THINGS THAT GO BOOM!

NOISE AND TOXIC EXPOSURES ASSOCIATED WITH WEAPON SYSTEMS

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Photo: US Navy

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Agenda

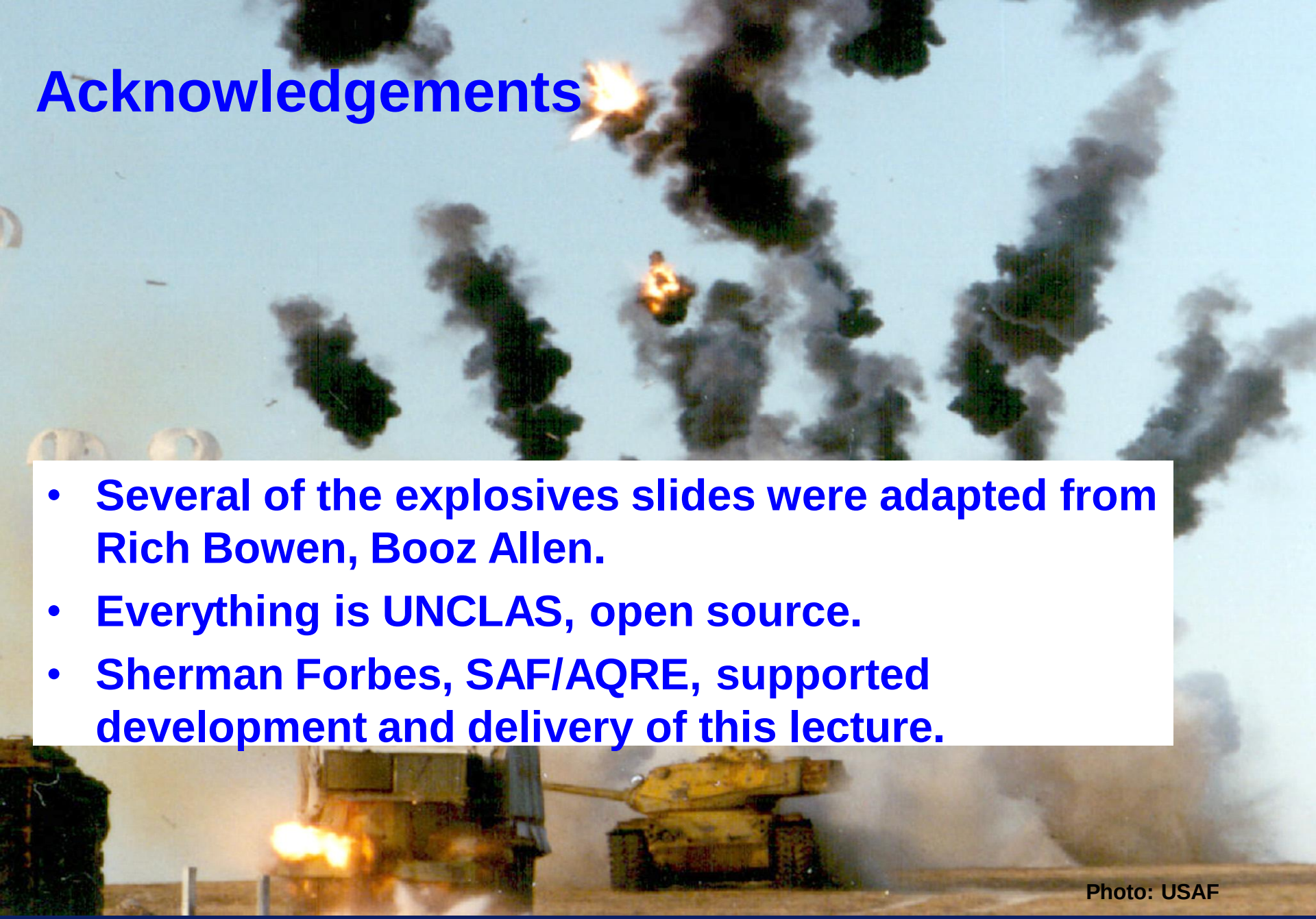
Introduction: Hazards of ordnance.

Explosives- basic information.

Noise related to weapon systems.

Toxicology of munitions.

Acknowledgements



- Several of the explosives slides were adapted from Rich Bowen, Booz Allen.
- Everything is UNCLAS, open source.
- Sherman Forbes, SAF/AQRE, supported development and delivery of this lecture.

Photo: USAF

What hazards are going to bite you?

Summary of weapon hazards

- Blast over pressure (personnel and equipment damage).
- Noise: impulse, impact, peak.
- Toxic exposure (personnel, equipment, and environmental damage).
- Ergonomics issues.
- Inadvertent launch (damage to self, own equipment, friendlies, others).
- Thermal hazards (fire, launch, jettison, during inadvertent activation).
- Slip, trip, fall, pinch, crush.
- Shock and vibration.
- Radiation- ionizing (uranium warhead) and non-ionizing (lasers).
- Electrical energy: Personnel shock or Damage to equipment.

NOTE: Only the first 3 be discussed in this lecture.

So what?

- You have to know your system and its intended operational and maintenance environment in order to reduce risks.
- Risk reduction early in the lifecycle (preferably during design) will save lives, reduce costs, and improve system performance in the long term.
- Changes in operating parameters and use can change personnel exposures to noise, toxic, and other hazards.

Weapon designs and operational environments change over time- noise and toxic exposures can also change.

Tight environment, lots of things going on.

Clearest weapon hazard- actual use. Photos: Anon. (l), Global Security (r).

The “other” hazards

- Noise and toxic exposures
  - During weapons firing (crew, collateral personnel, environment),
  - Maintenance (i.e., exposure to spent propellants and casing materials, like in DDG and CG VLS cells, or with USMC 120mm cartridge case residue), and
  - Production (gov and contract personnel at gov/contract facilities).
- Exposures to military personnel on vehicles and in the field, on ships, and in planes- and to everyone after IED use or in disposal.
- Don’t always know what you’re carrying/working with/cleaning up (militarized Agent Orange defoliant with unintended dioxins, CBRNE’s, degraded napalm, etc).

