Development and Characterization of New Families of Explosives Able to Generate Specific Effects

C. Collet, A. Combe, J. Groux, M. Werschiné

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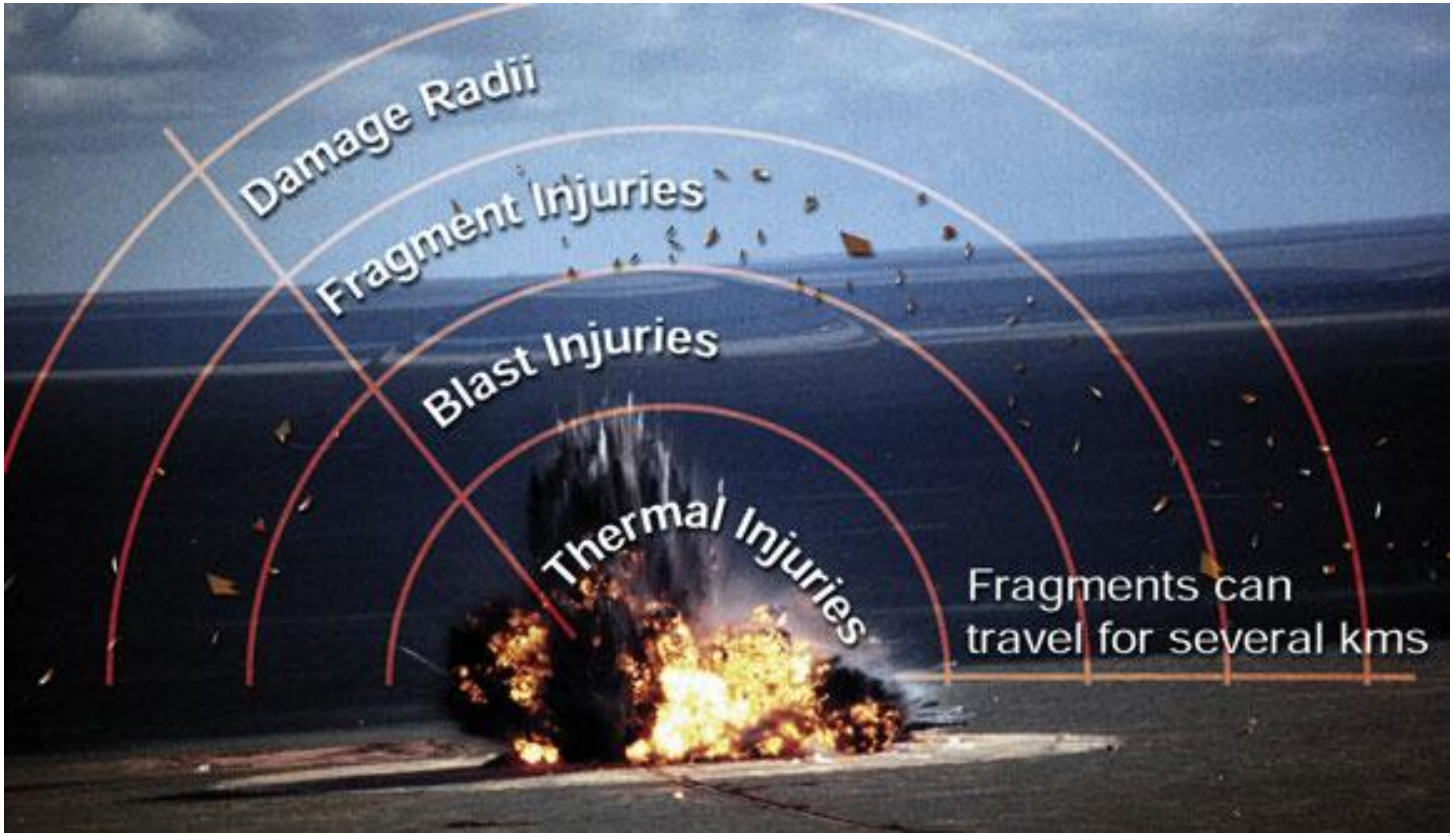
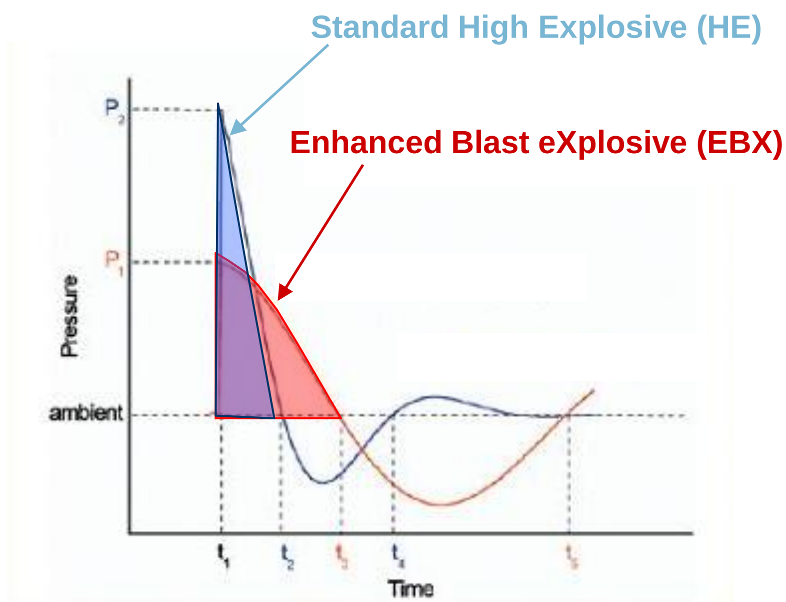
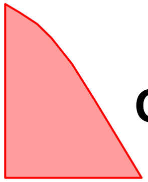
EFFECTS DUE TO THE DETONATION OF A STANDARD MUNITION



➔ What are Enhanced Blast Effects?

