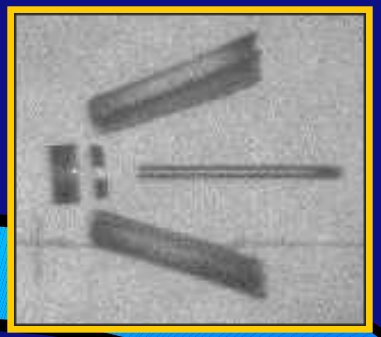
Development, evaluation and lifetime prediction of medium and large caliber ammunition

Gert Scholtes, 40th GARM, April 25-28, 2005

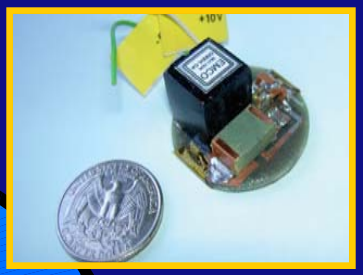
Overview

Propellant

Flight



Ignition train



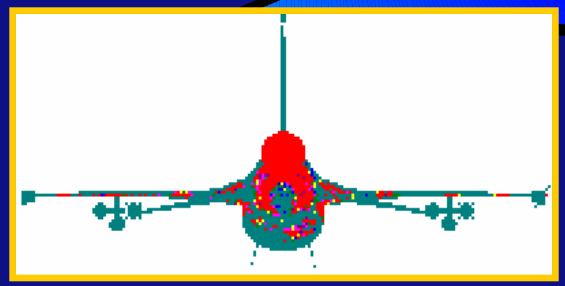
Ignition propellant

Lifetime prediction

Surveillance

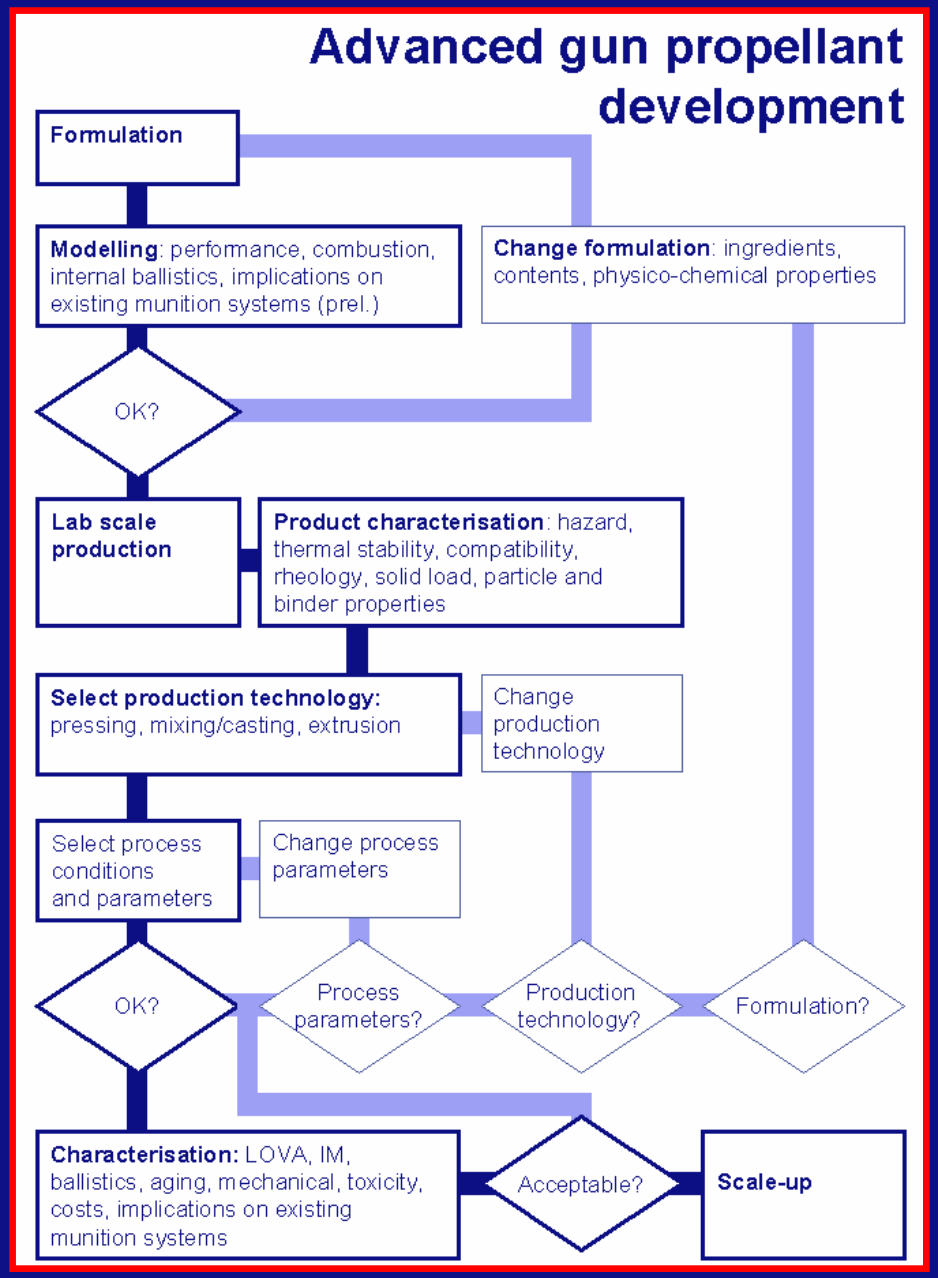
Performance

IM Warhead



Effectiveness