Explosives

- Most modern explosives are reasonably stable and require percussive shock or other triggering devices for detonation.
- Energetic materials used by the military as propellants and explosives are mostly organic compounds containing nitro (NO_2) groups.
- Three major classes of these energetic materials are:
  - Nitroaromatics (e.g., tri-nitrotoluene or TNT),
  - Nitramines (e.g., hexahydro-1,3,5 trinitroazine or RDX), and
  - Nitrate esters (e.g., nitrocellulose and nitroglycerine).

Explosives

- All of the common explosives are solid at normal environmental temperatures and pressures.
- Melting points for explosives solids are moderate (50-205ºC).
- Melting points are of little direct value in predicting environmental fate and transport, but several parameter estimation relations for solids incorporate the influence of molecular crystal bonding by including a term dependent on the melting point.
- Melting points are not available for many of the breakdown products.

Chemical/Physical Properties

- Most of the explosives and associated contaminants have very low volatility, with vapor pressures estimated to be less than 6×10^{-4} torr.
- Henry's law constants (k_H) range from 10^{-4} to 10^{-11} atm-m^3/mole. Only those with k_H greater than 10^{-5} volatilize significantly from aqueous solution.
- Though explosives compounds may not be volatile, some of the transformation products, other key reactants, or products may be volatile to semivolatile.

Weapon system noise may result in:

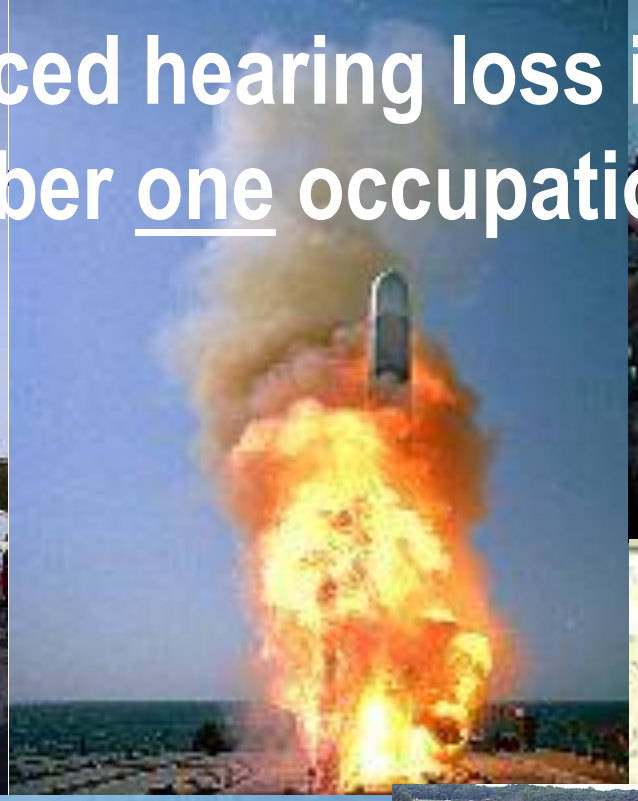
- Hearing loss (deafness), other physiological disorders (e.g. loss of balance, loss of awareness, fright).
- Interference with speech communication, acoustic signals.
- Most noise induced hearing loss occurs between the 5th and 10th year of exposure to hazardous noise levels.
- DoD + VA spend ~$1B per year for active + retiree hearing loss compensation & treatment.

  - Most military personnel are exposed to high levels of noise at some point in their career.

Toxic effects from weapon systems

- Effects often difficult to quantify and assess.
- Exposures and results-
  - Acute, chronic, sub-chronic effects, depending on the amount, route, duration, and repetition of exposure.
- Synergistic or additive effects?
- Use and effectiveness of personal protective equipment (PPE)?
- The hazardous material, its form (solid, dust, aerosol, fume, mist, smoke), and abundance.
- Dose makes the poison!

Noise-induced hearing loss is the DoD's number one occupational health hazard.



Photos: USN

Noise and toxic exposures can be from the propellant charge, the initial warhead impact, the secondary explosion, and from other sources.

- M1028 120mm Tank Round (M1A1/A2 Abrams tank round), Alliant Technologies. 1150 (est.) tungsten balls, which are expelled upon muzzle exit (no fuse). Photo: Defence Daily.

Hard to quantify toxic exposures

- Hard to pin down when exposures may have happened, amount ingested/inhaled, effectiveness of exposure, etc.
- Exposure to carcinogens may trigger greatly delayed response (years, decades).
- Single vs repeated exposures.
- Work, home, recreation?
- Mishaps?

Exposure during howitzer use (noise and combustion products). Photo: US Army

120mm mortar testing at YPG in an APC. Enclosure changes noise and personnel dynamics and exposures. Photo: US Army

New Russian 82 – mm mortar “Tray” in multipurpose light truck (MTLB). Mortar set can easily be disassembled, adapted for shooting from the vehicle and the ground. Photo: Indianfrontiernet

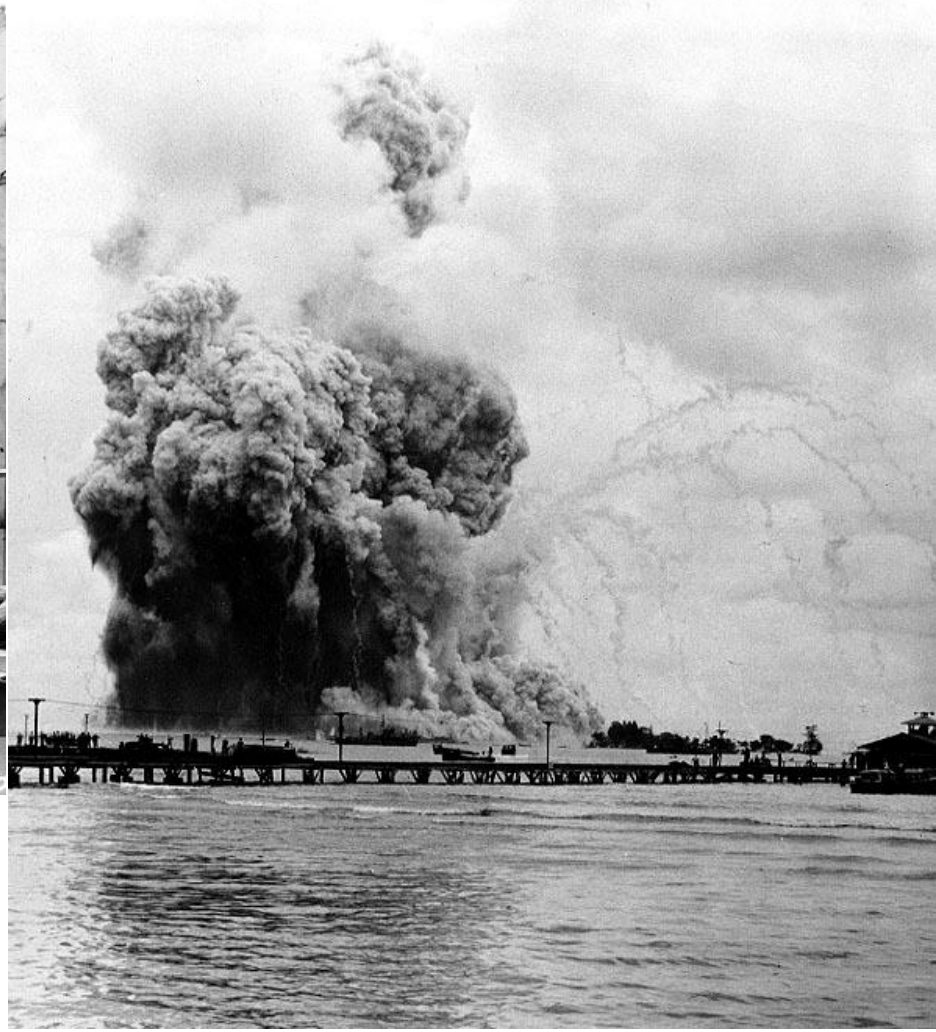
PPE? Who needs double hearing or eye protection?

