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EUROPEAN MANUFACTURERS GROUP

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METHODOLOGY TO PREDICT SYMPATHETIC DETONATION BETWEEN MUNITIONS STORED ON A PALLET

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CONTENTS

➢ CHALLENGES / METHODOLOGY

- NUMERICAL REACTIVE MODEL EXTENSION
- LABORATORY TEST – DESIGN AND CALIBRATION
- NUMERICAL REACTIVE MODEL FITTED ON THE LABORATORY TESTS RESULTS
- CONCLUSIONS

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CHALLENGES

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- For storage configuration, porous material is a good way to reduce sympathetic detonation risk
- But induced solicitations are modified (Pressure ↗ and duration ↘)
- Domain not covered by classical numerical reactive model or analytical initiation criteria

No prediction capacities with existing tools at the laboratory scale (necessity to perform expensive full scale tests to design barrier)

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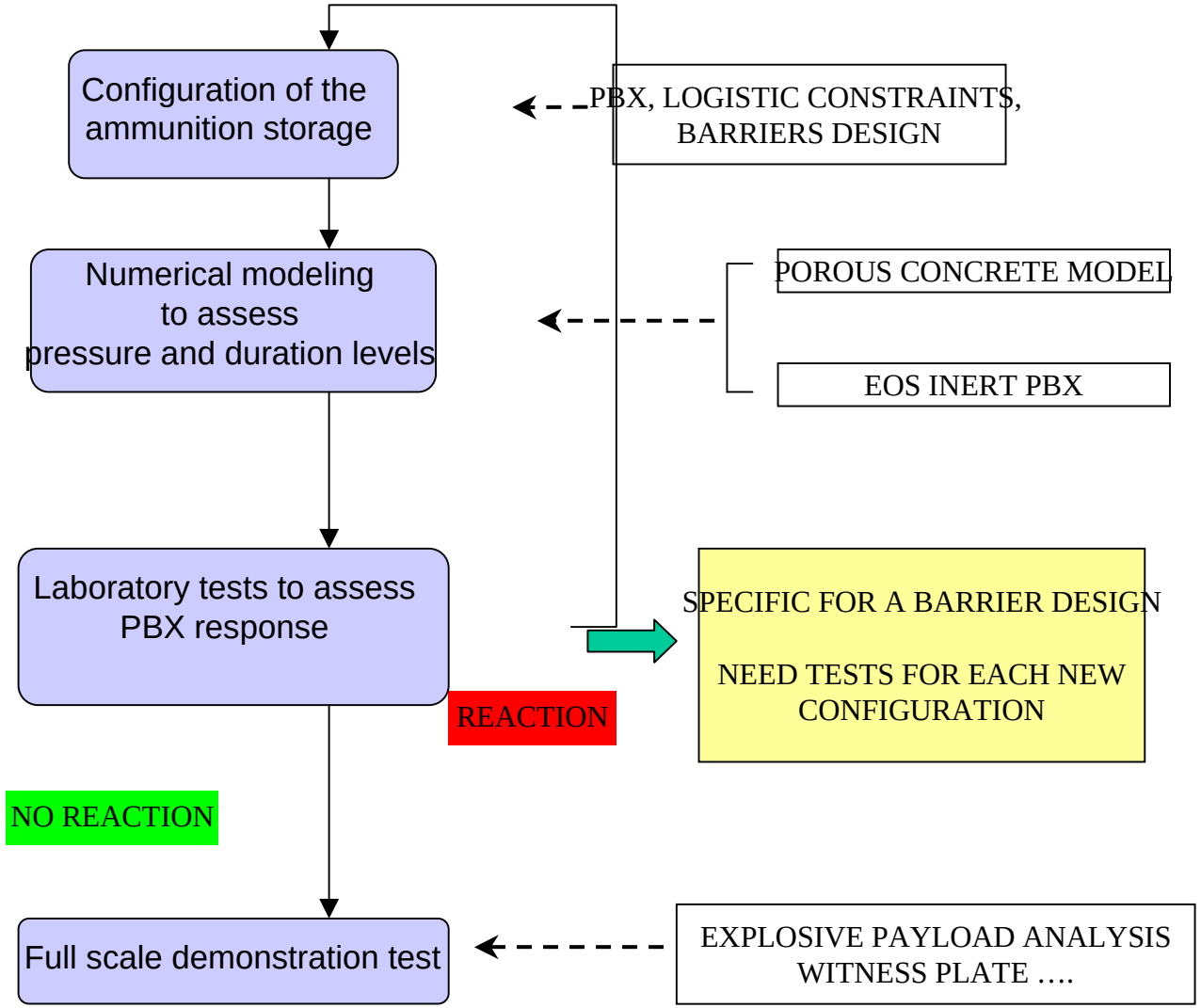
METHODOLOGY

