exposure at free-field conditions

- Repeat exposure to multiple small blasts may also harm individuals – exposure not tracked
  - Live fire training
  - Firing large weapons
  - Breaching operations
  - Exploding enemy ordnance
  - School instructors

LOW LEVEL BLAST EXPOSURE

Explosive Breaching (Forced Entry) Operations

Courtesy of Dallas PD, May 7-10 2012
International Breacher's Symposium

REPEAT LOW BLAST – TACTICAL / SPECIAL FORCES

Courtesy of Dallas PD, May 7-10 2012

Breaching (Forced Entry) Operations

- Training alone:
  - Many training sessions throughout year
  - Exposure to many blasts per training
  - Total number of exposures can be high: dozens, 100s, up to 1000 per year

- Scientific Investigations:
  - Mild Traumatic Brain Injury
  - New-Zealand Defence Forces – 2-week training course
  - Walter Reed/Bethesda/ARA/USMC Quantico

SYMPTOMS OF MILD TRAUMATIC BRAIN INJURY

Headache

Remembering Difficulties

Hearing Difficulties

Sleeping Difficulties

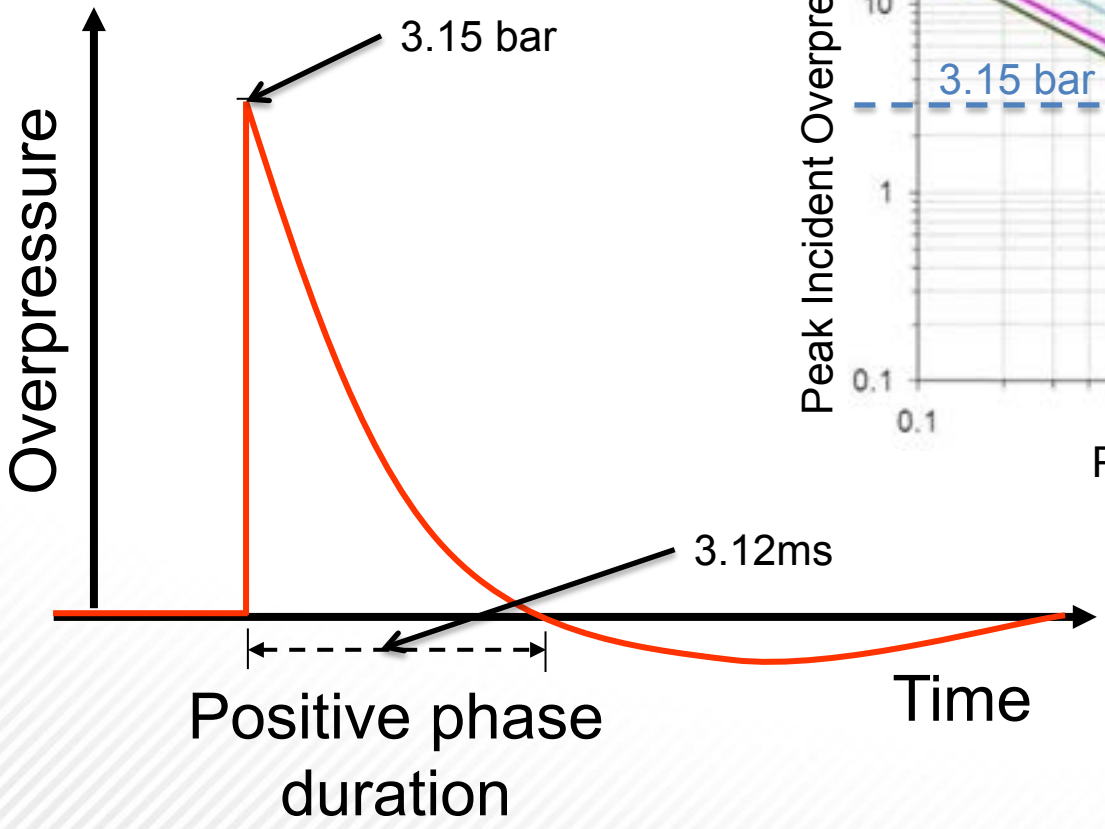
Ringing Ears

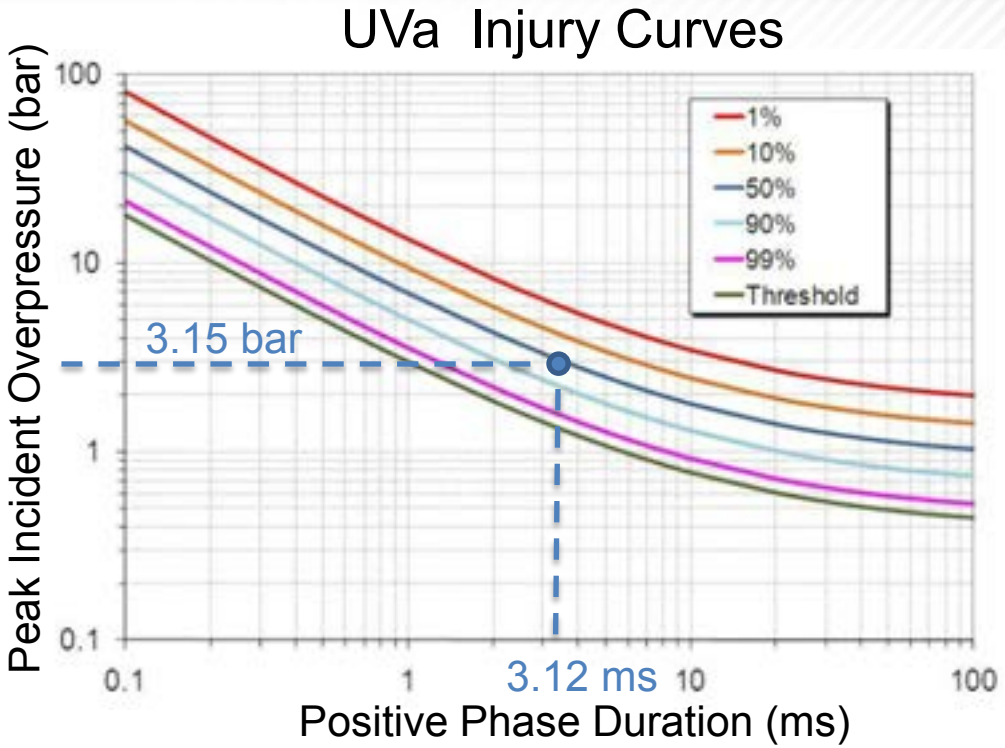
Energy Loss

MED-ENG

SINGLE BLAST EXPOSURE

5 kg C4 @ 3 m



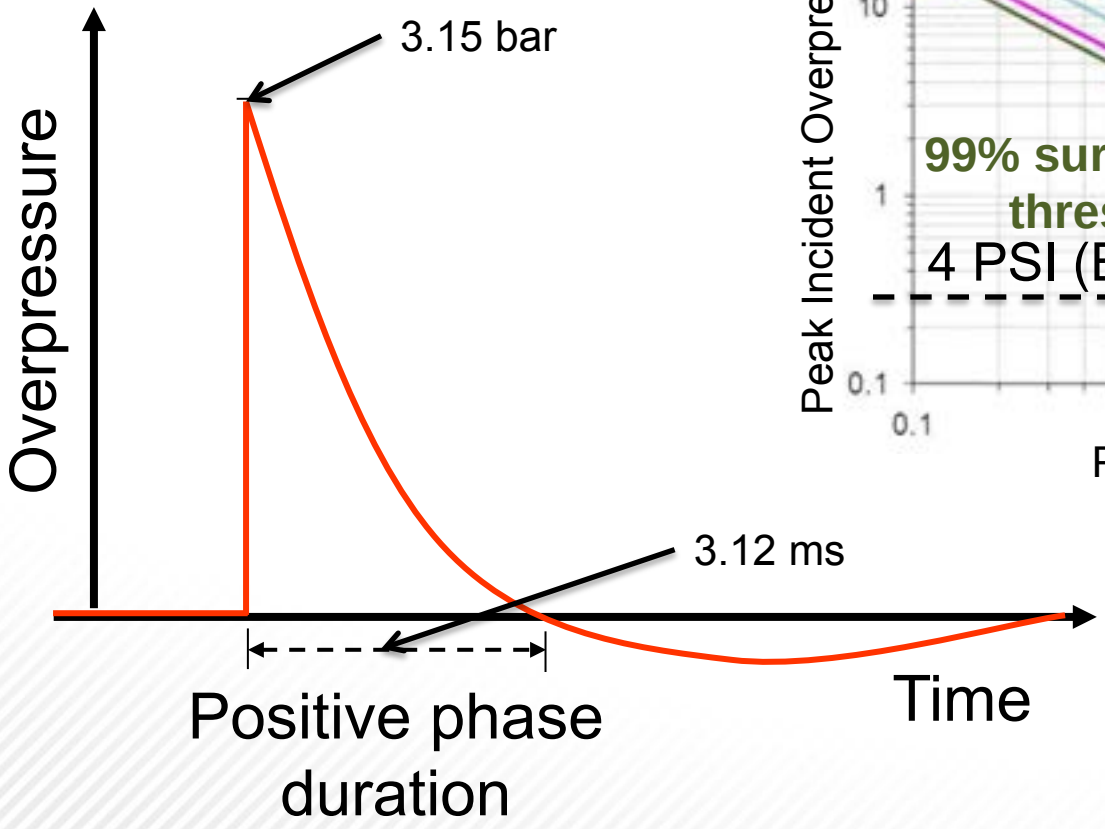


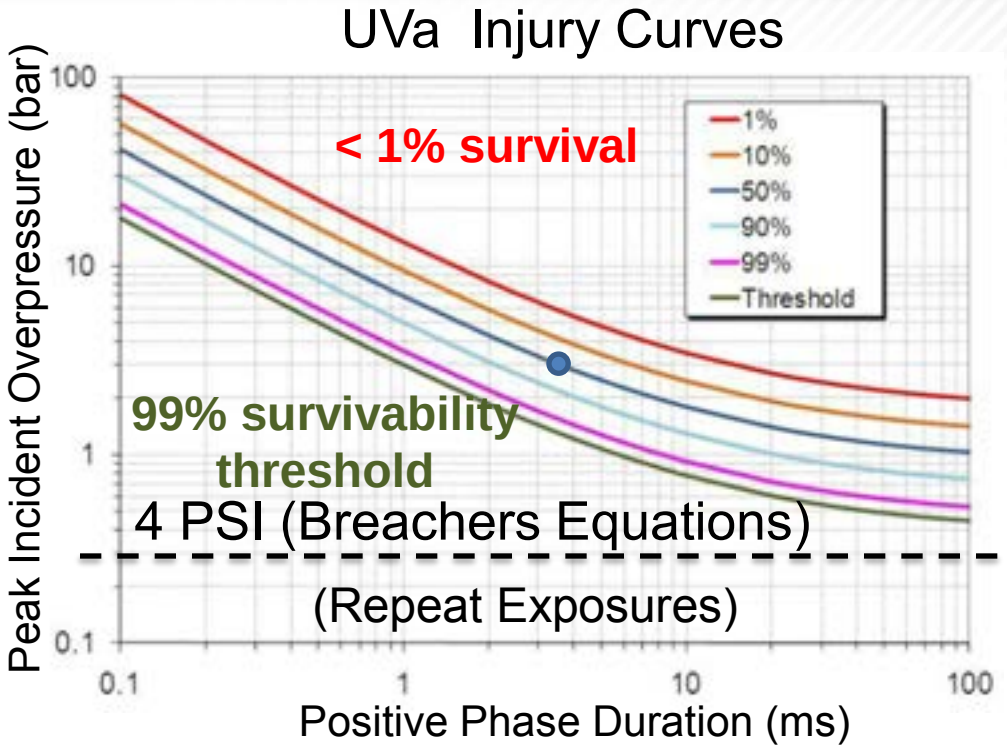
LONG AXIS OF BODY PERPENDICULAR TO BLAST WINDS, SUBJECT FACING ANY DIRECTION

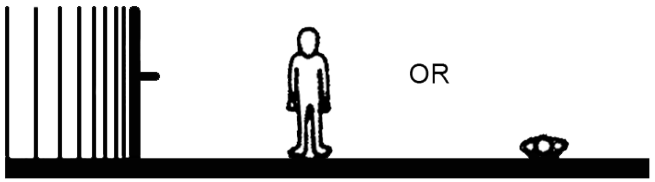
MED-ENG

SURVIVABILITY CURVES – SINGLE EXPOSURE

5 kg C4 @ 3 m







LONG AXIS OF BODY PERPENDICULAR TO BLAST WINDS, SUBJECT FACING ANY DIRECTION

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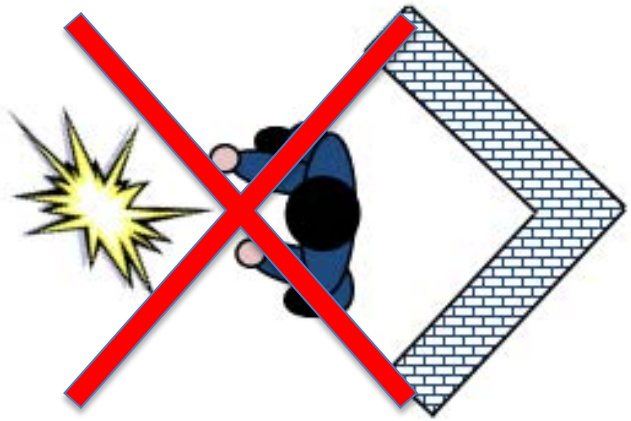
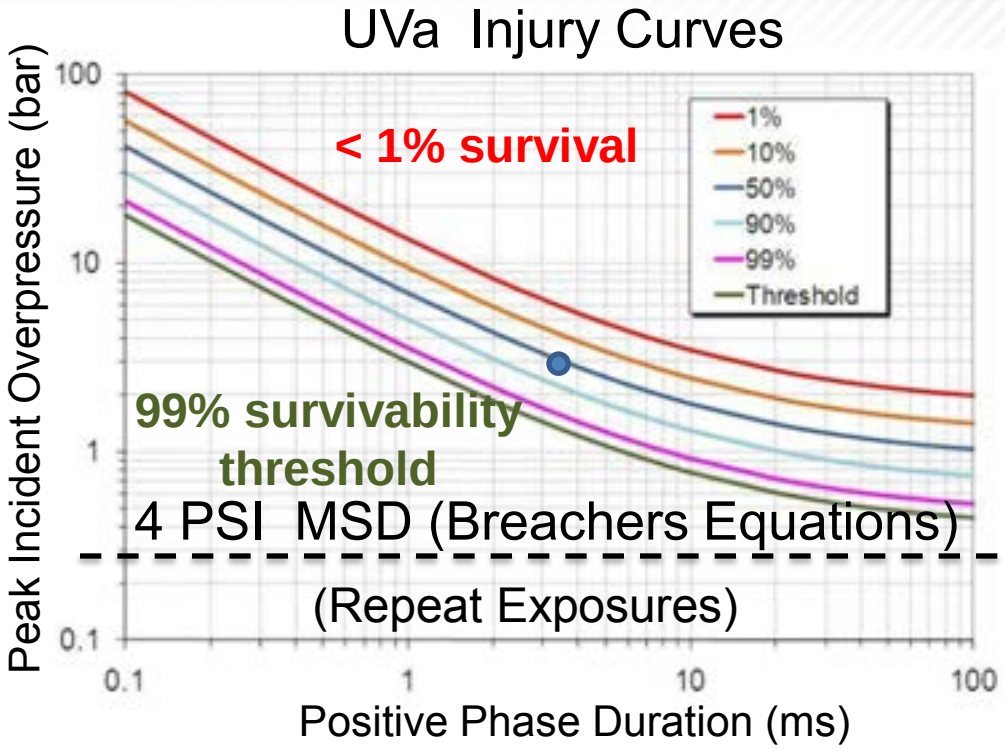
SURVIVABILITY CURVES – SINGLE EXPOSURE

Chart or MSDs not valid for reflected/internal blasts!





LONG AXIS OF BODY PERPENDICULAR TO BLAST WINDS, SUBJECT FACING ANY DIRECTION

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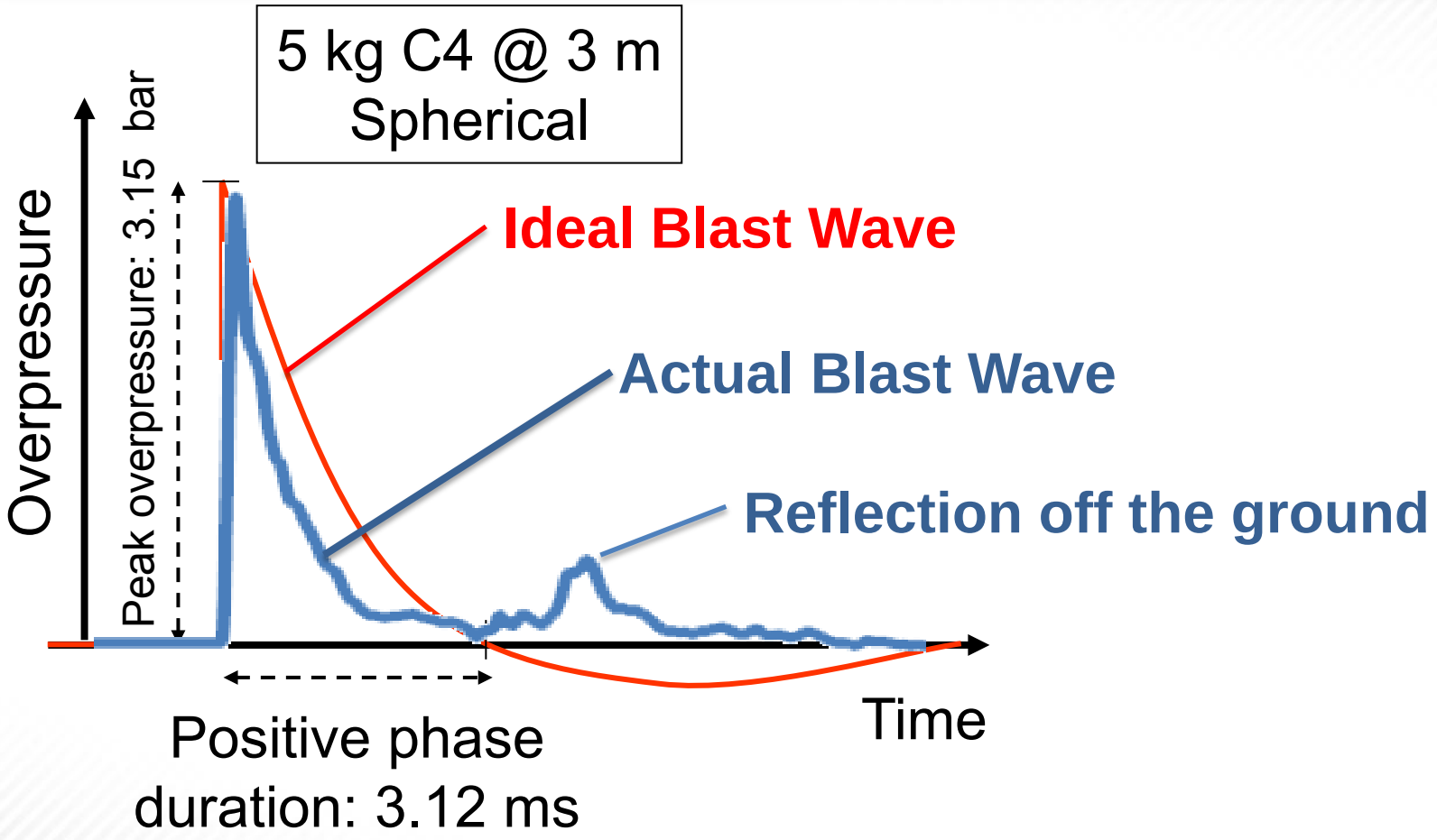
BLAST WAVE FUNDAMENTALS – FREE FIELD



