37th Annual Gun & Ammunition Symposium & Exhibition 2002

TNO-PML overview of enabling techniques for IM development
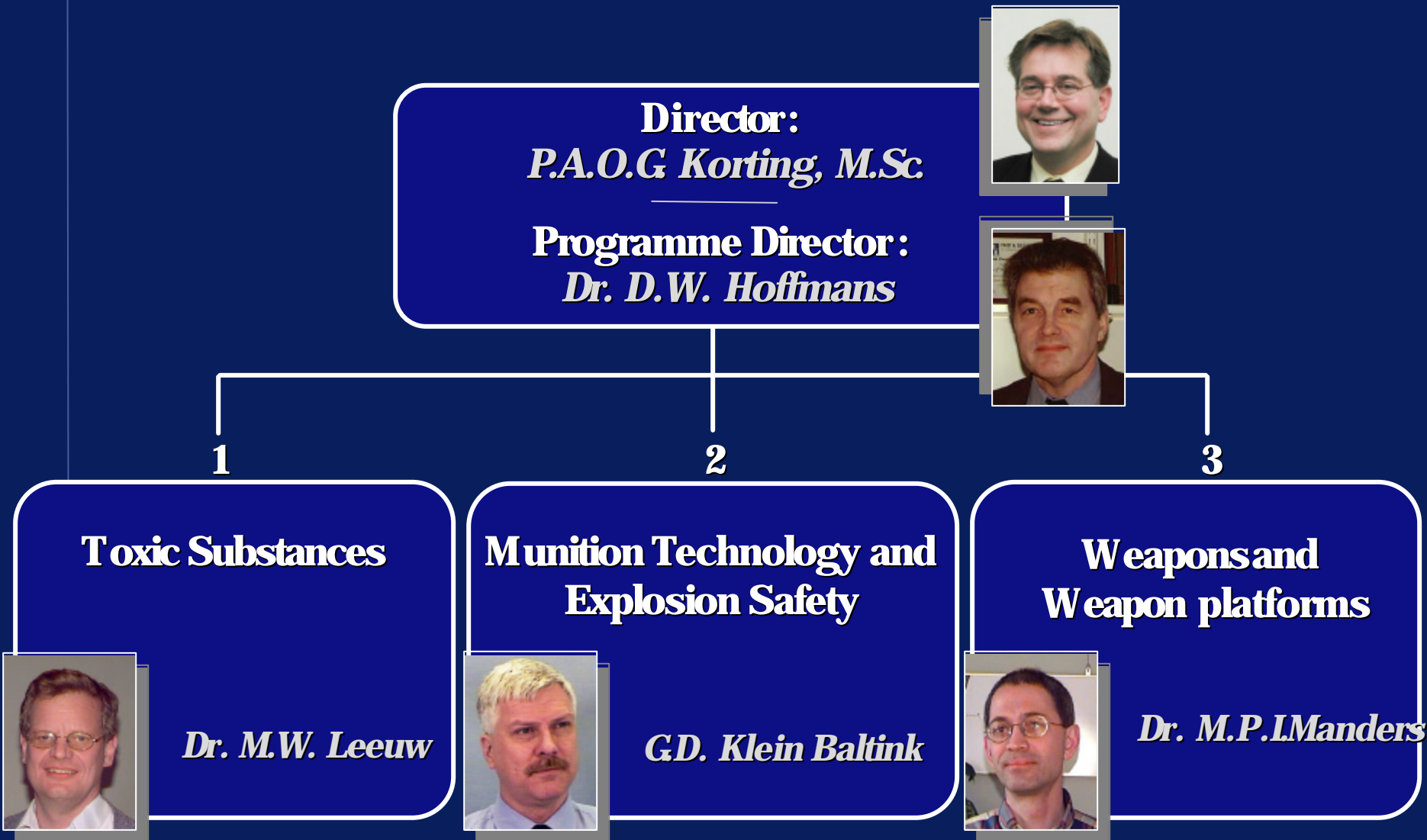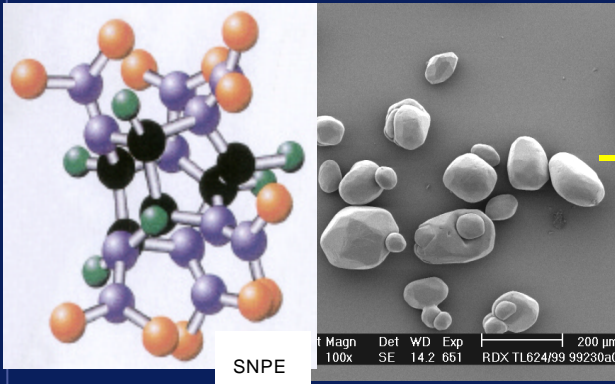
TNO Prins Maurits Laboratorium

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Overview

- **Introduction**
- **Levels to achieve safer use, storage and transport of munitions**
- **Properties of Energetic Material**
- **Properties of composite**
  - Damage research
  - Mechanism research
- **Properties of the system**
- **Other developments/techniques**
- **Summary**

TNO Prins Maurits Laboratory Organisation

Director:
P.A.O.G Korting, M.Sc.
_____

Programme Director:
Dr. D.W. Hoffmans

1

Toxic Substances

Dr. M.W. Leeuw

2

Munition Technology and Explosion Safety

G.D. Klein Baltink

3

Weapons and Weapon platforms

Dr. M.P.I.Manders

Levels to achieve safer use, storage and transport of munitions

Properties of EM

Properties of composite

Properties of the Munition item

SNPE

Properties of the storage lay-out and barriers

Properties of the storage/transport stockpile (with or without mitigation technique)

IA   Intrinsic properties of Crystalline energetic materials

- **Compromise between sensitivity and performance (CL20 Vs TATB)**
- **World wide search of new   energetic materials (synthesis)**
- **Except synthesis of "green Propellant HNF", TNO-PML stopped the synthesis research but focussed on improving the crystalline properties of the existing EMs**
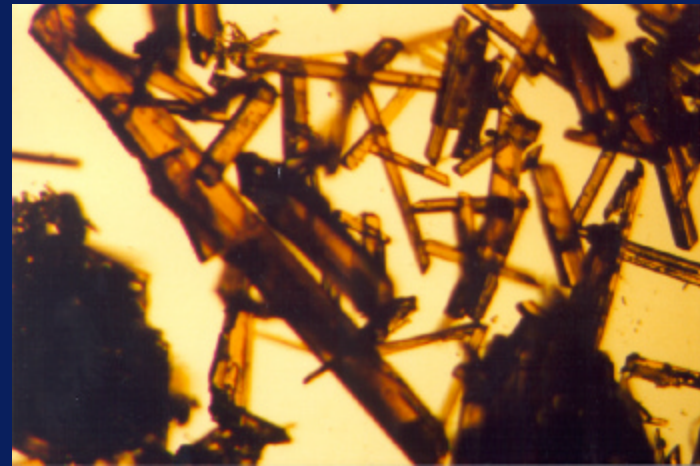

100 µm
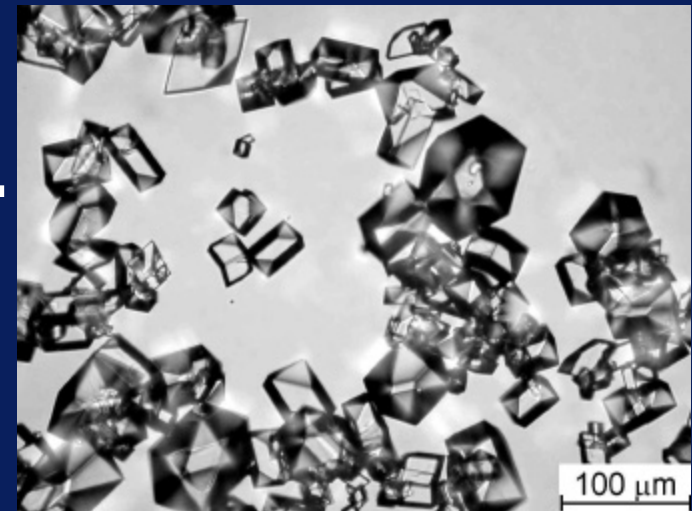
CL20

IB Crystal Quality

- **Crystal quality: External morphology and internal defects**
- **Crystal quality is influenced by:**
  - solvent used for crystallisation
  - growth kinetics
  - presence of impurities / additives
  - process parameters (stirring rate, impeller type, vessel geometry etc.)
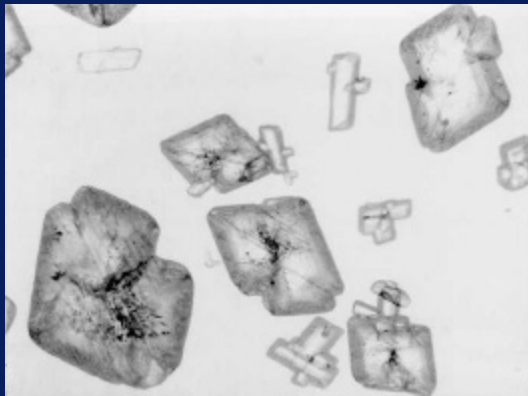- **Influence of solvent for HNF**