Key-steps of SME protocol



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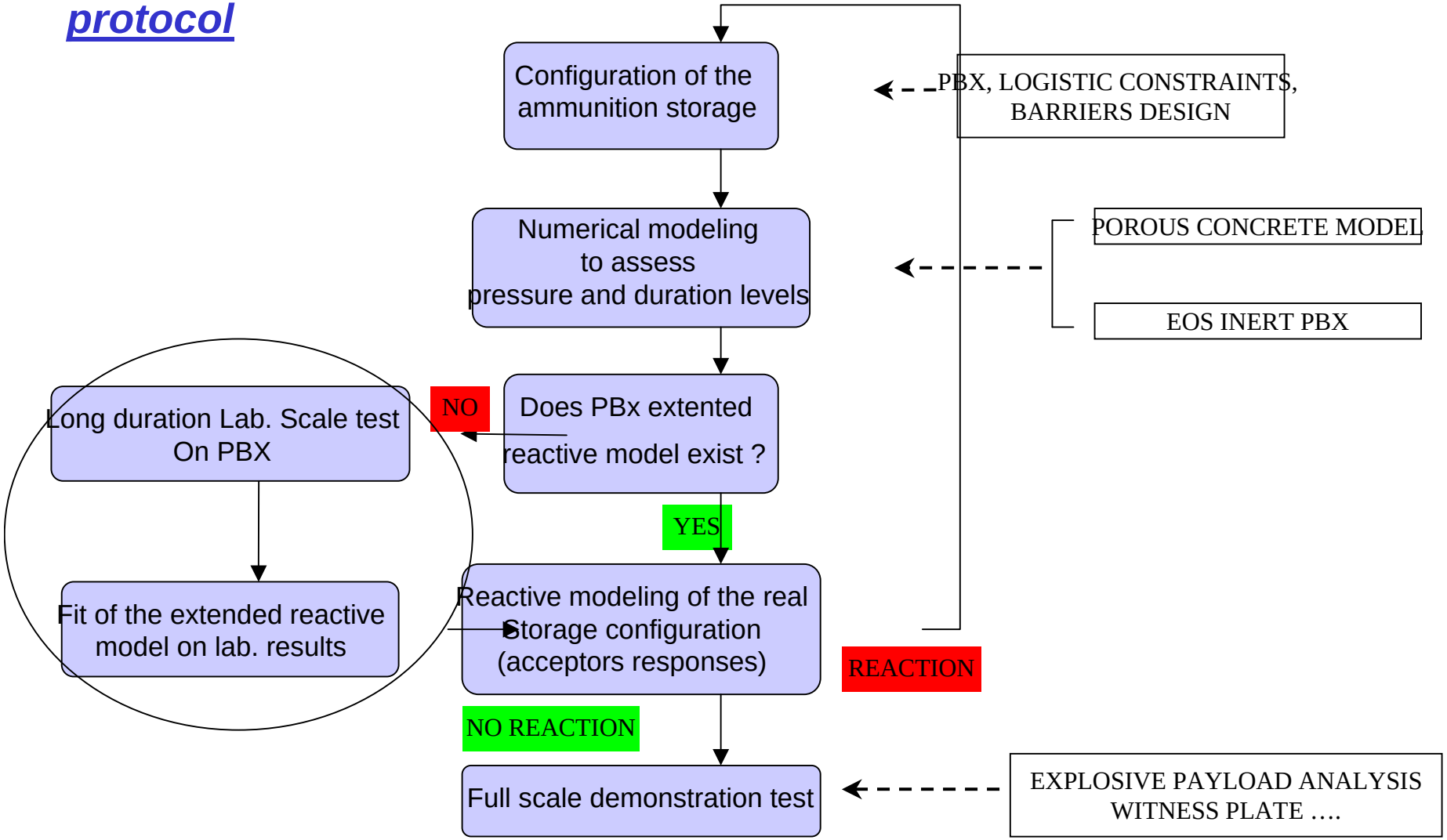
METHODOLOGY