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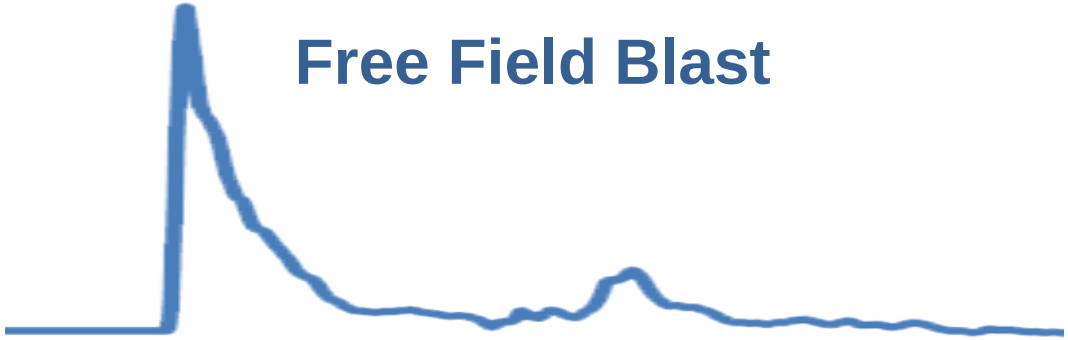
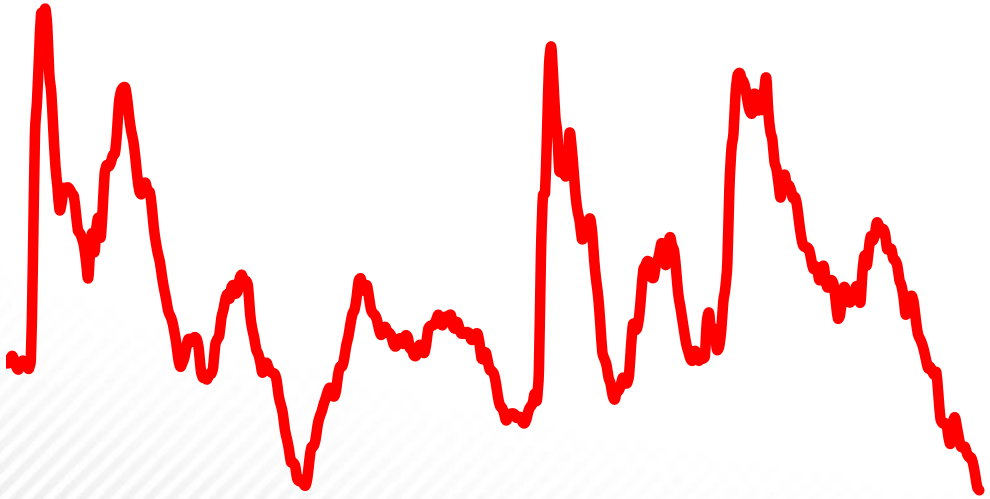
BLAST WAVE FUNDAMENTALS – COMPLEX BLAST

Free Field Blast



Complex (Interior) Blast



Complex Blast:

- Walls
- Obstacles
- Closed room
- Non-Ideal Explosion

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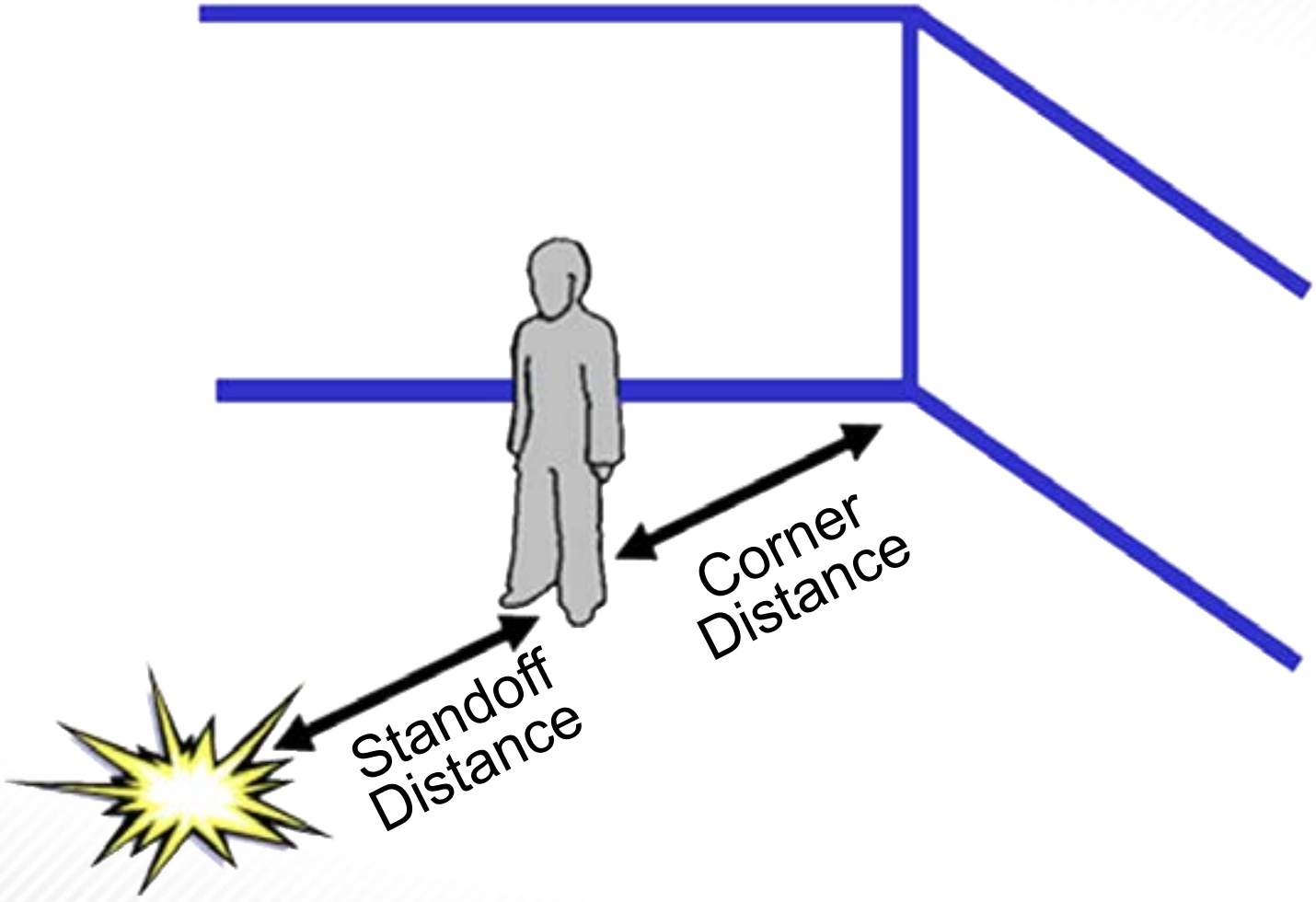
FREE FIELD VS. INDOOR BLAST (CORNER)



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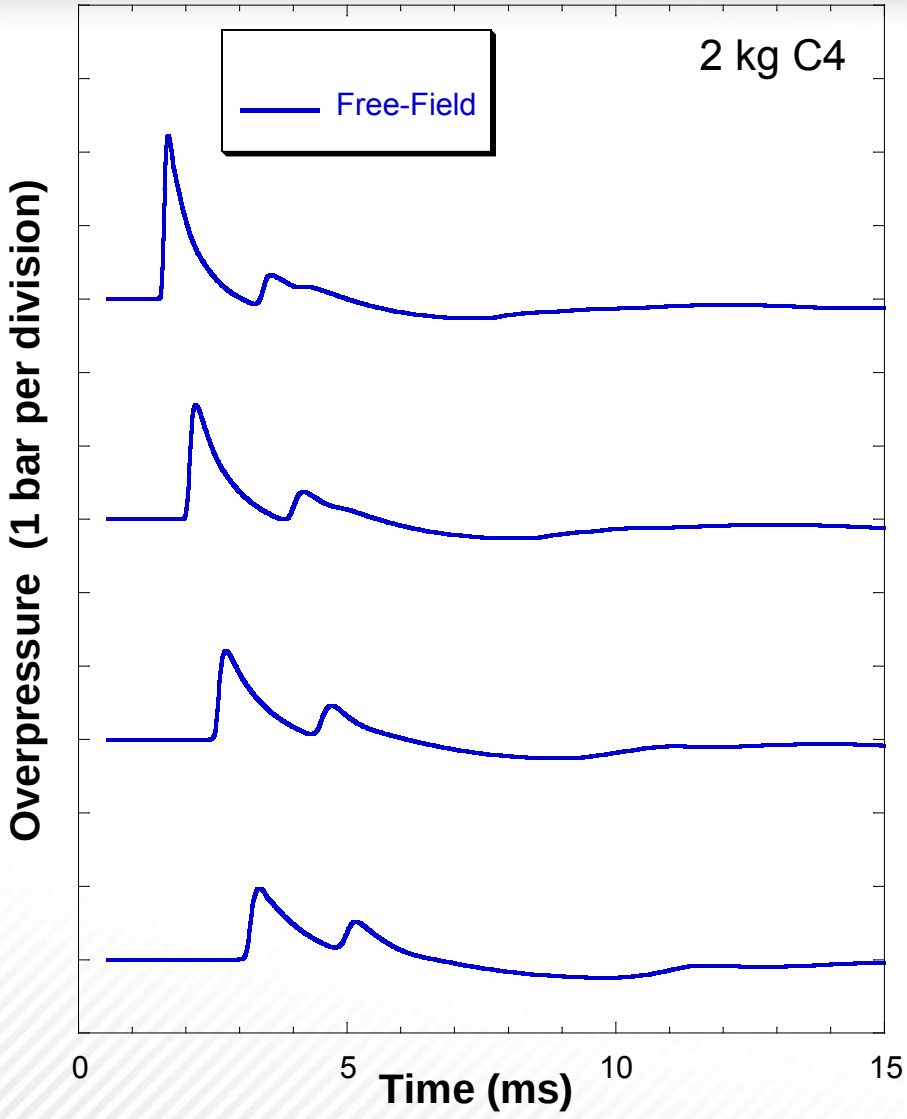
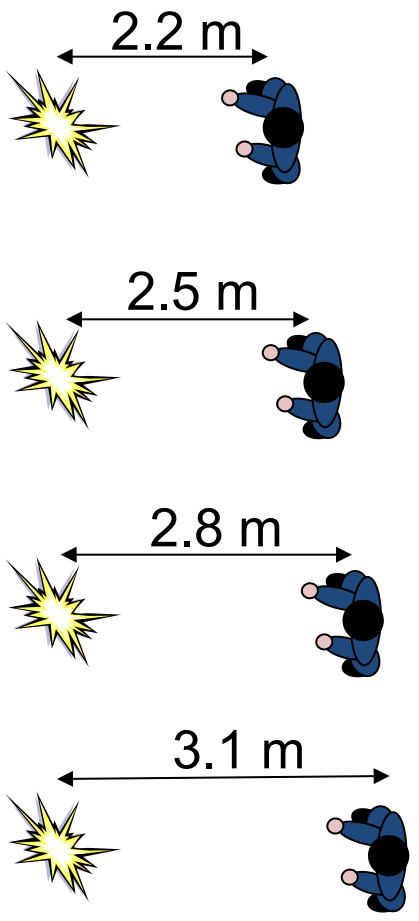
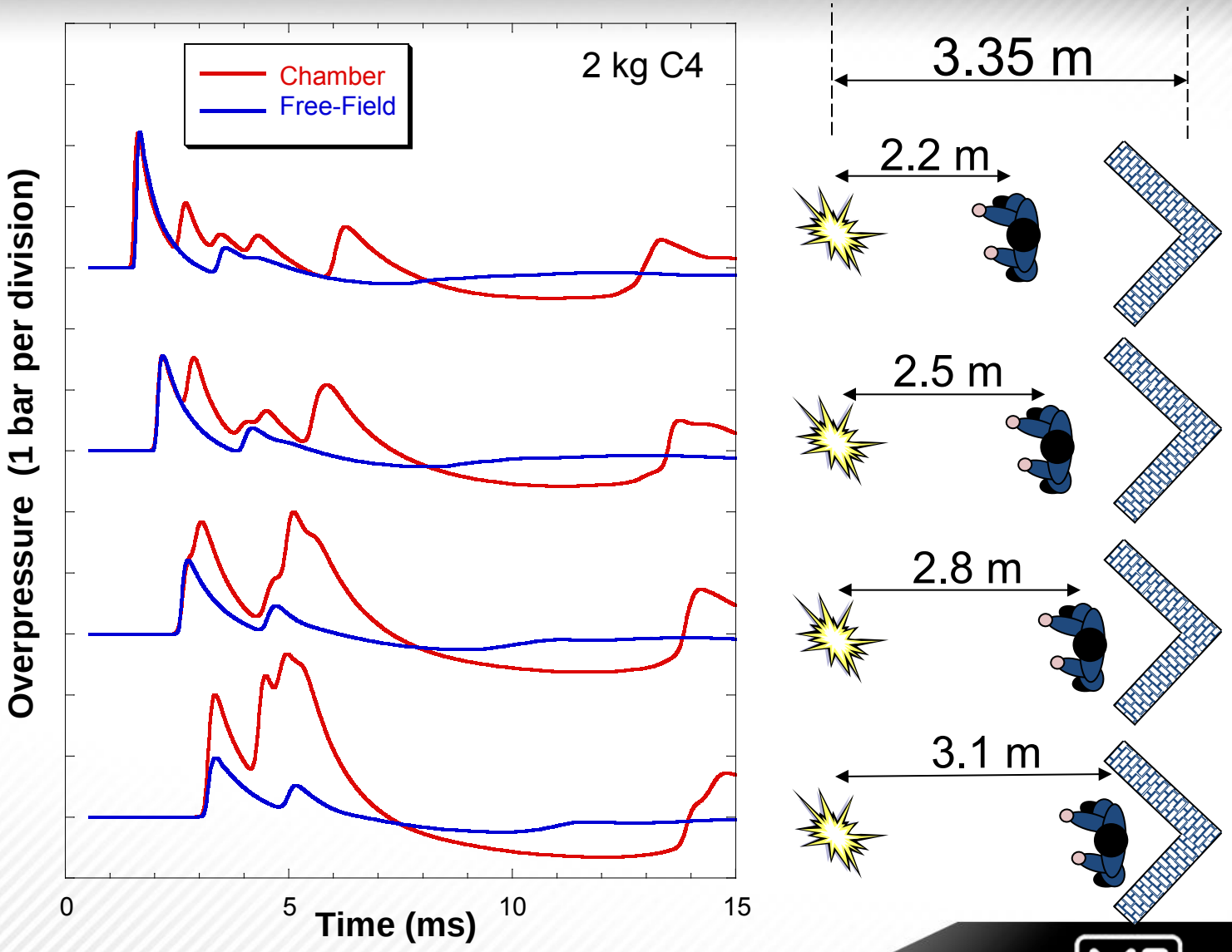
FREE FIELD BLAST – BLAST DECAYS WITH DISTANCE





MED-ENG

FREE FIELD VS. INDOOR BLAST (CORNER)



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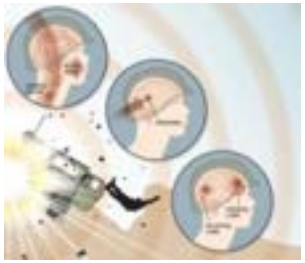
NEED FOR BLAST MEASUREMENTS IN BREACHING

- Optimize TTPs/Con-Ops for safety in Explosive Breaching



- Assess Occupational Health & Safety Issue
  - Establish overpressure exposure guidelines
  - Track individual blast exposure history over time

- Assess in triage of any blast victims

- Guide forensic analysis of an IED blast event
  - Charge size, standoff distance
  - Presence of reflecting surfaces
  - Direction of blast

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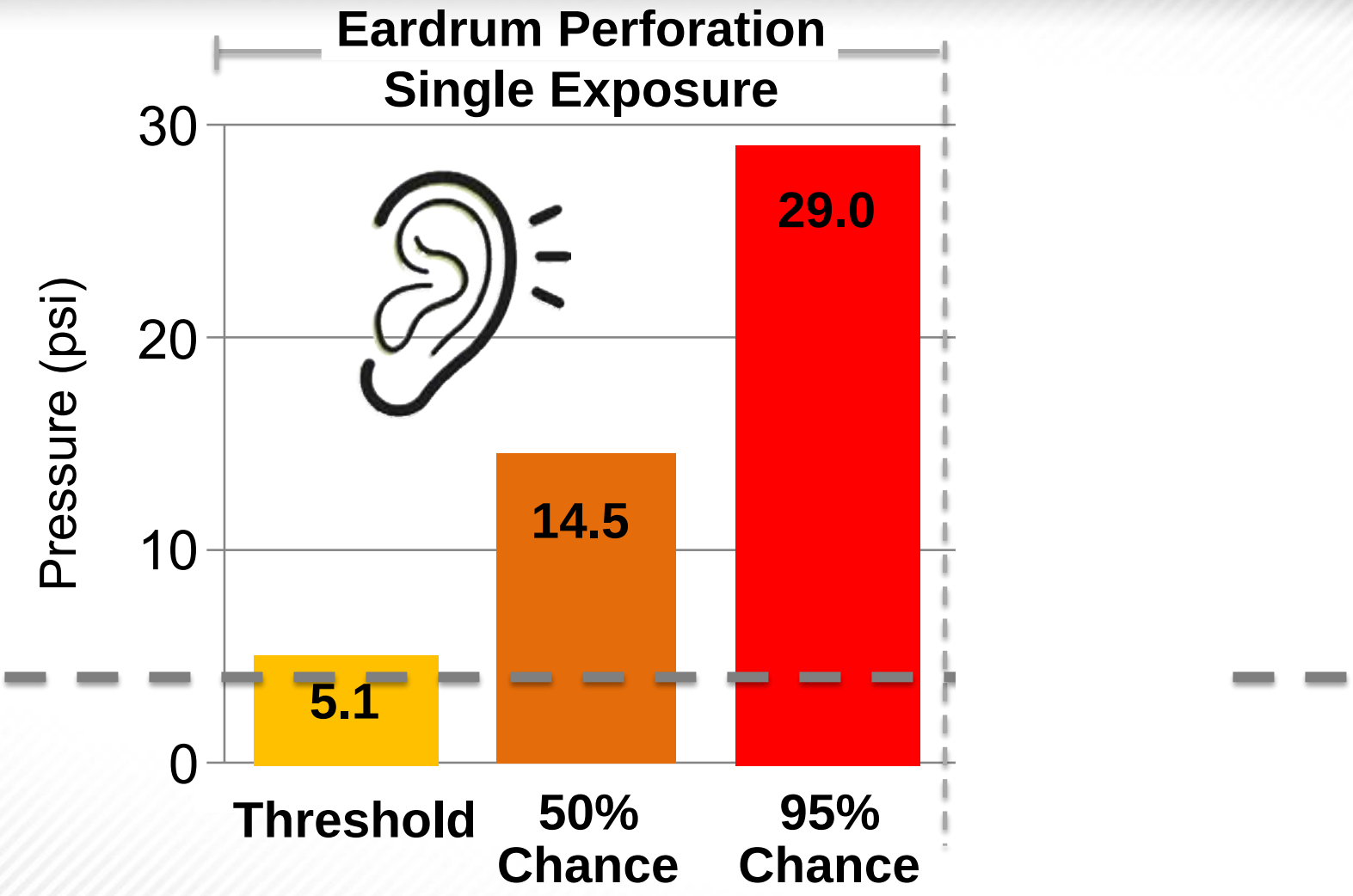
EAR INJURY THRESHOLD VALUES



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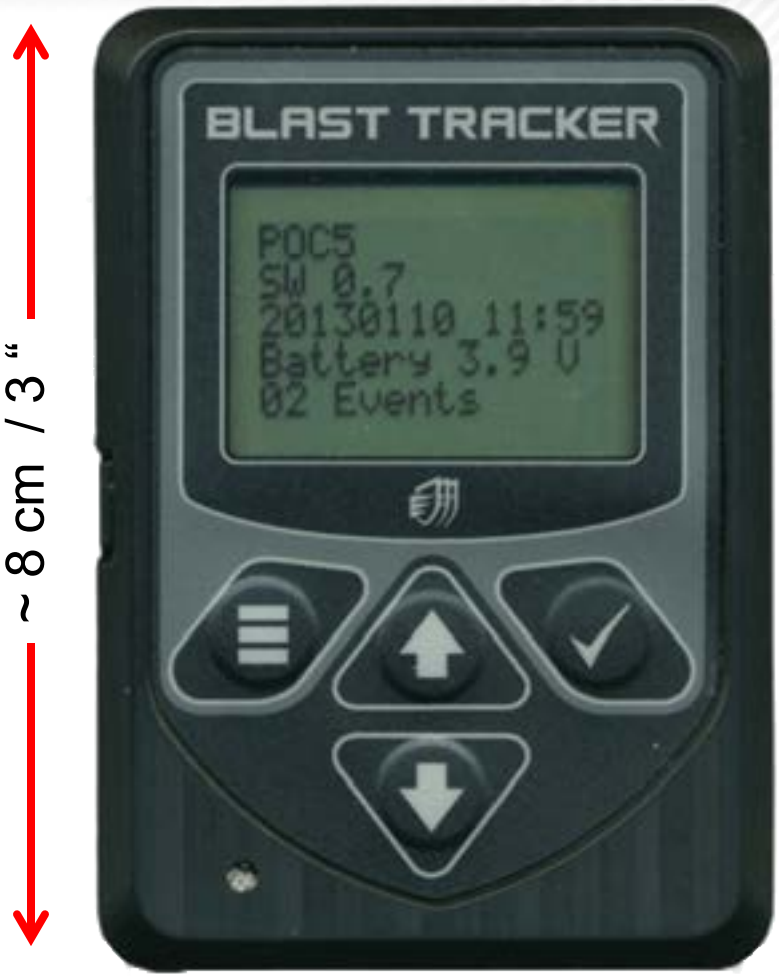
PERSONAL BLAST EVENT RECORDING DEVICE

