



Repeated Blast Exposure of Mortar and Artillery Operators

WRAIR Blast Research Program

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New and Continuing Research Efforts for 2016

- ESIT (Environmental sensors in training).
- STO Brain in Combat (VCS directed)
- Operator OP characterization (Acute, Chronic).
- *Immediate cognitive effects of OP (shotgun, Blast, etc).*
- Effects of high blast exposure (8-15 psi) on operator performance and safety.
- Continue evaluating the long term effects of repetitive blast exposure in operators.

PSI: Injury and Structural Damage Thresholds

Pressure		Effect on Human (1ms Pulse Duration)	Effect on Structure
psi	kPa		
0.3	2	140 dB (Noise limit for Unprotected Hearing)	
0.5	3		shattered glass plate
1	7		Stud and drywall -cracking
2	14		
3	20		
4	28		Reinforced concrete wall - cracking
5	34	Threshold for Eardrum Rupture	
6	41		Collapse of wood frame structure
7	48		
8	54		Reinforced concrete wall - Displacement
9	61		
10	68		Shattered Automotive Glass
15	102	50% chance of eardrum rupture	
20	136		Reinforced concrete wall - Destruction
30	204	Threshold for Lung Injury	
40	272		
50	340		4.5 ft. from 50 lb. bare explosive
100	680	Slight Chance of death (Pulmonary Related)	
150	1,020	50% Chance of Death (Pulmonary Related)	
200	1,360	100% Chance of Death (Pulmonary Related)	2.5 ft. from 50 lb. Bare Explosive

Artillery





M119 Field Artillery

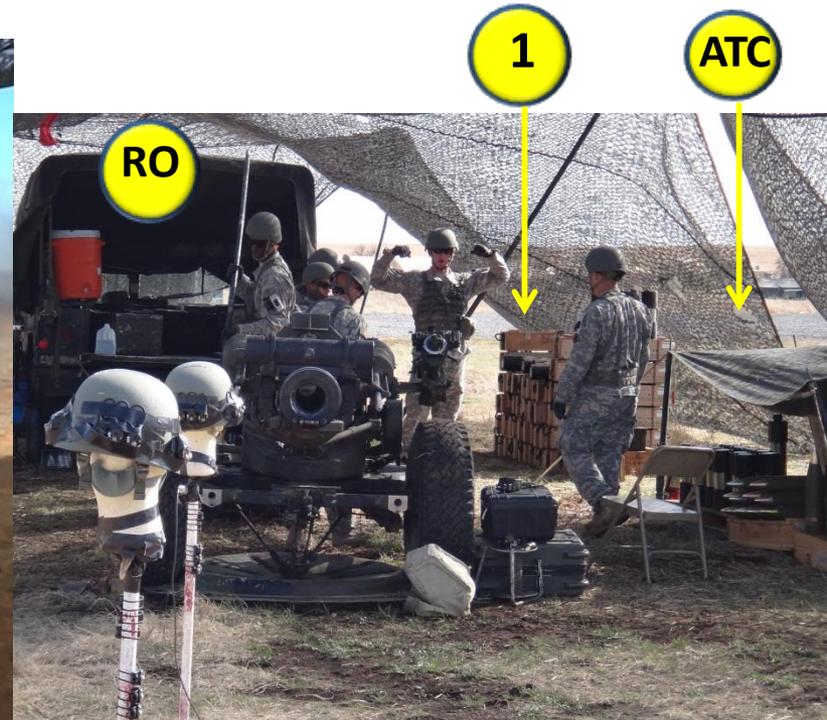
- **March/April 2014**
- **19 Crew members + 1 NCOIC instrumented with B3-HS Blast Gauges and HEADS Gen II HMSS**
- **B3-HS in DARPA configuration + additional locations**
- **PPE: Gen II HMSS, no body armor**
- **Reference pressure transducers and accelerometers used for comparison**
- **Sensors placed within a 180° field in order to study propagation dynamics**
- **Three Charges fired: 4, 5, and 7**
- **For Charge 4, two angles were used: low and high**

Charge	Total # of Rounds
4 <i>Low Angle</i>	145
4 <i>High Angle</i>	55
5	145
7	10



345 rounds in 1 week
(charge 7 was a special request)

M119 Crew Positions, Ft Sill, OK



Crew Member	Abbreviation	Primary Roles
Chief of Section	CS	Overall safety and training; 2 nd check on sight
Gunner	G	Primary assistant to the CS, lay howitzer, set data on sight, adjust for displacement
Ammunitions Team Chief	ATC	Maintaining accountability of ammunitions. Prepare and fuze ammo.
Assistant Gunner	AG	Opens/closes breech, removes shell casing
#1 Man	1	Prepare and fuze ammo, assemble powder charge, loads powder, prepares ammo.
Cannoneer #2	Divided among ATC & 1	Jacks up howitzer, sets out aiming posts and collimator, carries and rams projectile with #3, assemble powder charge, loads powder, prepares ammo
Cannoneer #3	RO	Communications

Exposure by Crew Position

Charge 4, normal angle

Crew Position	Max Peak Overpressure (psi)	Mean Peak Overpressure (psi)	Max Impulse Reading (psi*ms)	Mean Impulse Reading (psi*ms)
Ammunitions Team Chief	1.89	1.31	1.7	1.2
Assistant Gunner	1.70	1.18	1.8	1.2
Gunner	1.89	1.34	2.3	1.1
Loader	1.34	1.15	1.6	1.1
Radio Telephone Operator	1.70	1.47	1.9	1.8
Chief of Section	2.03	1.29	2.4	1.5

The Chief of Section is exposed to the highest peak overpressure, 2.03 psi.

Annual Artillery Exposure

- Unit fires 300 to 400 rounds a week
- 2 to 3 M119s
- 42 Weeks a year
- Minimum 4200 exposures per year

Mortars





Mortars

- 17-19 November 2014
- 4 students, 1 instructor instrumented with B3 Blast Gauges and HEADS Gen II HMSS
- DARPA configuration + additional locations
- PPE: IOTV Generation 3
- Reference pressure transducers used for comparison
- Sensors placed within a 360° field in order to determine propagation dynamics
- 2 Mortars used: 81 mm and 120 mm (120 mm shown)
- Data Analysis currently in progress