Hit

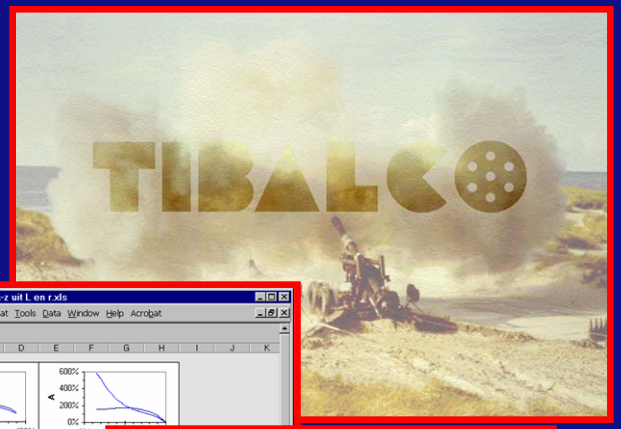


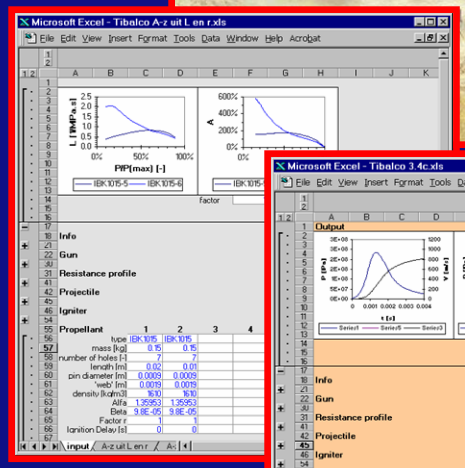
Propellant: Capabilities

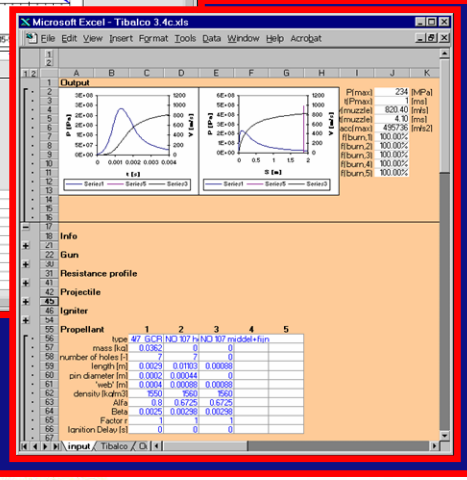
- Modeling & simulation
  - Thermodynamics
  - Processing
  - Internal ballistics
- Lab-scale production
  - Up to ~ 1 kg (analyses)
- 'Small scale' production
  - Up to ~ 300 kg
- Performance testing
  - Closed & vented bombs
  - Test guns
  - Thermal, IM & safety properties