Key-steps of SME protocol



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NUMERICAL MODEL

BASE REACTIVE MODEL : NIDEX

Fitted in high pressure domain

$$\frac{d\lambda_1}{dt} = I\,(1-\lambda_1)^{2/9}\left(\frac{\rho}{\rho_0}-1\right)^4 + G\,(1-\lambda_1)^{2/9}\lambda_1^{2/3}P^n$$ Lee – tarver model

$$I = 0, \lambda_i > \lambda_{i\max}$$

$$\frac{d\lambda_2}{dt} = K\ \lambda_1\ (1-\lambda_2)^a P^z$$ Guirguis model

Extension **When $P_{shock} < P_{threshold}$**

I, G and λ_{imax} : not constants

function of shock pressure

$$I = I_0\left\{\min\left(1, \frac{Ps}{Pth}\right)\right\}^n$$

$$G = G_0\left\{\min\left(1, \frac{Ps}{Pth}\right)\right\}^n$$

$$\lambda^* = \lambda_0^*\left\{\min\left(1, \frac{Ps}{Pth}\right)\right\}^n$$

NIDEX Modification to limit kinetic reactions below a threshold pressure

A single model is preserved for all the solicitations

Restricted number of SGT to adjust the parameters

$P_{treshold}$, n : parameters

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LABORATORY TEST DESIGN

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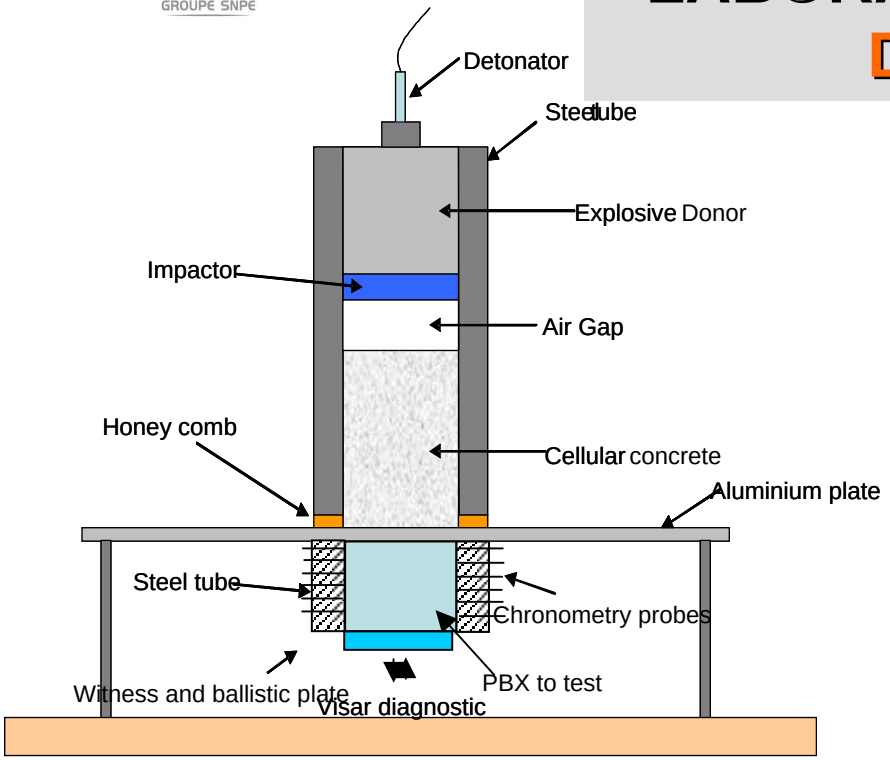
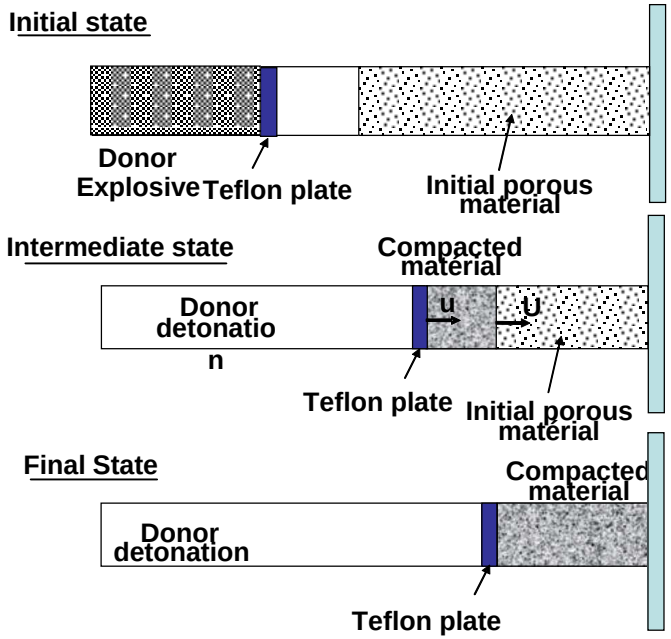
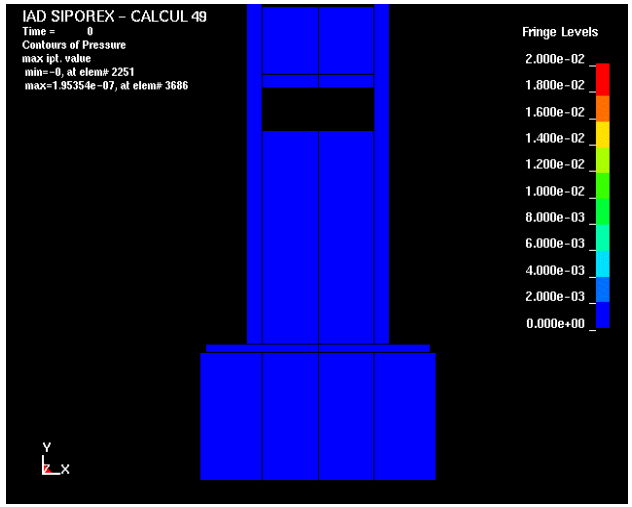