- Small portable and versatile
- Records sudden acceleration & overpressure
- Immediate display of pressure and acceleration after blast



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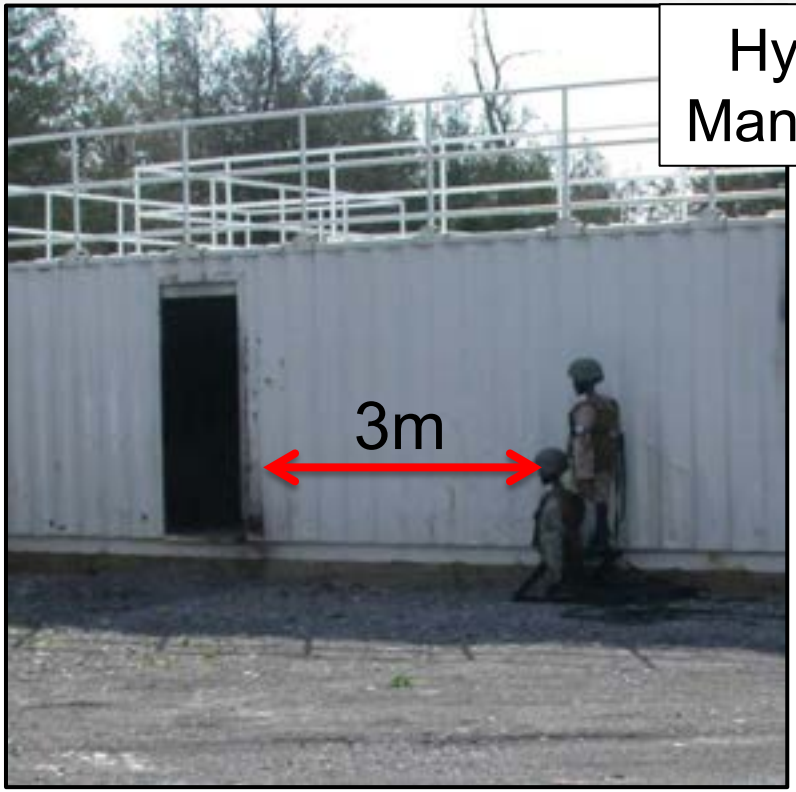
BLAST MEASUREMENTS – BREACHING SETUP



Technical and Protective Operations Facility (TPOF)
Breach Training Complex – Royal Canadian Mounted Police (RCMP)
Ottawa, Canada
April 19, 2012

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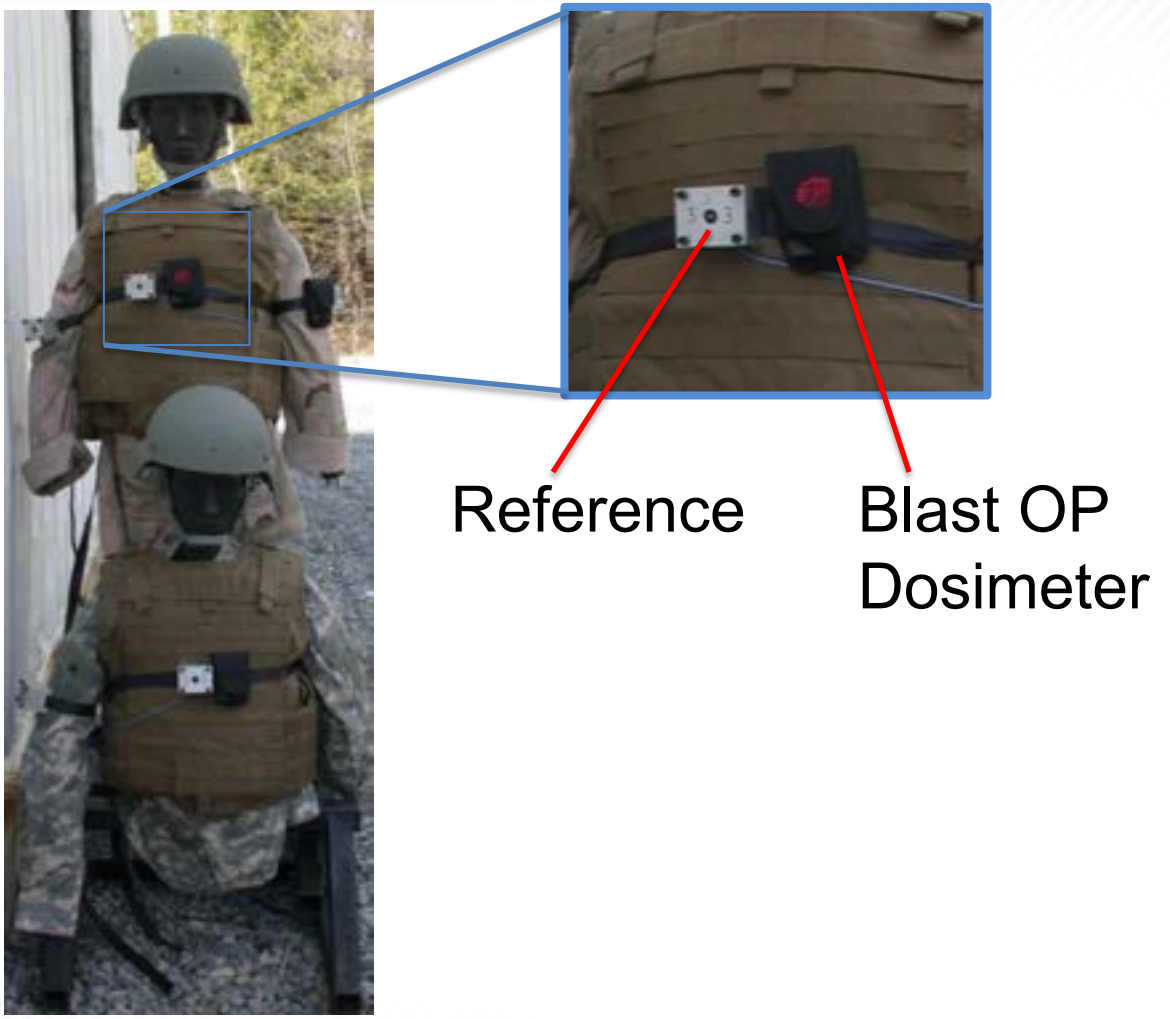
BREACHING SETUP – INSTRUMENTATION



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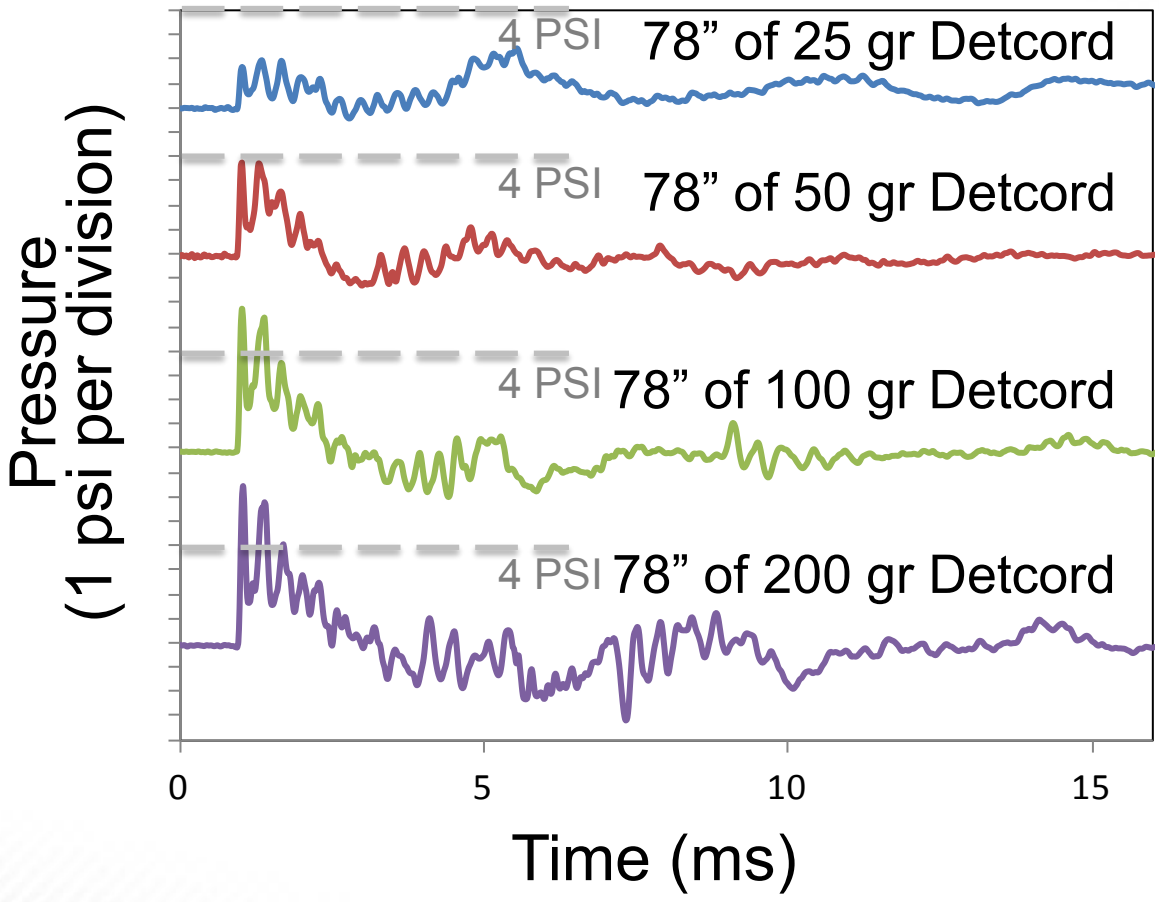
INCREASING BREACHING CHARGE SIZE @ 10 FT



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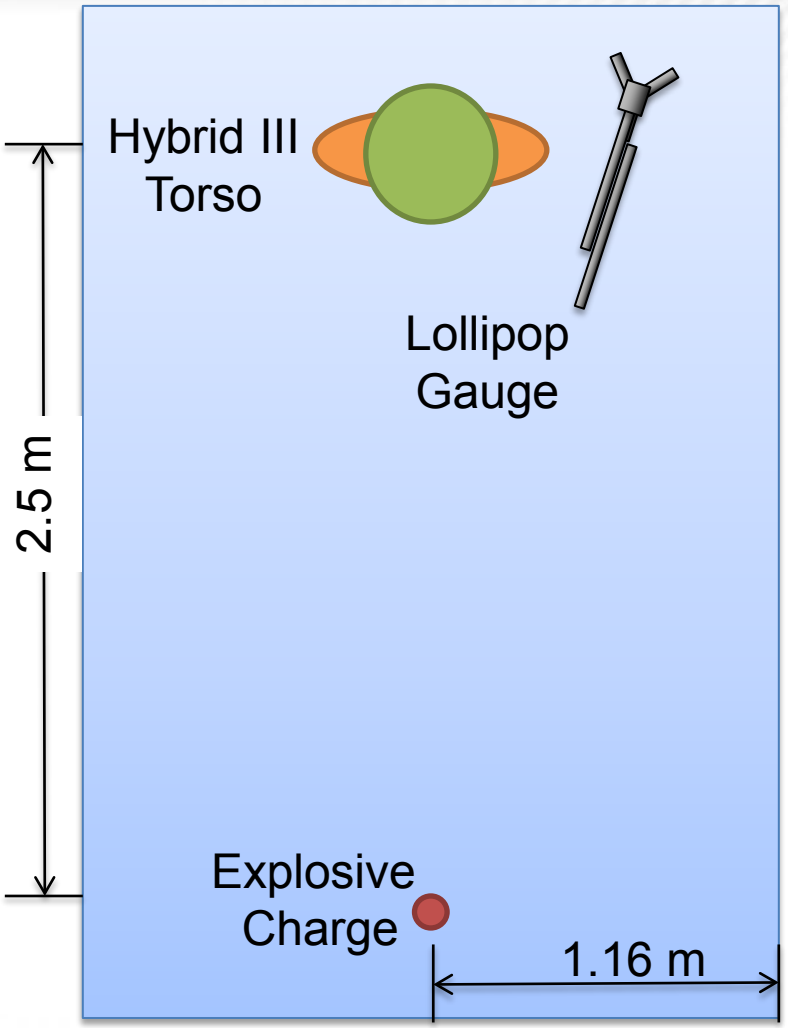
INTERIOR BLAST – BLAST CHAMBER TESTING

Canadian Explosives Research Laboratory (Ottawa) – *April 2012*



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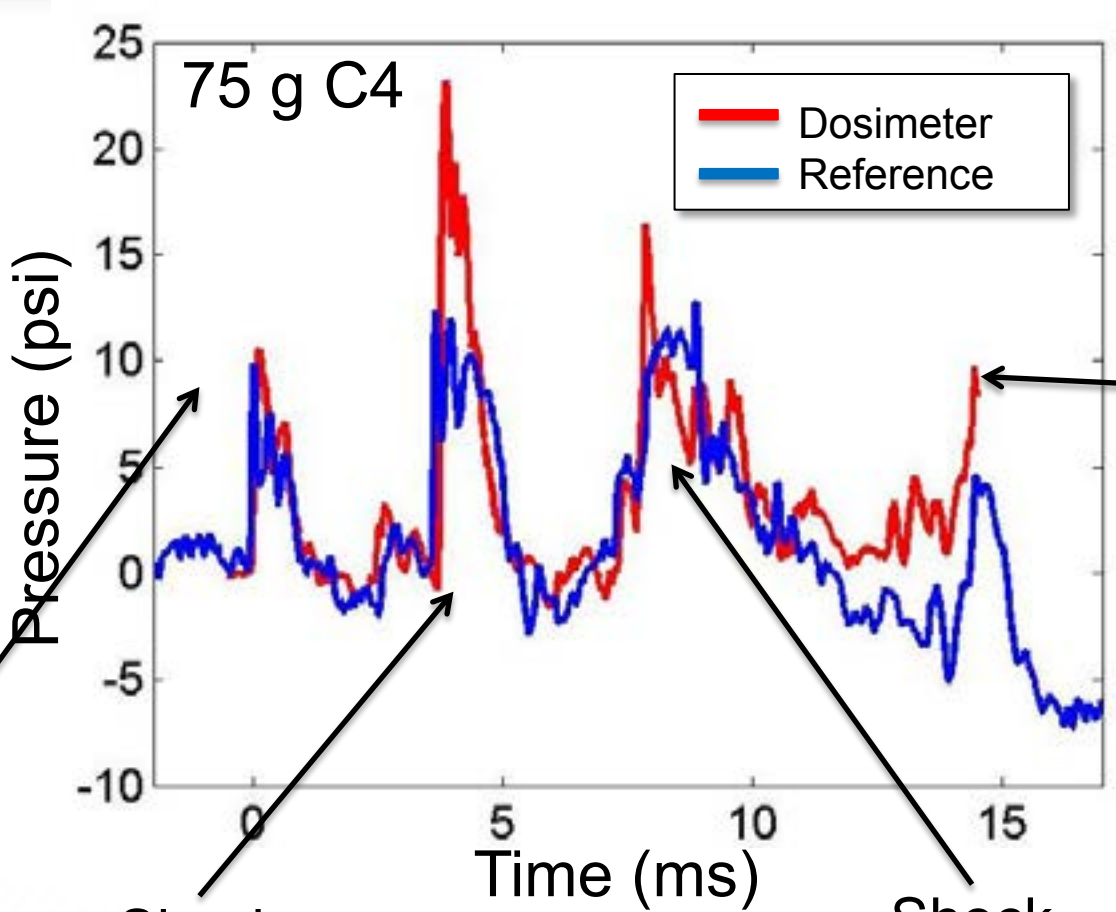
PRESSURE REFLECTIONS OFF WALLS



Primary Shock

Shock reflection off floor

Shock reflection off side-walls &ceiling

Shock reflection off far wall

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EXPLOSIVE FORCED ENTRY (EFE) WORKSHEET

- **Minimum Safe Distance**

$$MSD = 18 \cdot \sqrt[3]{N.E.W.}$$

  - K-Value of 18 for 4 psi
  - Net Equivalent Weight (N.E.W.) in TNT Explosive

Sûrete du Québec

RAPPORT ENTRÉE FORCÉES AUX EXPLOSIFS (T.E.E.S.)

☐ Operational ☑ Training — Location: 3030 Laurier QC — DR #: — Date: 2012-09-11 — Shot #: — ☐ Video ☑ Photos

Det. Cord / FLSC (# of Ft.)	Amounts	Grains	Grains TNT Eq.	Lbs. TNT Eq.	Ounces TNT Eq.
15 Grain Det Cord in Feet	0	0	0	0,000	0,000
18 Grain Det. Cord in Feet	0	0	0	0,000	0,000
25 Grain Det. Cord in Feet	0	0	0	0,000	0,000
35 Grain Det. Cord in Feet	0	0	0	0,000	0,000
50 Grain Det. Cord in Feet	1,2	60	99,6	0,014	0,228
100 Grain Det Cord in Feet	0	0	0	0,000	0,000
200 Grain Det. Cord in Feet	0	0	0	0,000	0,000
75gr Explosive Cutting Tape	0	0	0	0,000	0,000
125gr Explosive Cutting Tape	0	0	0	0,000	0,000
250gr Explosive Cutting Tape	0	0	0	0,000	0,000
Total	*1,2*	*60,000*	*99,600*	*0,014*	*0,228*
PrimaSheet 1000 (# of Sq. In.)	**Amounts**	**Grains**	**Grains TNT Eq.**	**Lbs. TNT Eq.**	**Ounces TNT EQ**
C-1 PrimaSheet	0	0	0	0,000	0,000
C-1.5 PrimaSheet	7,5	173,5875	288,15525	0,041	0,659
C-3 PrimaSheet	0	0	0	0,000	0,000
Total	*7,5*	*173,588*	*288,155*	*0,041*	*0,659*
Boosters (# of Units)	**Amounts**	**Grains**	**Grains TNT Eq.**	**Lbs. TNT Eq.**	**Ounces TNT Eq.**
1 - 20 Gram Booster	0	0	0	0,000	0,000
1/2 - 20 Gram Booster	0	0	0	0,000	0,000
1/4 - 20 Gram Booster	0	0	0	0,000	0,000
Total	*0,0*	*0,000*	*0,000*	*0,000*	*0,000*
C4 (# of Ounces)	**Amounts**	**Grains**	**Grains TNT Eq.**	**Lbs. TNT Eq.**	**Ounces TNT Eq.**
Composition C4	0	0	0	0,000	0,000
Total	*0,0*	*0,000*	*0,000*	*0,000*	*0,000*
Initiator(s) (# of Caps)	**Amounts**	**Grains**	**Grains TNT Eq.**	**Lbs. TNT Eq.**	**Ounces TNT Eq.**
Nonel Shocktube Detonators	1	15,43	25,6138	0,004	0,059
Total	*1*	*15,430*	*25,614*	*0,004*	*0,059*
Total Charge Weight	**Grains**	**Grams**	**Grains TNT Eq.**	**Lbs. TNT Eq.**	**Ounces TNT Eq.**
	249,018	**16,139**	**413,369**	0,059	**0,945**

PSI VALUES
***Safe Stand-off 4 PSI**
K Factor 18
(diviser par 2 avec bouclier)

Cube Root	PSI	Distance in Ft.	PSI	Distance in Ft.
0,389416	*4	7,01	2	11,68
	3	7,79	1	17,52
			Fragmentation	116,82

Interior Residual Over Pressure (I.R.O.P.)