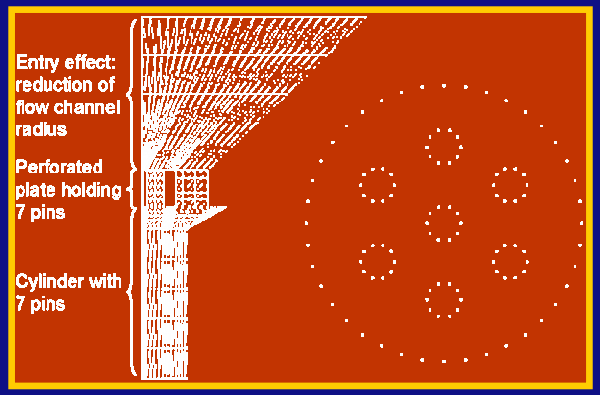
Propellant: Modeling & simulation

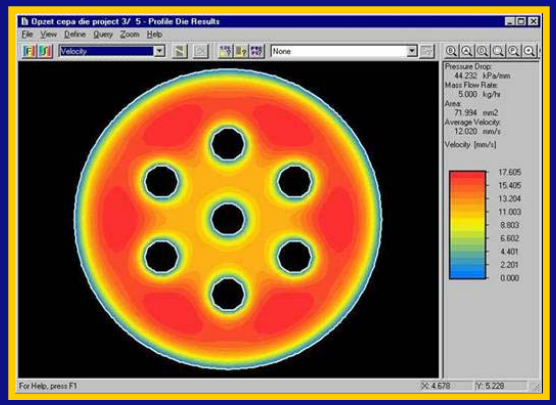
- Thermodynamics
  - NASA-Lewis, Blake, ICT-code
- Internal ballistics
  - TIBALCO (TNO Internal BALlistic Code)
- Processing
  - Rheology
  - Extrusion & shaping processes