Methanol: *L/D* ~ 2-3

2-Propanol: *L/D* ~ 5-10

Crystal quality (high sensitivity) examples
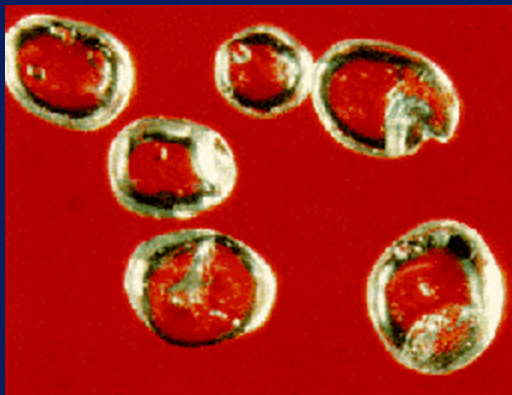
Defects (voids, cracks)
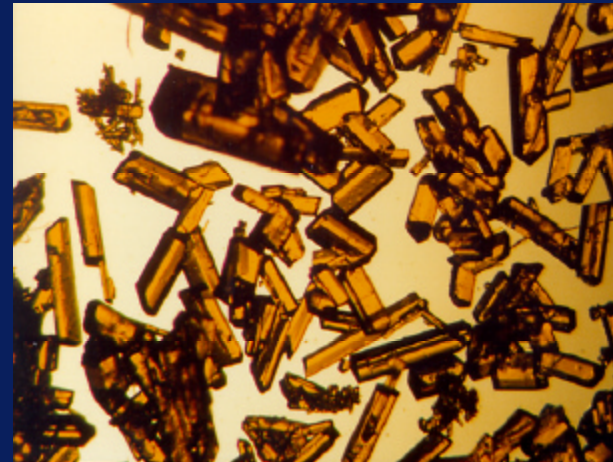
Agglomeration

HMX

CL20
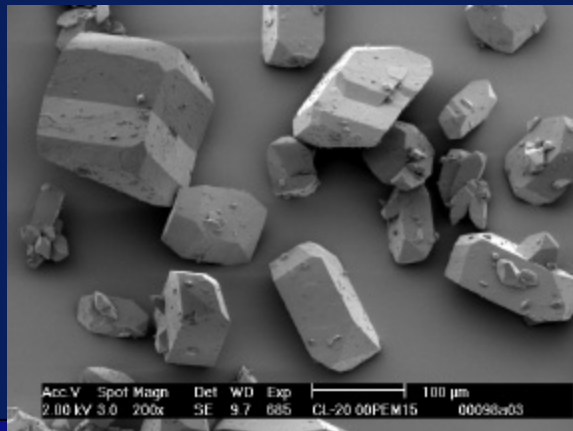

Twinning

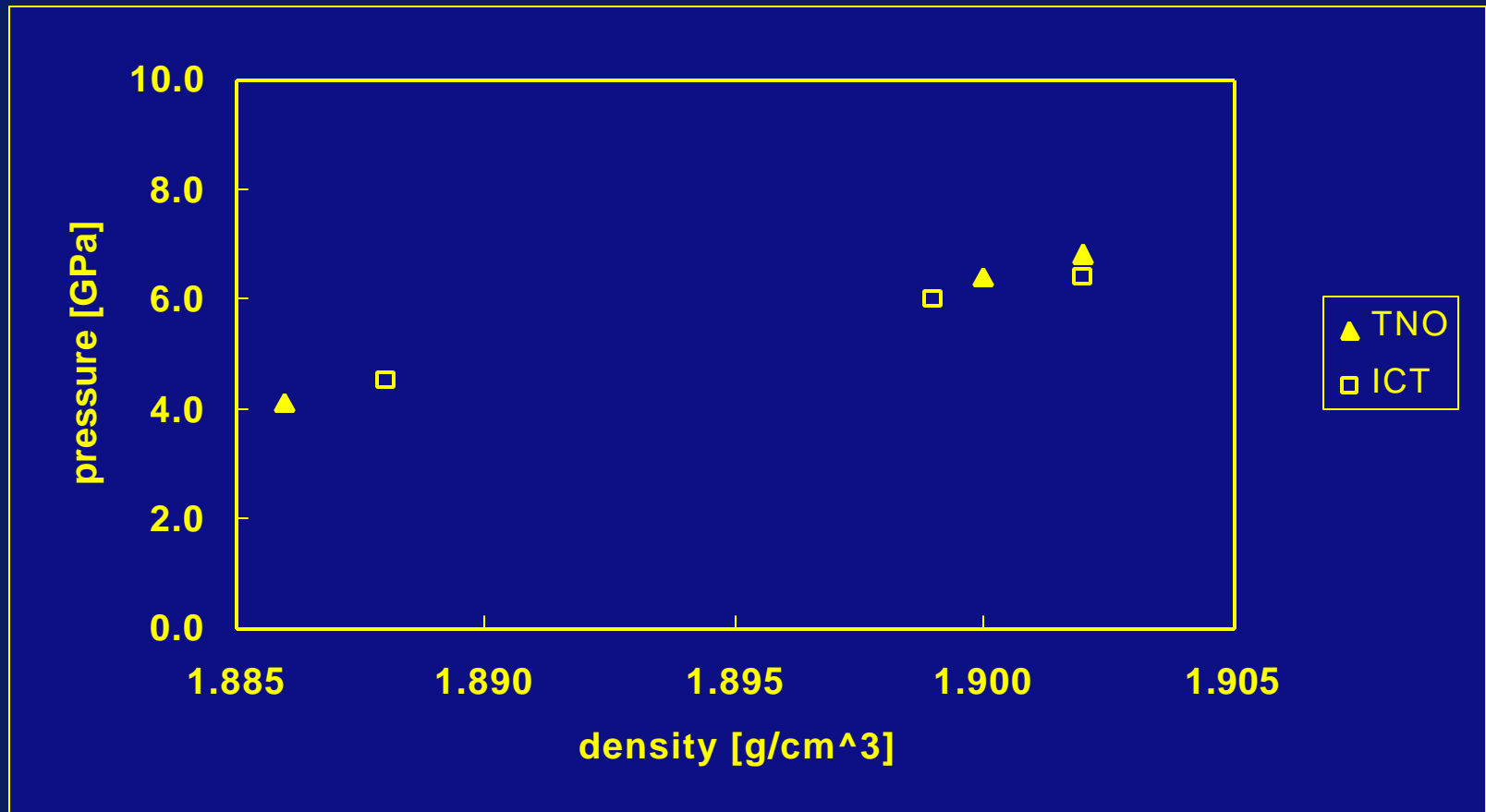**RDX**

Examples of Improved Crystal Quality

RDX
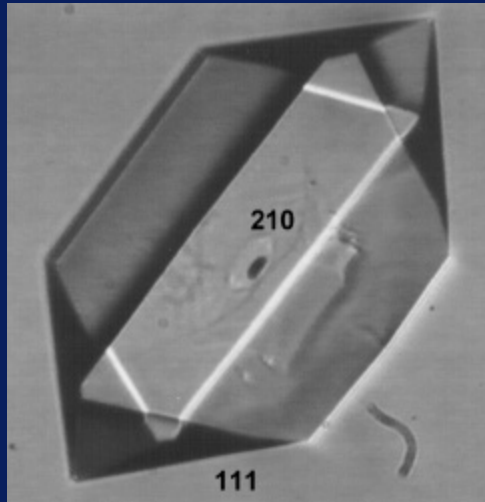
HNF

CL-20

HNS-IV

Shock sensitivity HMX/HTPB based PBX

## BICT water gap test

II Properties of Composite

- **Binder system around EM - crystals**
  - Improvement of Mechanical Properties   -->   influence on DDT en
  - Positive influence on porosity   -->   XDT phenomena
- **Compromise between sensitivity and performance**
- **Instead of inert binder an energetic binder**
- **Combination of "insensitive/improved" crystals (RDX, HMX and CL20) with binder system, leads to next generation of high performance insensitive explosives**

- **TNO-PML**
  - Investigation on the influence of mechanical properties on sensitivity (erosion/damage modelling, thermal as well as impact damage)
  - Investigation on mechanisms leading to and parameters influencing the response for several stimuli (Pure shock, bullet fragment Impact, Cook-off)