- Blast Effects are **all the effects due to the detonation products which expand in the air** after the detonation: aerial shockwave + fireball
- It is possible to obtain enhanced blast effects by **tailoring the constituents of the energetic material composition** so that the detonation products could react with air: afterburning phenomena





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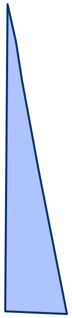

⚠ **Warning**: Enhanced Blast Effect strongly depend on obstacles, that is to say on the **chamber geometry**

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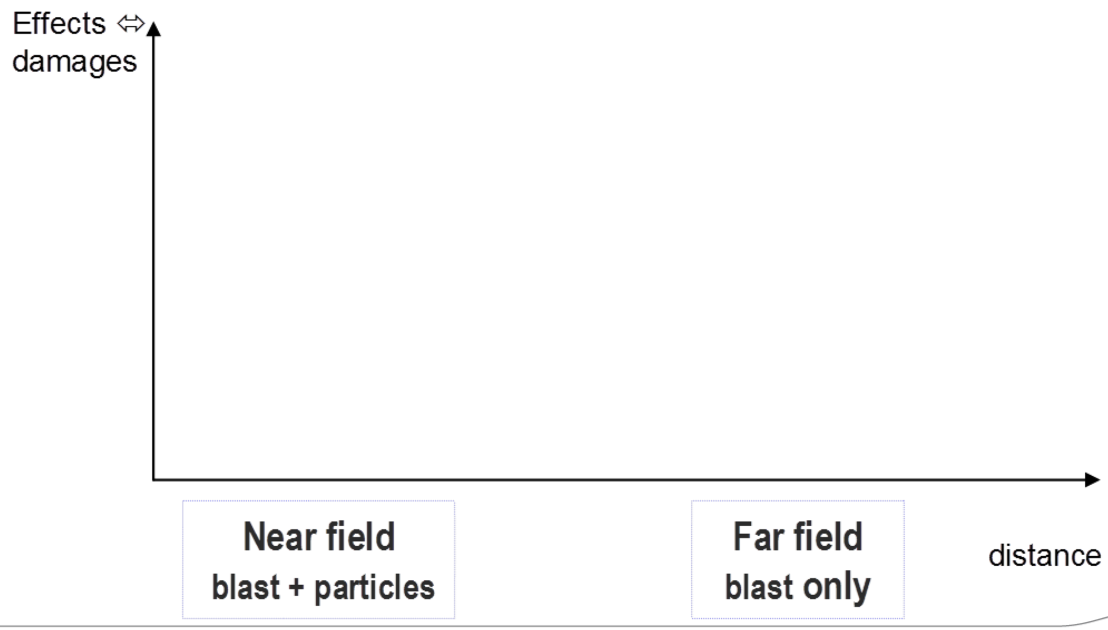
INTRODUCTION (2/2)

➔ What are Low Collateral Damages?

- The objective is dual:
  - **Increasing damages in a reduced area** around the explosion point
  - **Strongly decreasing the damage effects beyond the limits of this area**
- By **converting a part of the energy of detonation into kinetic energy** for the projection dense inert metallic particles, it is possible to reach the targeted effects:



OUTLINES

→ The protocol is similar for the optimization of both effects

→ Phase 1

- Evaluation of a **great number of compositions** at small scale:
  - Confined vessel for Enhanced Blast effects
  - Safety, mechanical behavior and ability to detonate for Low Collateral effects
- Choice of the best candidates (the “family leaders”) on the basis of pertinent criteria adapted to each effect

→ Phase 2

- Evaluation of **each family leader at larger scales** :
  - Performances regarding the considered effect
  - First characterizations in detonics and vulnerability
- Numerical simulations with a model able to reproduce the phenomena occurring in reactive flows containing gases and particles: DECO model

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Phase 1: Small Scale Selection

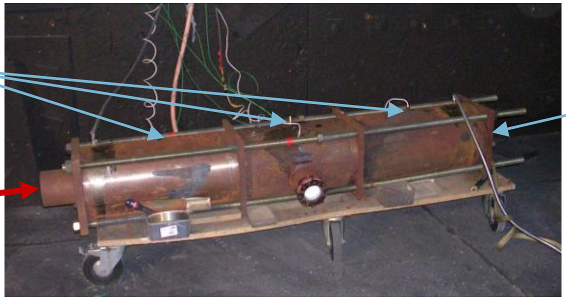
SMALL SCALE SELECTION FOR ENHANCED BLAST EFFECTS

- **The recipe for a good Enhanced Blast cast PBX (EB-PBX):**
  - **Energetic charges** (RDX or HMX or CL-20 + AP)
  - A **high content of metallic particles able to react with air** (Al, Mg, B…) because heat of combustion of metallic particles with air is generally much higher than heat of detonation of a typical explosive (e.g. heat of combustion of Al particles is 3 times greater than TNT heat of detonation)
  - A **polymeric binder**

- **Influence of formulation parameters and structural arrangement :**
  - **Content, type and particle size** of metallic particles & energetic charges
  - **Mono-compositions** vs **dual compositions** with an EB-PBX surrounding a standard PBX core