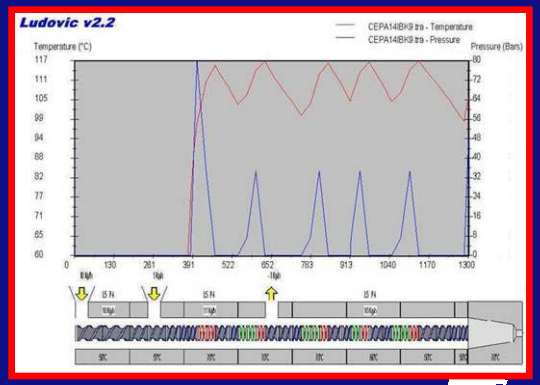




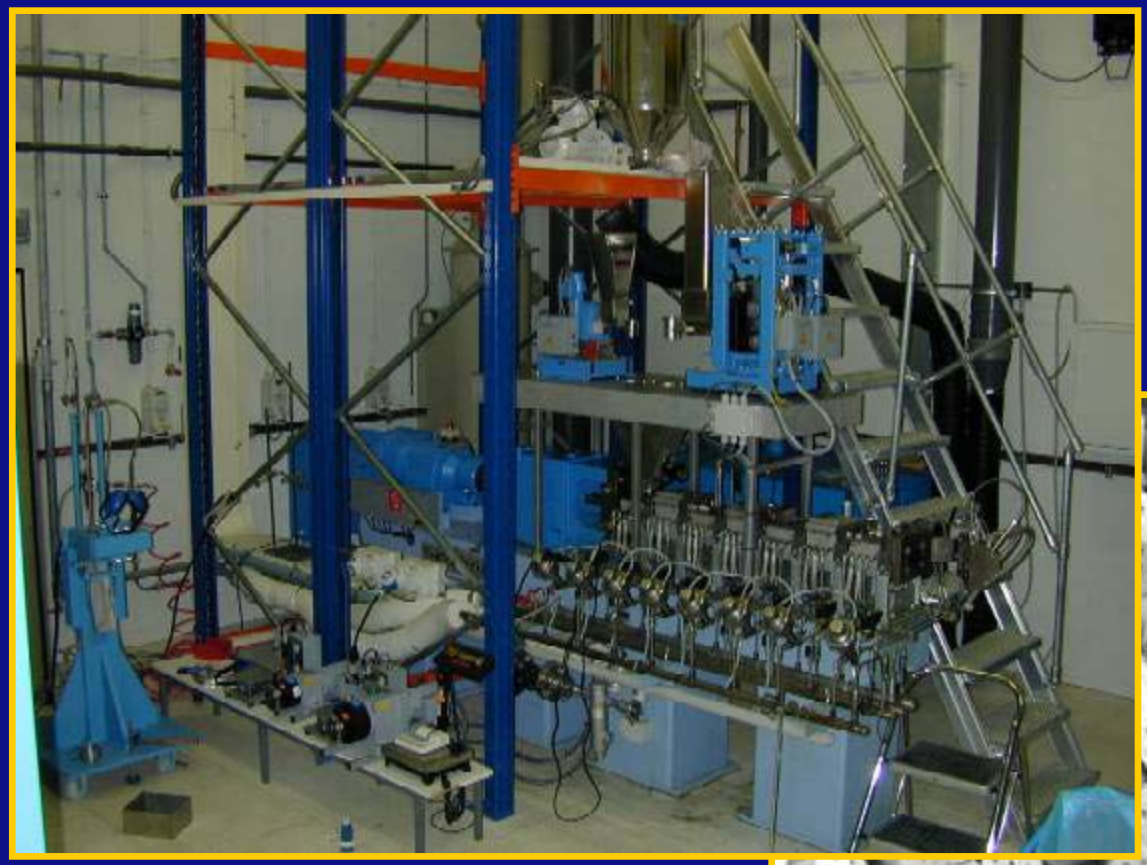








Propellant: Processing

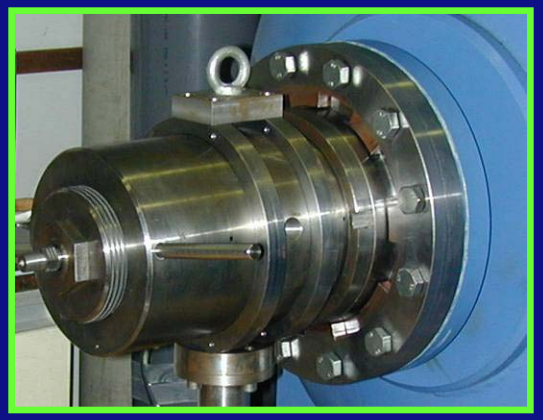


45 mm twin-screw extruder

Propellant: Test facilities

- Closed Vessels
  - 43.5 cc / 130 cc LPCV (20 MPa)
  - 25 - 700 cc CV (150 – 500 MPa)
  - 400 cc HPCV (1000 MPa)
- Erosivity & burning interruption tests
  - 130 cc – 20 MPa
  - 500 cc – 150 MPa
- Plasma ignition
- Instrumented guns
  - .50 gun
  - 29-mm / 50-mm / 78-mm accelerator

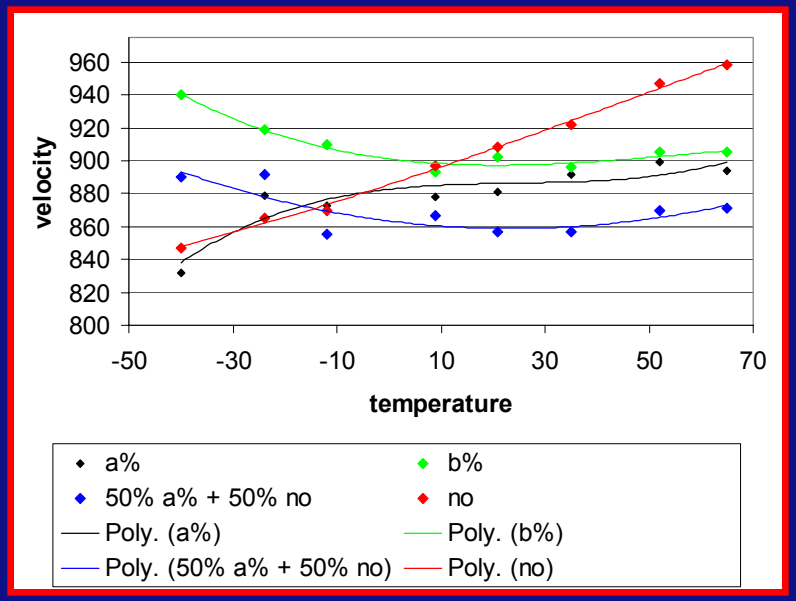
CV's (25 – 700cc)

