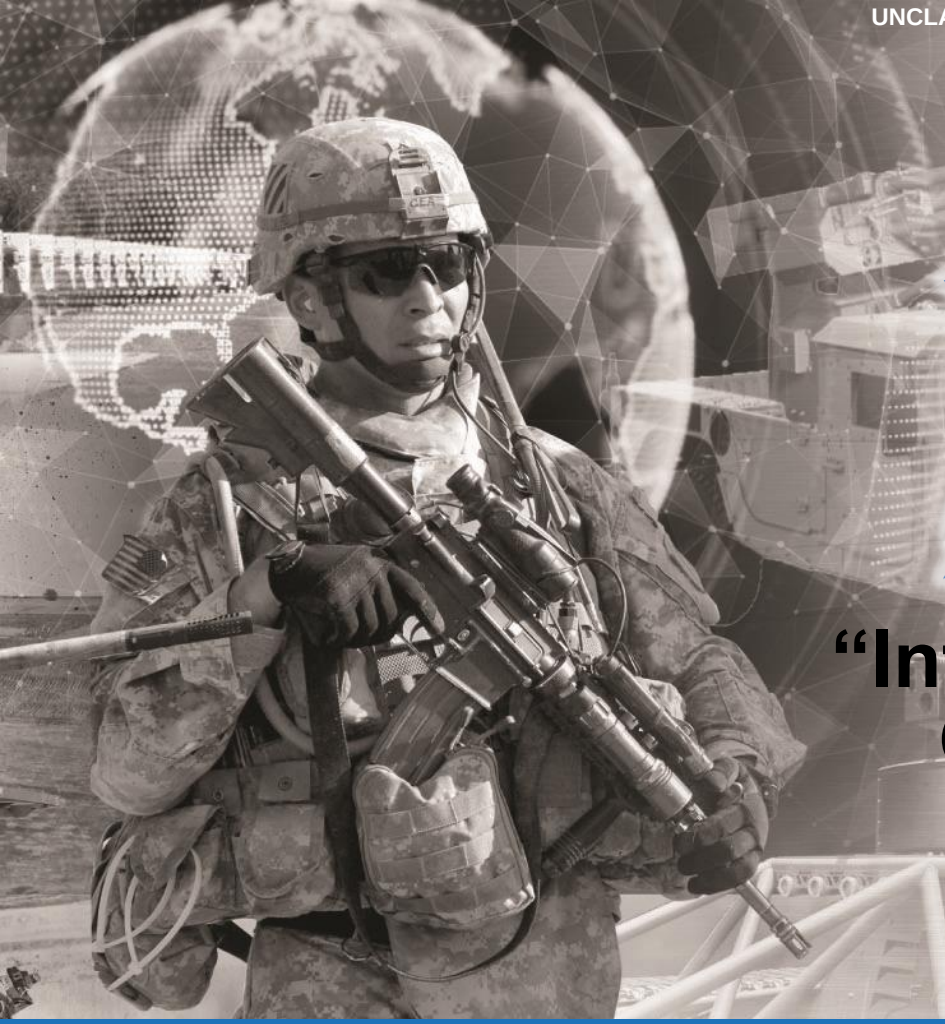

Always a Step Ahead

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ARMAMENTS

"Intended Use" and Hazard Classification Testing

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UNPARALLELED

COMMITMENT

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OVERVIEW

- Hazard classification tests are designed to accommodate all energetic materials
- A few of the TB 700-2/UN tests have conditional requirements based on the “intended use” of the energetic material
  - Function via detonation or deflagration
- This can lead to an underestimation of the hazards of deflagrating materials
  - Gun propellant case study
- Discussion of critical diameter and recommendations

A CASE STUDY, PROP X

- Gun propellant program requested supportability letter from the US Army Energetic Materials Qualification Board (EMQB)

- Double-base propellant, composition and grain geometry very similar to existing materials
  - Planned to qualify via analogy

- EMQB requested completion of several tests to justify analogy
  - Small-scale sensitivity tests (impact/friction/ESD/DSC)
  - Shock sensitivity (cap/gap)
  - Critical diameter

CASE STUDY DATA

Sample	Impact 50% (cm)	Friction TIL	Burn Time (s)	Cap Test Result	NOL Gap Test (cards)	Critical Diameter (in.)	HD
PROP X	31.6	0/10 at 192 N	3-4 s	Positive	251	0.250-0.375	1.3C
Booster Grade HE	35.5-42.1	0/10 at 360 N	~70 s[1]	Mixed[2]	~220	~0.100[3]	1.1D
IM Main Fill HE	> 100 cm	0/10 at 360 N	>90 s[1]	Negative	100-150	0.850-0.875[3]	1.1D