Mechanical/Thermal damage Research;
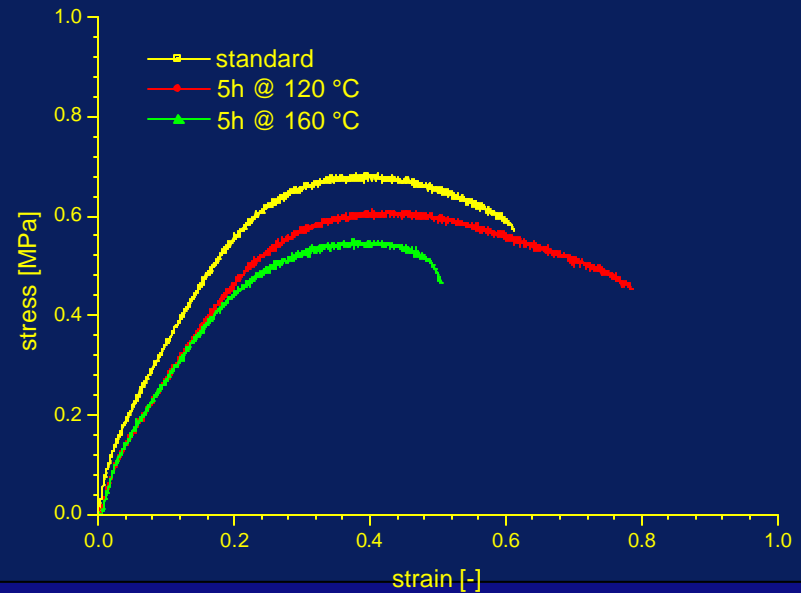## HMX-PBX after impact at 91, 110, 121 and 154 m/s

Damage after impact (SEM)
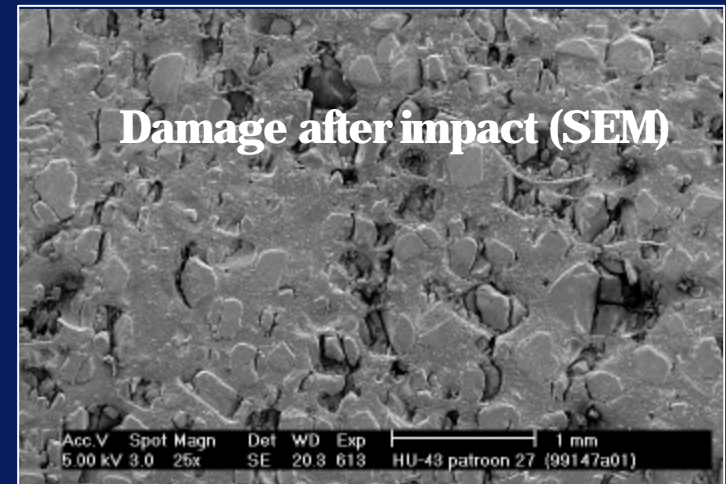
Thermal and mechanical Damaged of HMX-PBX
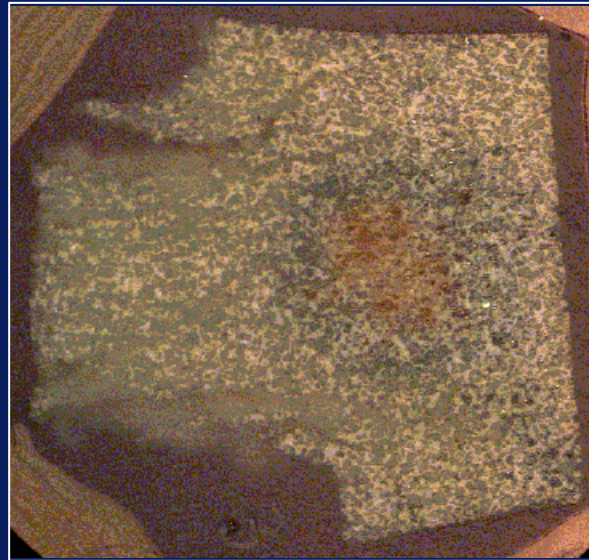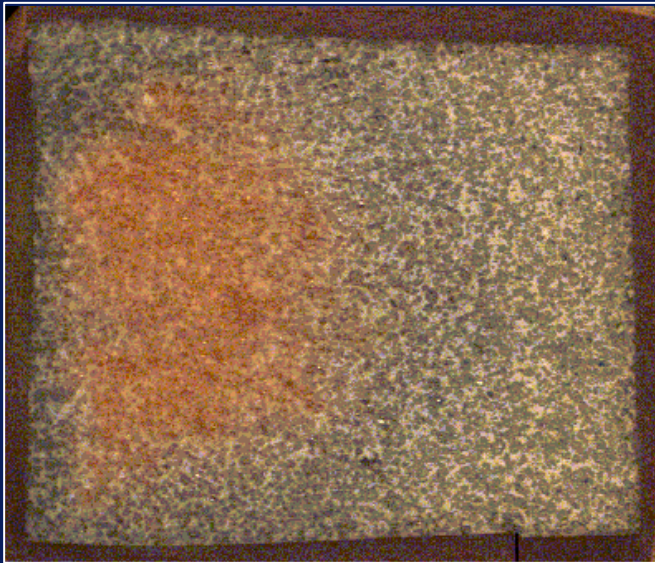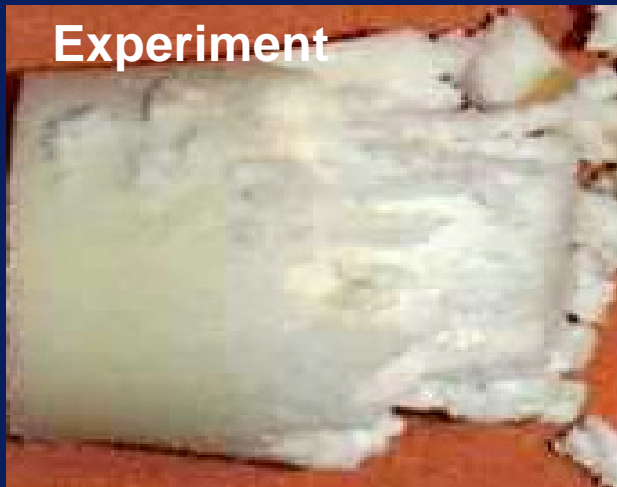

Impact damage at 91 and 154 m/s prepared for SEM
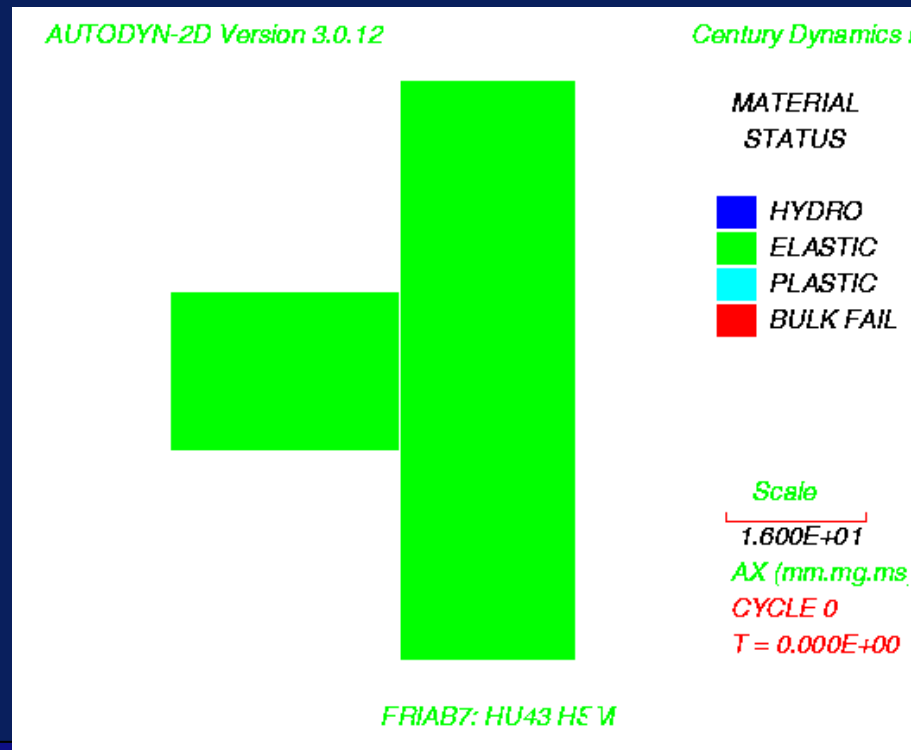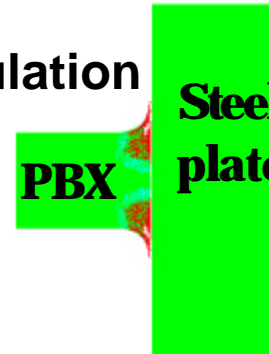
Thermal Damage; 5 hours at elevated Temperature