- Command Sgt. Maj. Dennis M. Carey, the command sergeant major of U.S. Forces Command, fires a M107 Caliber .50 Semi-Automatic Long Range Sniper Rifle (Barrett). Photo: US Army. ~150 dB Peak, depending on round.

USS Mount Hood (AE-11) explosion, 1944 and damage to neighbor ship on the pier. Explosion probably due to rough handling of ammo. Photos: US Navy

Photo # NH 96174 Damage to USS Mindanao from Mt. Hood explosion

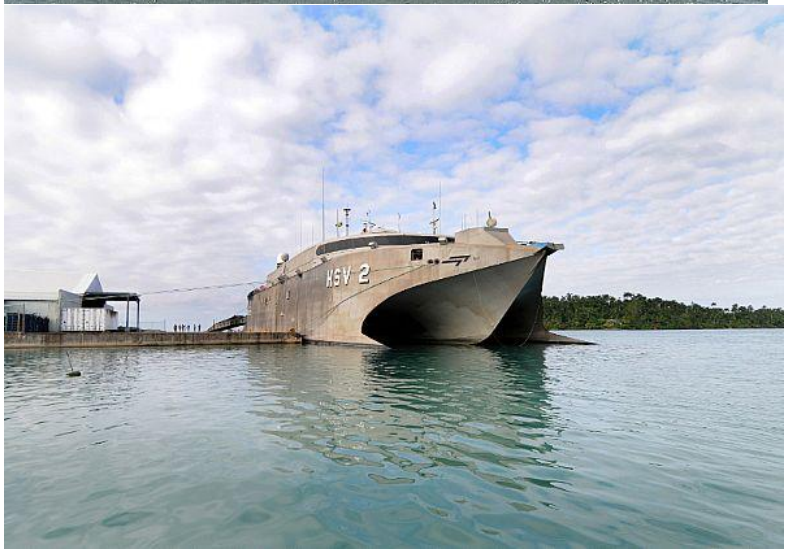
Photo # NH 96173 Mt. Hood explosion at Manus, Nov. 1944



A-10 Thunderbolt firing. Photos: USAF

Risks and exposures may depend on location. Trying to load weapons, etc on an LCAC would be different than on the ship or ashore. M1A1 offloading from LCAC. Photos: USMC

HSV-2 SWIFT, built to ABS rules, not a normal warship. Photos: US Navy



How do these innovative structures respond to noise (insulation, dampening, vibration, reverbation) and how are weapon effects mitigated (ventilation, warnings, etc)?

Even pyrotechnics (CADS, etc) in sonobuoys (like in this SH-60) or flares (on C-130) can be hazardous during use, storage, etc.

Photos: USN (l), USMC (r).

Explosives

- Ingredients of high explosives are classified as explosive bases, combustibles, oxygen carriers, antacids, and absorbents. Some ingredients perform more than one function.
- An explosive base is a solid or liquid which, upon the application of sufficient heat or shock, decomposes to gases with an accompanying release of considerable heat.
- A combustible combines with excess oxygen to prevent the formation of nitrogen oxides.

Low Explosive

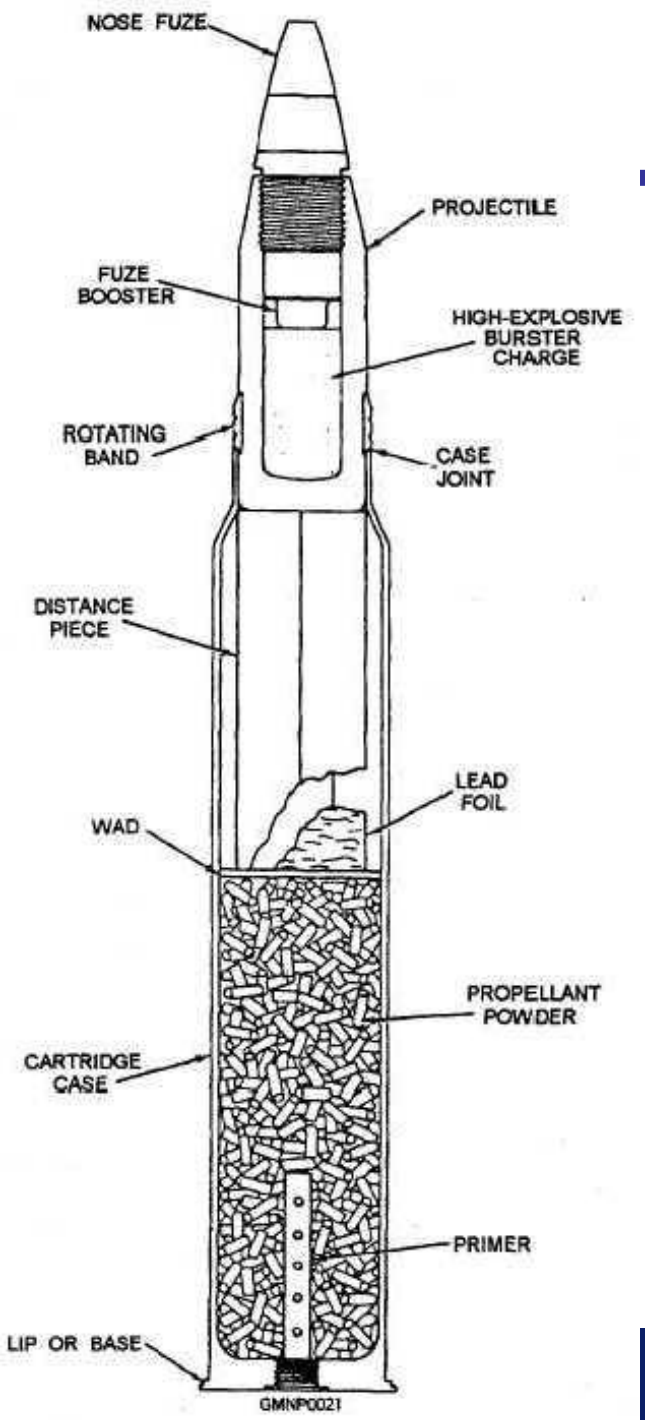
- Low-order explosives (LE) create a subsonic explosion [below 3,300 feet per second in air] and lack HE's over-pressurization wave. Examples of LE include most propellants, pipe bombs, gunpowder, and most pure petroleum-based bombs such as Molotov cocktails or aircraft improvised as guided missiles.