- **14 compositions were selected for small scale characterizations in a confined vessel, in comparison with 2 EB-PBX references: B2258A and B2211D**

3 thermocouples and
3 pressure gauges

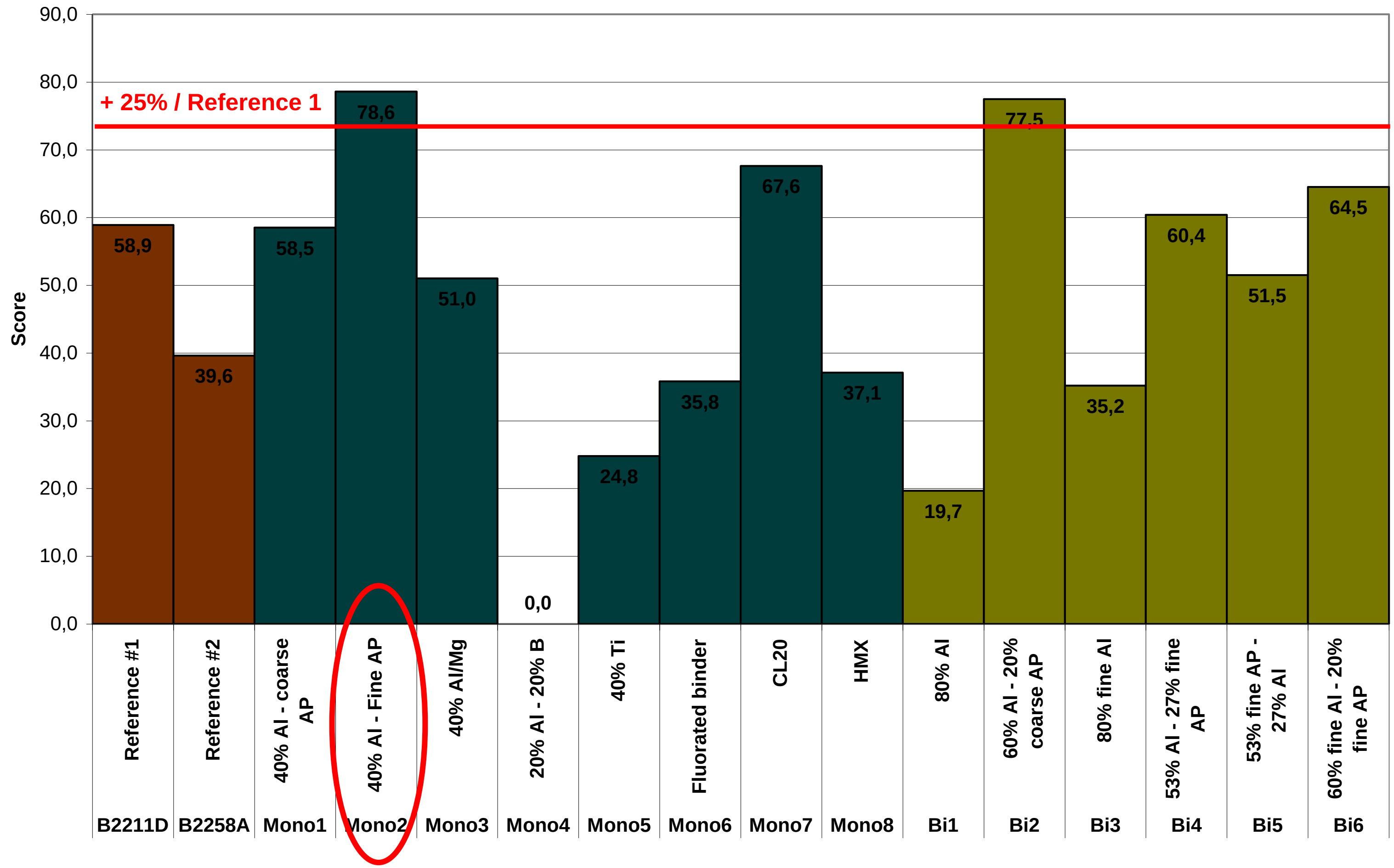


1 photodiode

Initiation

SMALL SCALE SELECTION FOR ENHANCED BLAST EFFECTS

➔ Score of EB-PBX Compositions vs EB-PBX References



1 concept has been selected for further investigations: Mono2 → B2514A

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SMALL SCALE SELECTION FOR LOW COLLATERAL EFFECTS

- **Low Collateral Effects PBX compositions have the following characteristics:**
  - They contain a **high weight ratio of tungsten (W) powder** (with different particle size distributions): from 51 to 79.5%
  - Hence, their density is **strongly increased** compared to a standard PBX: from 2.95 to 5.44
  - Only inert binder was used for these compositions, in association with explosive charges (RDX or CL20)

- **10 compositions have been chosen after a first selection on the basis of feasibility criteria. Then, they have been evaluated in:**
  - Safety
  - Mechanical properties
  - Thermal analysis
  - Ability to detonate in stationary regime in unconfined cylinders, Ø 30 and Ø 50 mm

- **After this second selection phase, the family leader for low collateral effects has been named B2277A**