((N.E.W. lbs TNT / Room Volume Cu. Ft.) 0.72) x 2410 = I.R.O.P. in PSI

Room Volume Cu. Ft: 7200.00

I.R.O.P: 0,5248 en haut de 4 psi, ne pas demeurer dans la pièce

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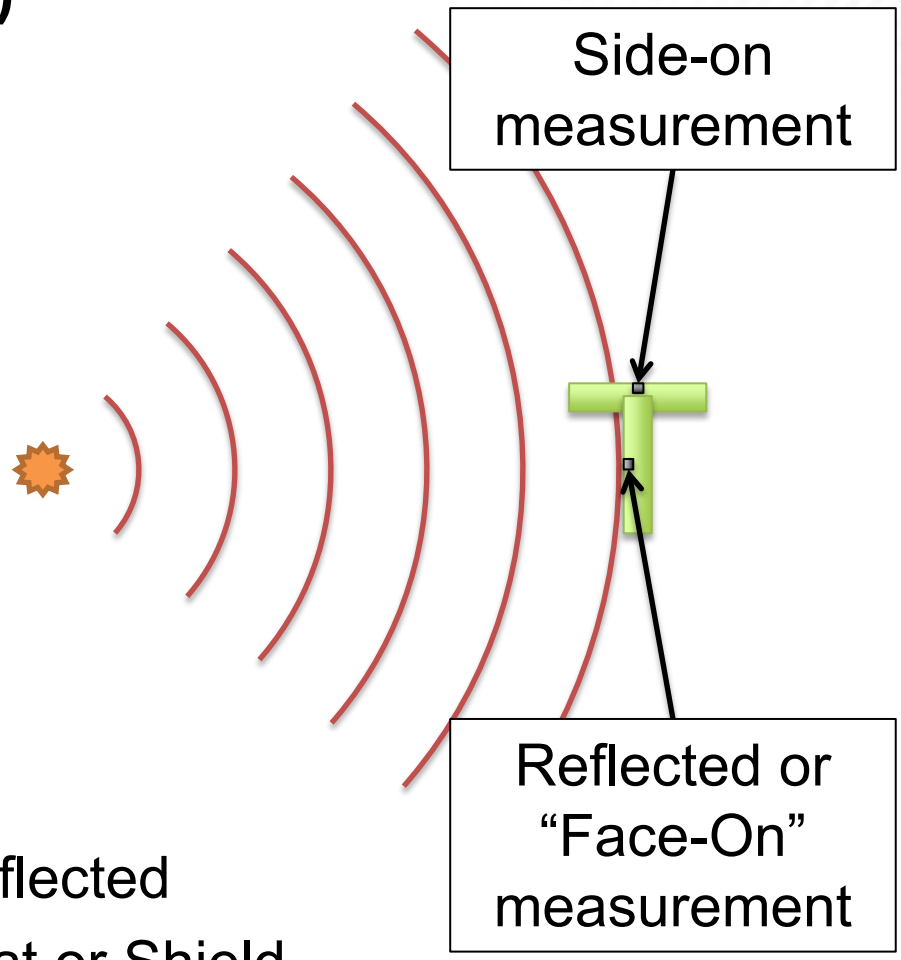
SIDE-ON VS. REFLECTED PRESSURE

- **Can calculate (EFE worksheet) a side-on pressure**
  - Pressure measured as shockwave passes sensor
  - Pressure measured at Shoulder, Arm or side Wall
- **Reflected or "Face-On" pressure can be calculated from side-on pressure based on standard fluid mechanics equations**
  - 4 PSI Side-On ≈ 8.9 PSI Reflected
  - Pressure measured on Chest or Shield



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CANADIAN BREACHERS TESTS (2012-2013)

- **Royal Canadian Mounted Police – CBRNE Unit, TPOF**
- **Canadian Explosives Research Laboratory (CERL)**
- **Montreal Police – Groupe tactique d'intervention**
- **Sûreté du Québec – Direction des services d'urgence**
- **Ontario Provincial Police**
- **Department of National Defence**

INDOORS OPERATIONAL TESTING WITH BREACHERS

- Pressure measurements on Breachers conducting test in indoor environments
  - Hotel
  - Warehouse
  - School
- Measurements compared with theoretical estimates (4psi) using existing MSD equations

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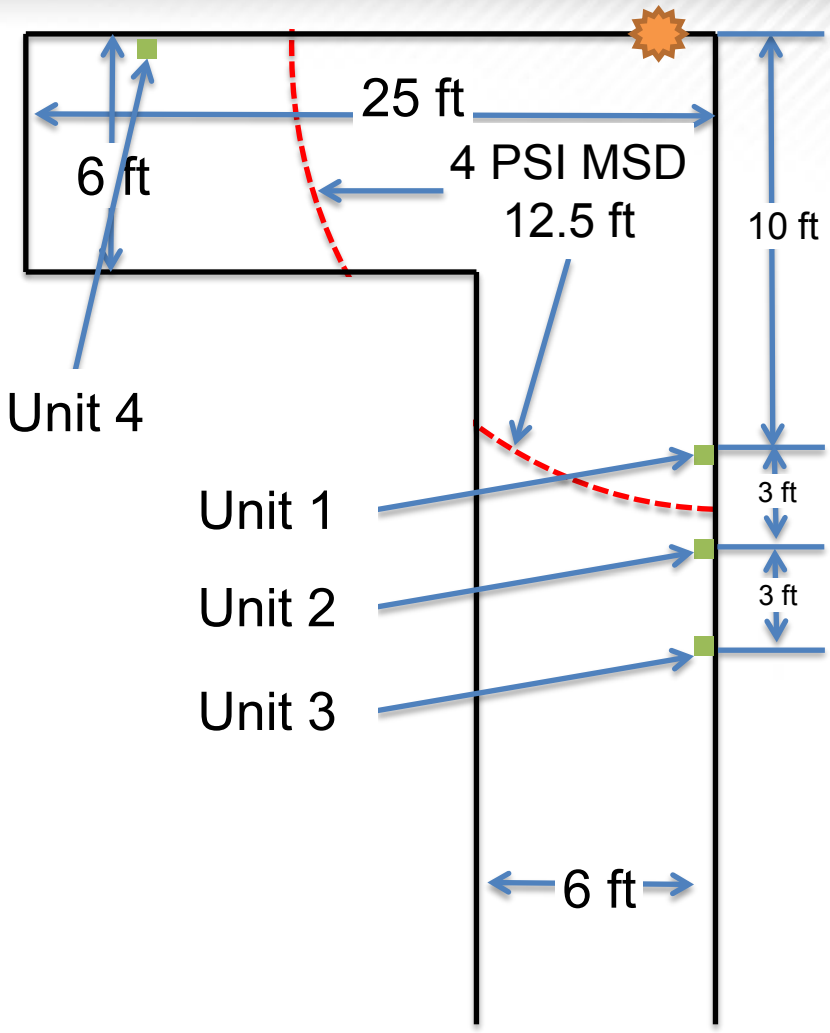
EXAMPLE TRIAL 1 – TEST CONFIGURATION

- **Explosive:**
  - 7 ft. 200-gr Detcord + NEQ = 0.336 lbs. TNT
- **4 PSI MSD = 12.51 ft.**
- **Date & Time:**
  - Sept. 12th at 10:40 AM



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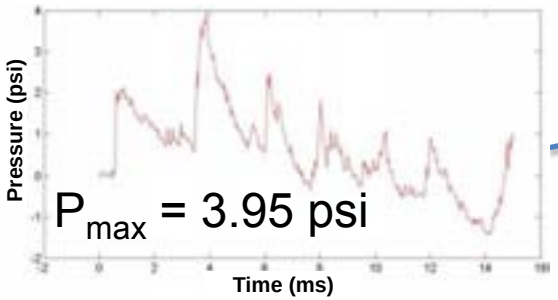
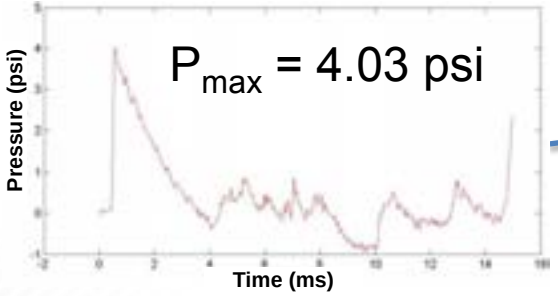
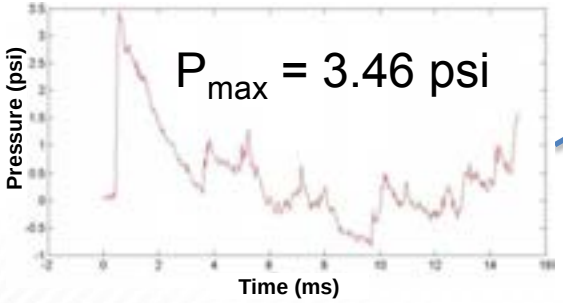
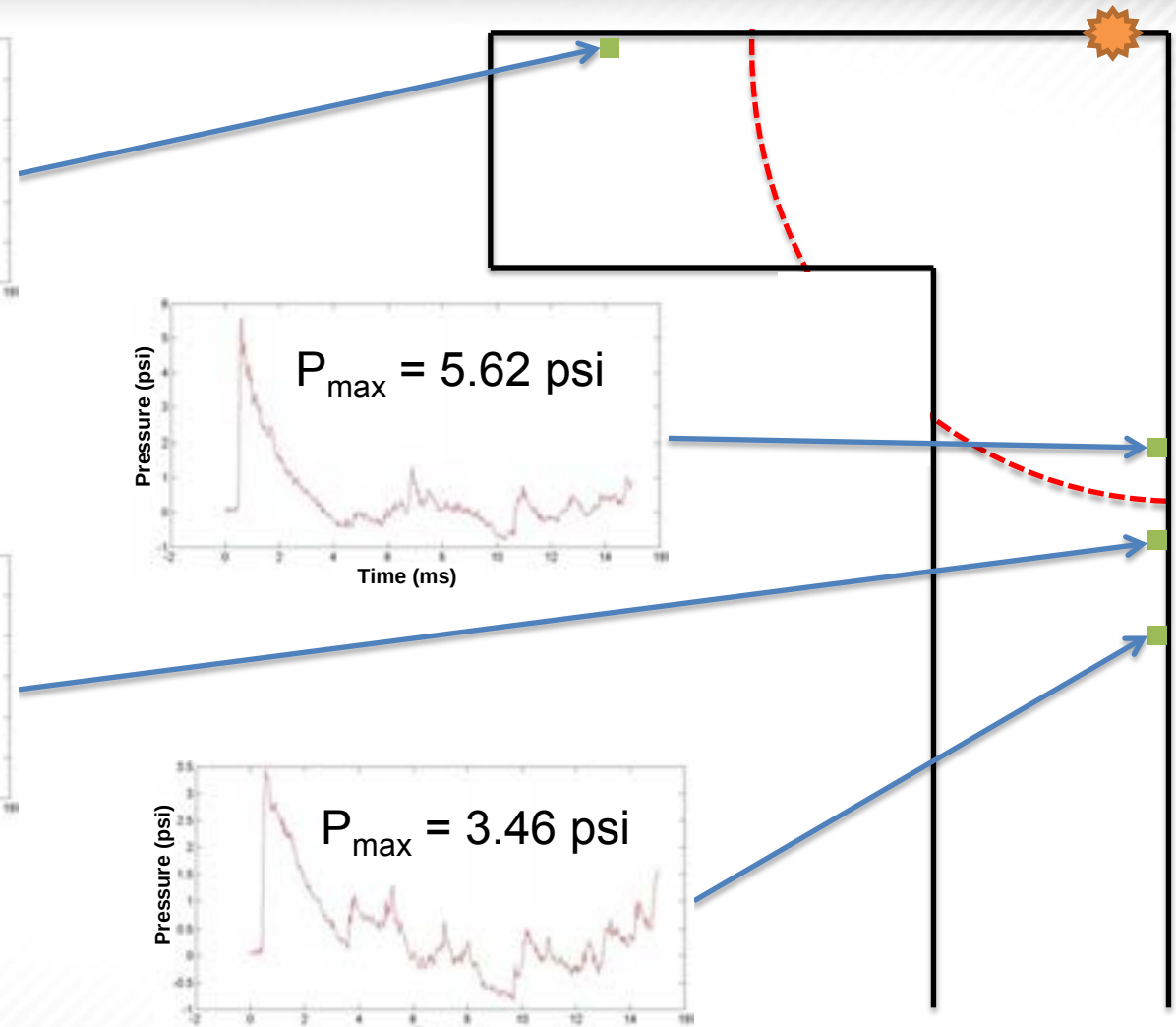
EXAMPLE TRIAL 1 – PRESSURE TRACES (PSI)









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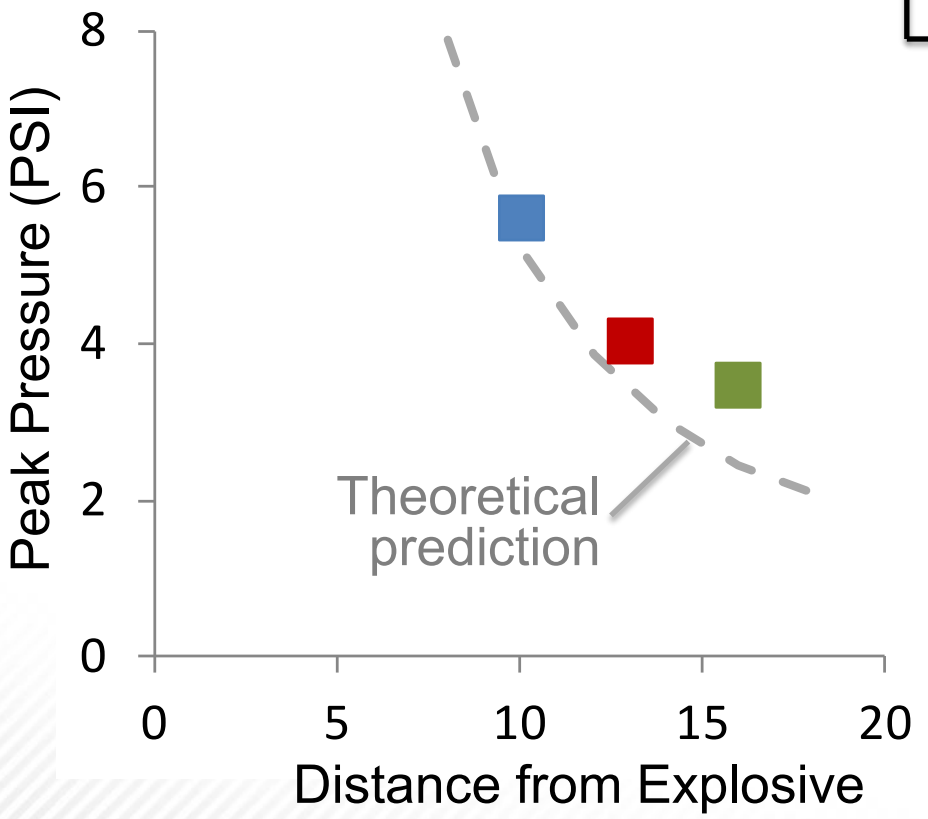
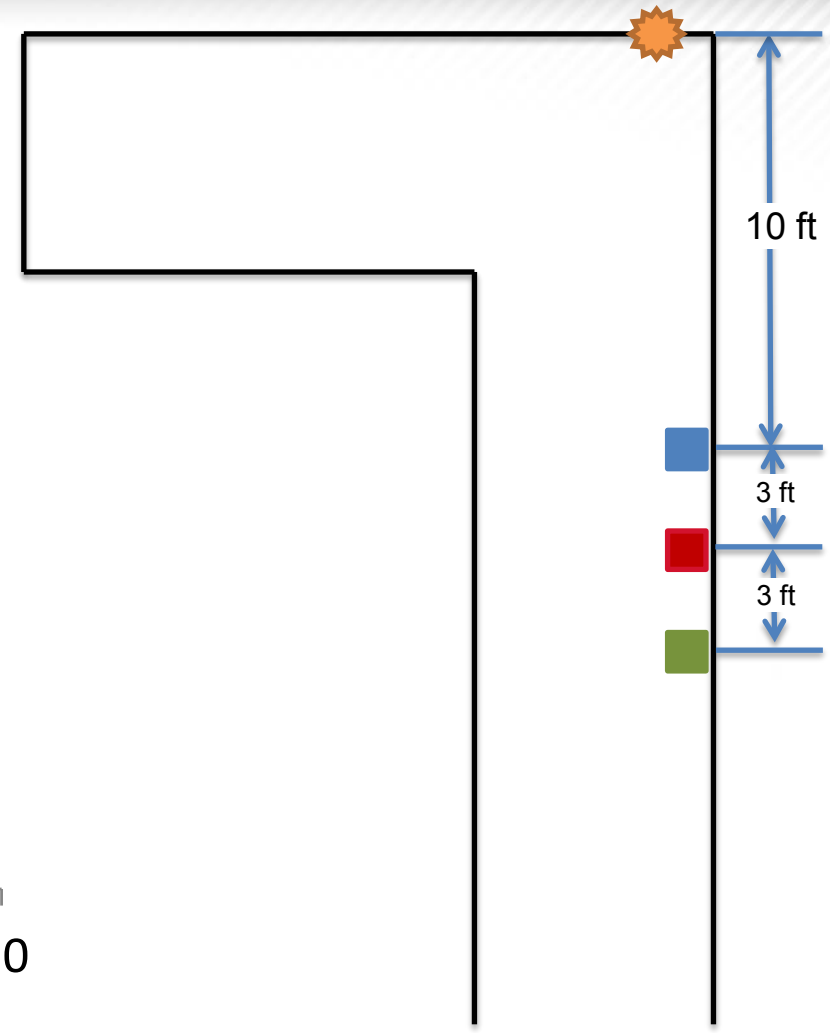
EXAMPLE TRIAL 1 – OBSERVATIONS





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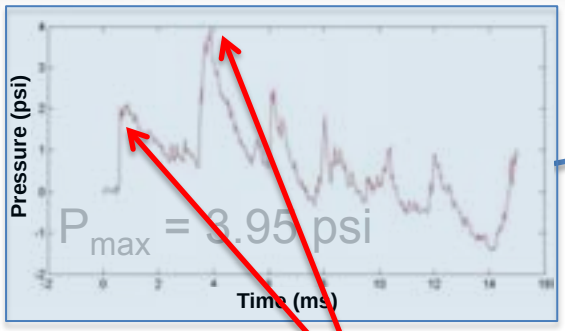
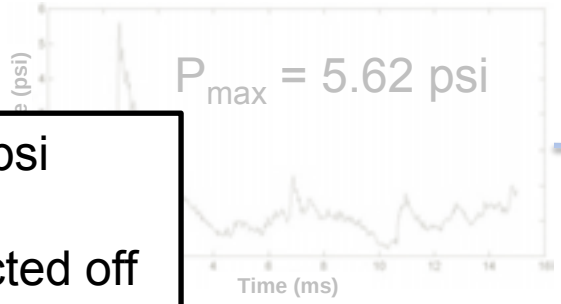
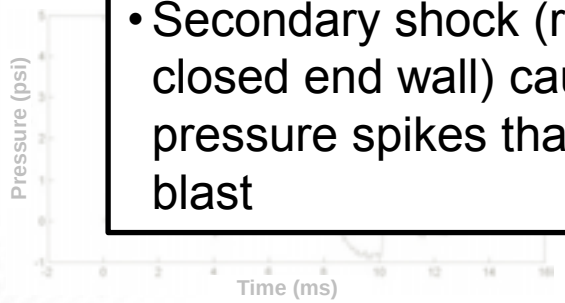
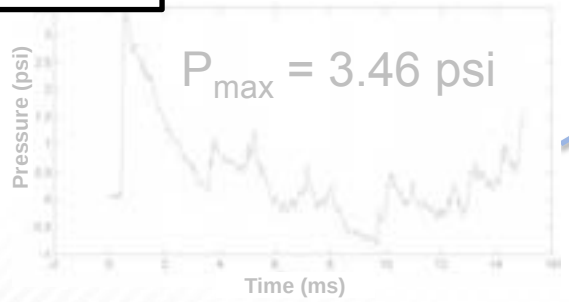
EXAMPLE TRIAL 1 – OBSERVATIONS



- Initial pressure peak <4psi since outside of MSD
- Secondary shock (reflected off closed end wall) causes higher pressure spikes than initial blast