81 mm Mortar

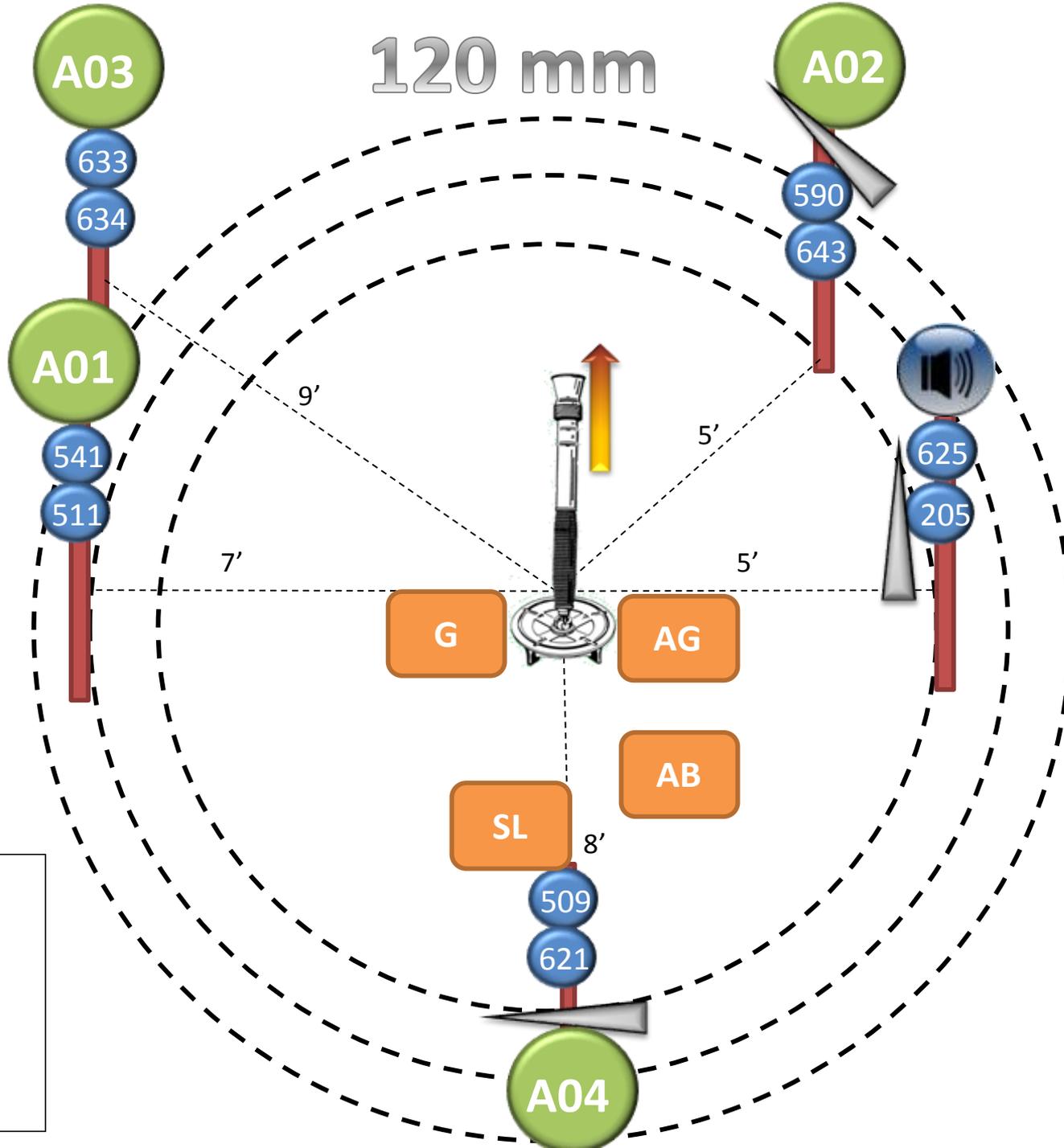
- Two Charges fired: 3 and 4
- XM931 FRTC

120 mm Mortar

- Two Charges fired: 2 and 3
- M889A2 HE



Mortar	Charge	Total # of Rounds
81 mm	3	10
	4	45
120 mm	2	12
	3	10



Gen II Helmet	
B3 Blast Gauge	
Crew member	
Pencil Probe	
Sound Meter	
Aiming Pole	