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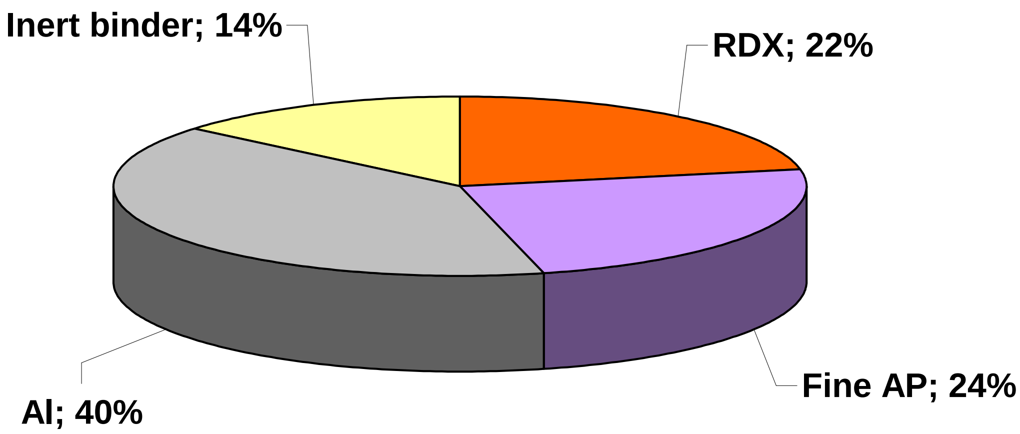
SMALL SCALE SELECTION – FAMILY LEADERS

➔ The constituents of family leaders for both effects are the following:

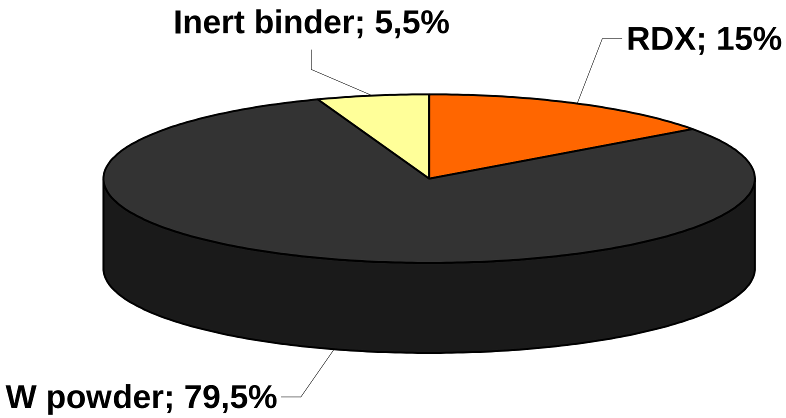
B2514A for Enhanced Blast Effects

Density = 1.87



B2277A for Low Collateral Effects

Density = 5.44



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Phase 2: Evaluations at Larger Scales

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PERFORMANCES AT LARGER SCALE – TEST SET UP

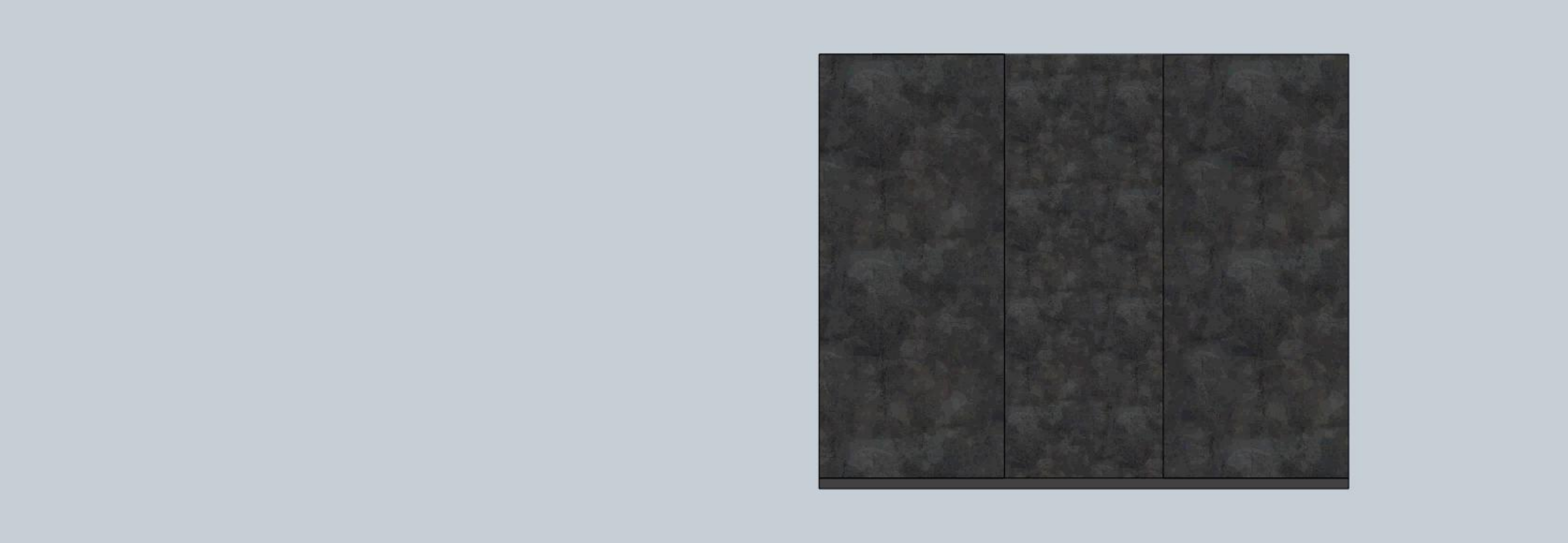
For B2514A:

- Explosive charge: ∅ 90 H 100 mm
- 1 overpressure sensor for incident pressure, at 4 m from the charge