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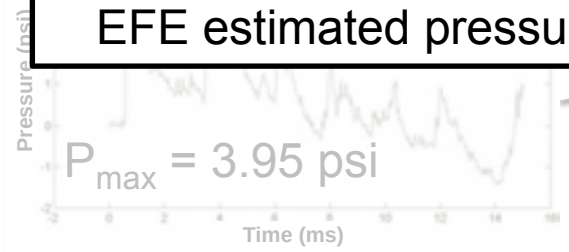
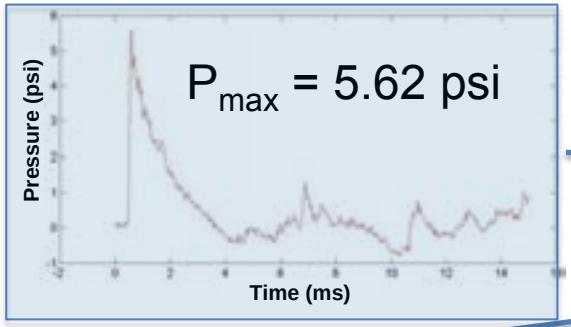
EXAMPLE TRIAL 1 – OBSERVATIONS

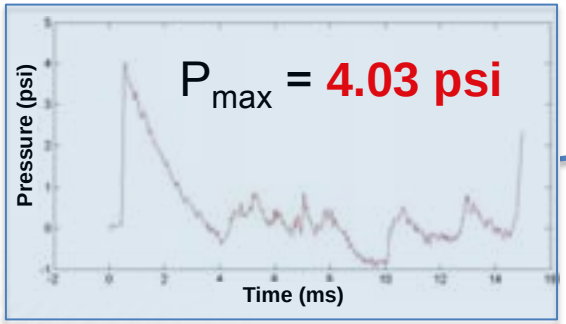
Peak pressures agree with EFE estimated pressures



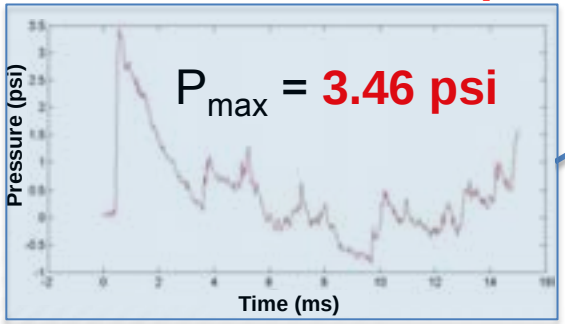
EFE Prediction: **5.24 psi**



EFE Prediction: **3.55 psi**



EFE Prediction: **2.99 psi**



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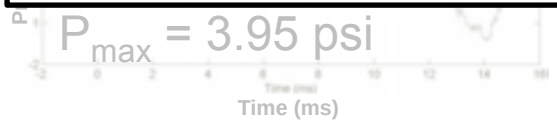
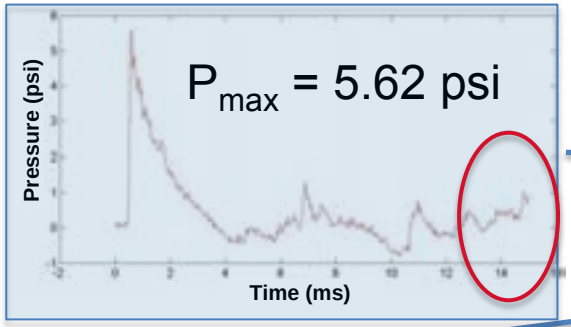
EXAMPLE TRIAL 1 – OBSERVATIONS

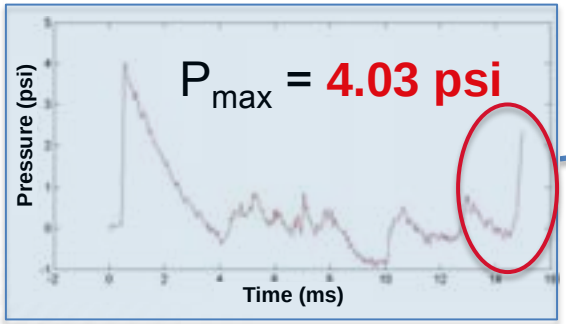
Late-stage increase in pressure due to arrival of wave complex from closed-end hallway



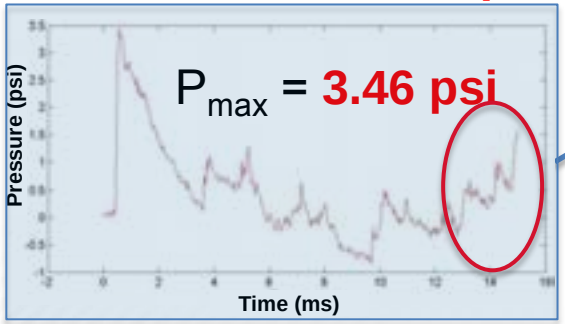
EFE Prediction: **5.24 psi**



EFE Prediction: **3.55 psi**



EFE Prediction: **2.99 psi**



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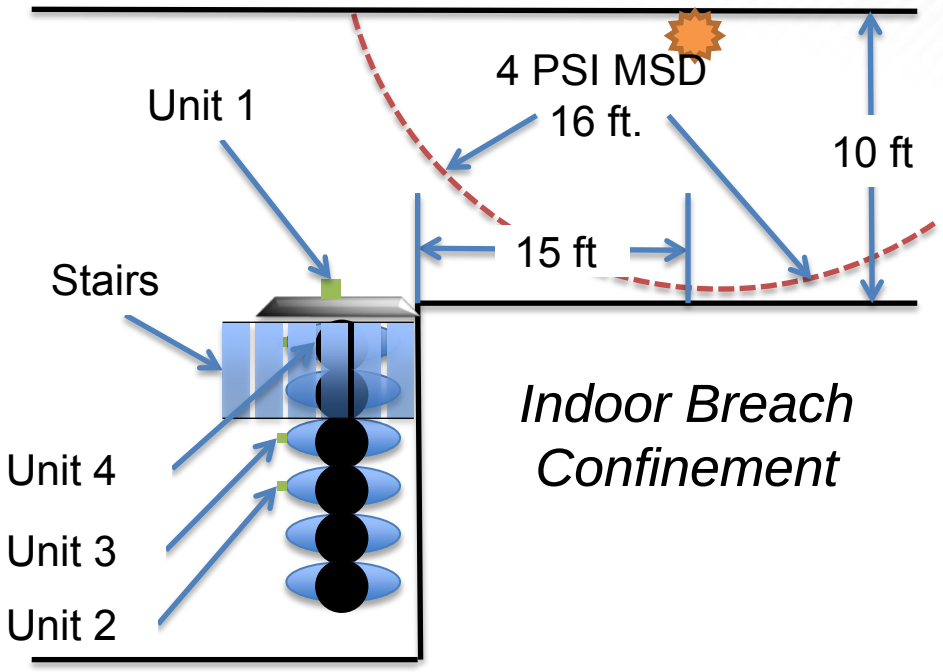
EXAMPLE TRIAL 2 – CONFIGURATION

- Wall breach using “Hydro Cut” explosive – 0.66 lbs TNT
- Six men in formation, measurements on the shield, and on the first, third and fourth breachers



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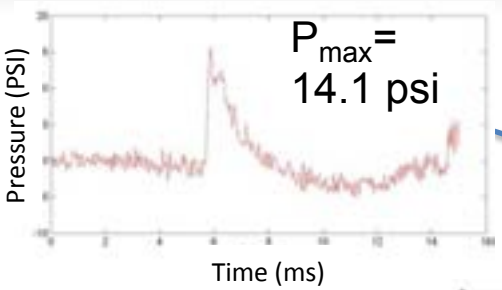
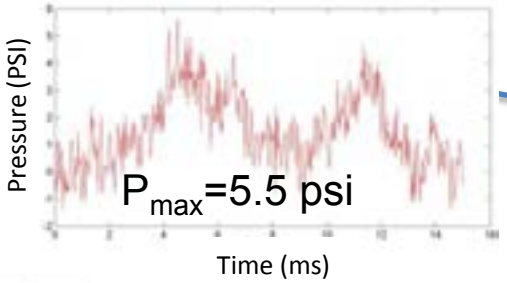
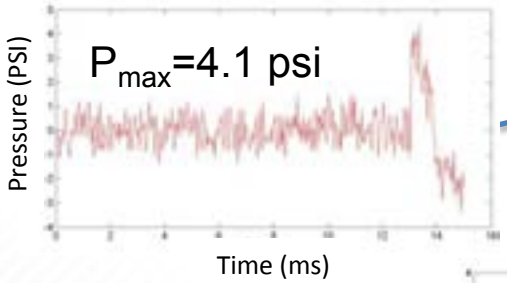
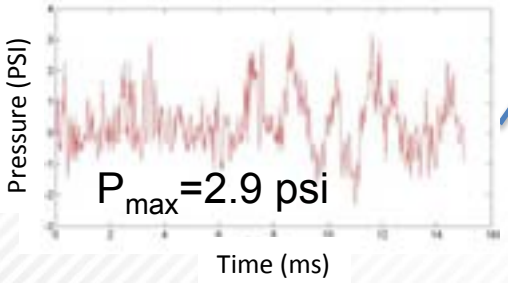
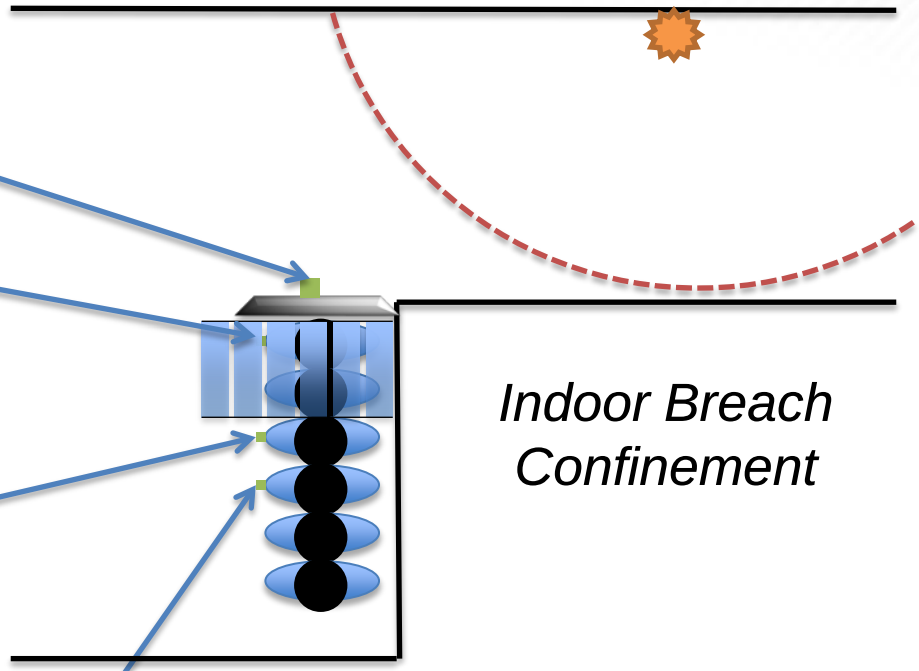
EXAMPLE TRIAL 2 – PRESSURE TRACES (PSI)











Indoor Breach Confinement

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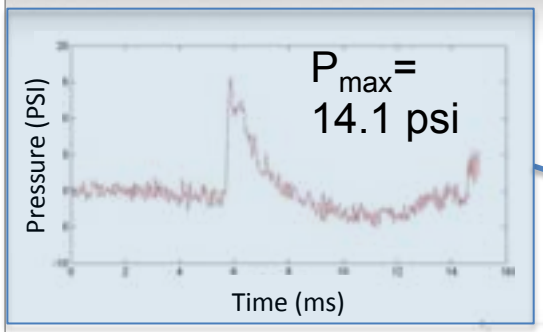
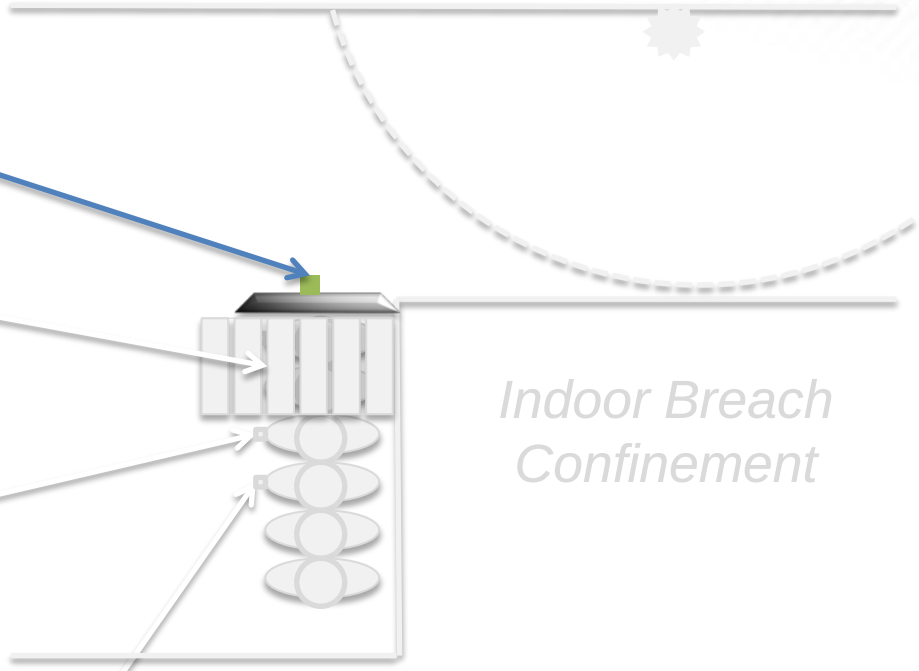
EXAMPLE TRIAL 2 – OBSERVATIONS



Highest pressure on shield (face-on) Well above 8.9 PSI



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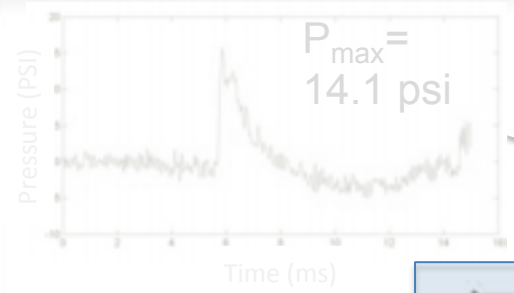
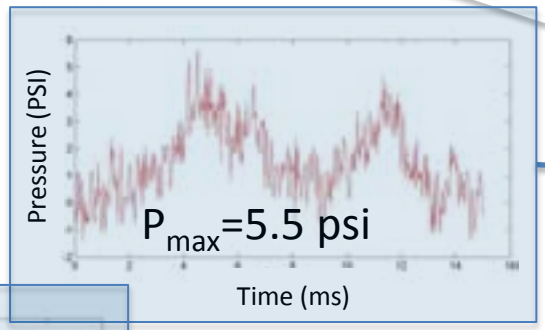
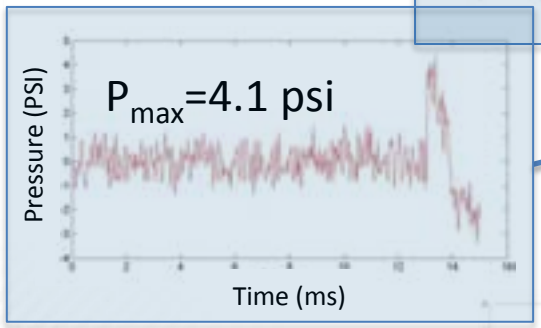
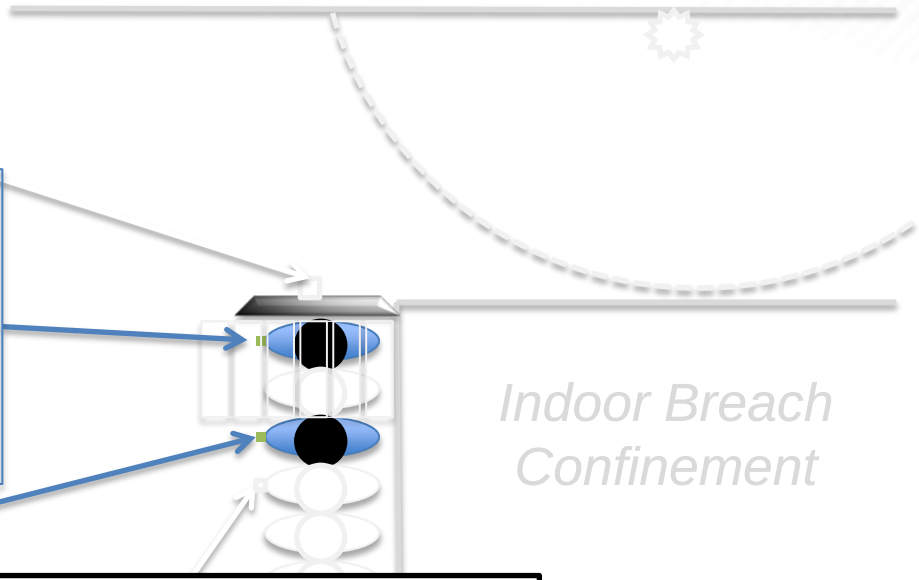
EXAMPLE TRIAL 2 – OBSERVATIONS



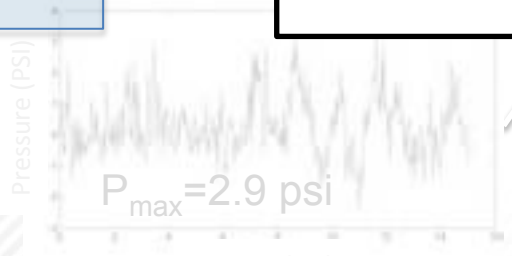






Indoor Breach Confinement

Pressure levels above 4 PSI, despite being outside of MSD and behind shield



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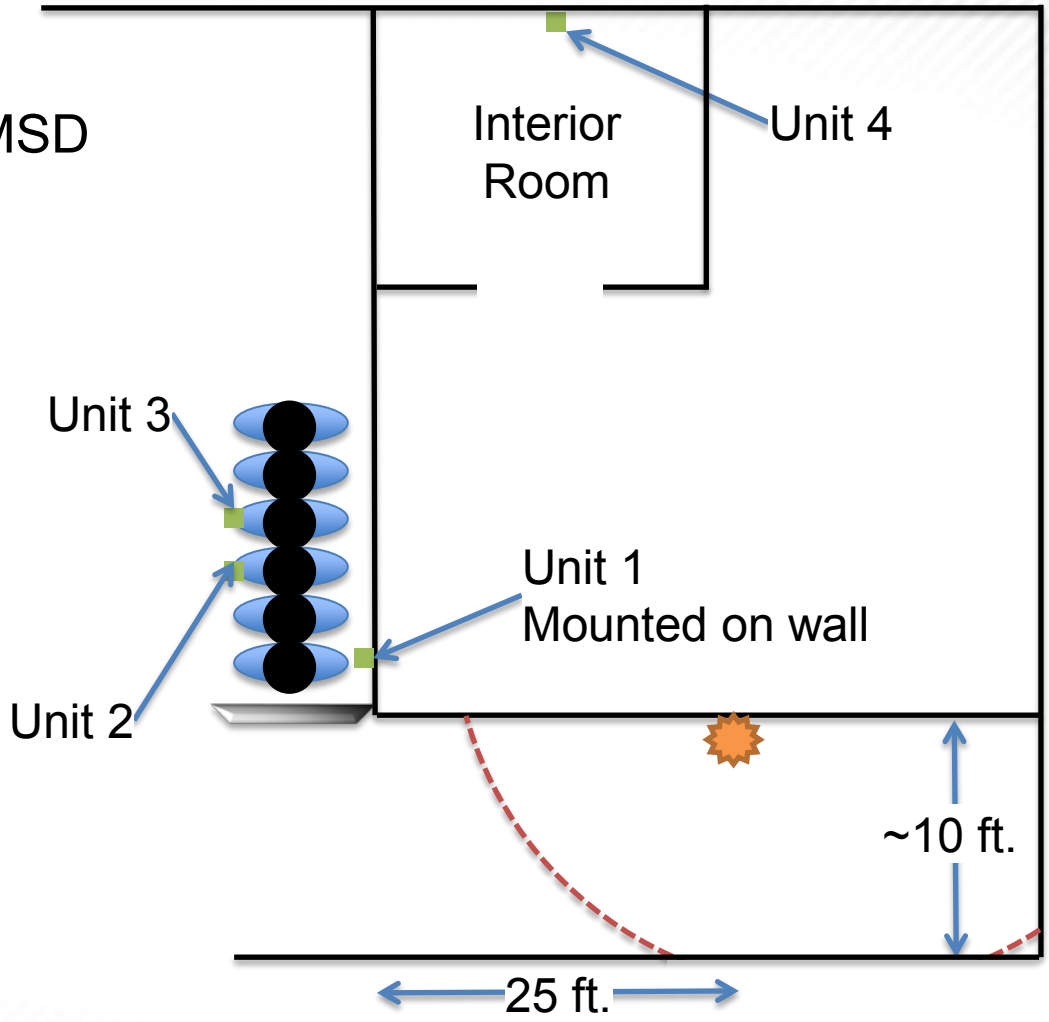
EXAMPLE TRIAL 3 – WALL BREACH