- Burn test conducted per the legacy 125 gram standard
- One lot of the booster grade material passed, the next lot failed (borderline)
- Critical diameter tests on the HE formulations were conducted on pressed/cast samples, not loose material

PROP X PATH FORWARD

- Preliminary testing indicated that the propellant had similar shock sensitivity and critical diameter to 90%+ nitramine HE formulations
- Full qualification of PROP X was required
- Received as a HD 1.3C material, but testing showed credible Mass Explosion and Mass Fire hazards
- Led to an internal review of TB 700-2 and UN test standards

TEST STANDARDS

- Relevant test documents when classifying the hazards of packaged energetic materials:
  - TB 700-2, Joint Technical Bulletin, Department of Defense Ammunition and Explosives Hazard Classification Procedures (DoD only)
  - Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria (UN) (International use)
- Series 6 Tests
  - **Single Package Test (a)**
  - **Stack Test or Sympathetic Reaction Test (b)**
  - External Fire Test (c)

"INTENDED TO …"

- A packaged substance **intended to function by detonation** should be initiated with the standard detonator
  - NOTE: Some substances may require a higher strength detonator *(TB 700-2 only)*
- A packaged substance **intended to function by deflagration** must first be tested with the standard detonator
  - If it does not detonate, then the subsequent trial must be conducted with an igniter…
- Exception for solid rocket motor propellants *(TB 700-2 only)*
  - Additional scrutiny on test plans and initiation methods

PROPELLANT/PYROTECHNIC DETONABILITY

- In effectively all cases, propellants and pyrotechnics are detonable substances
- Modern propellants often have similar constituents as high explosives
  - Competing requirements for insensitivity and performance for HE, propellants, and pyrotechnics
- To characterize the safety of these materials, need to know two initiation properties:
  - Critical diameter (monolithic or packed bed)
  - Shock sensitivity (amplitude and duration for detonation)
- Small changes in formulation can result in dramatic shifts in initiation and detonative properties

CRITICAL DIAMETER

- The critical diameter (or failure diameter) is the minimum diameter at which an explosive substance can maintain a detonation front
  - Diameter is usually evaluated since cylinders are the most common munition geometry
- Generally small (0-0.250”) for booster grade and legacy high explosives
- Tailorable for Insensitive Munitions HE (>4” in some cases)

BED CRITICAL DIAMETER

- For granular propellants, the packed bed of material can be evaluated for critical diameter
- Grain geometry is a major factor (effective packing density)
- Propellants/pyrotechnics results can vary widely depending on composition and grain structure (very small to 5+” critical diameters)
- During qualification of HE, critical diameter must be known for both safety and performance purposes
  - Propellant/pyrotechnic data is less available since detonation is not intended

SHOCK SENSITIVITY

- Gap testing is typically used to evaluate the shock sensitivity of an explosive substance
  - Vary the shock input from a standard donor charge by using plastic spacers (or other materials)
  - Determine the shock requirements for the material to detonate
  - Large Scale Gap Test (1.44”) or larger variants

- Existing hazard classification shock sensitivity tests are not iterative
  - UN Series 2 test offers only one diameter (1.44”) and two shock inputs (20.7 kbar or ~220+ kbar)

- Grain packing can pose challenges for gap test configurations

CONCERNS WITH EXISTING STANDARDS

- Many propellants and pyrotechnics will not detonate if initiated with the UN/TB standard detonator (~0.250-0.300” diameter)
  - Very likely misfire/dud event that’s unsafe for operators
- Most transportation/storage containers for propellants and pyrotechnics are above the critical diameter of the materials
  - These materials could be detonated given sufficient input
- Existing standards could mask detonative hazards due to under-testing with the standard detonator

RECOMMENDATIONS

- Conduct Series 6 tests with initiation schemes targeted to evaluate both the detonation and deflagration hazards
  - Detonation via standard detonator or higher strength initiation, as required
  - Deflagration via squib as prescribed

- Unconfined critical diameter testing would help ensure proper test design and yield important safety data for hazard classifiers
  - Part of the required qualification matrix for Army EMQB for propellants and pyrotechnics
  - **NOT** mentioned in UN Orange Book
  - TB 700-2 only references CD for solid rocket motor propellants

CONCLUSIONS

- Accidental initiation of explosive substances during processing, transportation, or storage often occurs via a different initiation mechanism than the intended function
- Propellant and pyrotechnic critical diameter and shock sensitivity is not well-characterized in many cases
- Hazard classification testing should be material-agnostic
  - No “intended to function via…” statements
- Modifications to the test standards would result in better qualification of the detonation and deflagration hazards of propellant and pyrotechnic materials

Questions?