Erosion/Damage research

Experiment

Simulation

PBX **Steel plate**

Break-up of PBX sample after impact on a steel plate

AUTODYN-2D Version 3.0.12   Century Dynamics

MATERIAL STATUS

- HYDRO
- ELASTIC
- PLASTIC
- BULK FAIL

Scale
1.600E+01
AX (mm.mg.ms
CYCLE 0
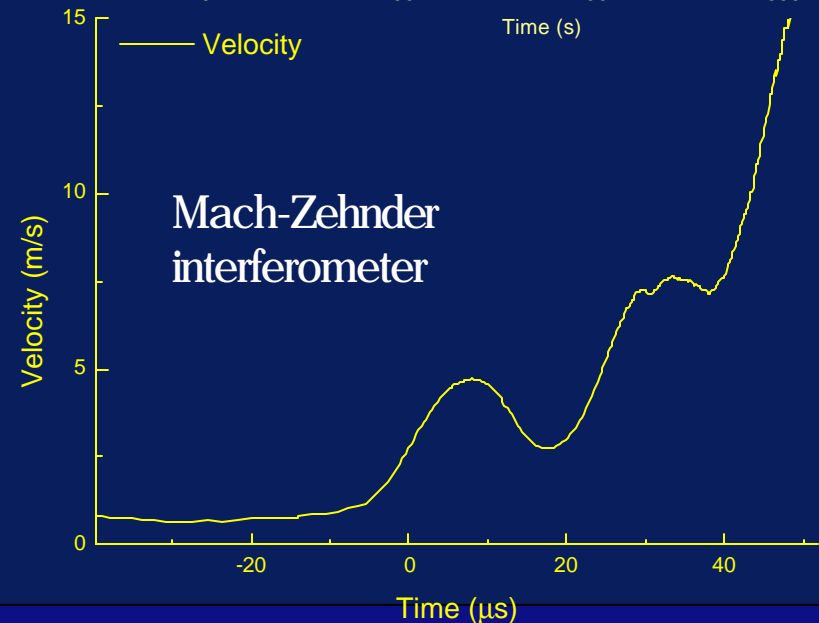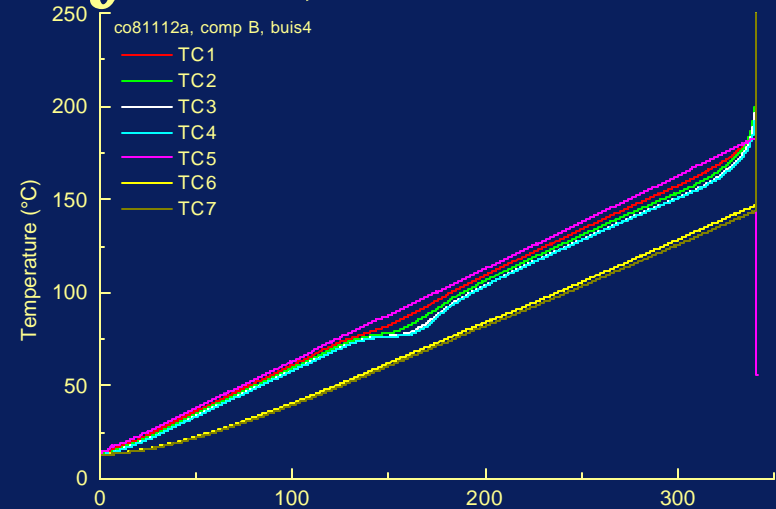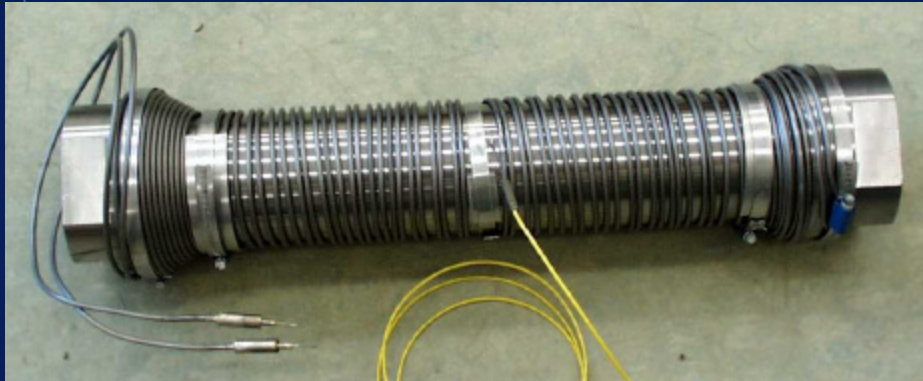T = 0.000E+00

FRIAB7: HU43 HE M

Mechanism Research

- **Development of improved laboratory-scale tests to assess the IM properties:**
  - Instrumented cook-off test vehicle
  - Instrumented bullet and fragment impact test (SDT, DDT and XDT)
  - Friability test (DDT behaviour)
  - Flyer-impact test (SDT behaviour of small samples)
  - Small shaped charge impact
- **Computer models under development to simulate**
  - Cook-off behaviour
  - Impact behaviour
  - Shock-to-Detonation transition
  - Use of Hydro codes in general

Thermal Runaway of HMX-PBX

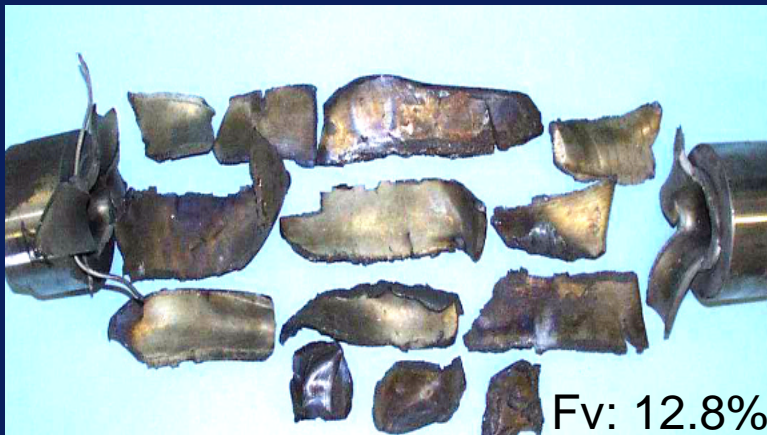Cook-off Experiment HMX PBX
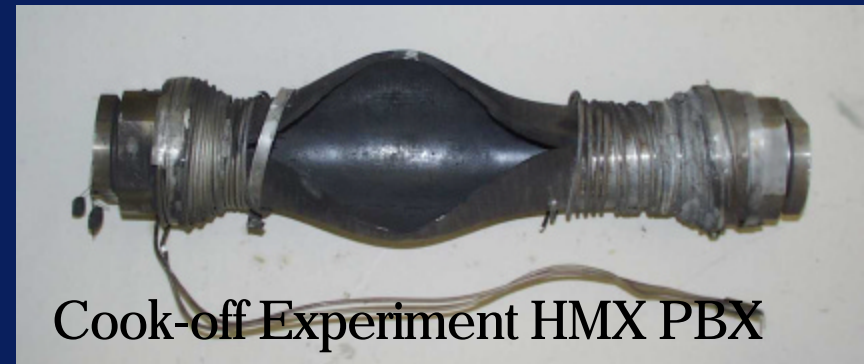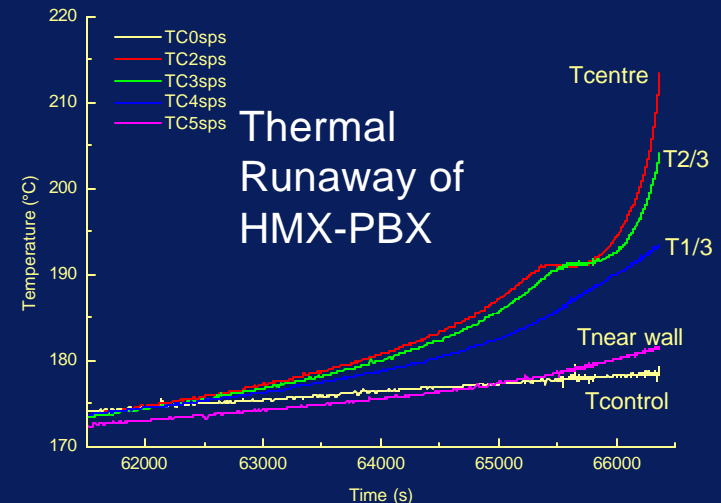
Instrumented cook-off test vehicle (top) and simulated temperature profile (bottom)