Softened Gap Test



Snowplough model

$$u_c = \frac{m_t u_t + m_{CC} u_{CC}}{m_t + m_{CC}} = \frac{m_t u_t}{m_t + m_{CC}}$$

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CALIBRATION - 1

Cellular concrete behavior law

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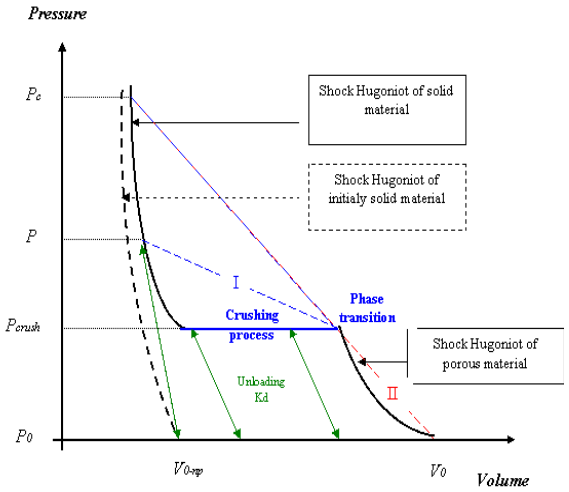
General behavior law



$$P(V,E) = F(V) + \gamma\, E$$

$$P(u) = Pcr + \frac{\rho_0}{Vcr}(C + S\,u)\,u$$

$$V(u) = \frac{Vcr}{\rho_0}\,\frac{C + (S-1)\,u}{C + S\,u}$$

Specific behavior law

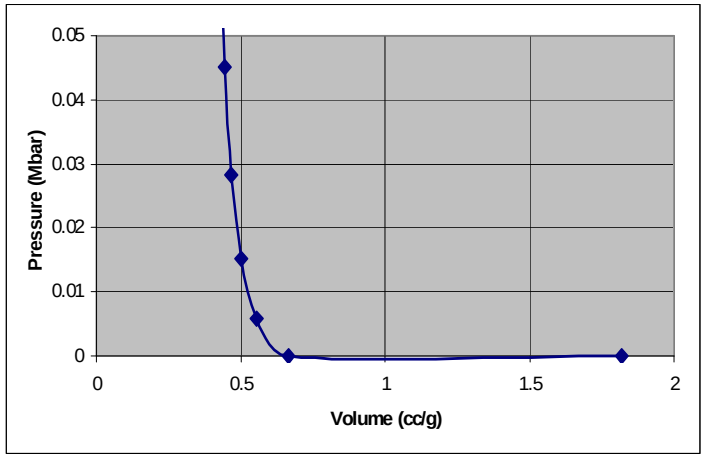
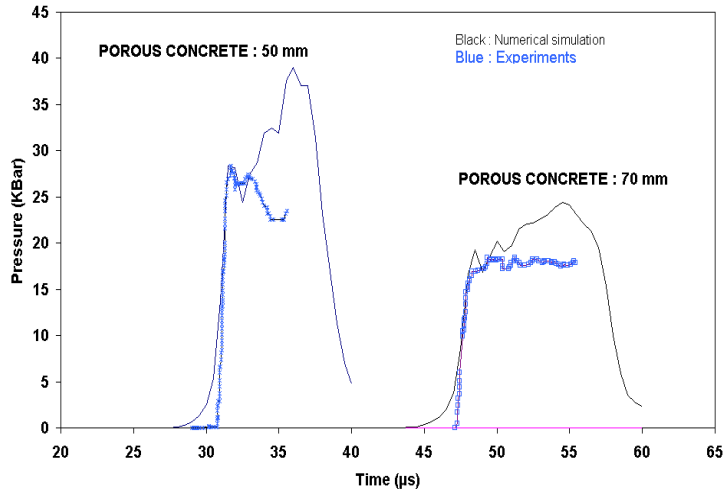
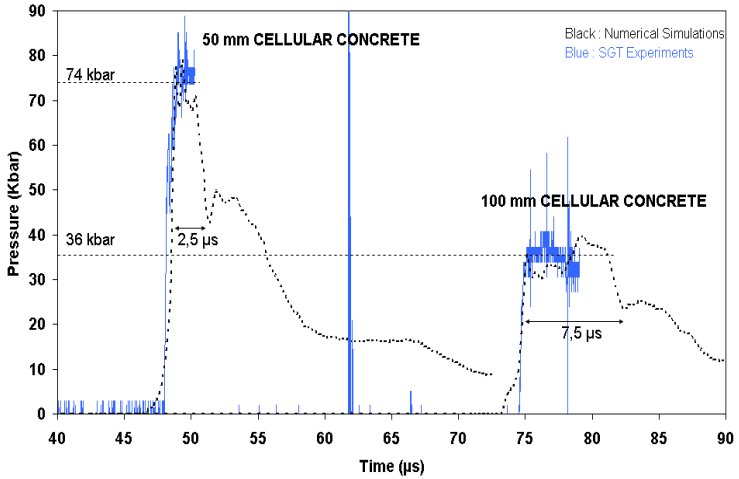