Photo: US Army

High Explosive

- A High Explosive (HE) is a compound or mixture which, when initiated, is capable of sustaining a detonation shockwave to produce a powerful blast effect. A detonation is the powerful explosive effect caused by the propagation of a high-speed shockwave through a high explosive compound or mixture. During the process of detonation, the high explosive is largely decomposed into hot, rapidly expanding gas.

Photo: Adam Henning

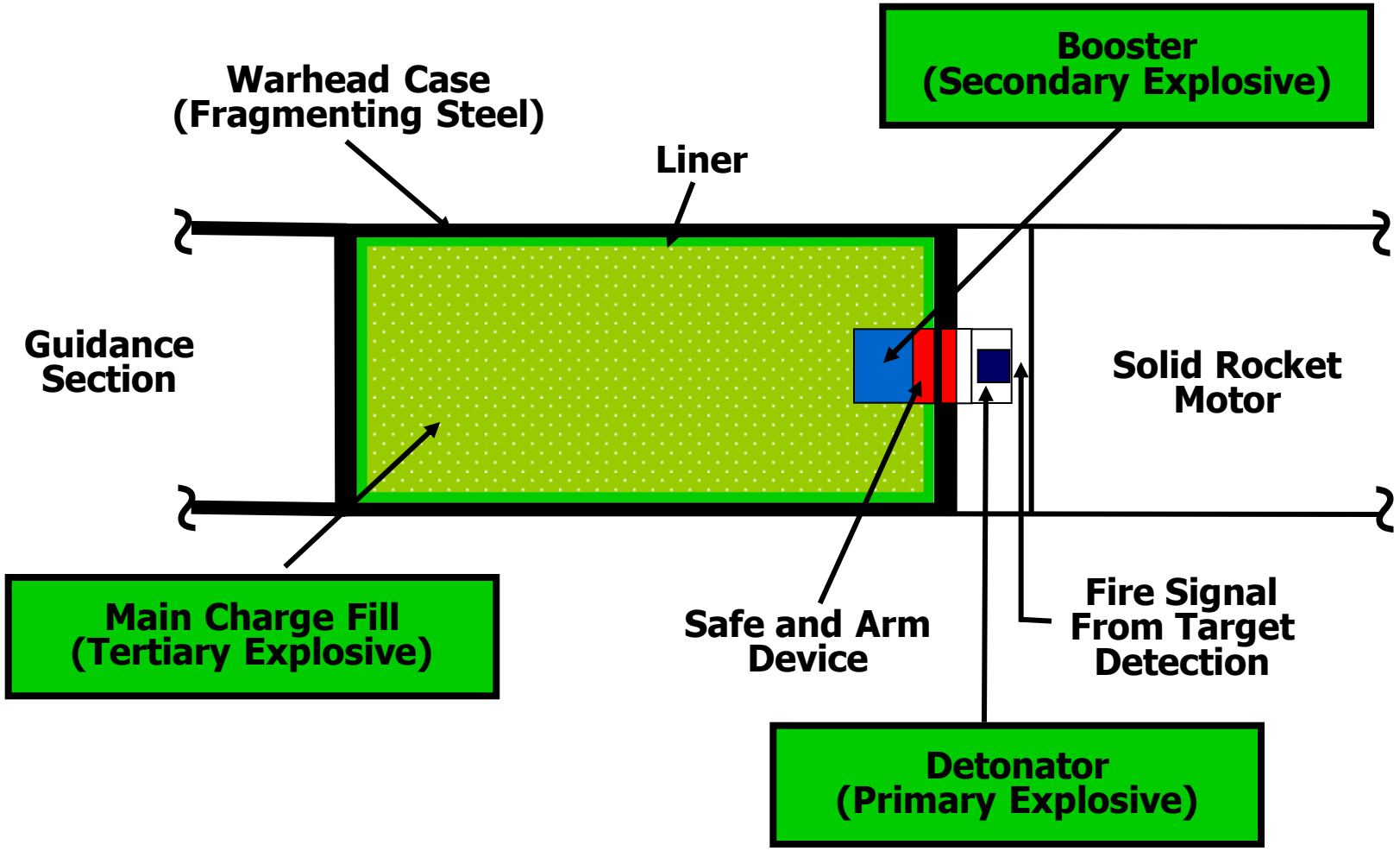


High Explosive Compounds

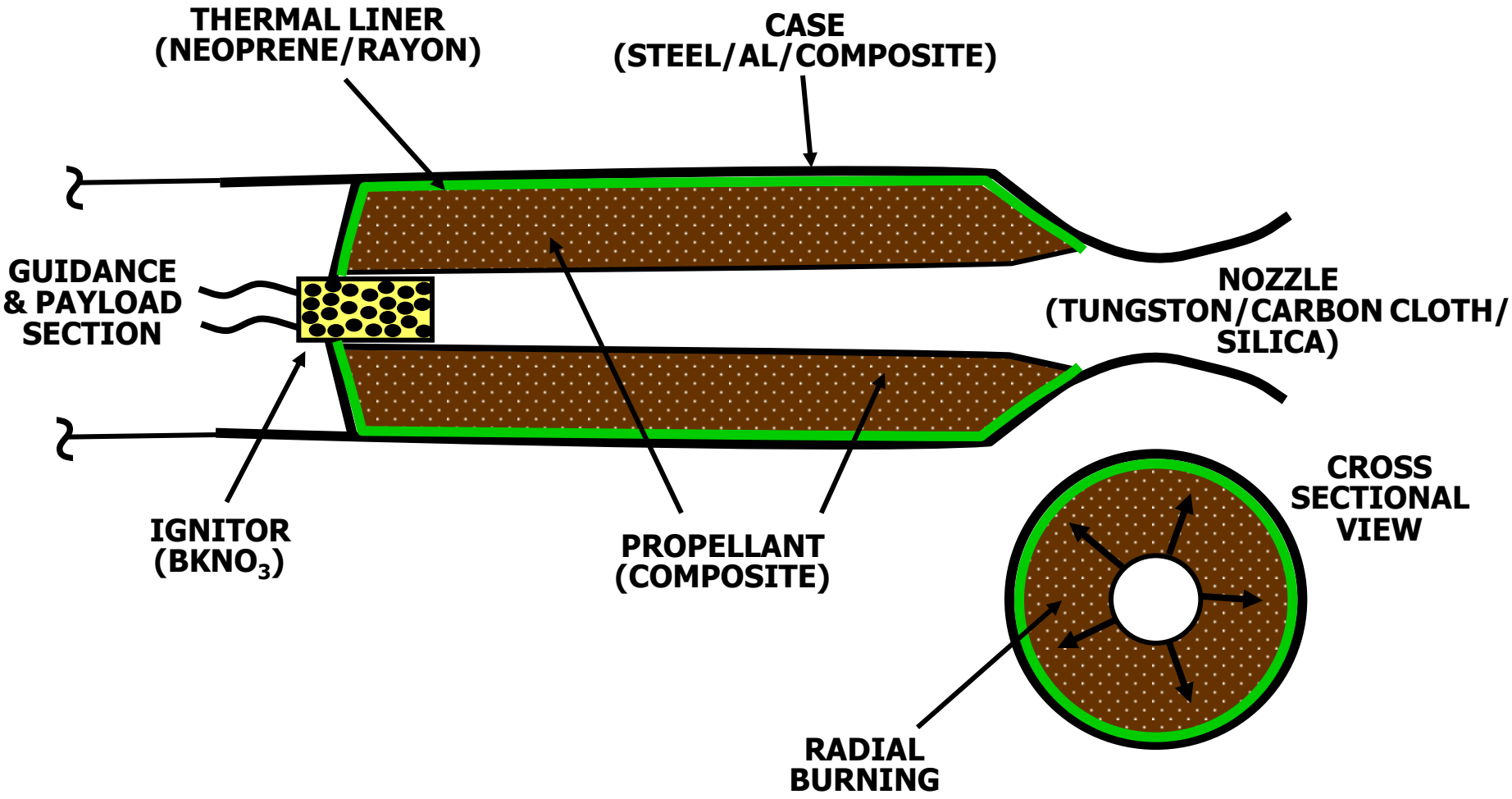
Common explosive materials for military use include:

- RDX
- HMX
- CL-20
- Nitroglycerine
- Nitrocellulose
- PETN
- TATB
- Lead Azide
- HNS

Missile Warhead, Generic



Solid Rocket Motor, Generic



Mortar rounds

Photo (l) Mszcsuz, (r,c) USA.

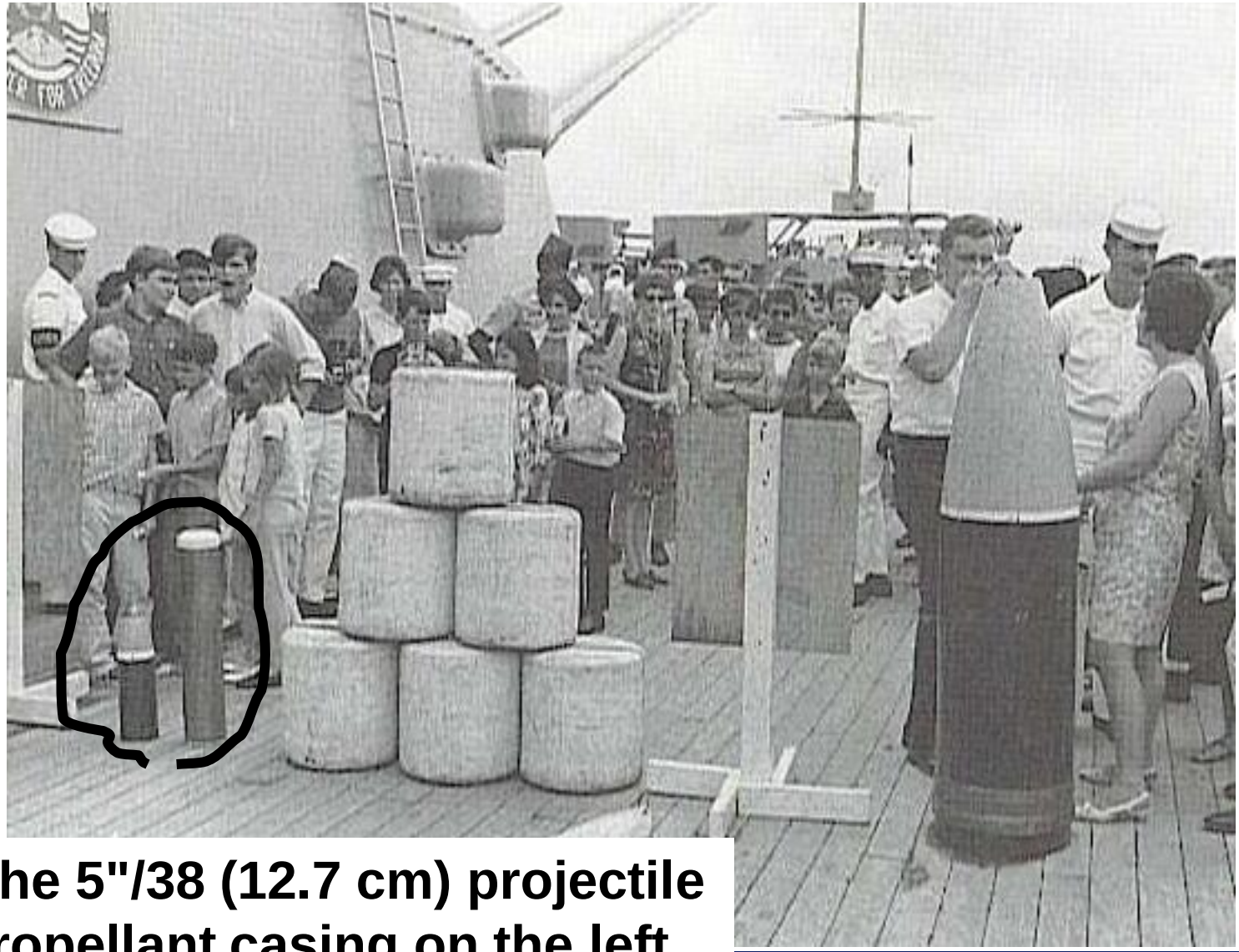
The 120mm M933/934 mortar round consists of the following major components:

Projectile Body Assembly
M230 Propelling Charge (with M45 Propellant)
M981 Ignition Cartridge (with M44 Propellant)
M31 Fin Assembly
M745 Point Detonating Fuze or M734/M734A1 Multi-Option Fuze
PA153 Fiber Container
PA154 Metal Overpack

Effects depend on exposure. Photo: USMC

155mm round and prop charge (older Comp B HE).

16“ gun powder bags and projectile, USS NEW JERSEY (BB-62), 1968. Photo: U.S. Navy.



Note the 5"/38 (12.7 cm) projectile and propellant casing on the left .

The Intended Effect

- 12 inch thick armor test plate (l), Iraqi tank (r).
- Photo: US Navy, AP News.

Noise

- Exposure Routes
  - Blast over pressure can affect whole body, including lung and skull bario-trauma.
  - Impulse, impact and/or steady state noise can each have effects of interest, especially from chronic exposure.
  - Ear and whole body effects possible, depending on exposure scenario.

BOP

- Blast overpressure (BOP) AKA high energy impulse noise, is a damaging outcome of explosive detonations and firing of weapons.
- Exposure to BOP shock waves alone results in injury predominantly to the hollow organ systems such as auditory, respiratory, and gastrointestinal systems.
  - In recent years, the hazards of BOP that once were confined to military and professional settings have become a global societal problem as terrorist bombings and armed conflicts involving both military and civilian populations increased significantly.

BOP

- In general, BOP-induced injuries are classified as:
- Primary when caused by the sudden increase in ambient pressure,
- Secondary when caused by objects (fragments, glass, projectiles) propelled by the blast shock waves,
- Tertiary when caused by physical displacement of the body by the blast wind against a solid surface, and
- Quaternary when the effects of BOP shock waves are combined with other factors such as fire, smoke, or released toxic gases causing burns and/or asphyxia.

YPG noise measuring equipment.

Photo: US Army.

Do you understand the total operational environment? 1 event or many?

Photo: USN, USA

Army has covered and open test ranges. Photo: US Army

- Aberdeen Test Center. Instrumented range is used to conduct precision accuracy firings and general small arms tests. The open-ended, 60-foot (18-meter) wide cover serves to prevent wind effects during firing; the remainder of the range is a narrow slot through tree cover, which minimizes atmospheric effects to a total range of 3000 meters.
- Range enclosed to 300 meters; open to 3000 meters.
- Instrumented for pressure, velocity, and action time.
- Acoustic scoring system operates with single-shot and burst firings.
- Instrumentation allows placement of acoustic transducers at target distances up to 3000 meters.
- Instrumentation for other ballistic data; video and toxic fumes available.

Measuring Weapon Noise

- Many sound level meters cannot consistently measure above 140 dB (clipping).
- Larger microphone (1/2” or larger) generally better.
  - Directional or omni-directional? Consult OEM.
- Need a high performance peak detector circuit with extremely fast rise time response to short duration impulse events, such as those generated on a firing range.
- Digital recording for later analysis is often required.
- Specialized equipment: strain gauges, etc.
- Noise array vs point measurement (i.e., determine sound levels in a flat plane around the weapon).

Noise Exposure at Firing Ranges

- Double hearing protection is best and generally required per Navy instruction.
  - Artillery personnel MAY have a helmet that provides hearing protection; infantry personnel (rifle, mortar, rocket, vehicle mounted, etc) almost universally do not.
- Training in wearing HPD is required.
  - Foamies often not worn correctly (ill-fitting).
  - Maintenance of HPDs is important and required.

Sailors at Marine QRF live fire, El Asad, Iraq, June, 2009. Photo: USMC.

Some wear PPE, some don't…. Photo: USMC

Sometimes folks don't use PPE….may be mission dependent (i.e., interfere with comms).

Photos: US Navy, Dan Delgado

Do we have the right equipment to measure noise and toxic exposures in future environments? Do we understand the CONOPS?

Source: Strange Dangers.Com

IED and shaped charge munitions are hard to defeat. Personnel exposures are also hard to quantify.

http://www.groundzerofx.com/explosions.htm

Noise- Considerations for equipment selection

- Hand held vs emplaced equipment.
  - Stands
  - Robustness
  - Dosimetry, instant, recording, etc
- Periodicity of the noise.
  - Impulse
  - Impact
  - Steady state
  - Intermittent
  - Related to vibration
- Equipment costs go way up for advanced measurement techniques.

Toxicology

- Exposure routes
  - Inhalation probably most common and most significant, depending on scenario.
  - Skin and other direct exposures common.
  - Ingestion possible.
- Adsorption, absorption, distribution, biotransformation, excretion, toxicokinetics of toxicants may be complex.
- Exposure
  - Route and site; duration and frequency.
  - Chronic vs acute; immediate vs delayed; reversible vs irreversible toxic effects; potency vs efficacy.