For B2277A:

- Explosive charge: ∅ 100 H 140 mm
- 3 momentum gauges for total impulse measurement (blast + particles effect), at 2, 3 and 4 m from the charge
- 3 overpressure sensors for reflected pressure associated to each momentum gauge
- 1 overpressure sensor for incident pressure, at 4 m from the charge

All the sensors are placed at 1.8 m from the ground, as well as the explosive charge



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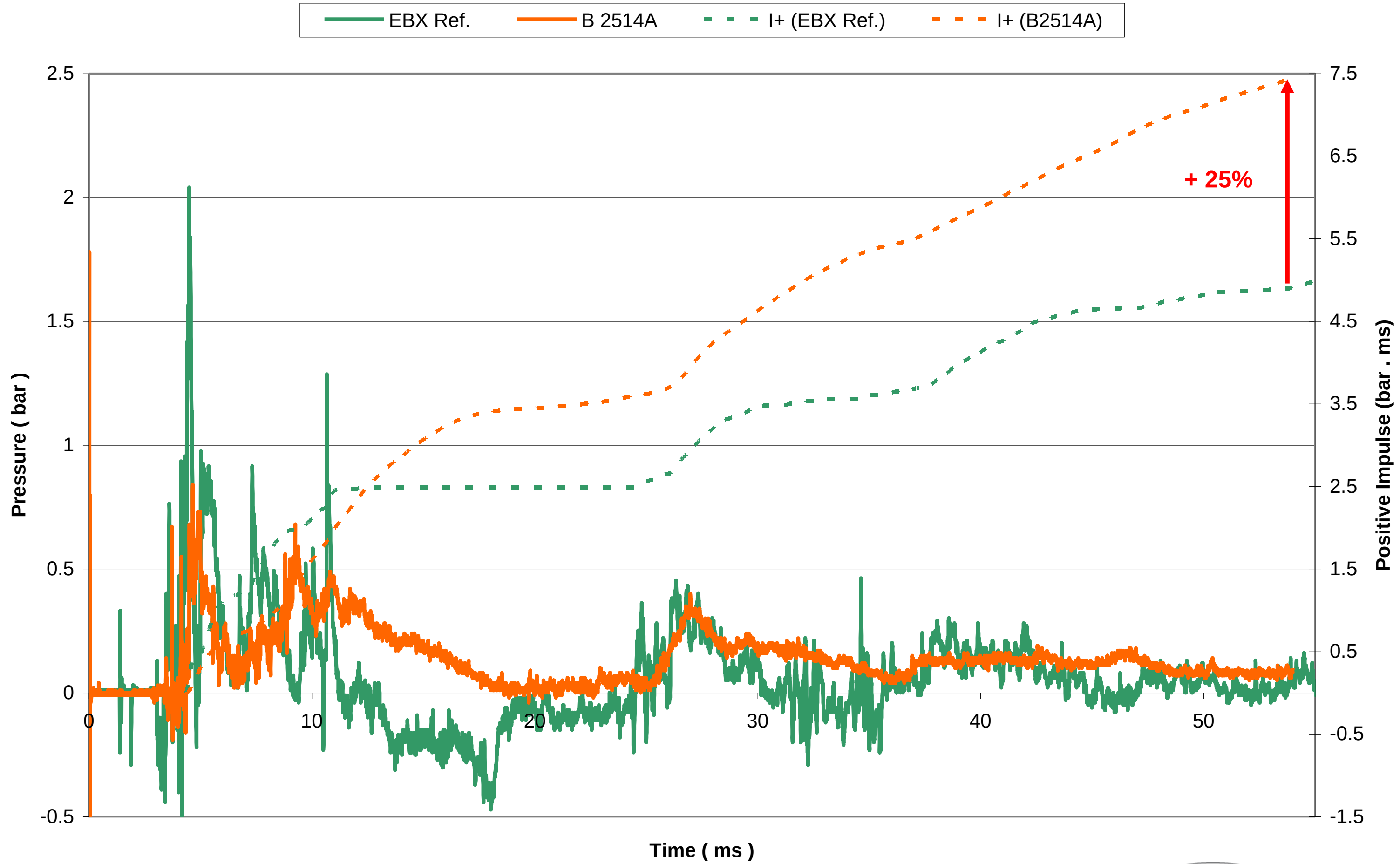
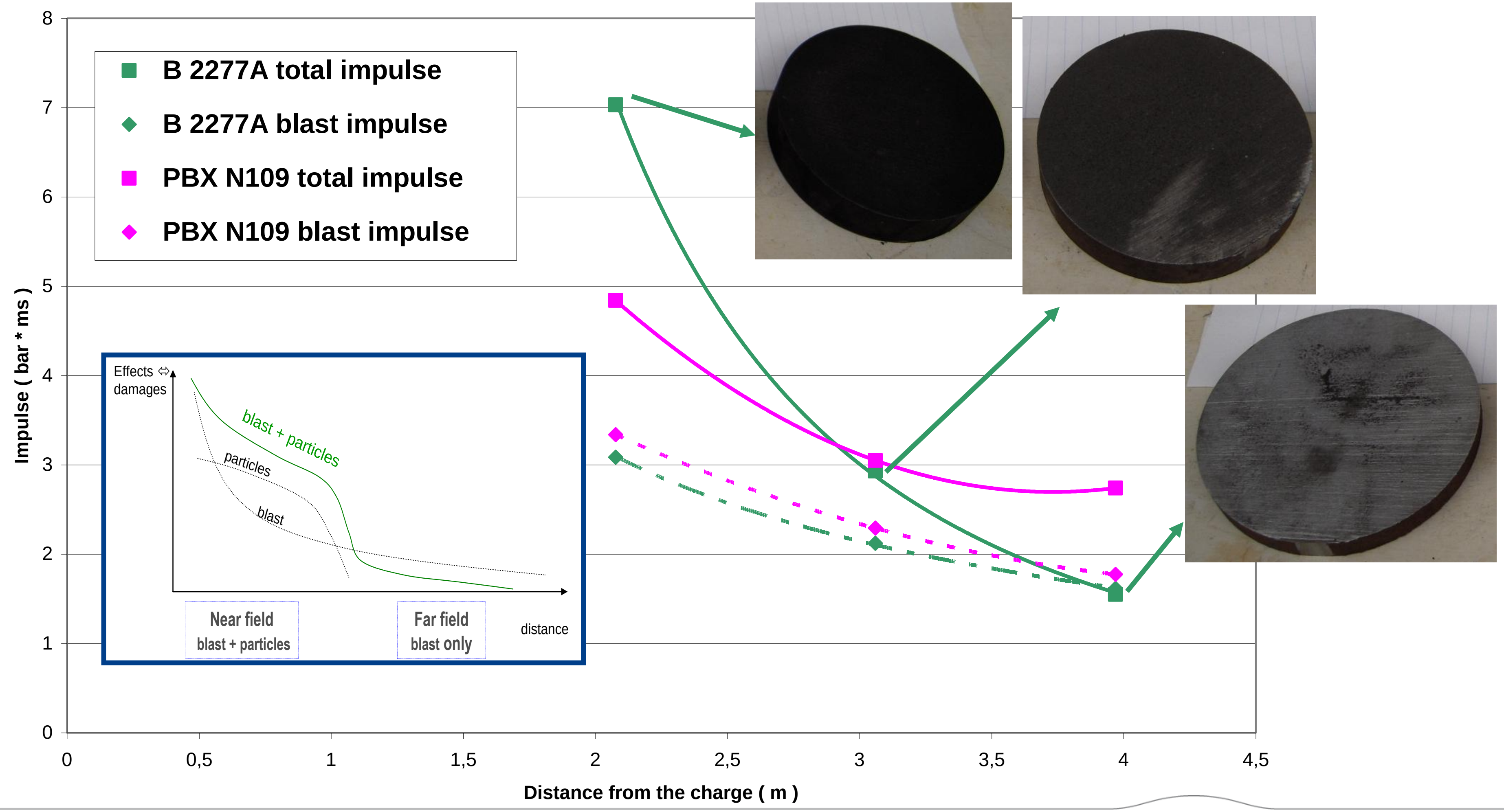
PERFORMANCES AT LARGER SCALE FOR ENHANCED BLAST EFFECTS