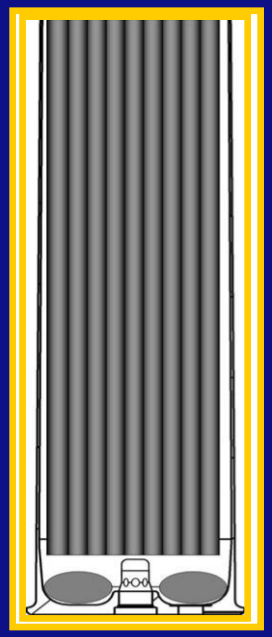


Vented HPCV and catch tank

Propellant: Examples of R&D projects

- Propelling charge development
- Temperature independent propellant
- Barrel erosion
- Ageing & lifetime assessment





Stick propelling charges for excellent ignition behaviour

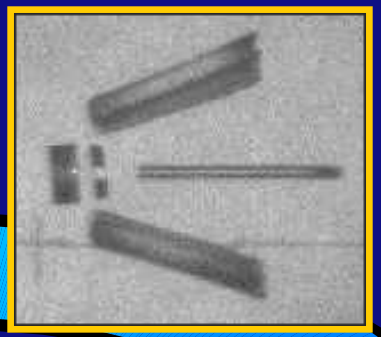
Proven temperature independency

Burning properties and mechanical integrity of aged propellants