Explosives and related compounds

- May be toxic, with various exposure pathways.
  - Inhalation of dust, vapor, combustion products.
  - Ingestion – primary (explosive event) or secondary (in or on food).
  - Skin contact- after event, during maintenance, etc.
- Most explosives not highly toxic, but improper handling can result in systemic poisoning, usually affecting bone marrow and liver.
- Some explosives are vasodilators, which cause headaches, low blood pressure, chest pains, and possible heart attacks.
- Some explosives may irritate or absorb via skin.

Products of reaction

- Some detonation or combustion products from explosives are toxic.
  - Possible respiratory and skin irritants.
  - May lead to systemic effects following short-term exposure to high levels.
- Soot from detonated explosives is not mutagenic;
  - Soot from burned gun propellants may be mutagenic and is therefore treated as a mutagen.

Products of reaction

- Contamination usually occurs in dilute, aqueous solutions or in relatively low concentrations in the soil and present no explosion hazard.
- Masses of pure crystalline explosive material (RDX, HMX) have, however, been encountered in soils associated with wastewater lagoons, leach pits, burn pits, and firing ranges.
  - Materials remain hazardous for long periods of time and great care must be used during the investigation and remediation process.

DOT Hazard Classes

Hazard class	Material
Class 1	Explosives
Class 2	Gases
Class 3	Flammable liquids
Class 4	Flammable solids
Class 5	Oxidizing substances & organic peroxides
Class 6	Toxic & infectious substances
Class 7	Radioactive materials
Class 8	Corrosive substances
Class 9	Miscellaneous dangerous substances & articles

DOT Hazard Class 1 Divisions

Hazards due to explosive nature generally perceived to be much more important than toxic properties.

Haz Division	Hazard
1.1	Mass Explosion
1.2	Non-mass explosion, fragment producing
1.3	Mass fire, minor blast, or fragment
1.4	Moderate fire, no blast, or fragment
1.5	Explosive substance, very insensitive (with mass explosion hazard)
1.6	Explosive article, extremely insensitive

ACUTE AMMO EXPOSURE.
Wrong place + wrong time + pilot error = OOPS!

Photo: Naval Safety Center

Toxicology

- Hypergolic fuels, byproducts from combustion liners, hazards from burned and unburned propellants and explosives (fuze, main charge, etc),
- Insulation,
- Ceramic armor and coatings,
- Reactive armor,
- Paint coatings,
- Nano-materials,
- Composites (missile bodies, etc).

Exposure pathways

- During maintenance and EOD-type operations.
- Before, during, after operation of the weapon system.

L: AO's attach a laser guidance unit to a BLU-111 500-pound general-purpose bomb in an ammunition magazine aboard USS Kitty Hawk (CV-63). Photo: USN
A: Napalm, Vietnam. Photo: USMC.

Explosives Byproducts

- Explosive byproducts generated when ordnance does function as designed (high-order detonation), or experiences a low-order detonation, also generate constituents of concern.
- Major explosive byproducts of organic nitrated compounds such as TNT and RDX include water, carbon dioxide, carbon monoxide, and nitrogen.
- High-order detonations result in almost complete conversion of explosives (99.997%+) into such inorganic compounds, whereas low-order detonations result in incomplete conversion (i.e., a mixture of the original explosive and its byproducts).
- Heavy metals may be present (lead in propellants, missile liners, shaped charges with DU liners, or warheads/rounds with preformed DU or tungsten fragments.

Soil sampling

- Soil sampling at military ranges indicates that concentrations of explosives residues often detectable but generally not present at concentrations that pose acute or chronic hazards.
- Ft Greely, Alaska, soil concentrations (USACE 2001a):
- TOW missile range, RDX 0.002 to 0.17 ppm.
- 40-mm grenade range, RDX 0.01 to 1.7 ppm.
- Median concentration in soil was 0.021 ppm RDX, 0.004 ppm TNT.

Some ordnance constituents of concern

Training Munitions	Constituent of Concern
Pyrotechnics Tracers Spotting Charges	Barium chromate Potassium perchlorate
Oxidizers	Lead oxide
Delay Elements	Barium chromate Potassium perchlorate Lead chromate
Propellants	Ammonium perchlorate
Fuses	Potassium perchlorate
Detonators	Fulminate of mercury Potassium perchlorate
Primers	Lead azide

Table 3.4-5: Estimated Number of Expended Training Materials in SOCAL OPAREAs, No Action Alternative

Activity Area	Expenditures, Annual (#/year)								
	Gun Shell	Small Arms	Missile / Rocket	Bombs	Mine Shapes	Torpedo Ballast / Hose	Flare / Chaff / Smoke	Target	Sonobuoy
Anti-Air Warfare	496	1,420,000	18	0	0		0	900	0
Anti-Submarine Warfare	0	0	0	0	0	263	321	1,290	3,550
Anti-Surface Warfare	5,950	277,000	57	397	0	0	8	800	0
Electronic Combat	0	0	0	0	0	0	146	0	0
Mine Warfare	0	0	0	0	86	0	0	0	0
Naval Special Warfare		0	0	0	95	0	0	0	0
USCG	0	33,000	0	0	0	0	0	0	0
Research, Development, Test, and Evaluation	0	0	0	0	0	10	0	35	3,178
Total	**6,450**	**1,730,000**	**75**	**397**	**181**	**273**	**475**	**3,020**	**6,730**
Estimated # of Failures (at 5%)	332	NA	4	20	NA	12	25	15	374
Estimated # of Low-Order Detonations (@ 0.2%)	13	NA	0	1	NA	NA	1	NA	NA
Total Weight (tons/year)	**174**	**72**	**21**	**21**	**6**	**15**	**0.2**	**15**	**94**

Notes: Numbers of training items are estimates, and are rounded to three significant digits to indicate their relative imprecision. Torpedoes are normally recovered, but their accessories are expended. Number (#) of failures is the number of training items that do not function properly.

Source: DoN. 2007. SOCAL Operations Data Book.