- **Explosive: Hydro Cut**
  - 0.70 lbs. TNT – 16 ft. MSD
- **Time: 11:37 AM**



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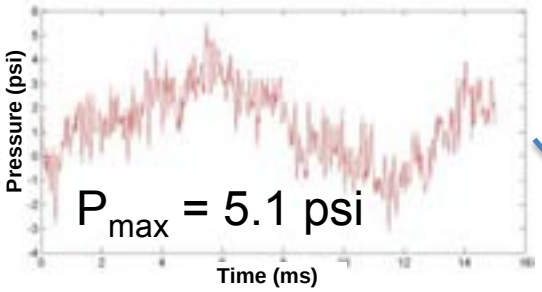
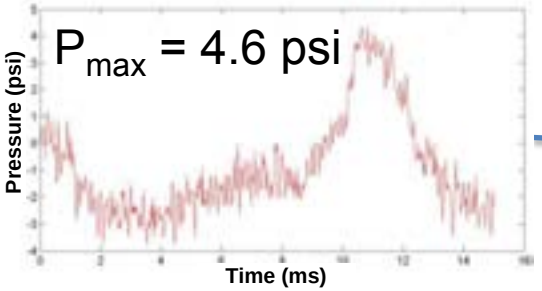
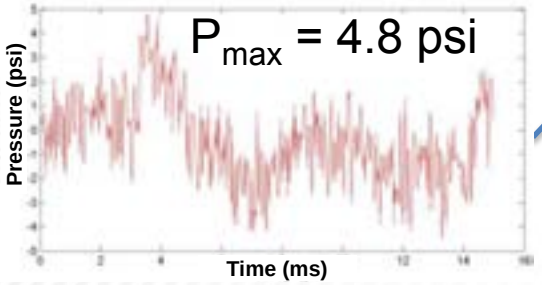
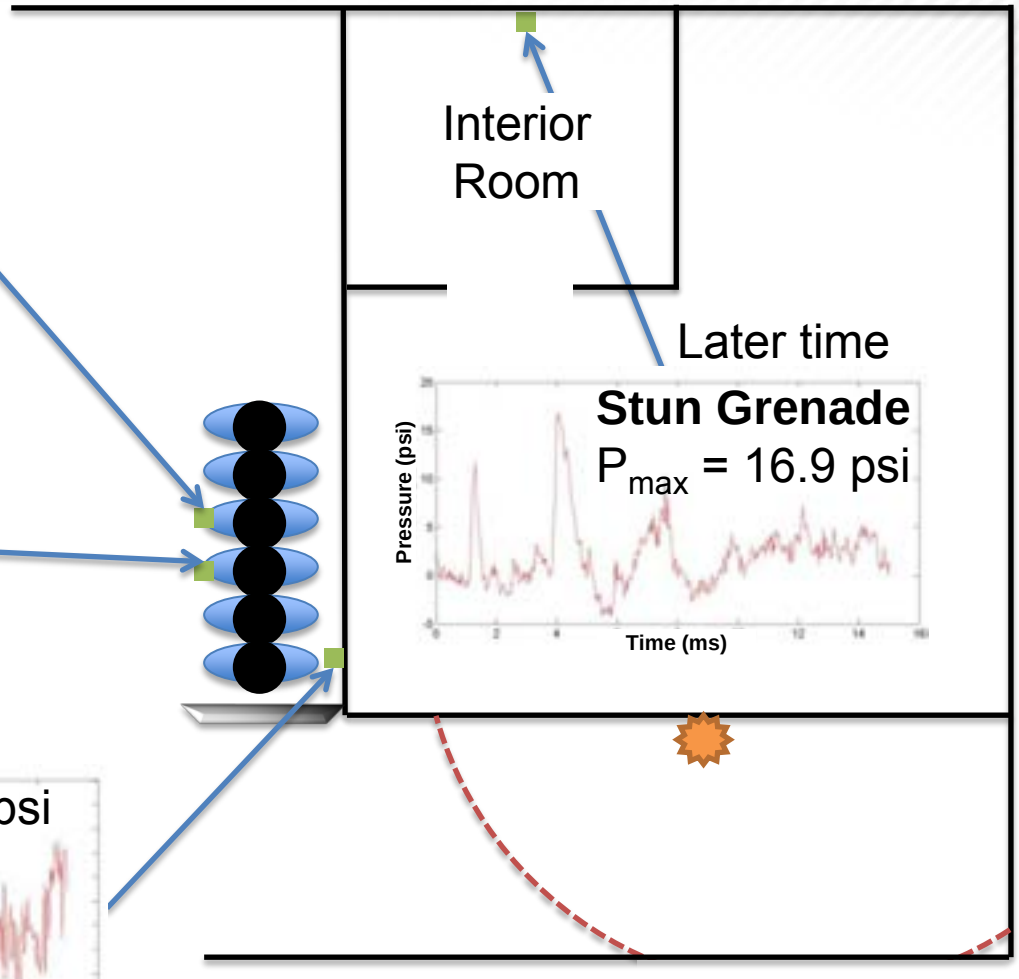
EXAMPLE TRIAL 3 – PRESSURE TRACES (PSI)









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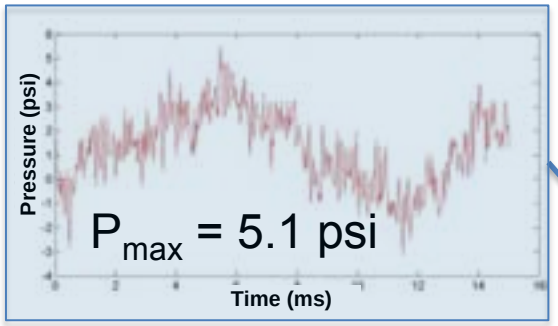
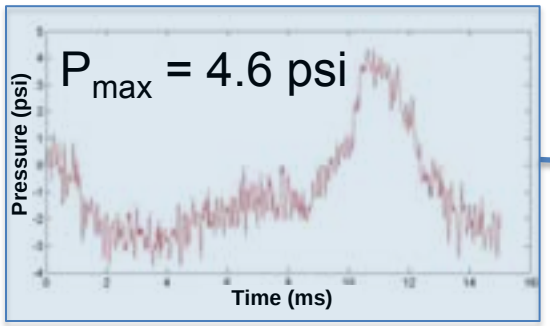
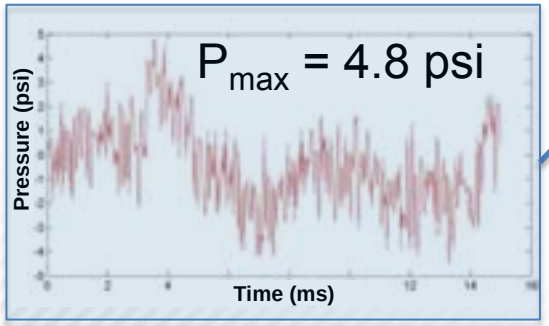
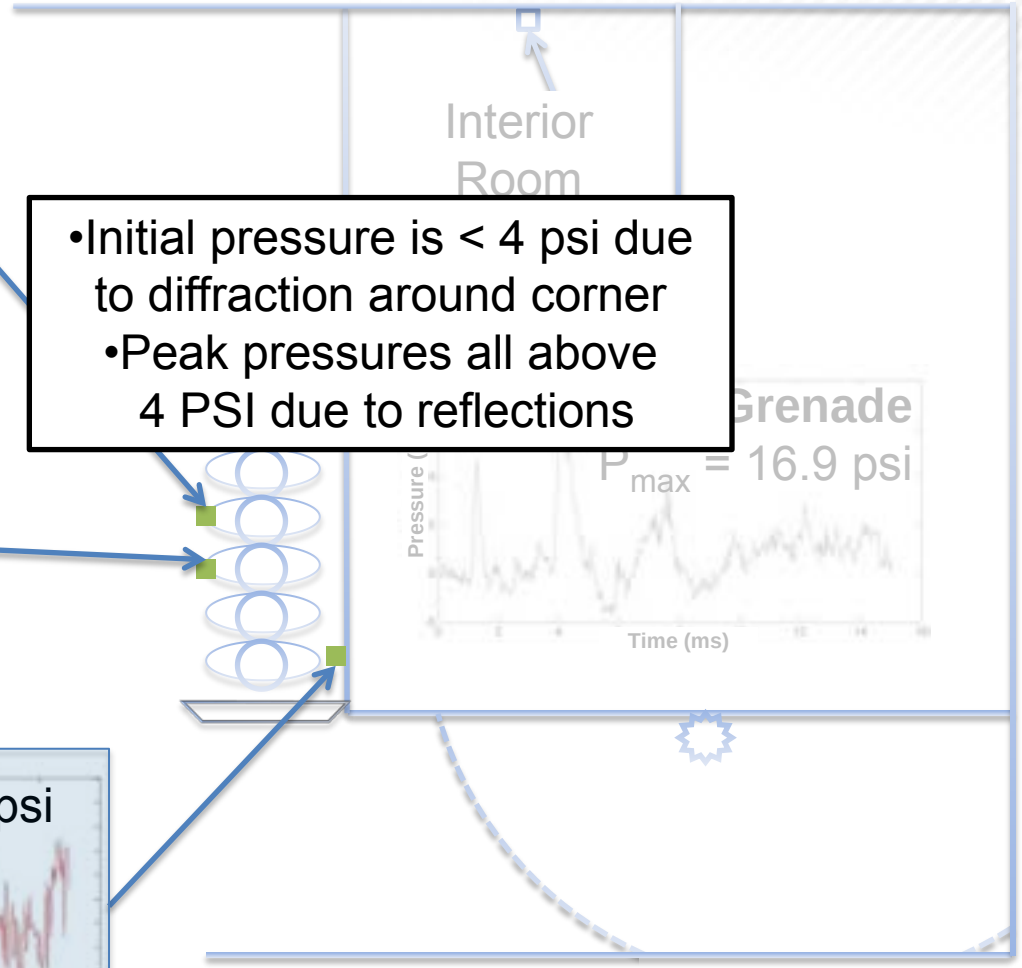
EXAMPLE TRIAL 3 – OBSERVATIONS









- Initial pressure is < 4 psi due to diffraction around corner
- Peak pressures all above 4 PSI due to reflections

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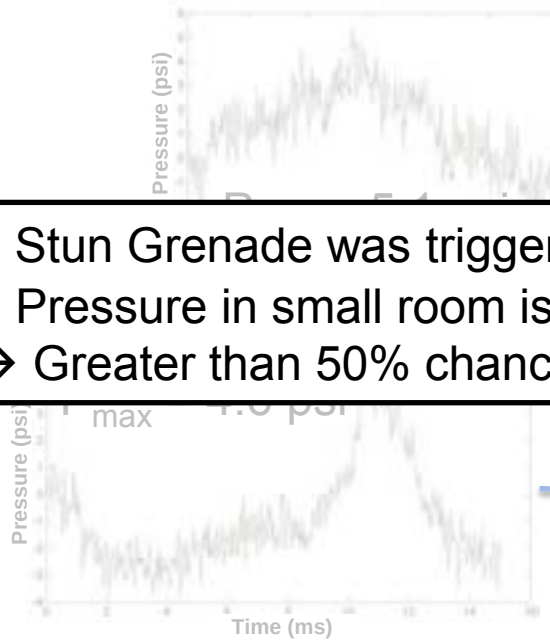
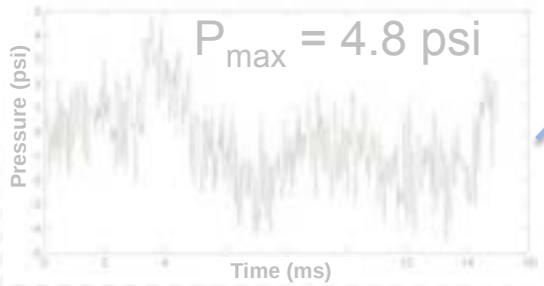
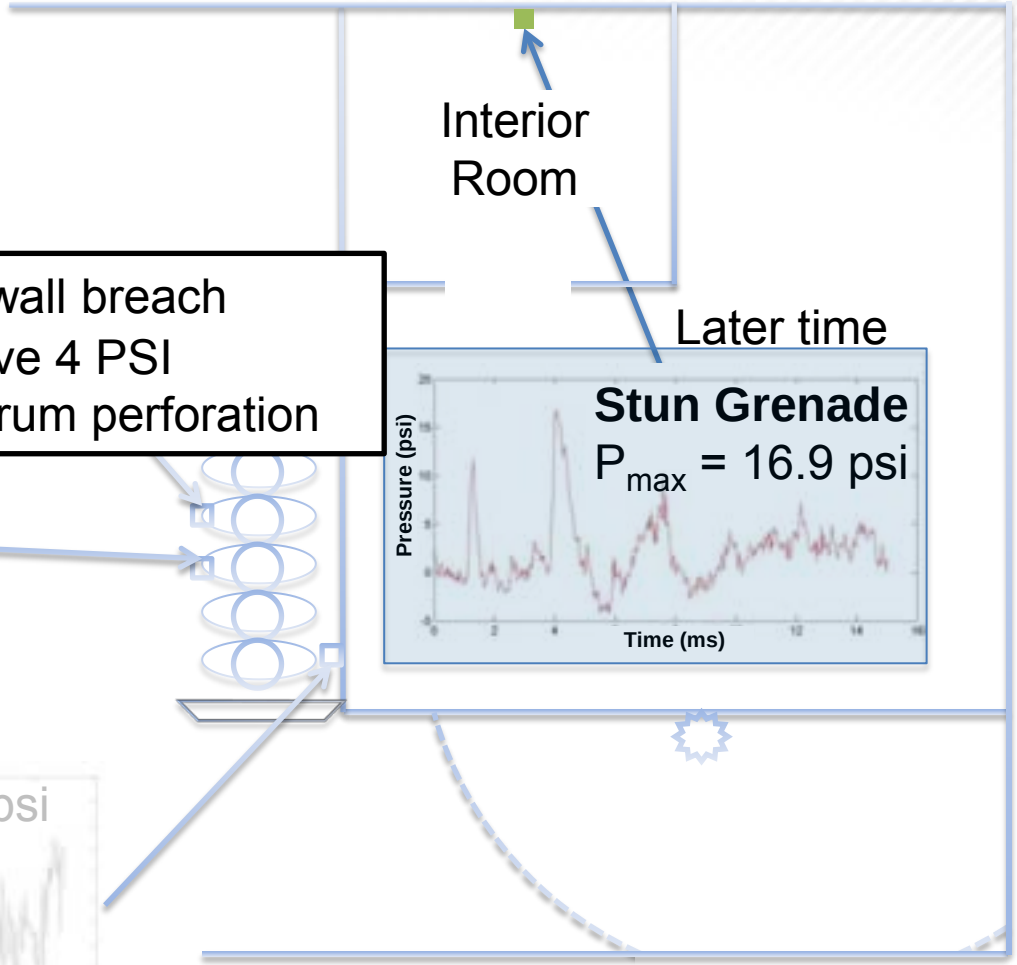
EXAMPLE TRIAL 3 – OBSERVATIONS

- Stun Grenade was triggered after wall breach
- Pressure in small room is well above 4 PSI

→ Greater than 50% chance of Eardrum perforation







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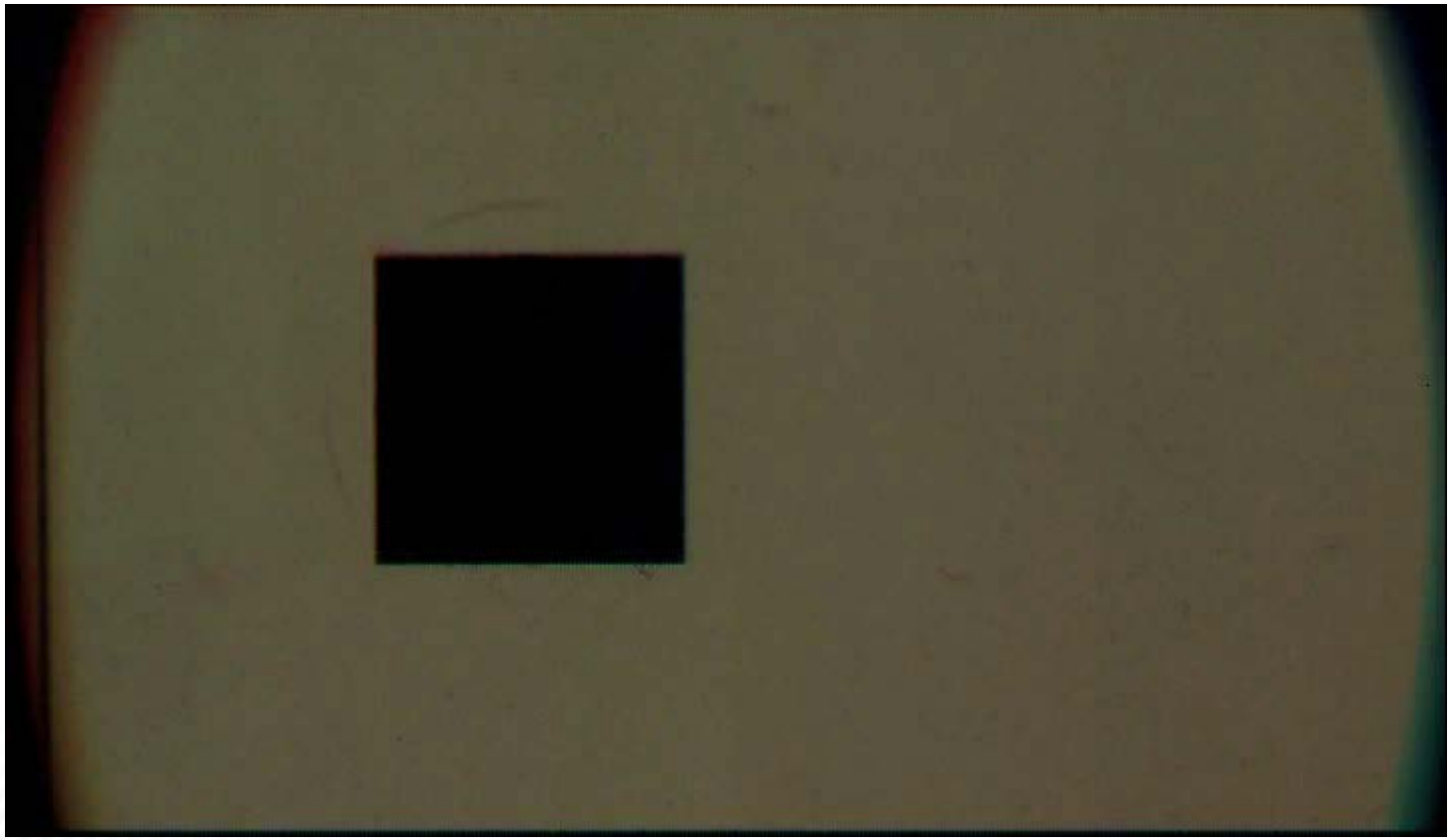
USING PHYSICAL BARRIERS FOR BLAST SHIELDING