- **Comparison between B2514A and an EB-PBX Reference**
- **Overpressure histories at 4m from the charge and corresponding positive impulses**



PERFORMANCES AT LARGER SCALE FOR LOW COLLATERAL DAMAGES

➔ **Total and Blast impulses at different distances from the charge – Comparison between B2277A and PBXN109**



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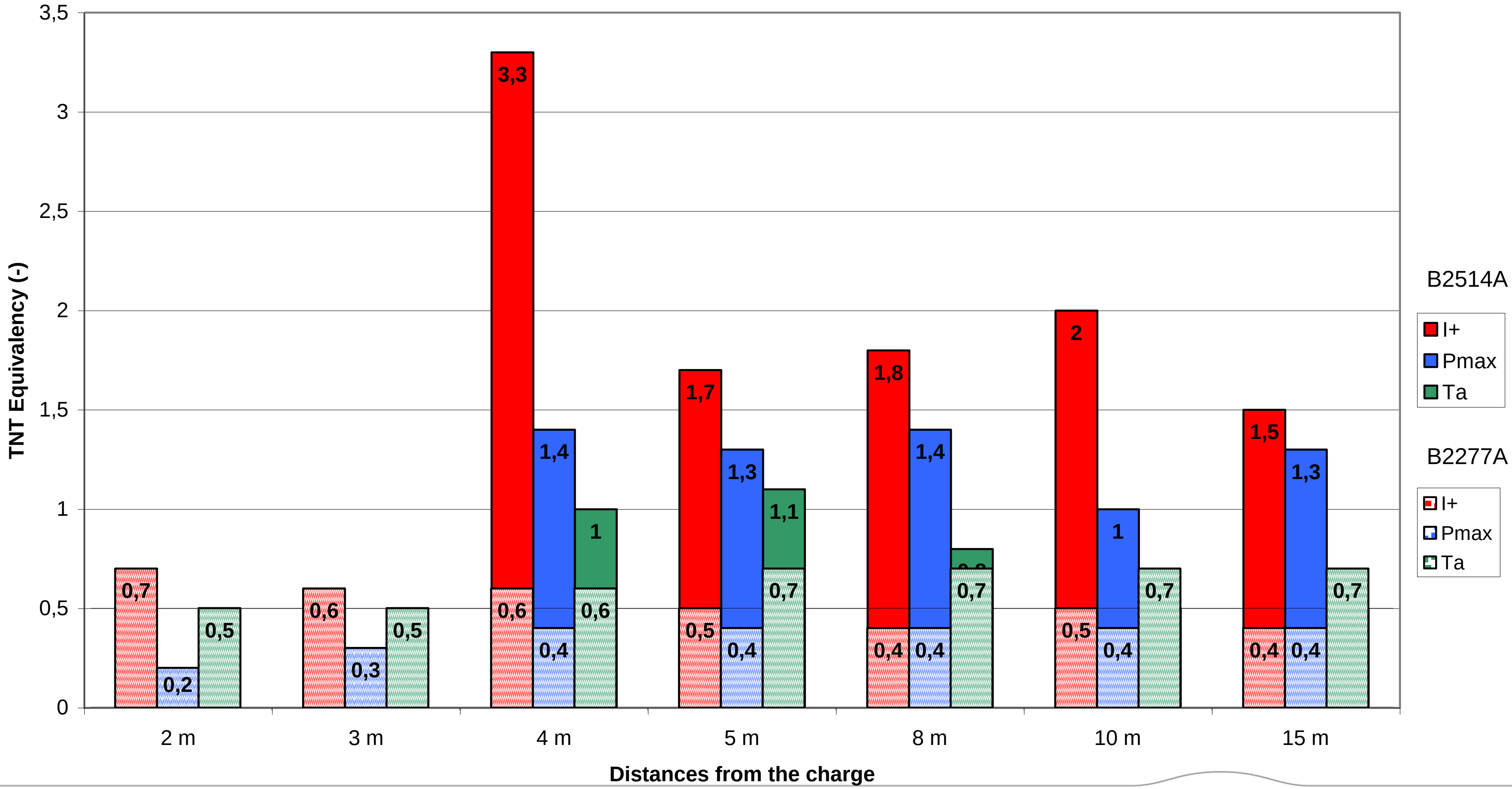
TNT EQUIVALENCIES IN OPEN FIELD