Table 3.4-13: Hazardous Materials Associated with Use of the MK-46 Torpedo

MATERIAL	
Torpedo Hydraulic Fluid (MIL-H-5606E mineral oil base)	Practice Arming Rotor (Lead Azide)
Grease (Dow Corning 55M Grease)	Scuttle Valve (Lead Azide)
Lubricating and Motor Oils	Frangible Bolt (Lead Azide and Cyclonite)
Luminous Dye (Sodium Fluorescein)	Propellant (Ammonium Perchlorate)
Solder (QQ-S-571, SN60)	Gas Generator (Barium Chromate and Lead Azide)
Ethylene Glycol (two speed valve backfill fluid)	Release Mechanism (Barium Chromate and Lead Azide)
Ballast Lead Weight	Stabilizer (Barium Chromate and Lead Azide)
Explosive Bolts (Lead Azide and Cyclonite)	Cartridge Activated Cutter (Barium Chromate and Lead Azide)
Pressure Actuated Bolt (Potassium Perchlorate)	Propulsion Igniter
Practice Exploder (Lead Azide)	Exercise Head Battery

Source: DoN 1996b 4A

Table 3.4-14: Estimated Lead in Torpedo Ballasts, No Action Alternative

TORPEDO		AMOUNT OF LEAD IN BALLAST AND HOSE			
Type	Number	Per Item		Total	
		lb	kg	lb	kg
MK-46 REXTORP	109	180	82	19,600	8,940
MK-46 EXTORP	74	72	33	5,330	2,440
MK-48 EXTORP	73	53	24	3,870	1,750
MK-54 EXTORP	2	53	24	106	48
MK-50 REXTORP	18	180	82	3,240	1,480
Total	**276**			**32,100**	**14,600**
Note: Numbers rounded to three significant digits to indicate relative precision of the estimate.					
Source: DoN 1996a, DoN 1998, DoN 2002					

- What new hazards will exist with new weapons?
- How will propulsive charges, breaking charges, warheads, etc be used in space, underwater, and on new planets?
- Will chemical explosives still be used or will lasers, electrical and rad energies replace them?

Agenda

Introduction: Hazards of ordnance.

Explosives- basic information.

Noise related to weapon systems.

Toxicology of munitions.

Noise and Toxic Effects of Weapons

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Backup Slides

Army CHPPM Steady-State Noise Levels

Model	Name, Condition	Location	Speed km/hr (mph)or	Sound Level dB(A)
M966, also: M996 M997 M998 M1037 and other non-heavy	High mobility multi-wheeled vehicle (HMMWV), at 2/3 payload	Crew positions	0(idle) 48(30) 88(55)	78 84 94

Army CHPPM Steady-State Noise Levels

Model	Name, Condition	Location	Speed km/hr (mph)or	Sound Level dB(A)
M113A3 family including M106A2 M1064A3 M1059A3 M58A3 M730A2 M901A3 M981A3	Armored Personnel Carrier A3 version. M113, M113A1, M113A2, OSV(BMP2) have similar noise levels		Idle 16(10) 32(20) 48(30) 63(40)	85-92 106 109 114 118

Army CHPPM Steady-State Noise Levels

Model	Name, Condition	Location	Speed km/hr (mph)or	Sound Level dB(A)
M1A2,	Abrams tank	In vehicle	Idle	93
M1, M1A1			Tac idl	103
M1 chassis similar			16(10)	108
	Grizzley breacher, Wolverine Heavy assault bridge (HAB)		48(30)	114
			63(40)	117

Army CHPPM Steady-State Noise Levels

Model	Name, Condition	Location	Speed km/hr (mph)or	Sound Level dB(A)
M270	Multiple Launch Rocket System (MLRS) vehicle	In vehicle	Idle Moving, various speeds	83-98 99 to 111

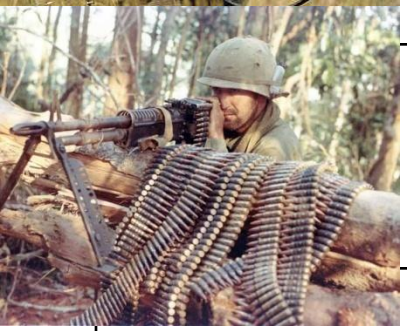
Army CHPPM Steady-State Noise Levels

Model	Name, Condition	Location	Speed km/hr (mph)or	Sound Level dB(A)
M109A3E2 other versions similar	Paladin, 155 mm self propelled howitzer	In vehicle	Idle Moving, various speeds	83-98 99 to 111

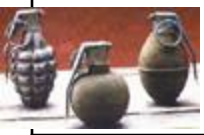
Army CHPPM Impulse Noise Levels

Photo	Model	Name	Location	Sound Level dB(P)
	M16A2	5.56mm rifle	Shooter	157
	M9	9mm pistol	Shooter	157

Army CHPPM Impulse Noise Levels

Photo	Model	Name	Location	Sound Level dB(P)
	M249	5.56mm Squad Automatic Weapon (SAW) fired from a HMMWV	Gunner	159.5
	M60	7.62mm machine gun fired from a HMMWV	Gunner	155
	M2	0.50 caliber machine gun fired from a HMMWV	Gunner	153

Army CHPPM Impulse Noise Levels

Photo	Model	Name	Location	Sound Level dB(P)
	MK 19 Mod 3	Grenade machine gun fired from a HMMWV	Gunner	145
	M26	Grenade	At 50 ft	164.3
	M3	MAAWS recoilless rifle	Gunner	190
	M72A3	Light Antitank Weapon (LAW)	Gunner	182

Army CHPPM Impulse Noise Levels

Photo	Model	Name	Location	Sound Level dB(P)
		JAVELIN	Gunner open Position Gunner enlosed position Gunner fighting position	159.9 166.2 172.3
	M119	105MM towed howitzer at charge 8	Gunner	183
	M198	155mm towed howitzer firing M203 propellant	Gunner	178

Army CHPPM Impulse Noise Levels

Photo	Model	Name	Location	Sound Level dB(P)
	M109A5 /6	Paladin, 155mm self propelled howitzer firing M4A2 zone 7 charge	In fighting compartment, hatches open except driver's	166.1
	M110A2	8-inch self propelled howitzer firing M106 projectile with a M188A1 zone 9 propelling charge,	Gunner	176.9
	M224	60mm mortar, M888 round, charge 4, QE 800 mil	0.5 m from the muzzle, 0.9 m above ground, 105 degree azimuth	185

Army CHPPM Impulse Noise Levels

Photo	Model	Name	Location	Sound Level dB(P)
		TOW II Missile from HMMWV	Gunner	179.4
	M29A1	81 mm mortar, M374A3 round with charge 4	1 m from the muzzle, 0.9 m above ground, 135 degree azimuth	178.8