120 mm Mortar Crew Positions

Squad Leader

Gunner

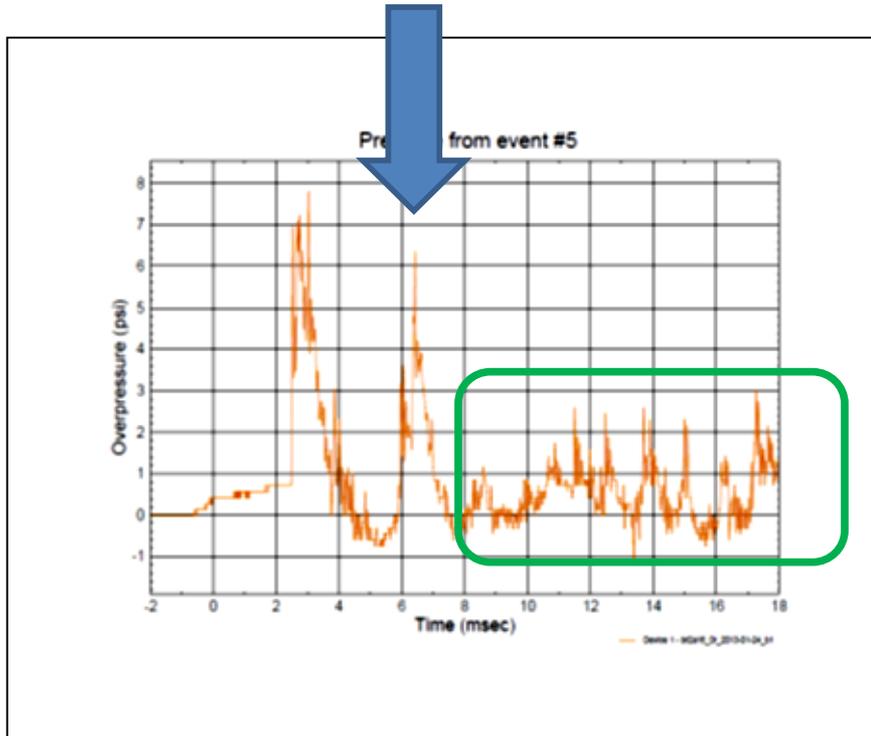
Assistant
Gunner

Ammo
Bearer

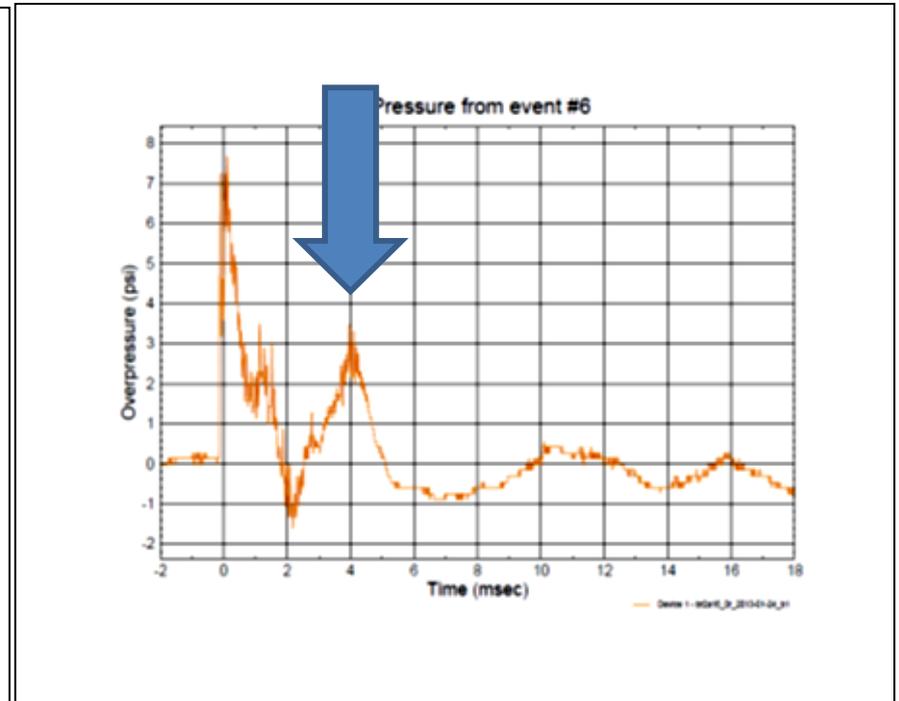




Peak and Impulse Energy

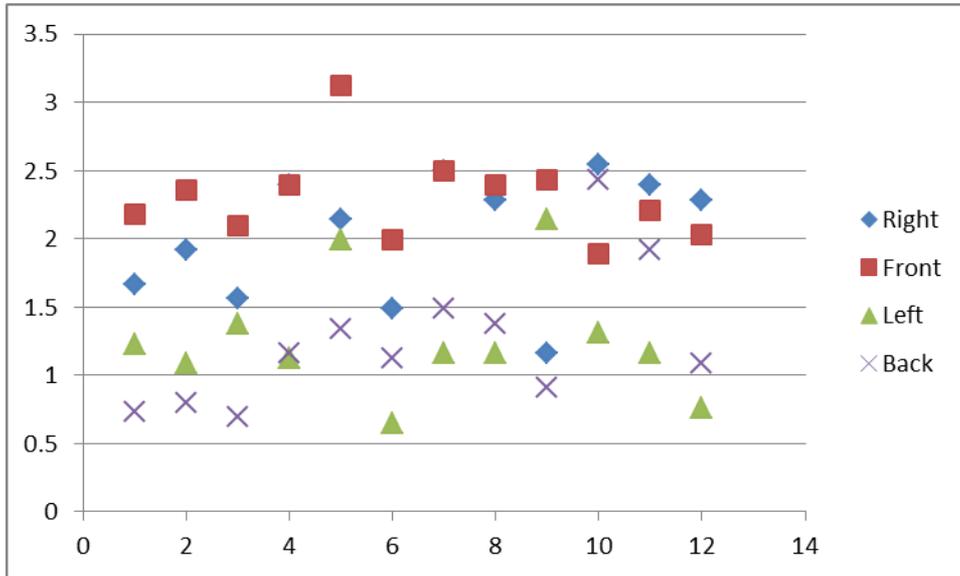


All doors closed



Hallway door open

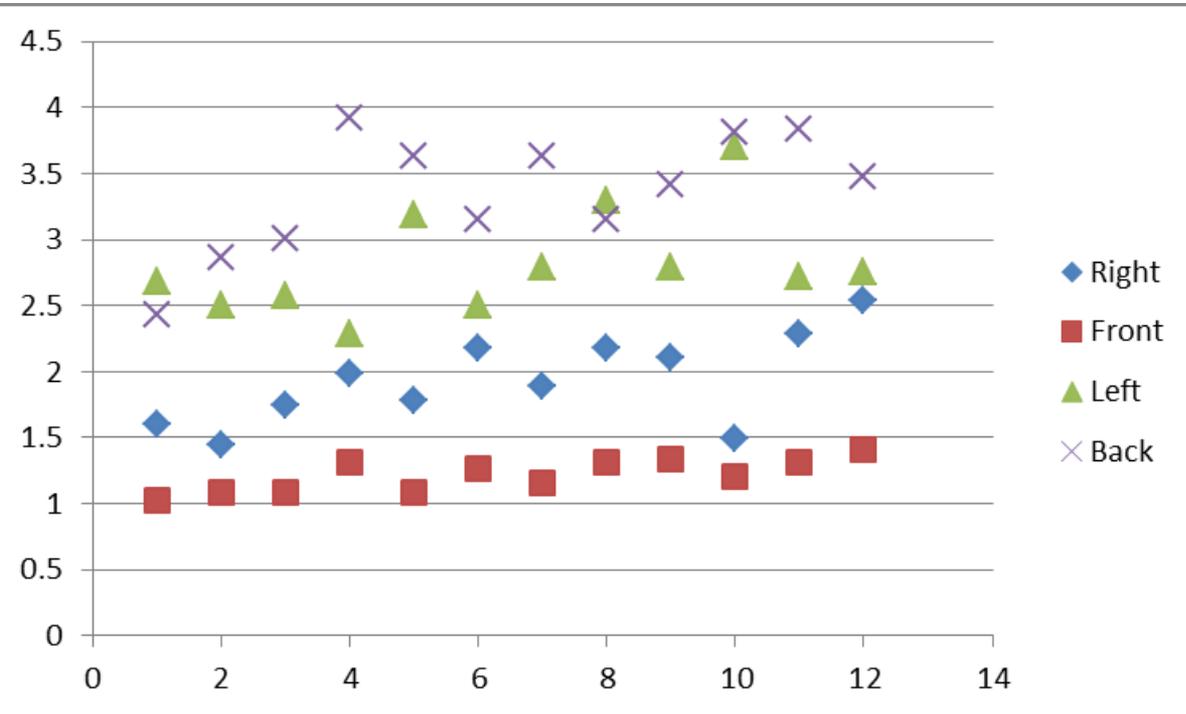
Ammo Bearer



	Right	Front	Left	Back	Chest	L.SDR	R.SDR
Mean	2.03	2.30	1.26	1.26			
SEM	0.132	0.093	0.124	0.148			

	Right	Front	Left	Back	Chest	L.SDR	R.SDR	R.SDR.T
Mean (psi*ms)	1.7	1.9	1.5	1.6	SM	SM	SM	SM
SEM	0.124	0.102	0.086	0.081	SM	SM	SM	SM

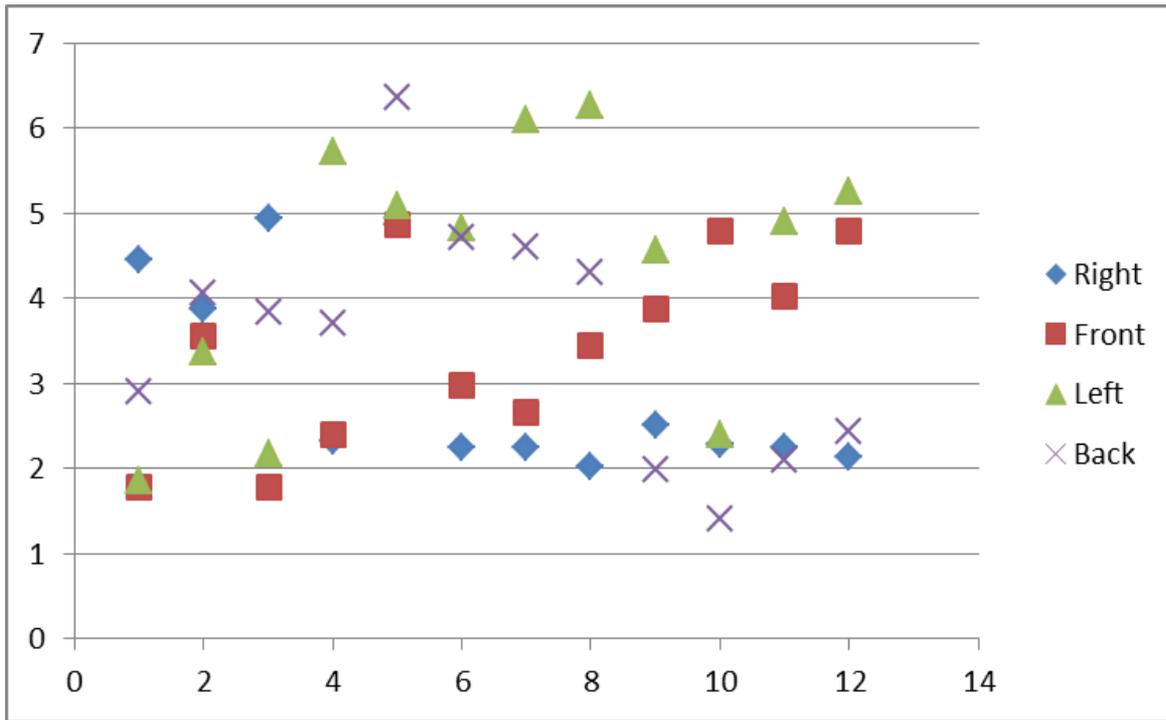
Assistant Gunner



	Right	Front	Left	Back	Chest	L.SDR	R.SDR
Mean	1.94	1.22	2.82	3.36			
SEM	0.097	0.036	0.115	0.130			