Cook-off Research with instrumented test vehicle (T, P, Strain/velocity wall)

SCB - RU 158-2.
(SC00120a / 20°C/min)

co81112a, comp B, buis4

- TC1
- TC2
- TC3
- TC4
- TC5
- TC6
- TC7

Temperature (°C) vs Time (s)

Velocity

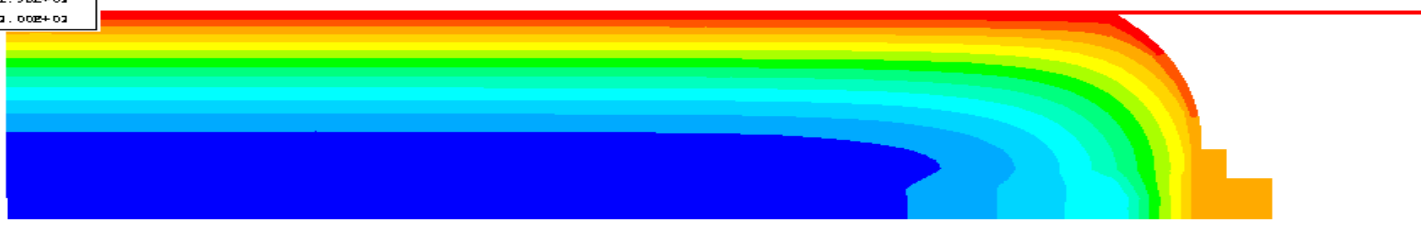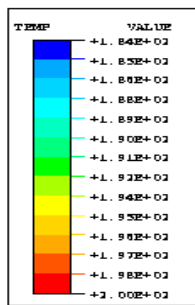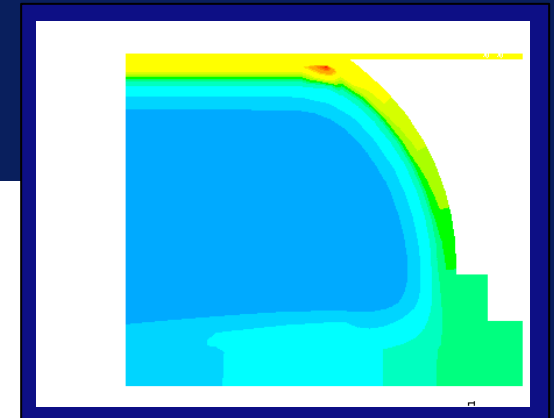Mach-Zehnder interferometer

Velocity (m/s) vs Time (µs)

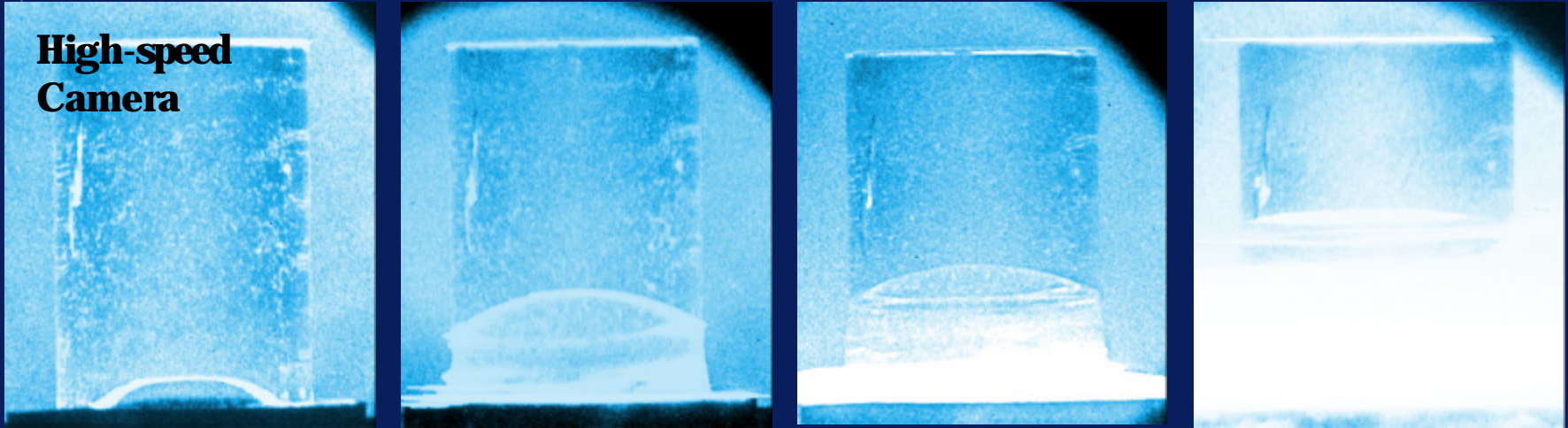# Fragmentation as a function of Free Volume (cook-off of Comp B)

Fv: 0%

Fv: 2.6%

Fv: 12.8%

Fv: 30%

Simulation of rocket motor (Cook-off)

Impact/shock Research
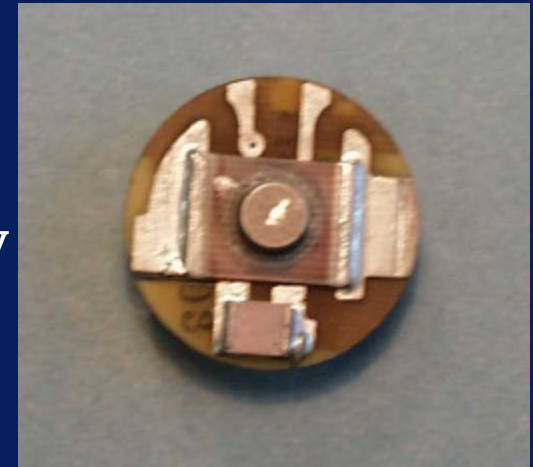

High-speed Camera

85wt% HMX-PBX after fragment impact

KSI-Scherven, J1965.

III Mitigation Techniques

- **Insensitivity is a system property--> techniques on a system level like**
    - composite casings
    - Venting holes
    - MEMS-EFI……
- **Example of MEMS-EFI (With commercially available electronic systems)**

State of the Art EFI and MEMS EFI (mock-up) same scale, replacement of conventional ignition train