Plate impact



SG tests (donor explosive)



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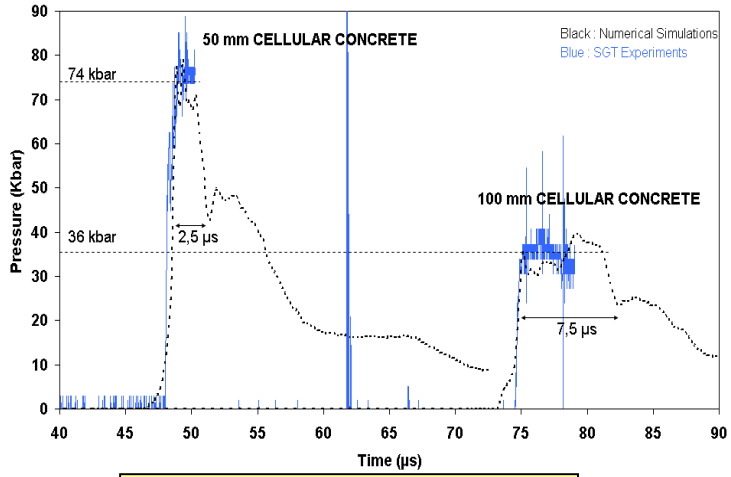
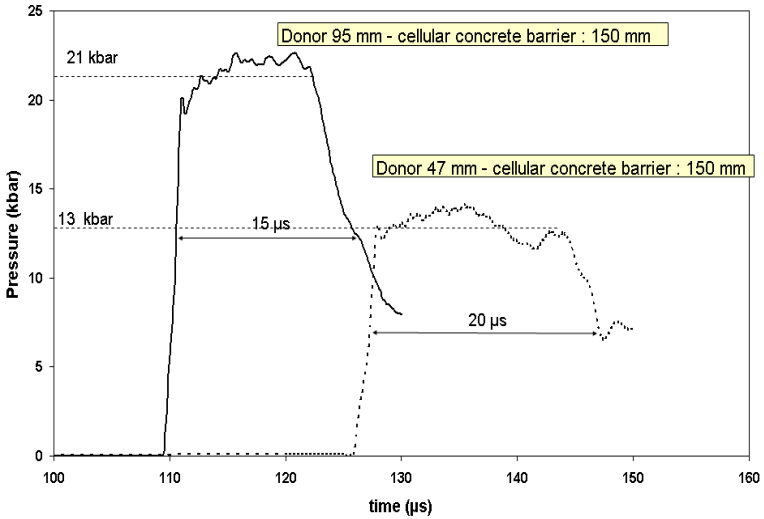
CALIBRATION (2)

Calibration curve (pressure – duration domain)