	Right	Front	Left	Back	Chest	L.SDR	R.SDR	R.SDR.T
Mean (psi*ms)	2.5	2.0	2.9	3.4	SM	SM	SM	SM
SEM	0.109	0.056	0.069	0.106	SM	SM	SM	SM

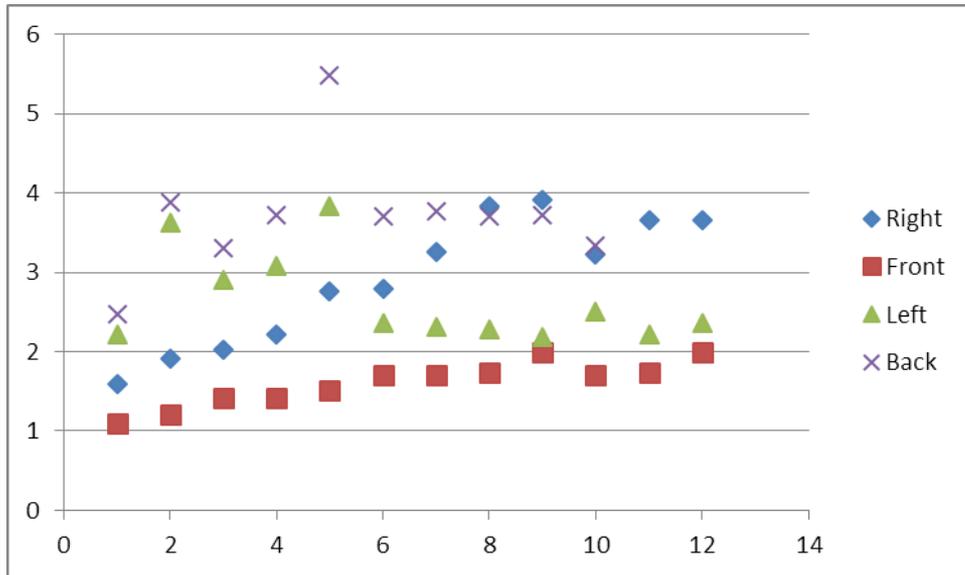
Squad Leader



	Right	Front	Left	Back	Chest	L.SDR	R.SDR
Mean	3.01	3.41	4.38	3.53			
SEM	0.334	0.322	0.446	0.408			

	Right	Front	Left	Back	Chest	L.SDR	R.SDR	R.SDR.T
Mean (psi*ms)	3.1	5.3	3.7	3.0	SM	SM	SM	SM
SEM	0.176	1.788	0.227	0.258	SM	SM	SM	SM

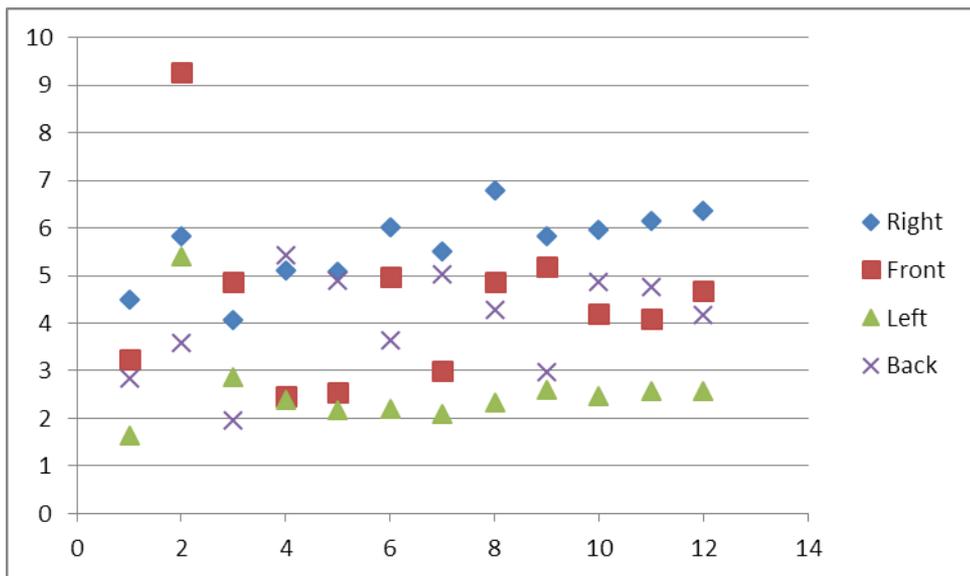
Gunner



	Right	Front	Left	Back	Chest	L.SDR	R.SDR
Mean	2.91	1.60	2.66	3.71			
SEM	0.234	0.081	0.167	0.215			

	Right	Front	Left	Back	Chest	L.SDR	R.SDR	R.SDR.T
Mean (psi*ms)	3.0	2.2	2.9	4.0	SM	SM	SM	SM
SEM	0.166	0.090	0.085	0.235	SM	SM	SM	SM