Power FET

EXPLOSIVE

CAPACITOR

TRANSMISSION LINE
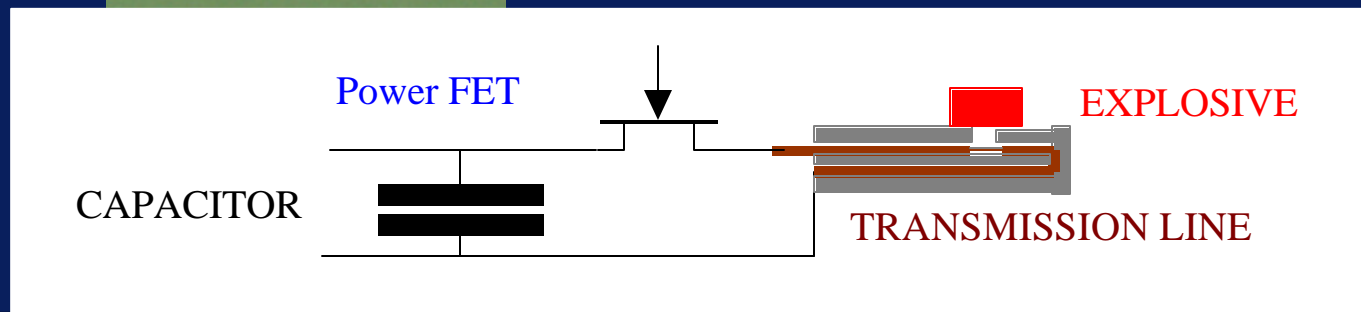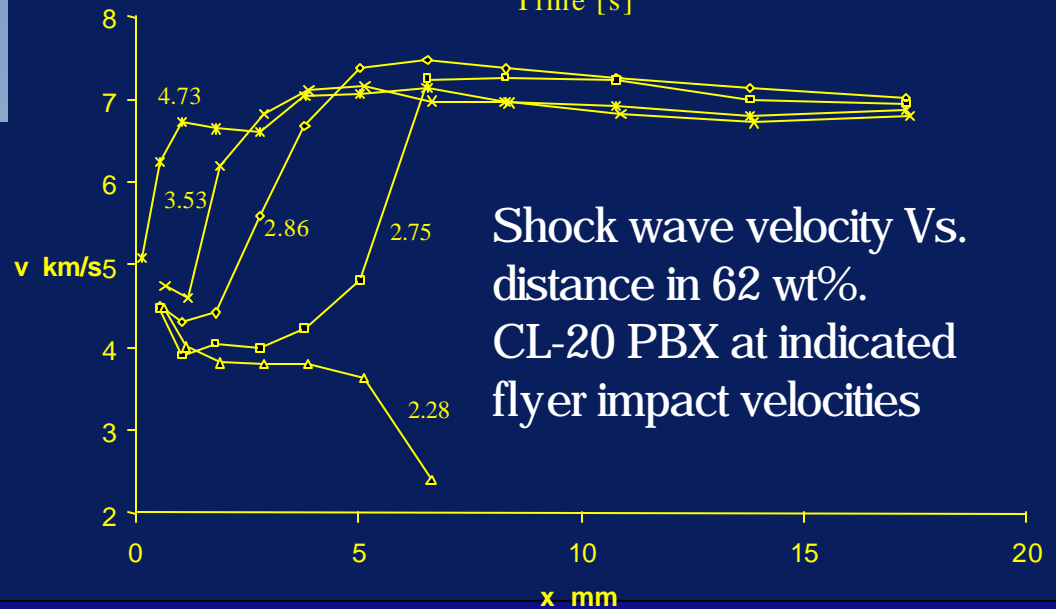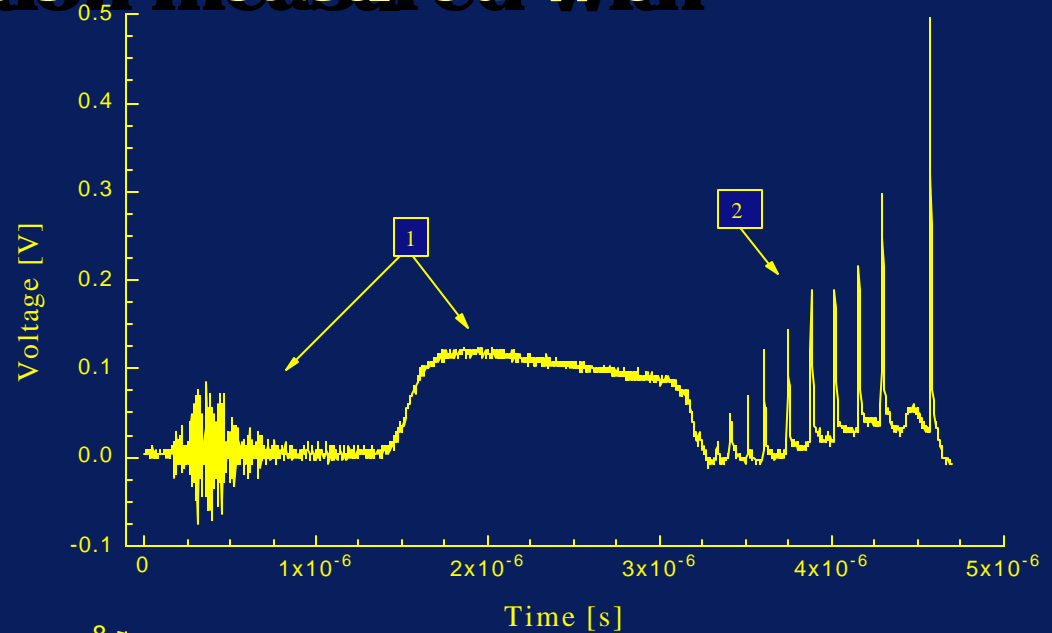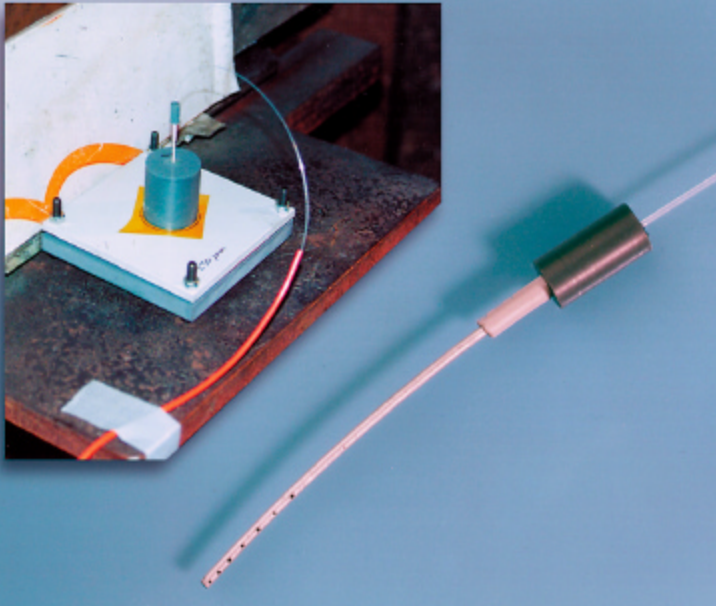
Other techniques (example)

- **History of IM: Fire on board a ship in relation to munition**
- **Database on individual munition items--->**
- **Simple formula, spreadsheet or 1-Dim calculations**
- **Estimation of Time-to-Cook-off**

Spreadsheet Calculation

Comparison Formula Calculations vs experiments
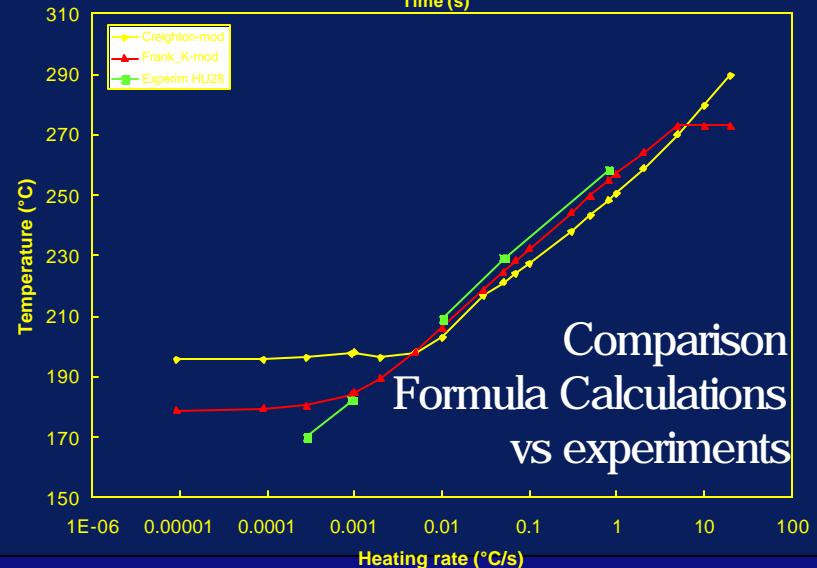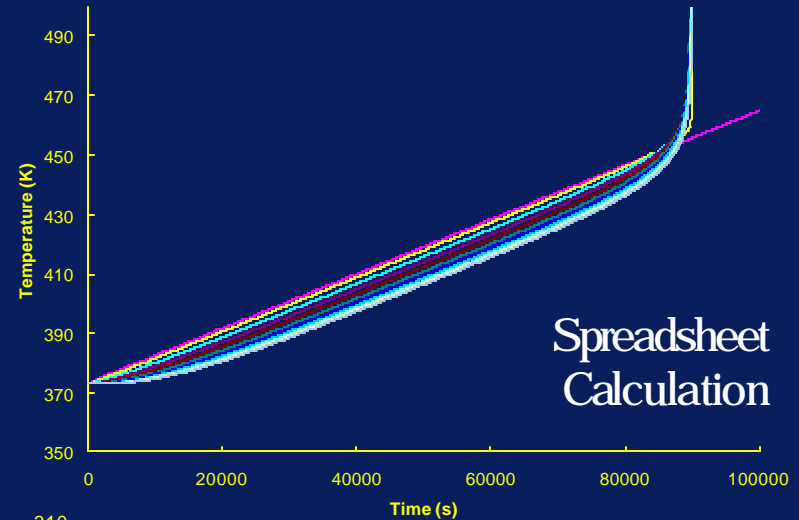
Other developments/techniques