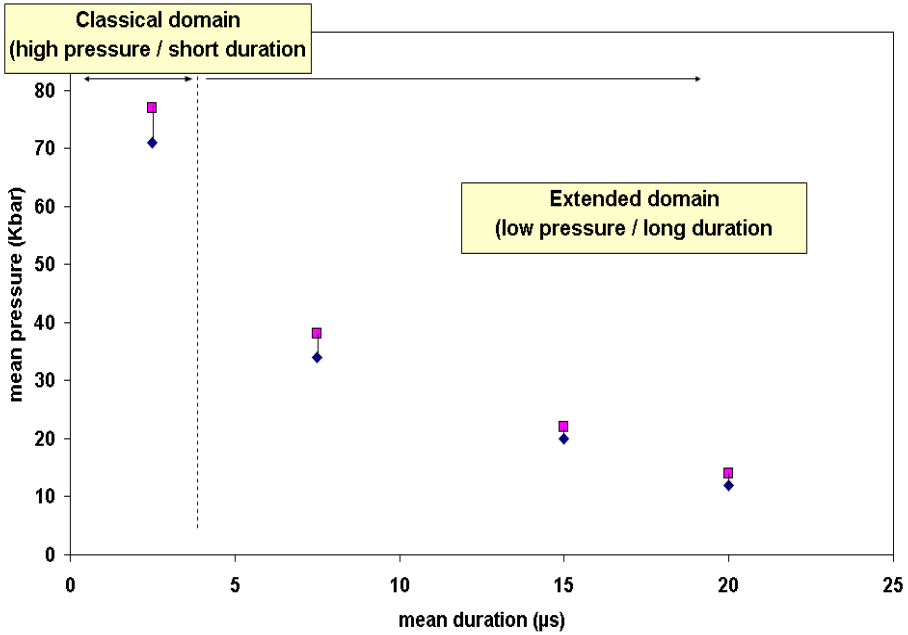
SG Tests and simulations



SG Tests simulations



Pressure – duration domain cover by the SG Test



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Laboratory tests results (1)

TESTED COMPOSITION HBU 88B (88%RDX, 12% PBHT)

Shot number	Explosive Donor height (mm)	Cellular concrete height (mm)	Sample dimensions ϕ /h (mm/mm)	Test sample Mean pressure (Kbar)	Mean duration (µs)
1	95	100	90/45	36	7.5
2	95	150	90/45	21	15
3	47	150	90/45	13	20

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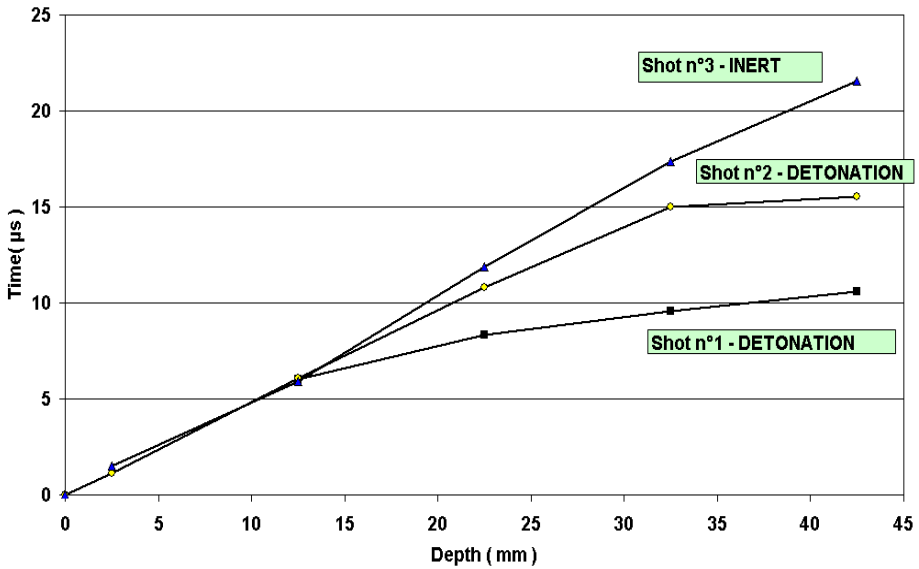
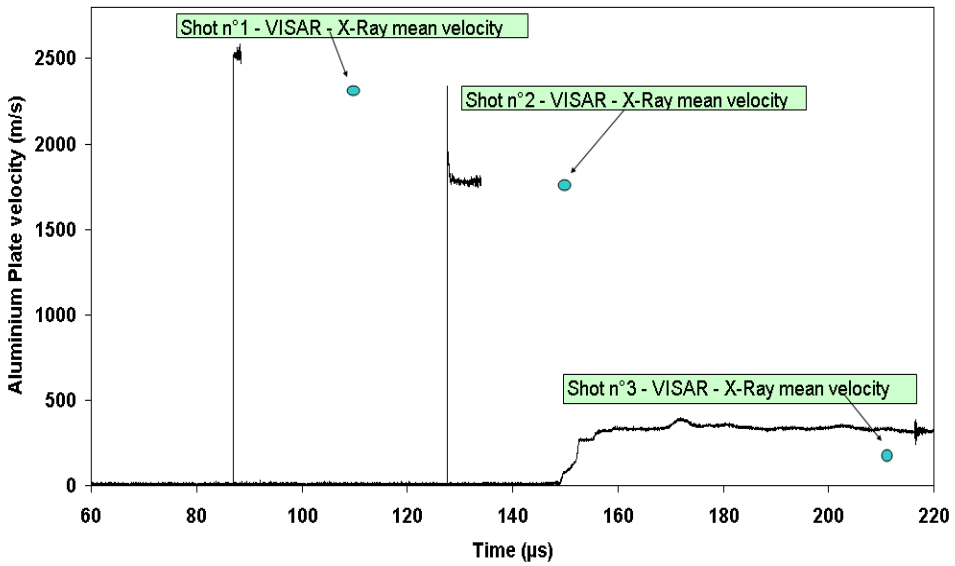
Mean trajectories