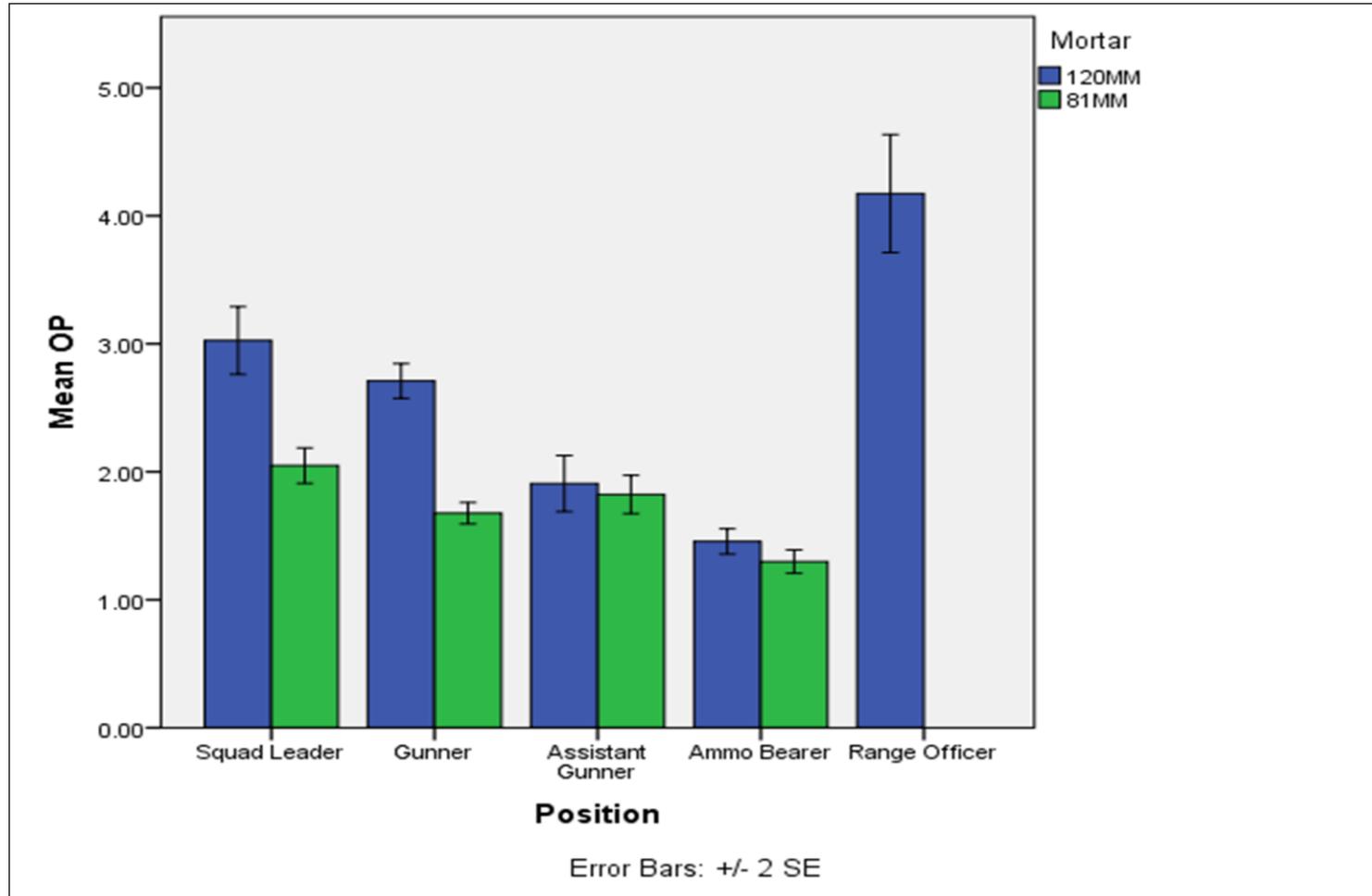
Range Officer

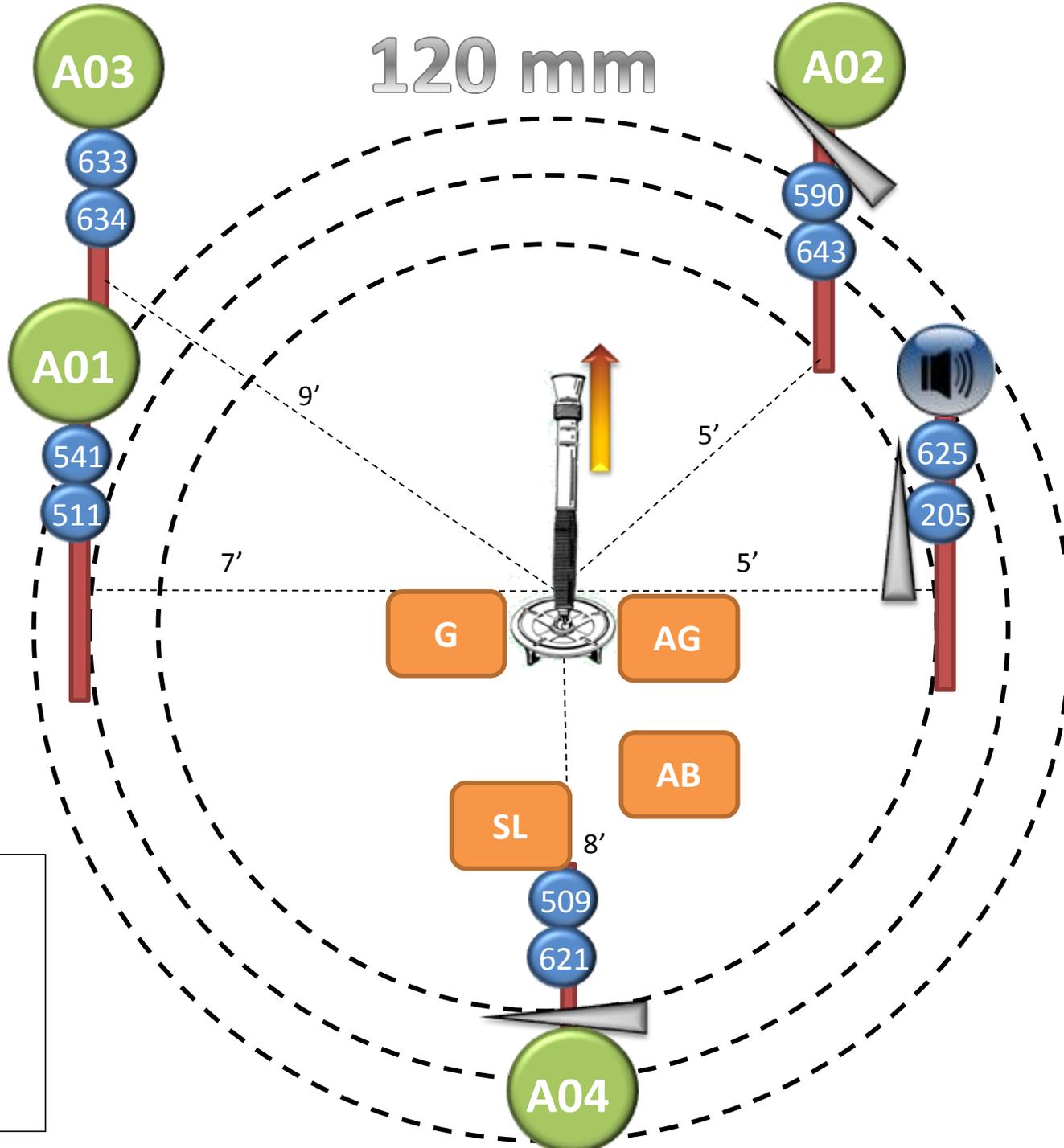


	Right	Front	Left	Back	Chest	L.SDR	R.SDR
Mean	5.60	4.45	2.61	4.04			
SEM	0.227	0.521	0.269	0.305			

	Right	Front	Left	Back	Chest	L.SDR	R.SDR	R.SDR.T
Mean (psi*ms)	4.0	3.1	2.4	3.0	SM	SM	SM	SM
SEM	0.202	0.330	0.108	0.133	SM	SM	SM	SM