- **Fibre Optic Probe**
- **HPM payload**
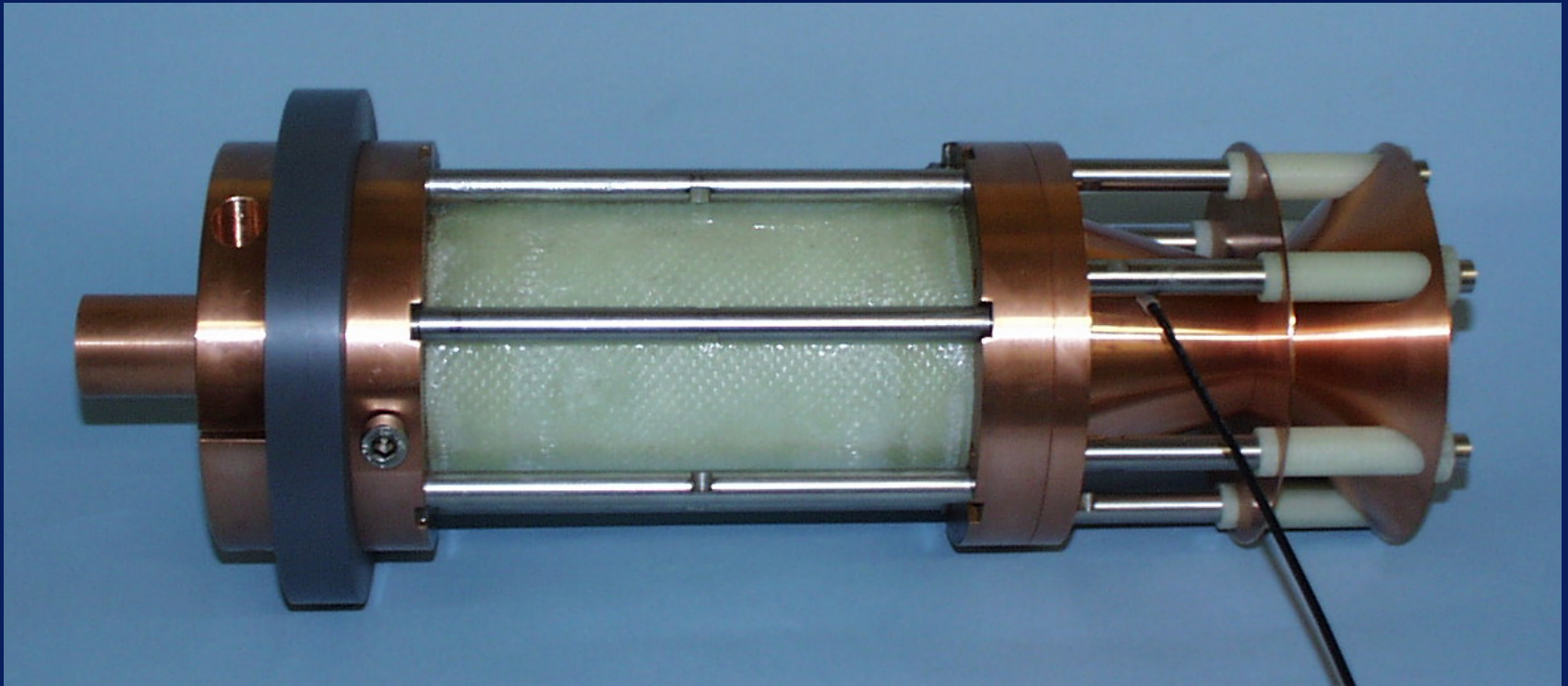- **Simulation with Hydro-code**
- **Explosive forming and cladding**

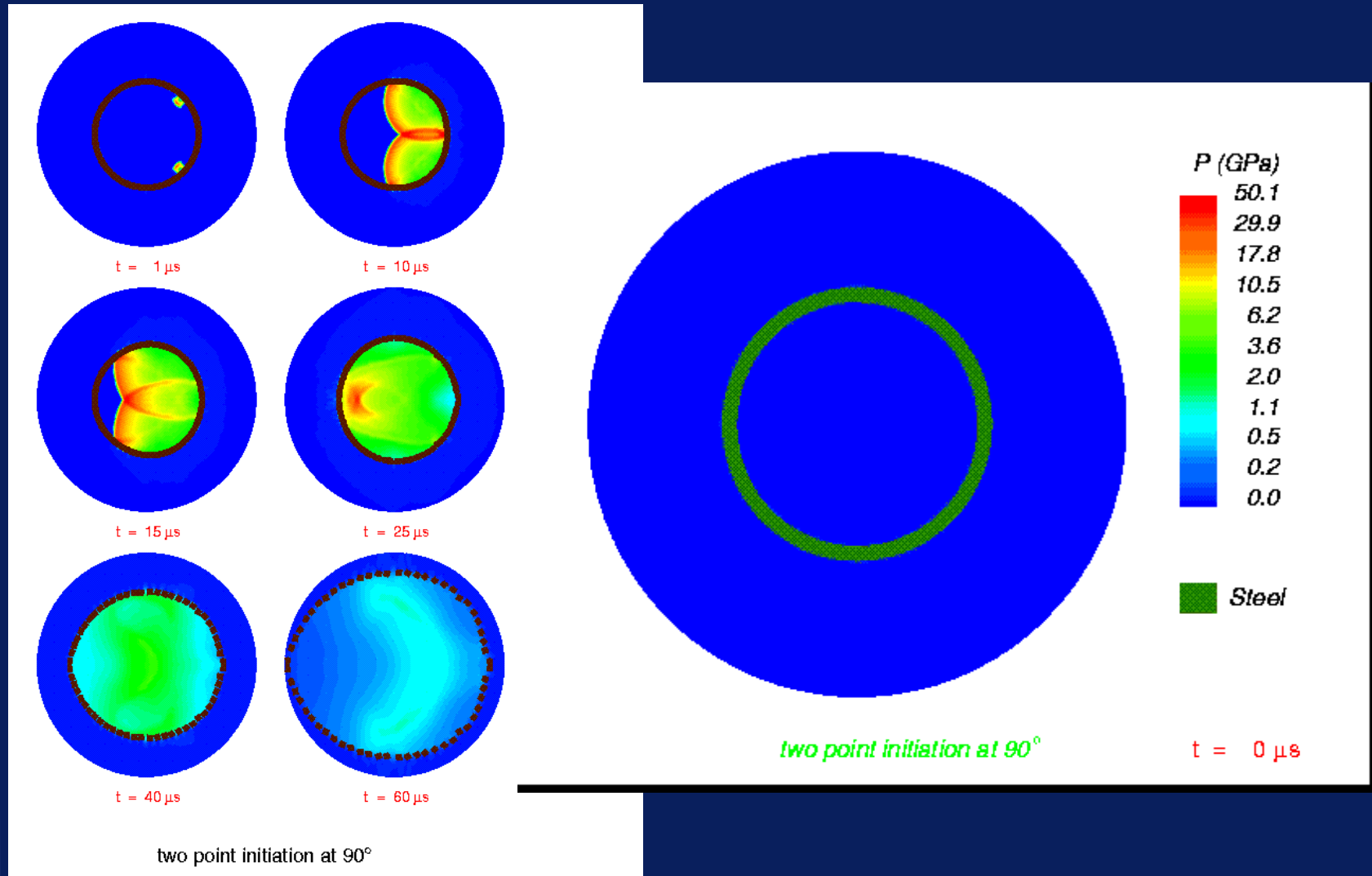# Flyer impact initiation measured with fibre optic probe

- **Optical fiber in which several holes are drilled**
- **Fiber optic probe is inserted into explosive, perpendicular to shock front**
- **Passage of shockwave causes ionisation of air**

Shock wave velocity Vs. distance in 62 wt%. CL-20 PBX at indicated flyer impact velocities