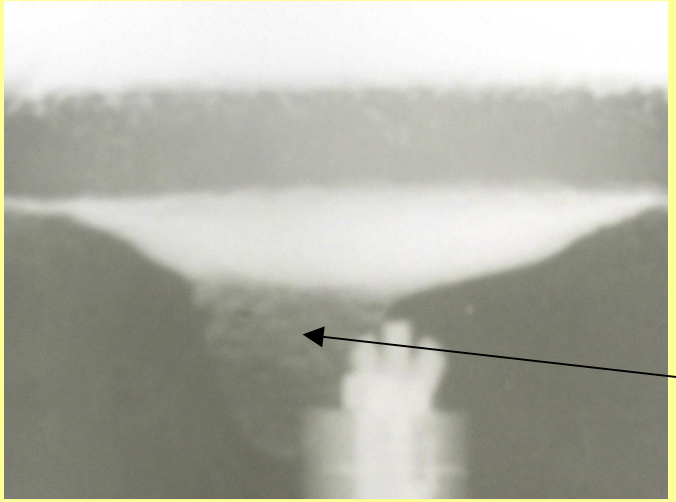


VISAR and X-Rays velocities

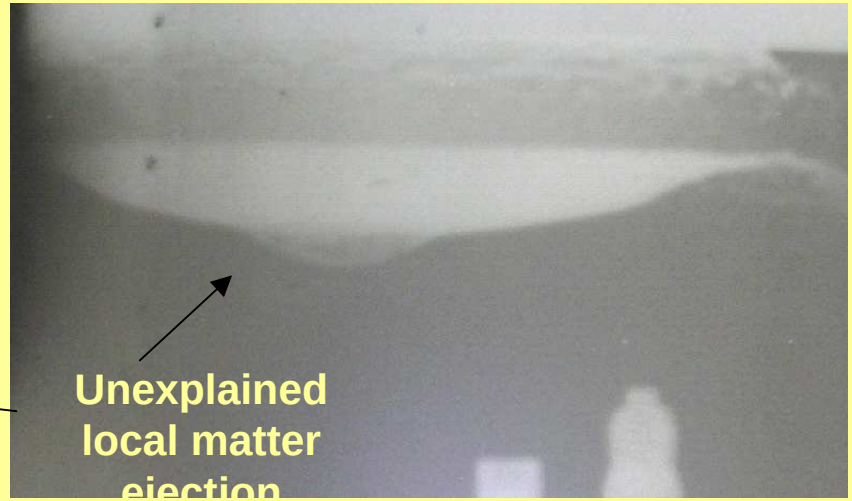


Laboratory tests results (2)