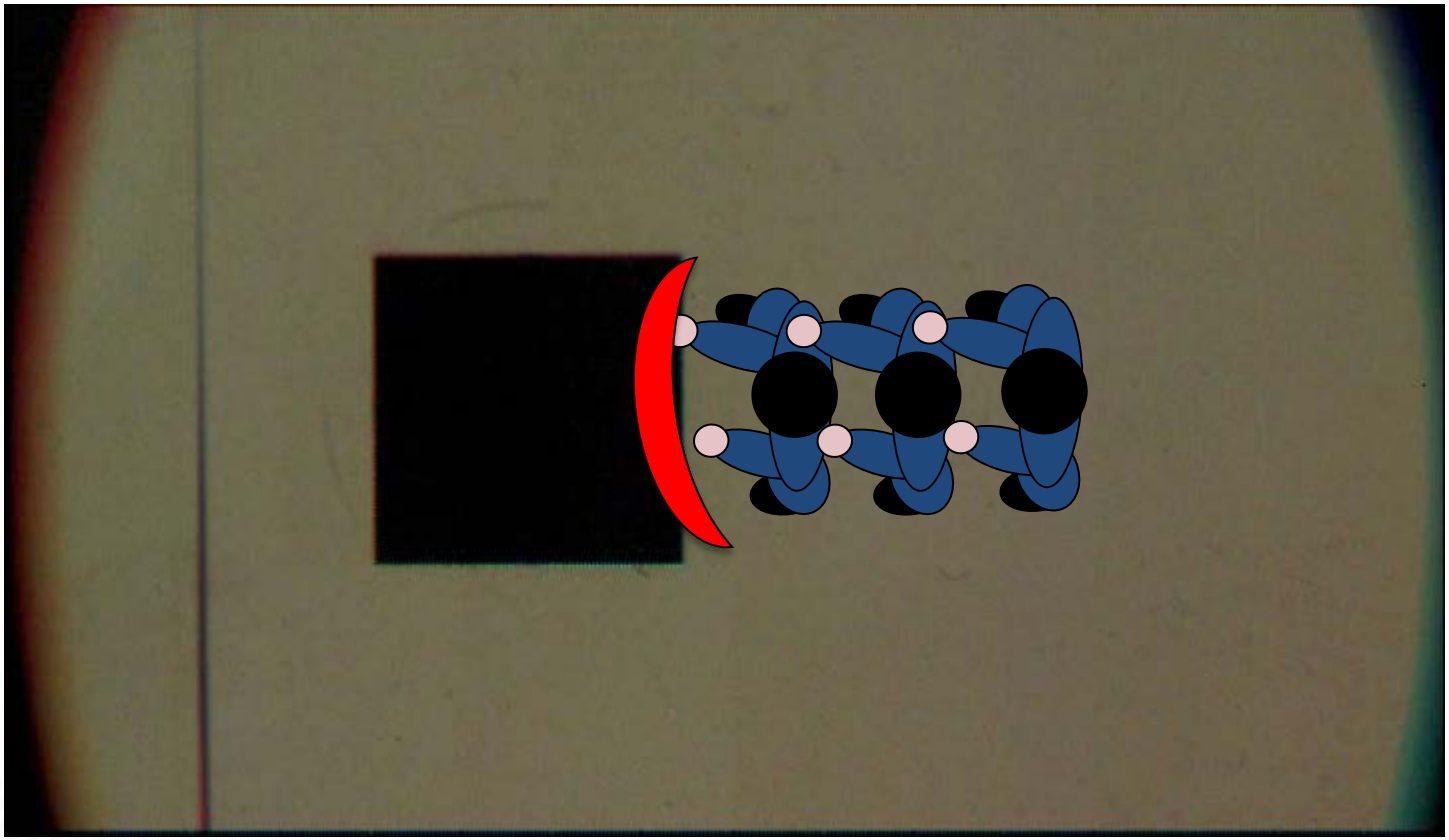
M = 2.55 shock in air passing over a square block
Color Schlieren at 330,000 frames per second



Courtesy of H. Kleine, University of New South Wales Canberra, Australia

BLAST PROTECTION REQUIRED BEHIND SHIELD

M = 2.55 shock in air passing over a square block
Color Schlieren at 330,000 frames per second



Courtesy of H. Kleine, University of New South Wales Canberra, Australia

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M = 2.55 shock in air passing over a square block
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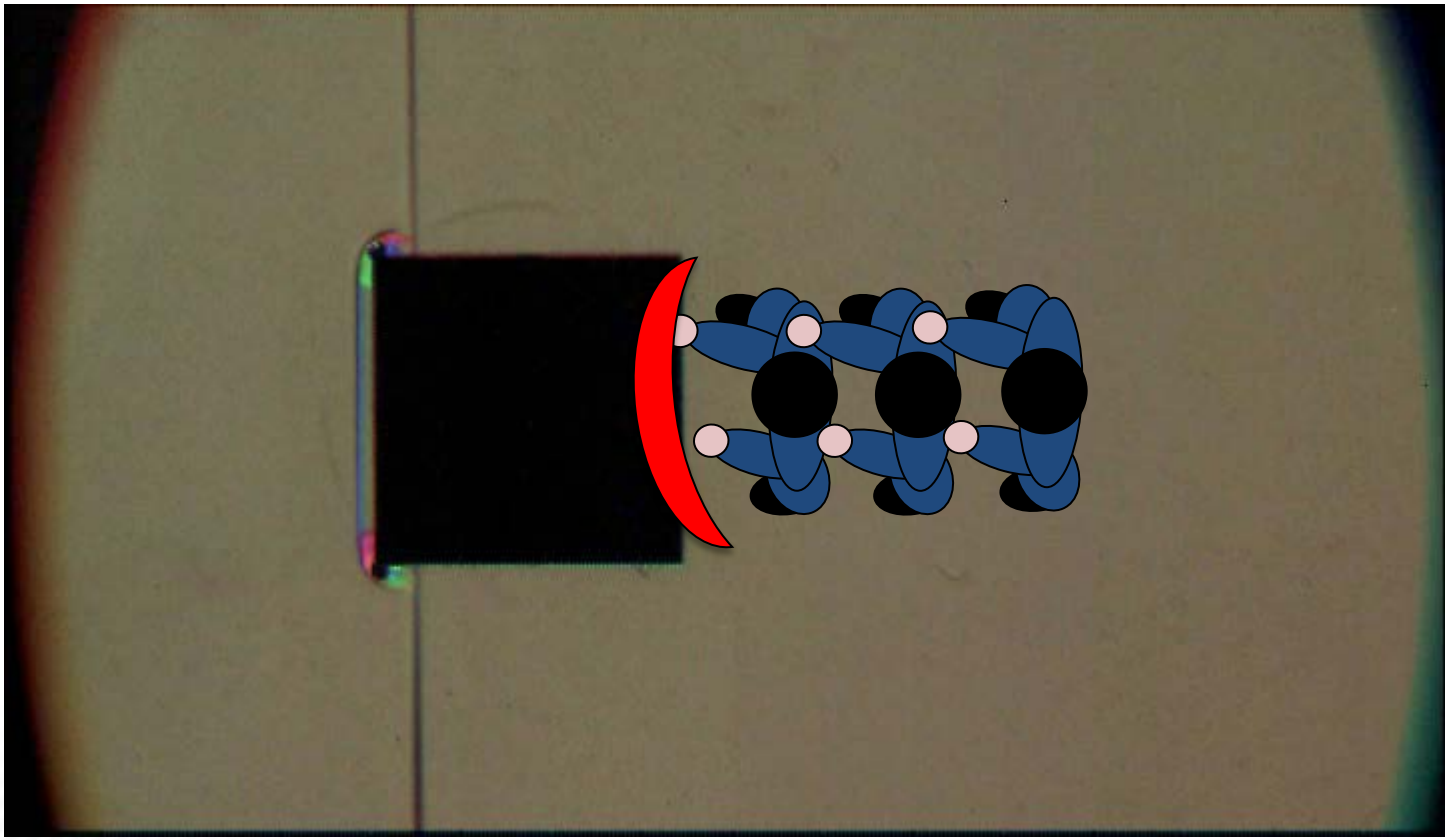

Courtesy of H. Kleine, University of New South Wales Canberra, Australia

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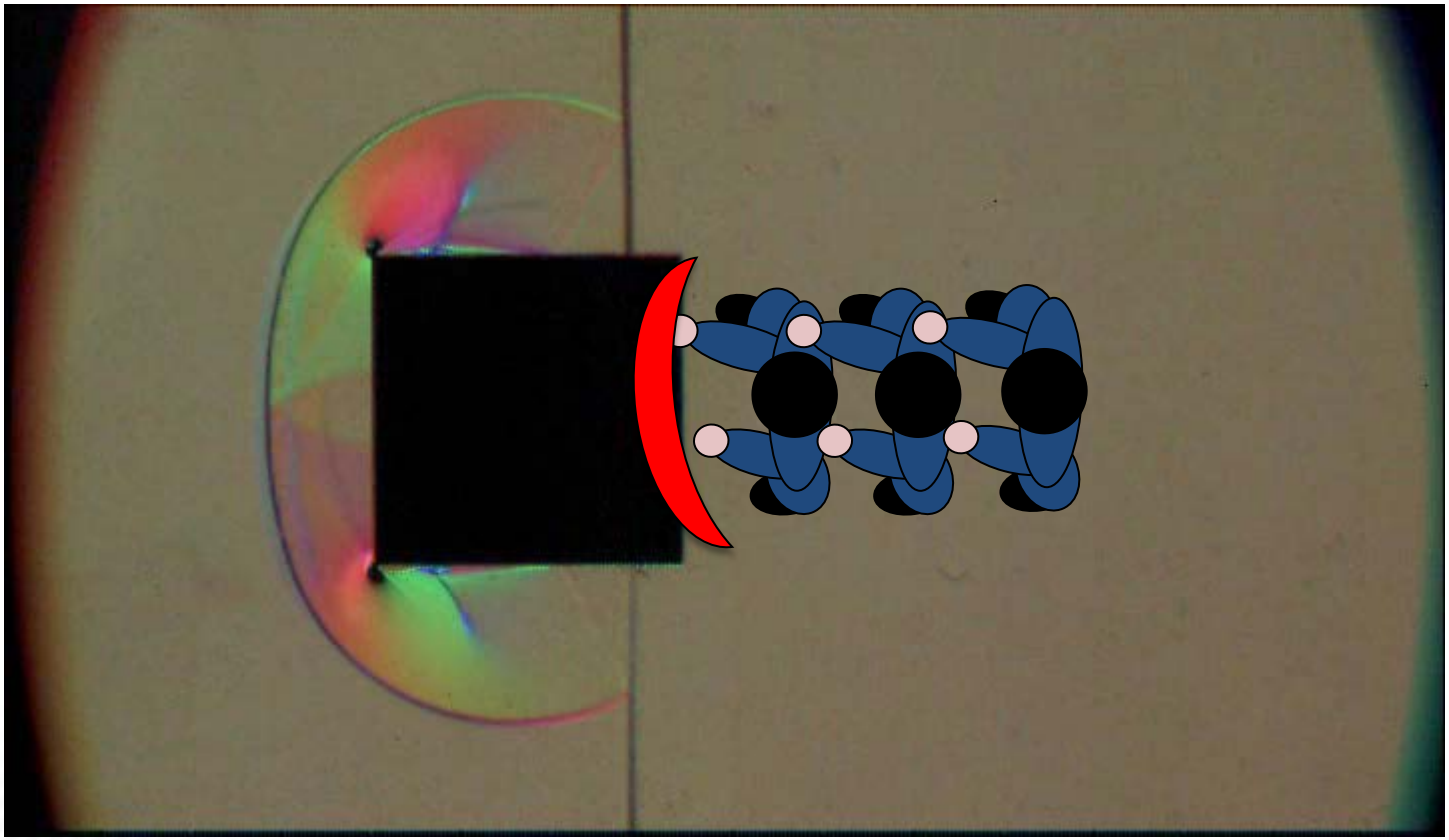

Courtesy of H. Kleine, University of New South Wales Canberra, Australia

BLAST PROTECTION REQUIRED BEHIND SHIELD

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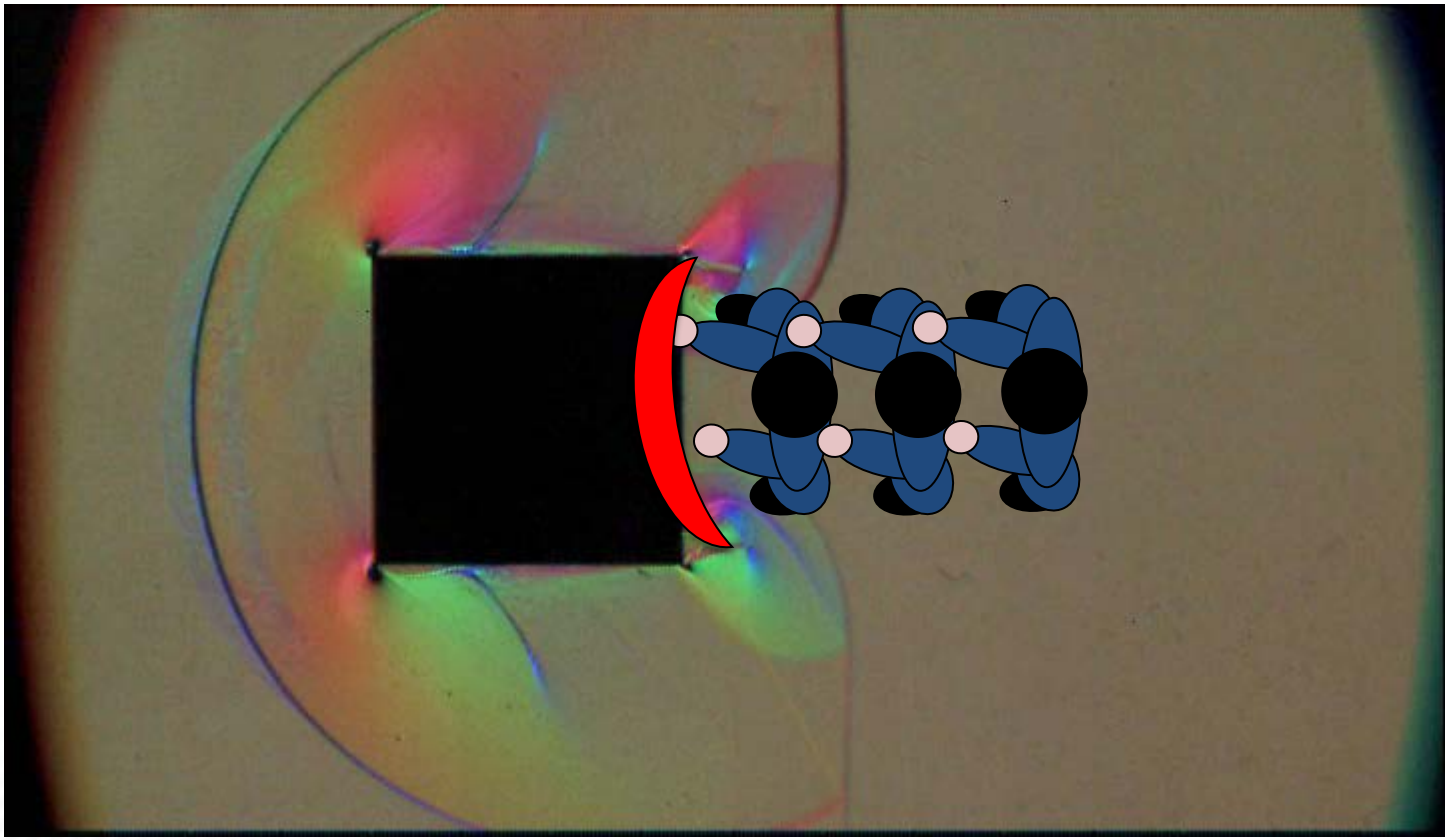

Courtesy of H. Kleine, University of New South Wales Canberra, Australia

BLAST PROTECTION REQUIRED BEHIND SHIELD

M = 2.55 shock in air passing over a square block
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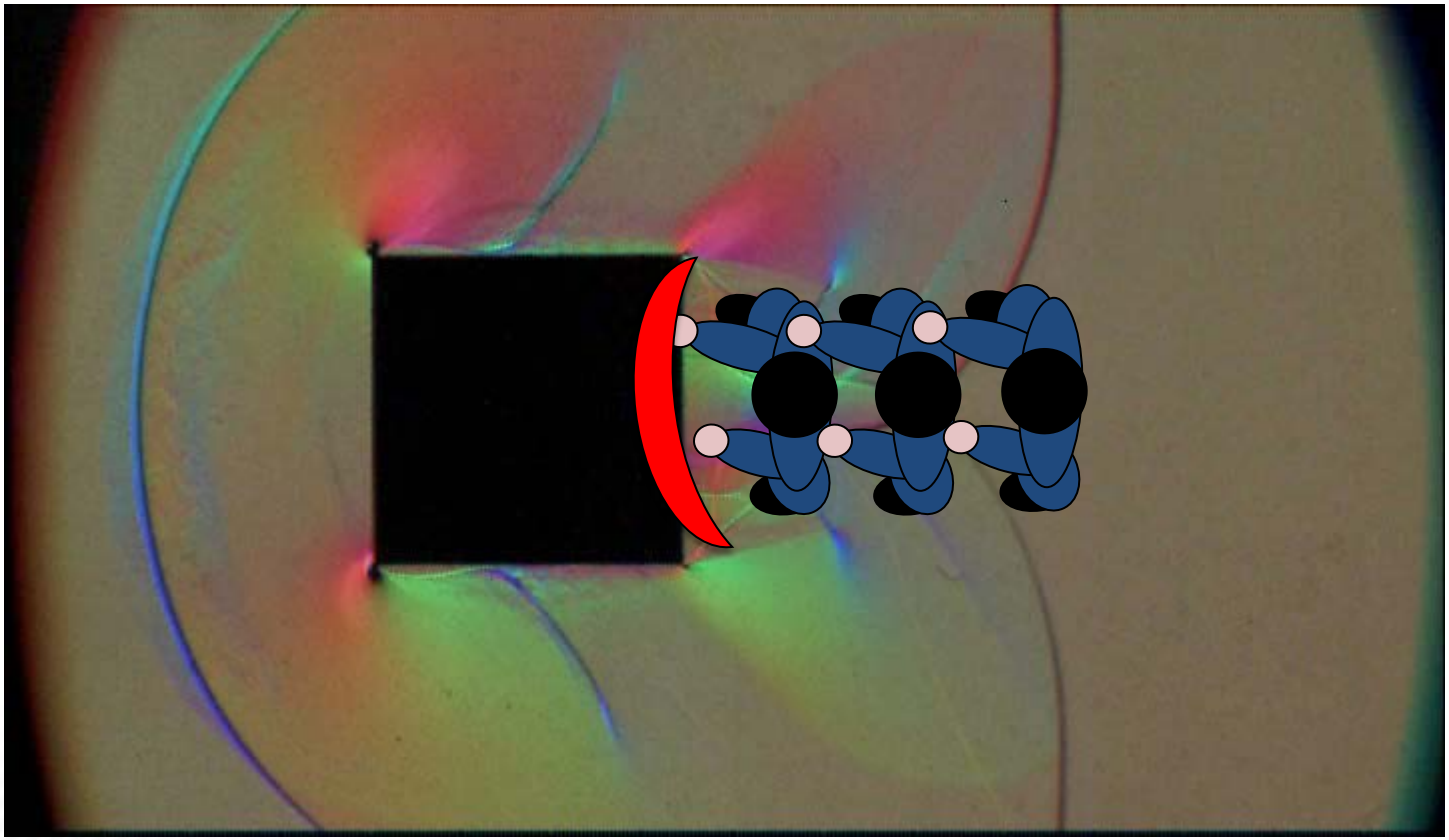
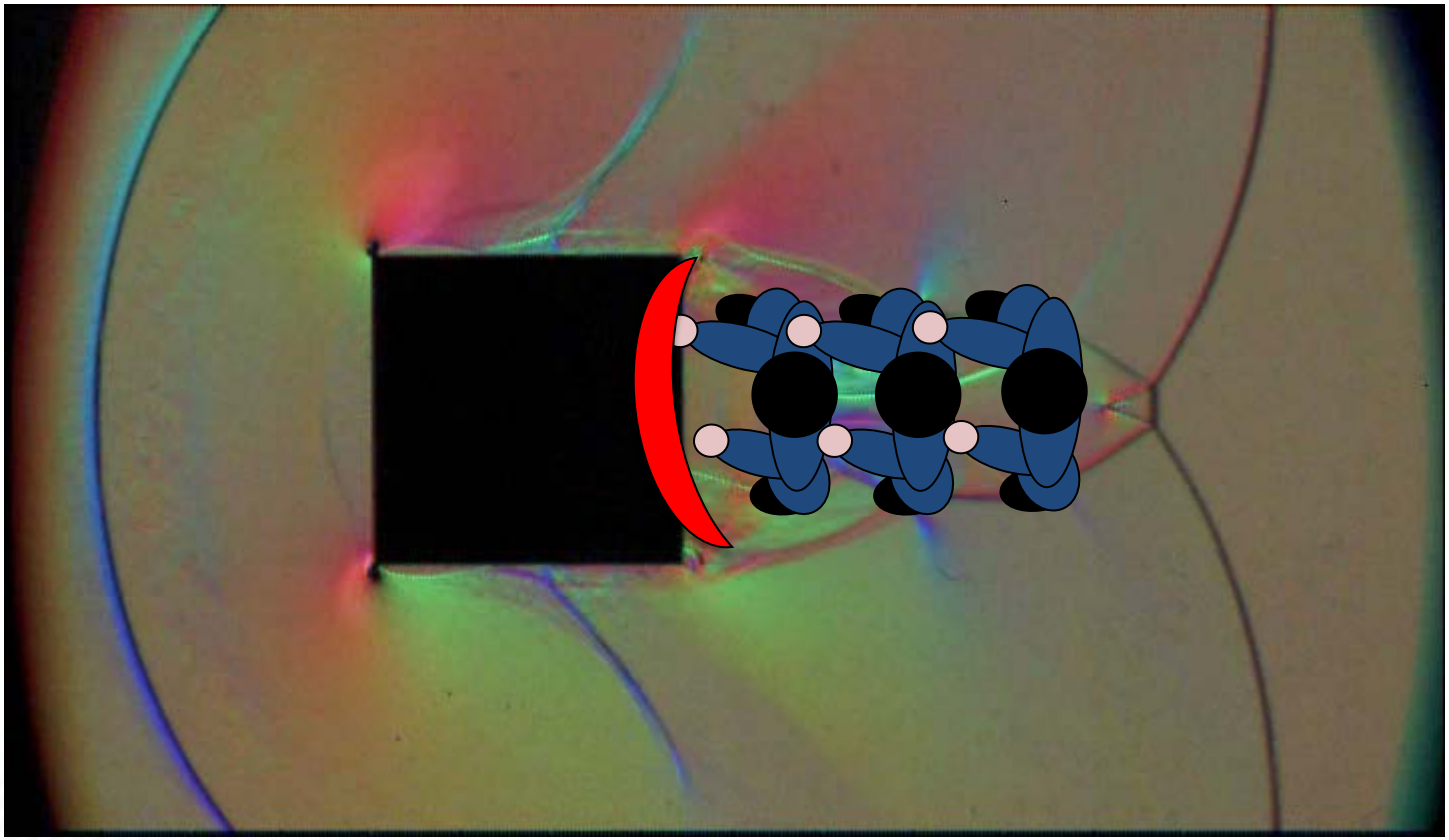