- ➔ **Evaluation of both concepts in open field (Ø 160 H160 on the ground)**
- ➔ **TNT Equivalencies from overpressure histories at 2 to 15 m from the charge**



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FIRST CHARACTERIZATIONS IN DETONICS AND VULNERABILITY

CHARACTERIZATIONS	B2514A Enhanced Blast PBX	B2277A DIME PBX
Safety at small scale	Not sensitive to impact, friction nor ESD	Not sensitive to impact, friction nor ESD
Self Ignition Temperature	226°C	217°C
Gap Test	> 70 mm of PMMA (LSGT, ∅ 75 mm)	165 acetate cards (ISGT, ∅ 40 mm)
Detonation Velocity (∅ 50 mm, unconfined)	6000 m/s	4400 m/s
Critical diameter	30 mm < ∅c < 40 mm	5 mm < ∅c < 10 mm
Asymptotical velocity of cylinder expansion (inner diameter: 3 in.)	1175 m/s	960 m/s
Thermal Initiation Temperature	163°C	133°C (no violent reaction)
Bullet and Light Fragment Impacts (STANAG procedures 4241 & 4496)	Type VI at BI (420 m/s) Type V at BI (850 m/s) Type V at LFI (1830 m/s)	n/a

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PRESENTATION OF THE NUMERICAL MODEL DECO

- **DECO = DEtonation + COmbustion model**

- **OBJECTIVES:**
  - **To support development studies of new kinds of explosives**, such as Multiphase Blast eXplosives (MBX), from small scale to representative scale
  - **To predict performances**: pressure levels, velocity, temperature profiles, even in complex configurations

- **The physical phenomena involved require a multiphase and multispecies model able to take into account:**
  - **Detonation and reactive expansion** of detonation products (non-ideal explosive)
  - **Instable interface with air** (pressure gradients, shock waves, impacts on obstacles) drives the mixing with air and possible afterburning (especially for Al particles in B2514A Detonation products)
  - **Thermal and mechanical non-equilibrium** between gas and particles (especially for W solid particles in B2277A detonation products)

- **To solve accurately sharp discontinuities (shocks and instable interfaces), An Adaptive Mesh Refinement strategy is coupled with the DECO model**

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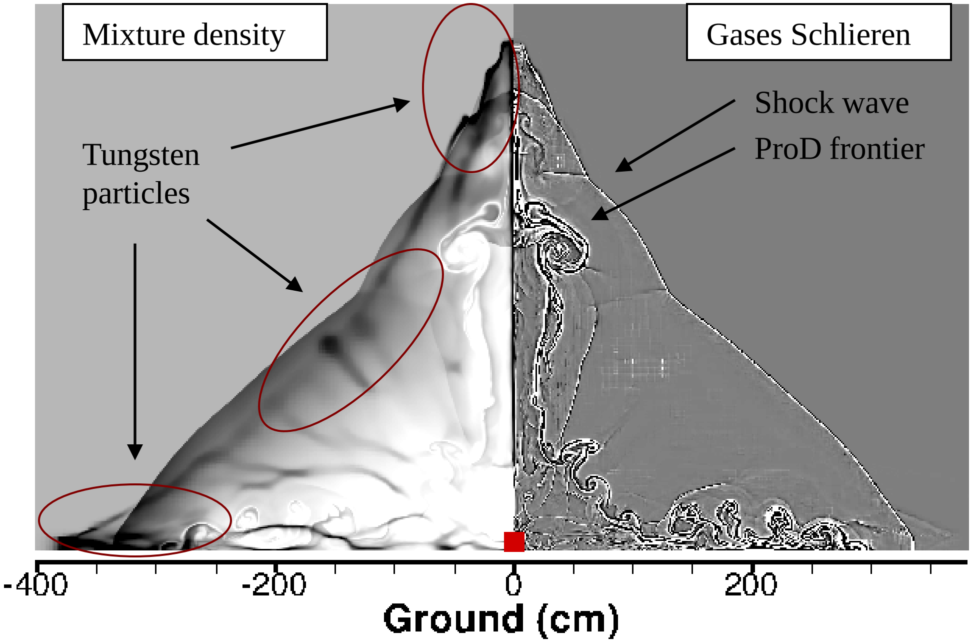
PRESENTATION OF THE NUMERICAL MODEL DECO