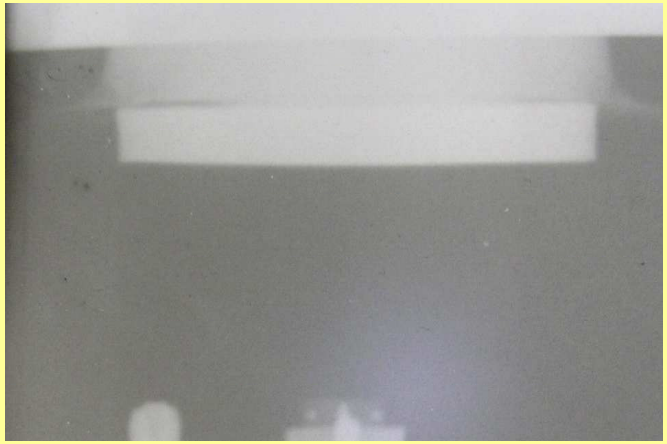
X-RAYS PICTURES



Shot n°1 – Detonation - Mean velocity : 2268 m/s



Shot n°2 – Detonation -Mean velocity : 1712 m/s



Shot n°3 – No Detonation - Mean velocity : 250 m/s

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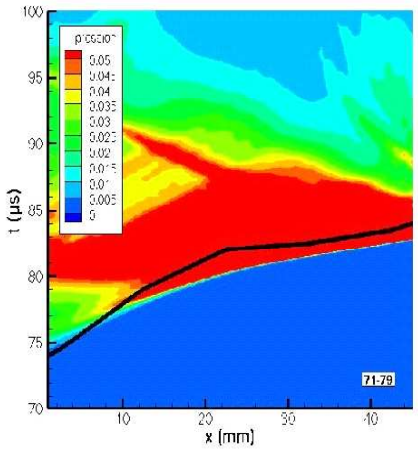
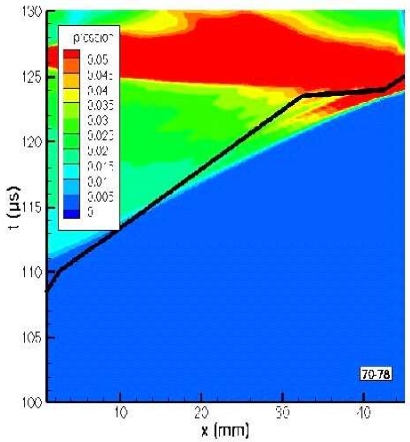
Extended model results

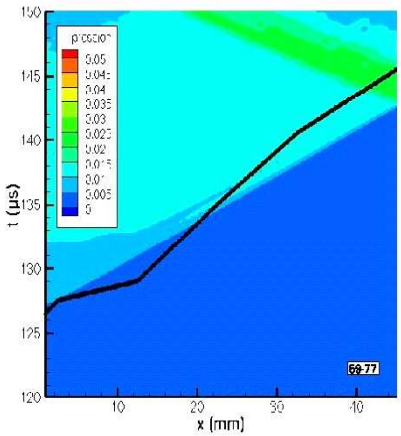
Measured shock trajectories and calculated pressure fields in the HBU SGT shots



Shot 1



Shot 2

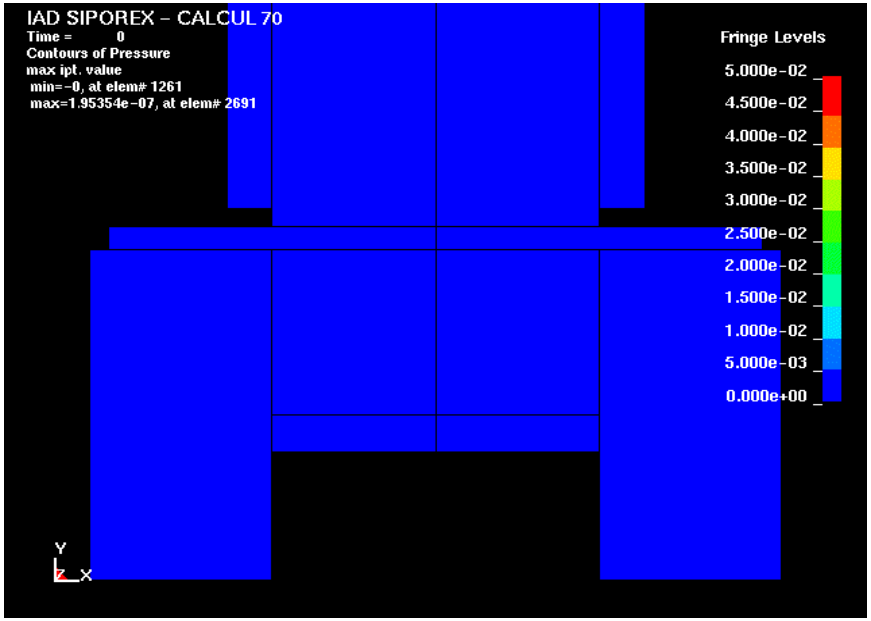


Shot 3

<u>Extended Model parameter</u>

$P_{threshold}$ = 30 Kbar

n = 2



Good agreement between experimental / calculated :

Diagnosis and trajectories

Tendency to overestimate reactivity

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CONCLUSIONS

- A numerical tool has been developed and integrated in the SME protocol to predict sympathetic detonation for ammunitions storage configurations

- NIDEX existing numerical model has been modified to take into account low pressure long duration shock domain

- New laboratory test has been designed: Softened Gap Test to produce required levels of solicitation

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CONCLUSIONS

- **Extended model has been fitted on HBU88B SG tests**

- **Good agreements have been found between calculated/experimental results for diagnosis (go/no go) and waves trajectories.**

- **Some improvements must be made for cellular concrete behavior law and low pressure explosive modeling (chronometry + VISAR)**

- **Next step : application of the whole methodology to a real case**

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