Experimental HPM payload: Generation of strong EM Pulse using HE

Aimable warheads simulation: 2-Point initiation

two point initiation at 90°

two point initiation at 90°

t = 0 µs

P (GPa)
50.1
29.9
17.8
10.5
6.2
3.6
2.0
1.1
0.5
0.2
0.0

Steel

t = 1 µs t = 10 µs

t = 15 µs t = 25 µs

t = 40 µs t = 60 µs

Aimable warhead simulation
2-Point initiation Vs central initiation
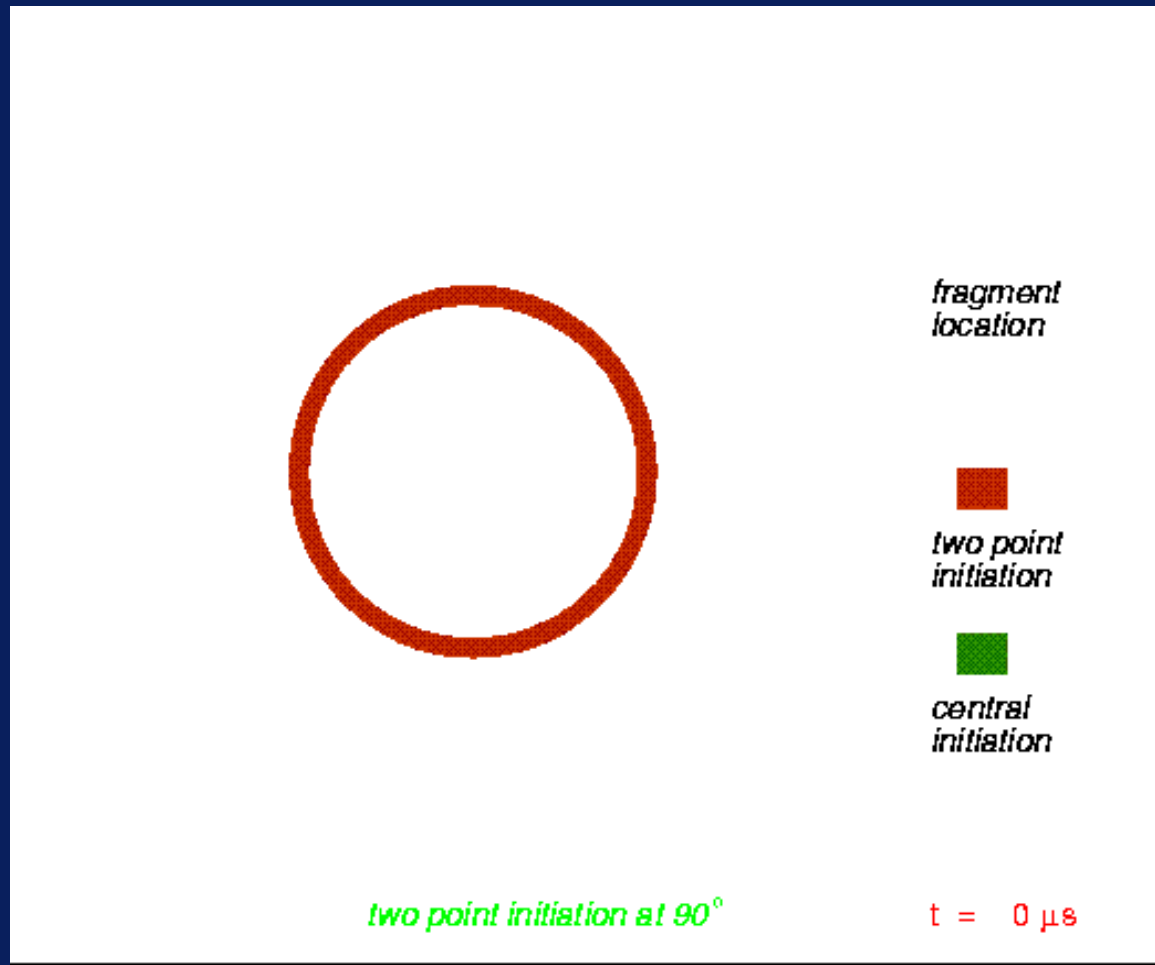
Simulation: explosive forming
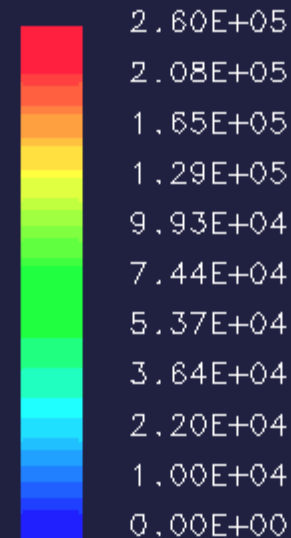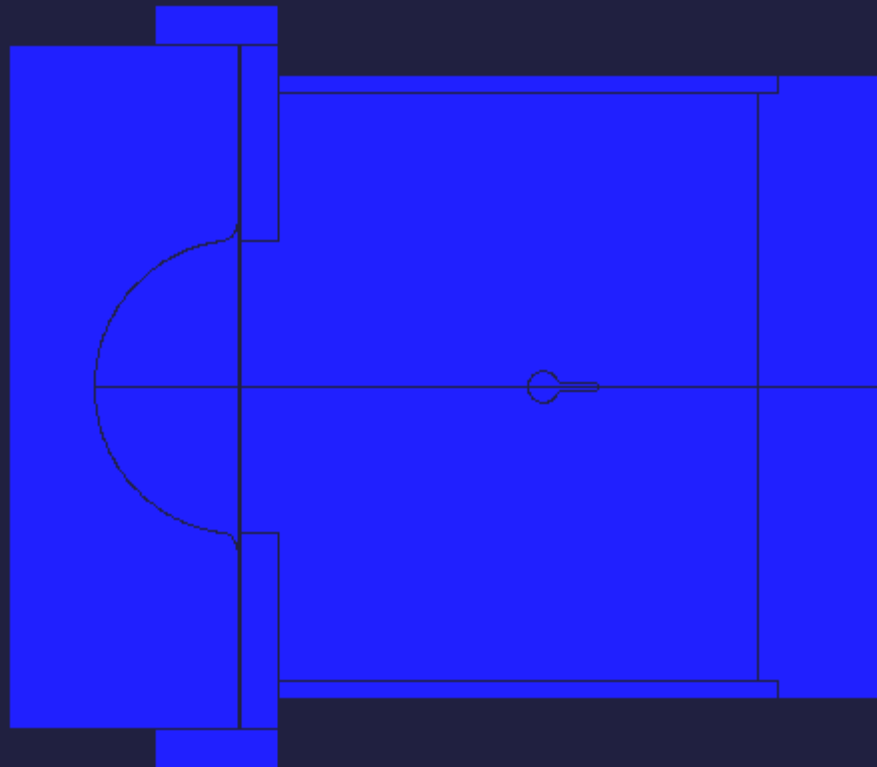
Explosive cladding/ Welding
High temperature/erosion resistance

0.3 mm

Ta-Cu
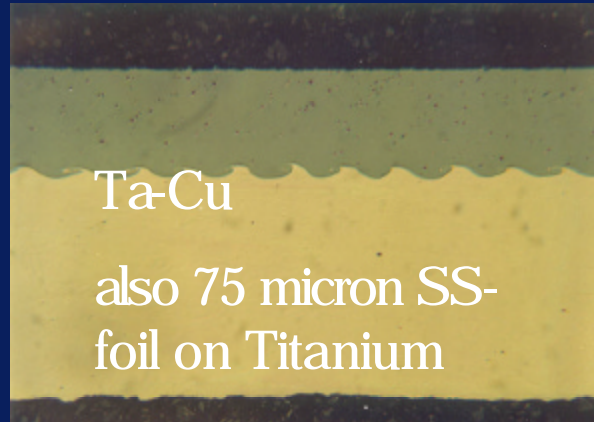
also 75 micron SS-foil on Titanium

Inexpensive line-welding: Cu-SS
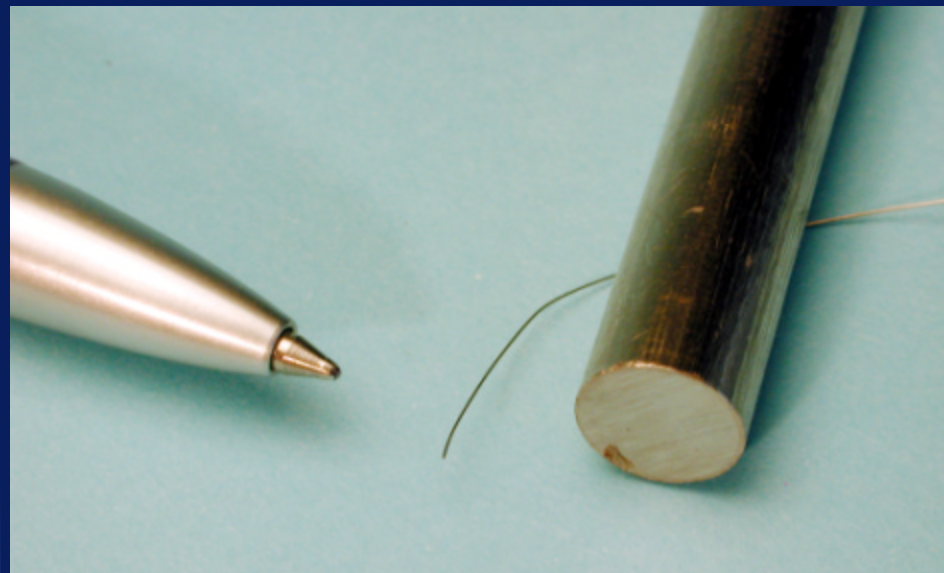
Silver (300 micron) on Stainless Steel (10 mm) --> Coated wire of stainless steel with 8-micron silver coating

Summary

- **Several technical levels have been shown to achieve a safer use, transport and storage of munitions**
- **Some of the highlights of research on IM/EM and other techniques have been shown**
- **TNO-PML will carry on with the research on IM/EM not only in Dutch MoD programs but also within international collaborations and partnerships**