- **An example : Detonation of a B2277A cylinder (Ø 160 H160 mm) put on the ground**
- **Experiments and simulations are in qualitative agreement:**



- **Numerical works are still in progress:**
  - To validate the particles motion
  - To improve the representativeness (effect of confinement, Detonation wave role on particles trajectories)

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CONCLUSION & PERSPECTIVES

- **For the last 5 years, new families of cast PBX compositions have been developed and are now available for the generation of 2 different kinds of effects:**
  - For enhanced blast effects → **B2514A**
  - For low collateral effects → **B2277A**
- **Both compositions have demonstrated their respective performances considering the required effects, from small scale to larger scales**
- **They have also been characterized in safety, mechanics, shock sensitivity, detonics and vulnerability**
- **All the data are now available for up scaling their manufacturing at industrial scale**
- **In parallel, works have been conducted on a numerical model able to simulate the potentially reactive propagation of multiphase multispecies detonation products generated by such MBX: DECO**

- **Acknowledgement:**
  - This work has been funded by the French MoD, DGA

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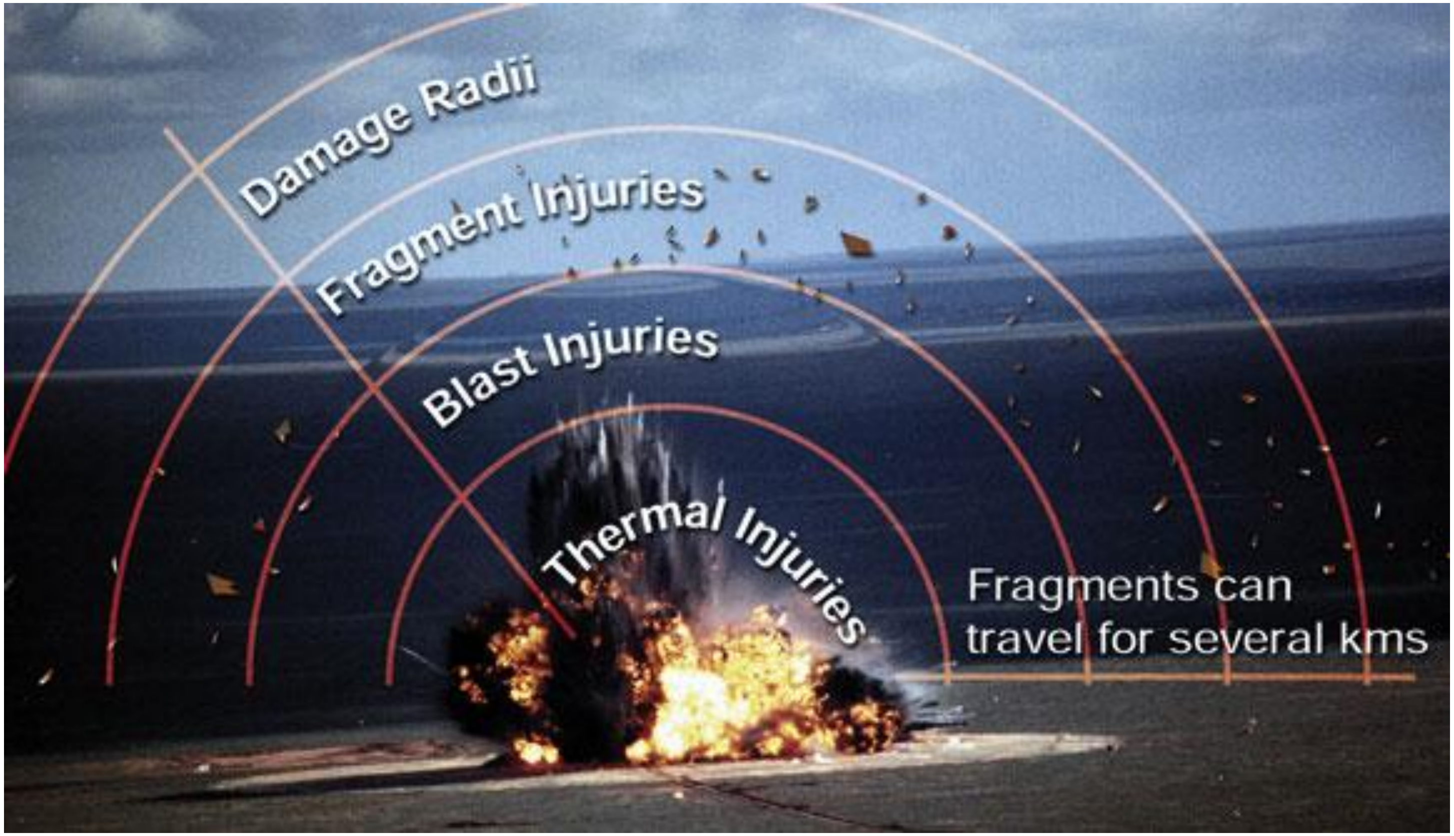
Thank you for your attention



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KEY MISSIONS, KEY TECHNOLOGIES, KEY TALENTS

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