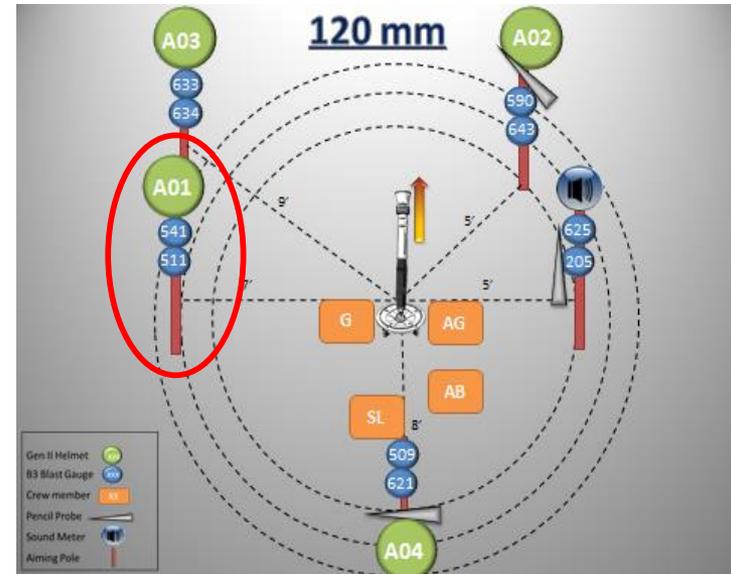
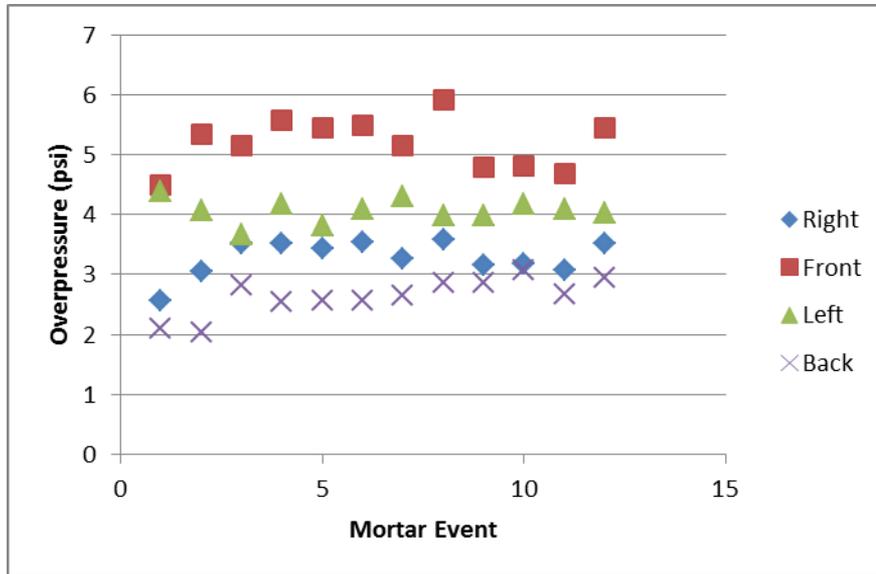
Mortar OP exposure by Position





Gen II Helmet	
B3 Blast Gauge	
Crew member	
Pencil Probe	
Sound Meter	
Aiming Pole	

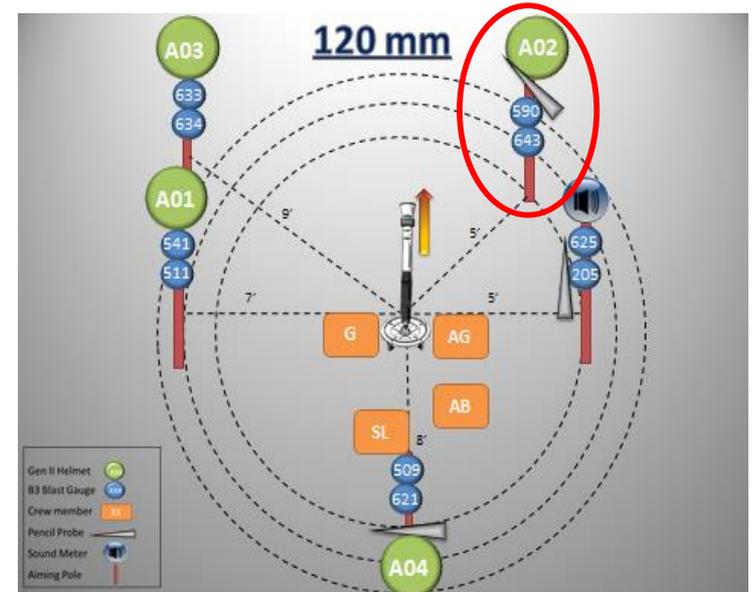
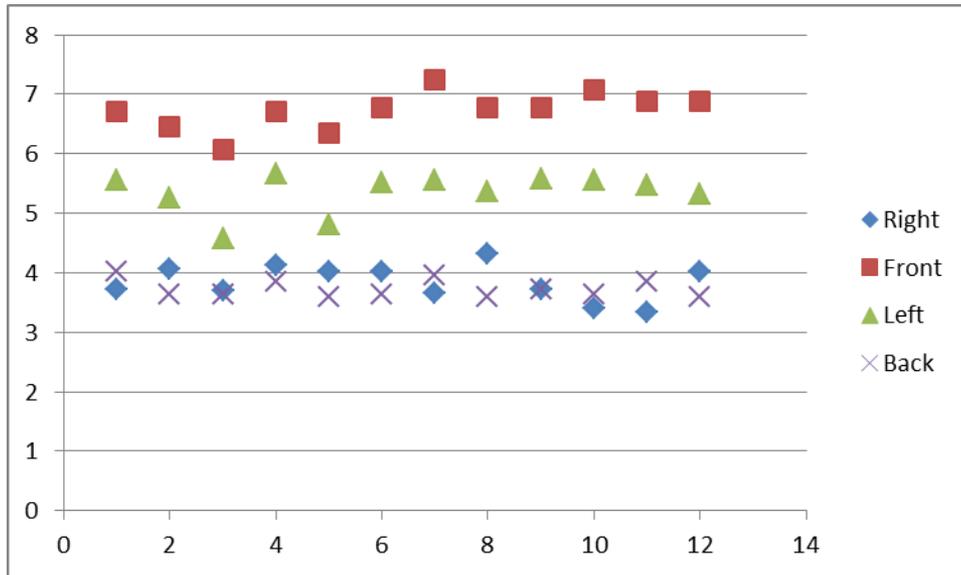
A01 Helmet



	Right	Front	Left	Back
Mean	3.29	5.19	4.06	2.64
SEM	0.087	0.121	0.057	0.091

	Right	Front	Left	Back	T.SNR	B.SNR
Mean (psi*ms)	2.4	3.4	3.3	2.1	NR	NR
SEM	0.087	0.031	0.030	0.037	NR	NR

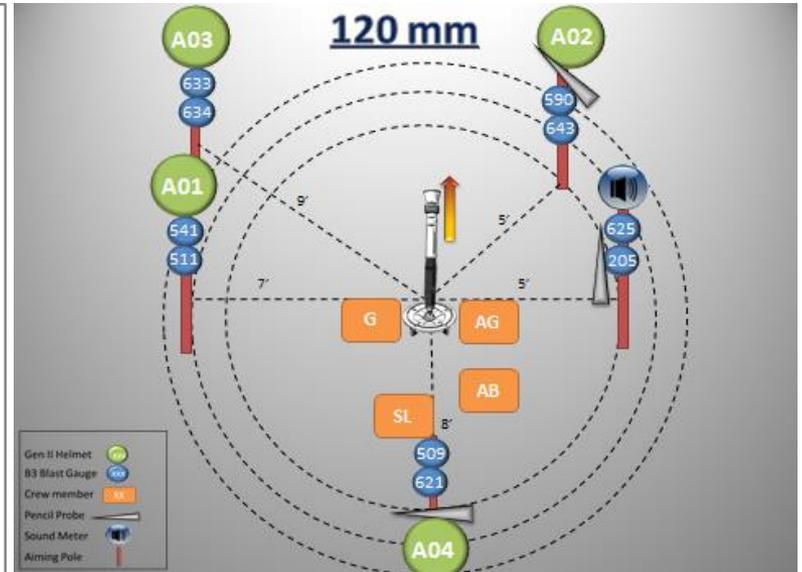
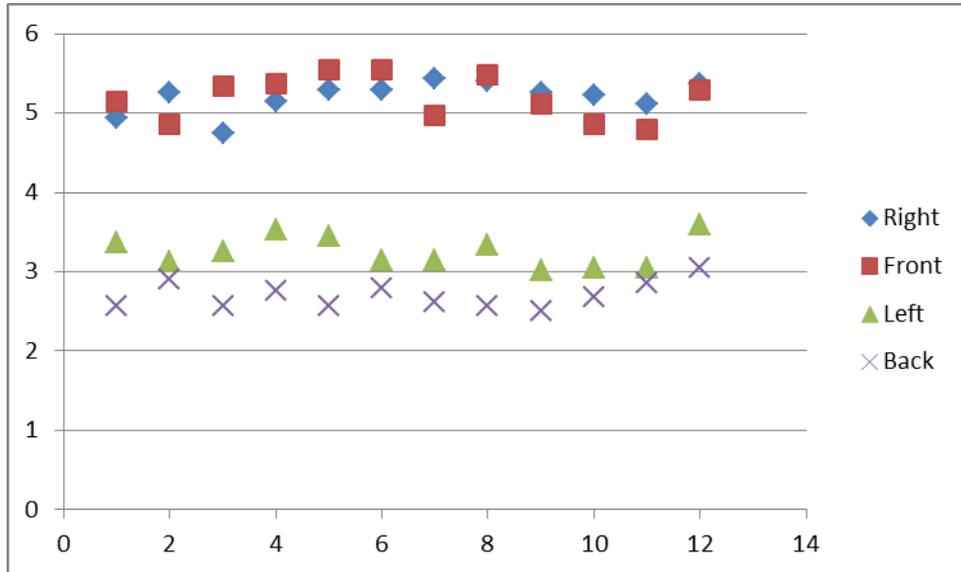
A02 Helmet