Courtesy of H. Kleine, University of New South Wales Canberra, Australia

BLAST PROTECTION REQUIRED BEHIND SHIELD

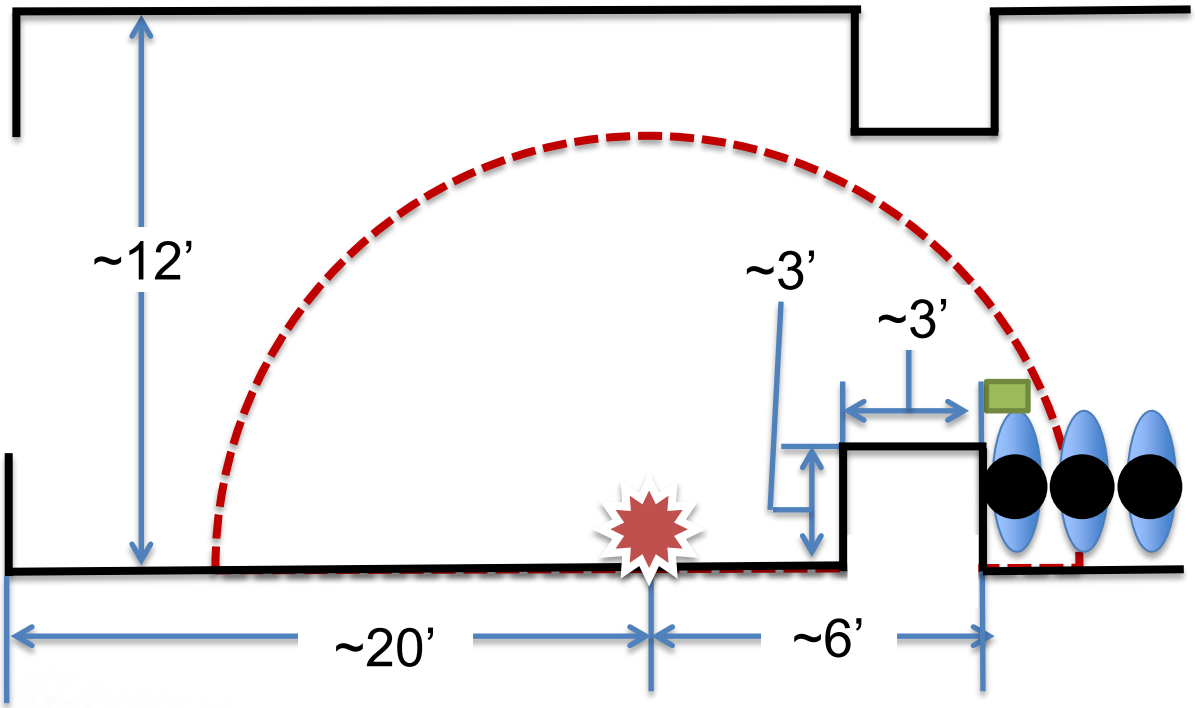
M = 2.55 shock in air passing over a square block
Color Schlieren at 330,000 frames per second



Courtesy of H. Kleine, University of New South Wales Canberra, Australia

EXAMPLE TRIAL 4 – HALLWAY WITH COLUMNS

- Explosive:
  - 7 ft. 100-gr Detcord
  - NEQ = 0.17 lbs. TNT
- 4 PSI MSD = 9.96 ft.
- Date & Time:
  - February 5th, 2013
- Location
  - Breacher Shoulder



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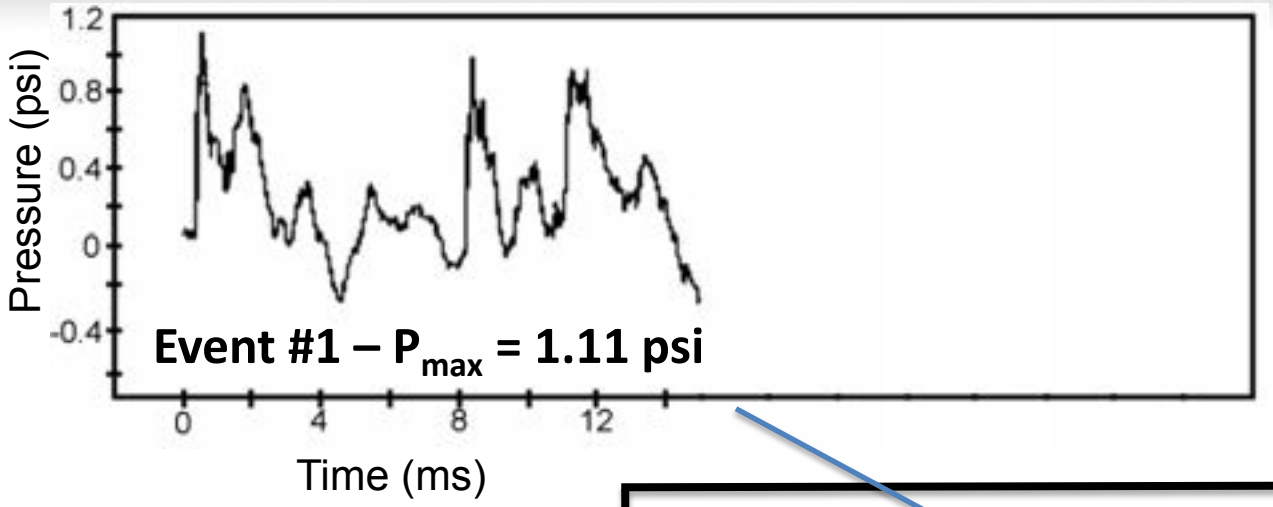
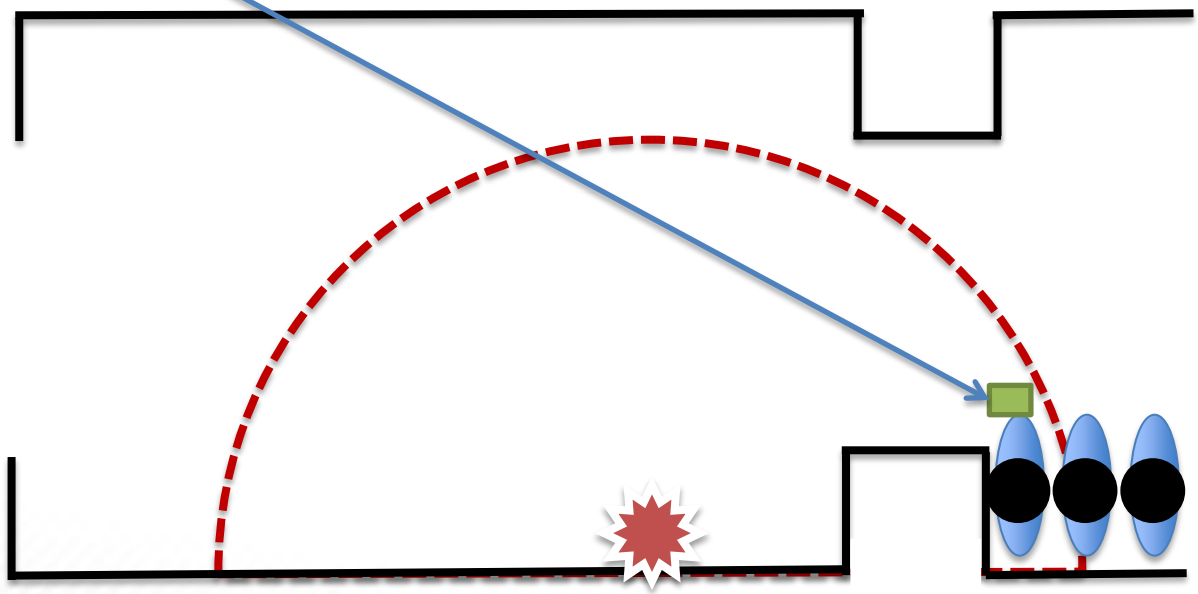
EXAMPLE TRIAL 4 – PRESSURE TRACES (PSI)





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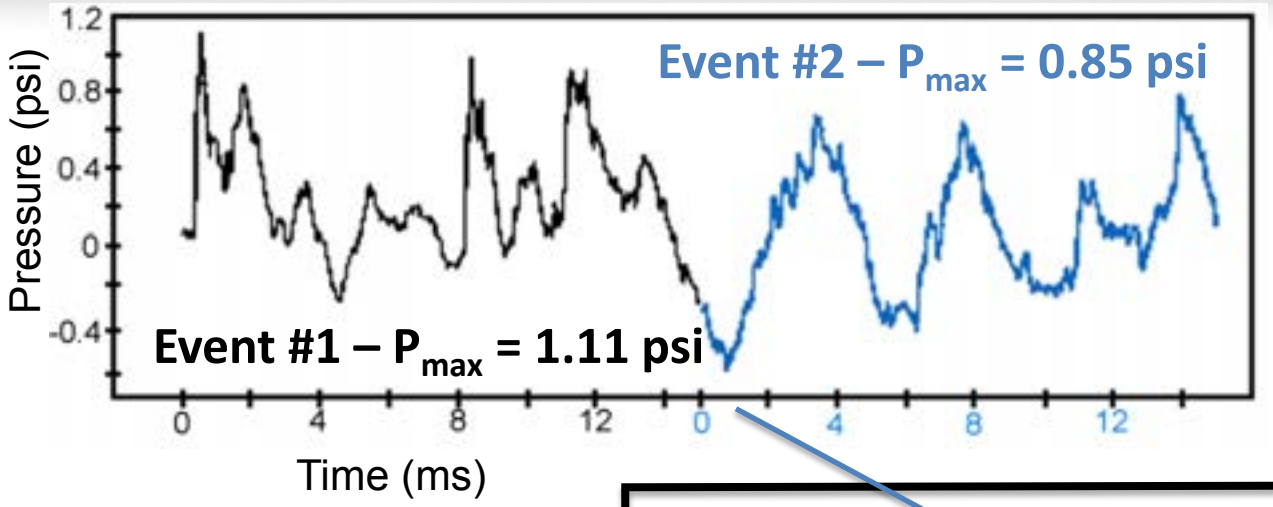
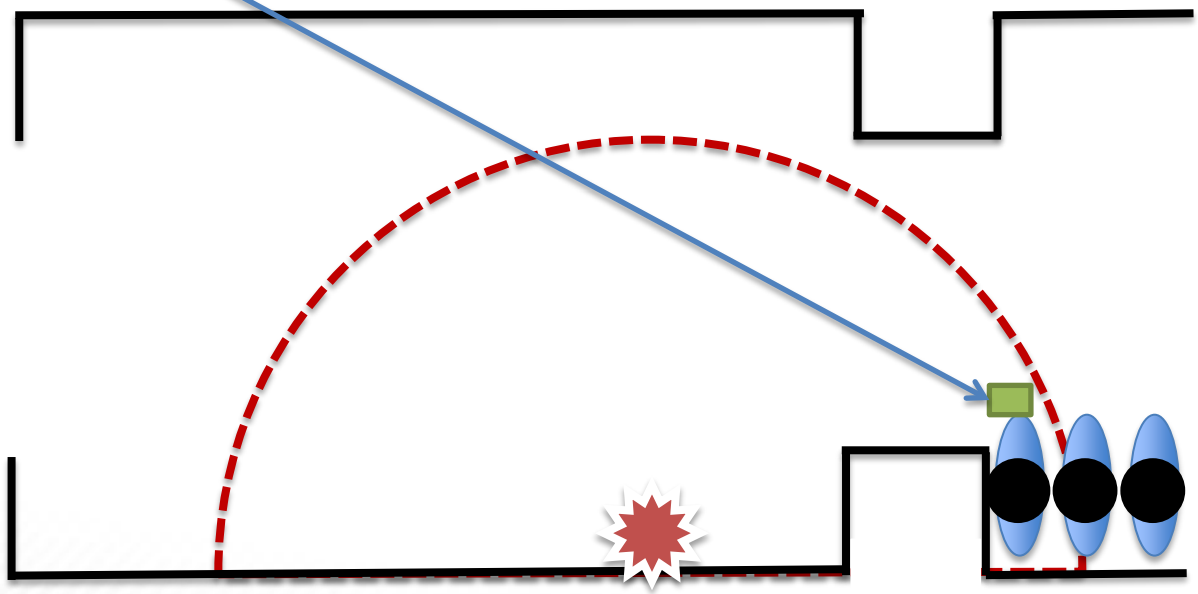
EXAMPLE TRIAL 4 – PRESSURE TRACES (PSI)





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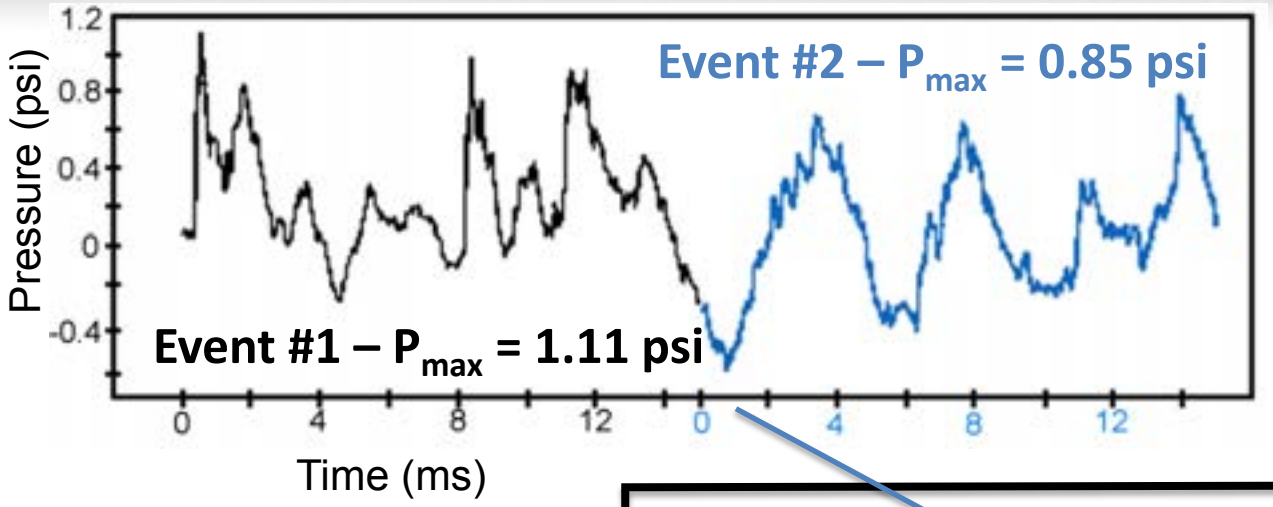
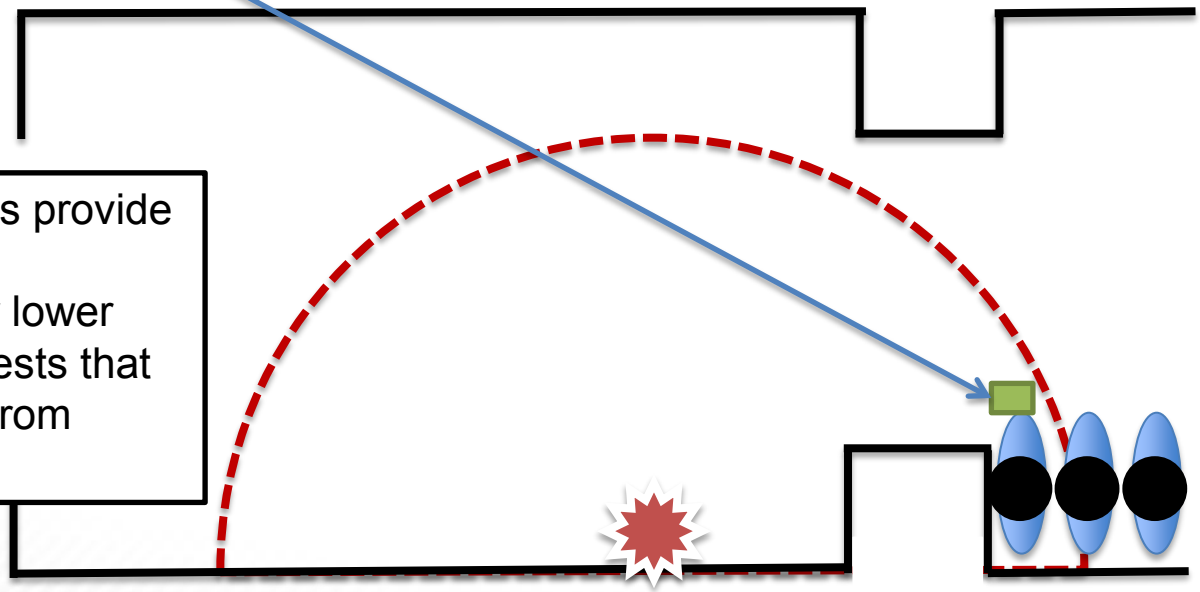
EXAMPLE TRIAL 4 – PRESSURE TRACES (PSI)



- Multiple low level reflections provide extended blast dose
- Peak pressure significantly lower than EFE Worksheet suggests that column protects breacher from direct blast



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DEBRIS – PROTECTION REQUIRED IF CONFINED

Courtesy of Dallas PD, May 7-10 2012
International Breacher's Symposium

BLAST & EXTREMITY PROTECTION MAY BE REQUIRED

Courtesy of Garland PD

- In view of threats from blast, debris, bullets, impact, need mobile PPE that provides :
  - Protection against all threats
  - Extremity Protection (Frag)
  - Permits mission mobility

TAC 6

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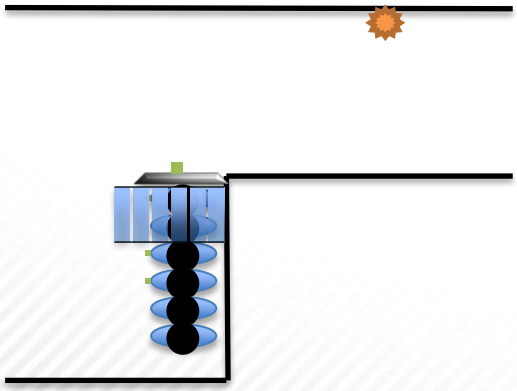
SUMMARY REMARKS



Theoretical (rule of thumb) calculations (4psi) have limited applicability

- Useful for less confined areas, simple geometries – in line with blast direction
- Limited for confined areas & reflections
- Secondary peaks, reflections, corners can exceed incident pressures

Actual pressure measurements from personal blast dosimeter more useful for:

- Training
- Actual operations
- Internal complex geometries
- Optimized CONOPs
- Personal blast exposure log
- Blast forensics

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