	Right	Front	Left	Back
Mean	3.84	6.73	5.35	3.72
SEM	0.085	0.092	0.096	0.044

	Right	Front	Left	Back	T.SNR	B.SNR
Mean (psi*ms)	2.7	4.7	3.3	3.3	NR	3.1
SEM	0.073	0.071	0.072	0.037	NR	0.058

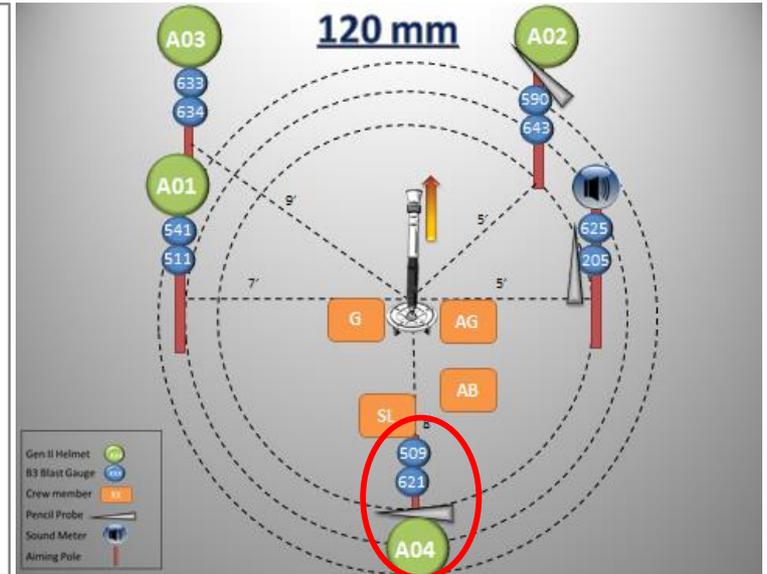
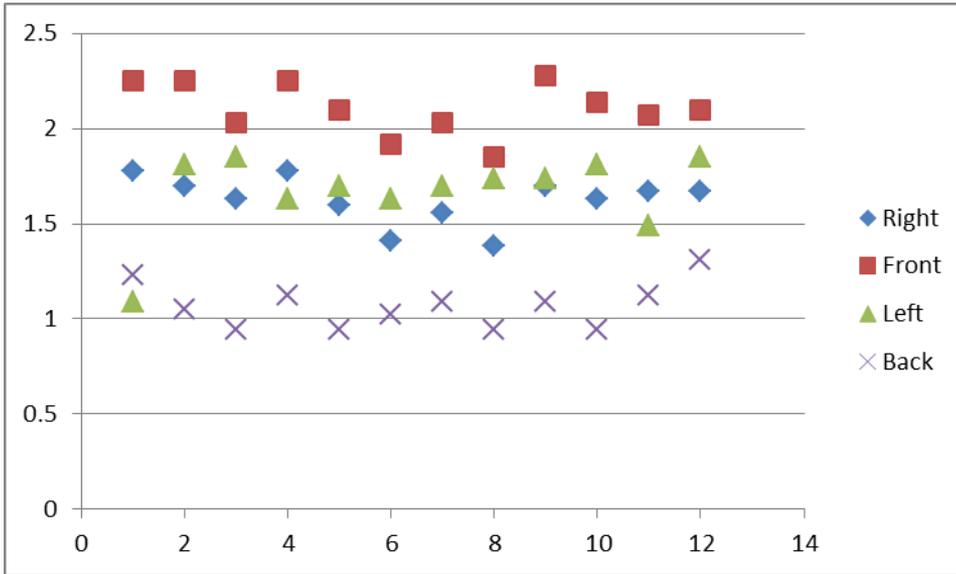
A03 Helmet



	Right	Front	Left	Back
Mean	5.21	5.19	3.25	2.70
SEM	0.057	0.080	0.057	0.049

	Right	Front	Left	Back	T.SNR	B.SNR
Mean (psi*ms)	3.5	4.0	3.2	3.0	SM	SM
SEM	0.087	0.061	0.030	0.029	SM	SM

A04 Helmet



	Right	Front	Left	Back
Mean	1.63	2.11	1.67	1.07
SEM	0.036	0.040	0.061	0.035

	Right	Front	Left	Back	T.SNR	B.SNR
Mean (psi*ms)	1.5	2.1	2.7	1.3	NR	NR
SEM	0.053	0.057	1.181	0.046	NR	NR

Annual Exposure

- 100 Round Per Day, 2 days per course spread between 3 firing Stations
- ~8 courses per year
- Students change, Cadre remains
- 60-100 exposures per course for Cadre
- Potentially 500+ exposures per year

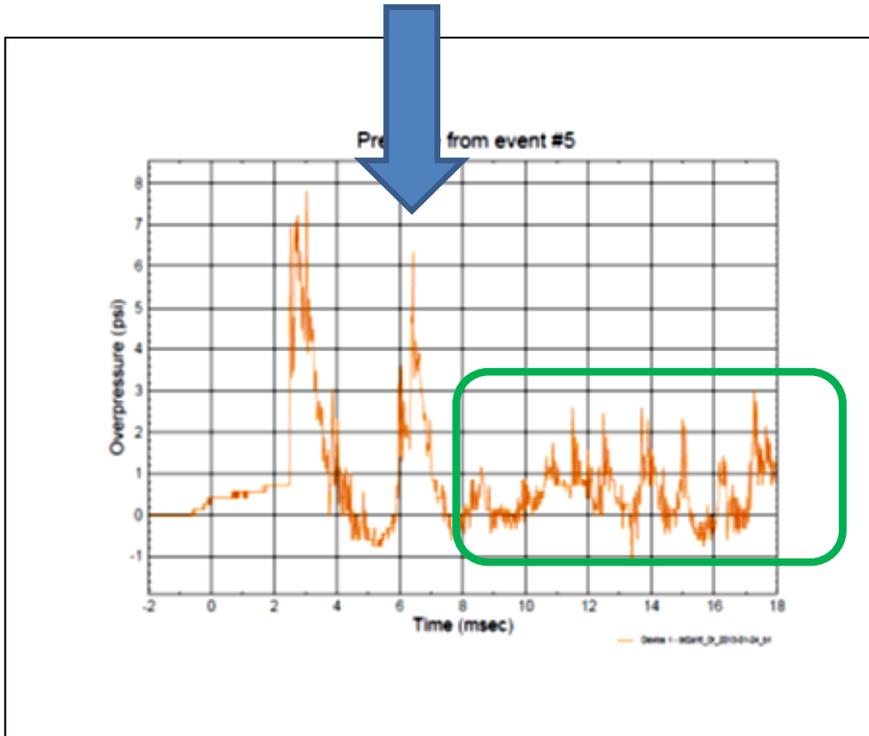
PSI: Injury and Structural Damage Thresholds

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psi	kPa		
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0.5	3		shattered glass plate
1	7		Stud and drywall -cracking
2	14		
3	20		
4	28		Reinforced concrete wall - cracking
5	34	Threshold for Eardrum Rupture	
6	41		Collapse of wood frame structure
7	48		
8	54		Reinforced concrete wall - Displacement
9	61		
10	68		Shattered Automotive Glass
15	102	50% chance of eardrum rupture	
20	136		Reinforced concrete wall - Destruction
30	204	Threshold for Lung Injury	
40	272		
50	340		4.5 ft. from 50 lb. bare explosive
100	680	Slight Chance of death (Pulmonary Related)	
150	1,020	50% Chance of Death (Pulmonary Related)	
200	1,360	100% Chance of Death (Pulmonary Related)	2.5 ft. from 50 lb. Bare Explosive

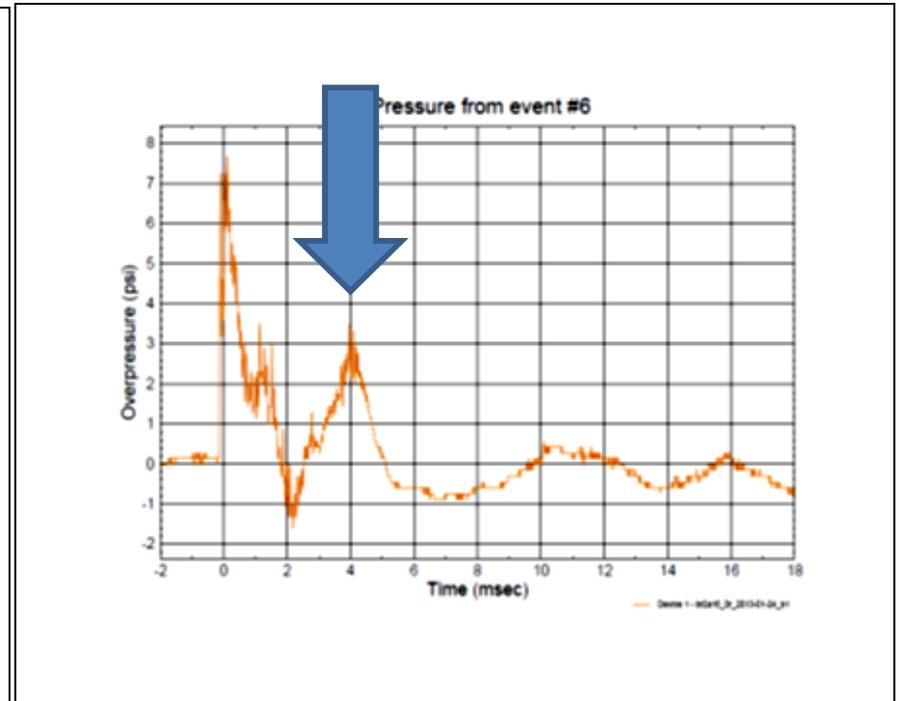




Impulse Energy



All doors closed



Hallway door open



Shotgun Breaching

Royal Arms

FLASHBANG #FB-82H (Red Cap)

Less Lethal / Diversionary Round 185 dB will Breach solid wood doors, light steel, sliders, car windows, and use in crawl spaces

Material: Powder compressed with two hard fiber wads

Use: Diversionary / Disorientation / Breaching / Crowd Control

Hearing Protection MUST be worn by team.

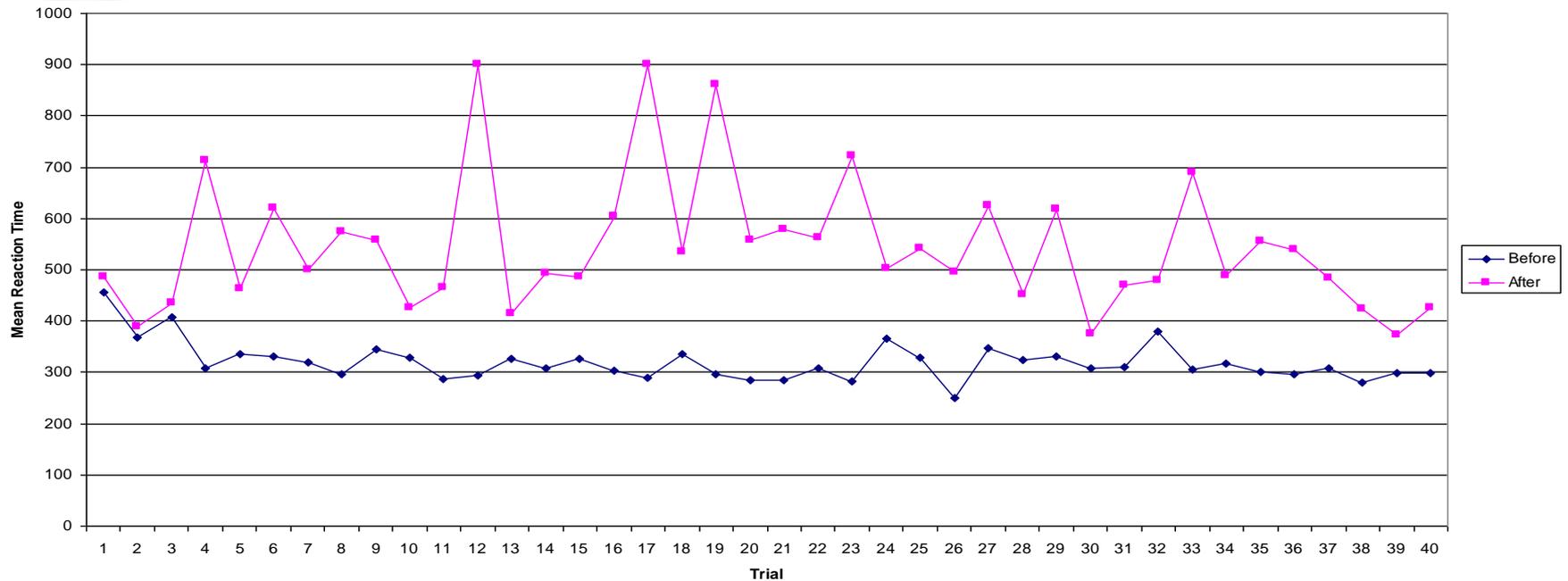
Only to be used in 21" or shorter cylinder bore

Barrel (RAI recommends use of a stand off)





Simple Reaction Time before and after flash bang round



Sensor #:	Location:	1 st door psi	2 nd door 1 st shot psi	2 nd door 2 nd shot psi	2 nd door 3 rd shot psi
7	Front and center of helmet	9.40	10.46	9.44	8.41
5	Chest	9.26	10.45	9.66	8.08
11	Left Shoulder	11	10.64	10.84	9.86

Operator Self Report

- Short term memory
- Sleep disturbance
- Persistent headache
- Mood



Questions?

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