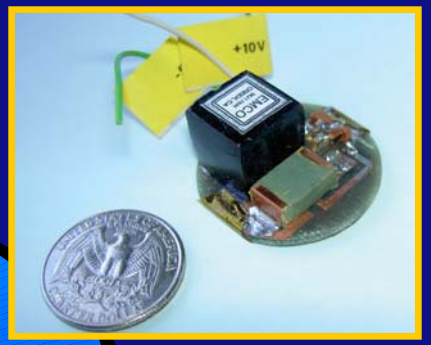
Overview

Propellant

Flight



Ignition train



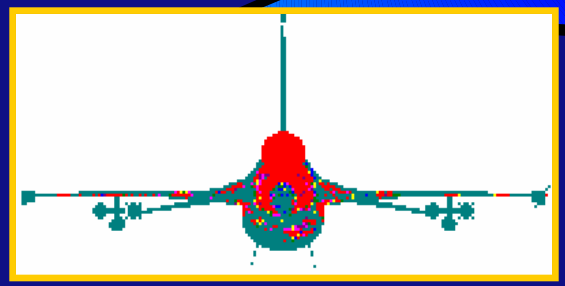
Ignition propellant

Lifetime prediction

Surveillance

Performance

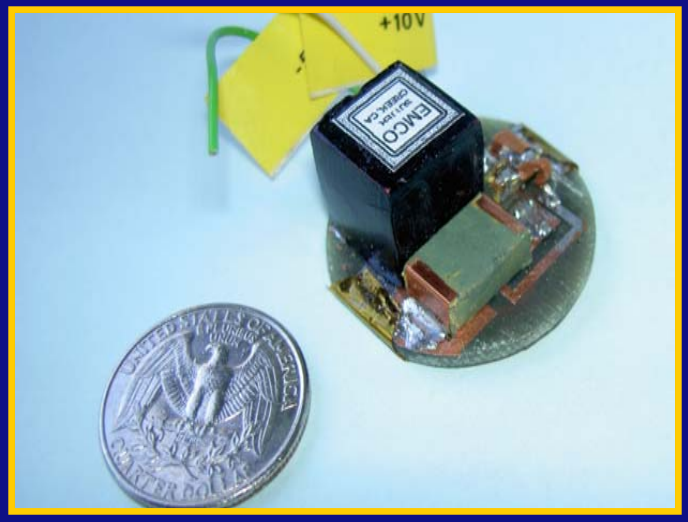
IM Warhead



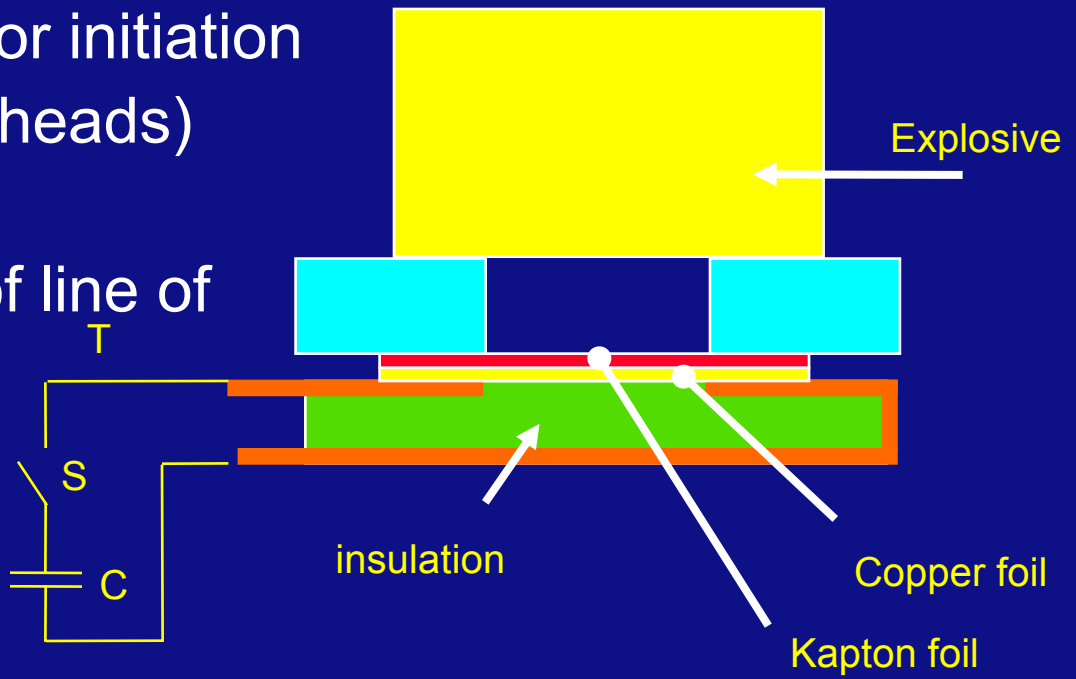
Effectiveness

Hit

MEMs Exploding Foil Initiator (EFI)



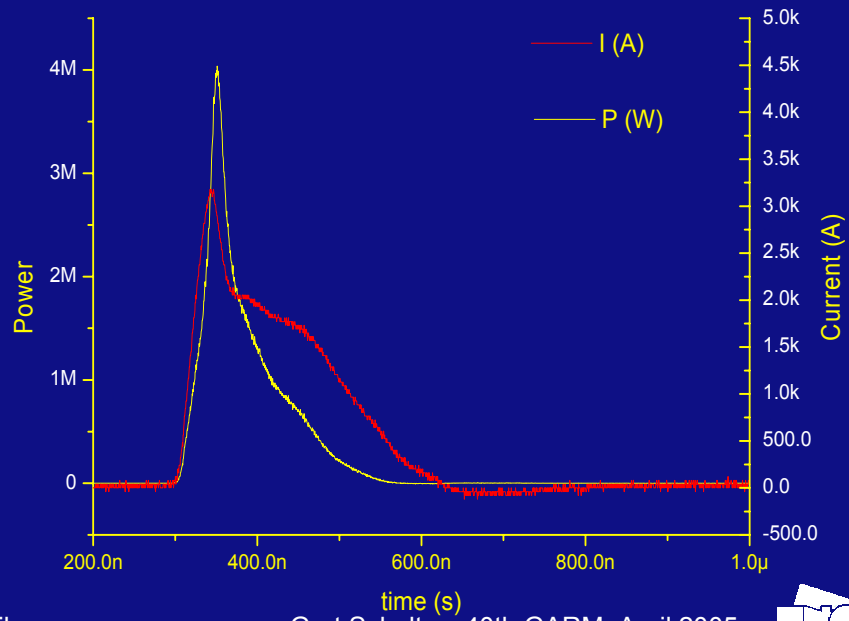
- Intrinsic safe
  - No primary explosives
  - Not sensitive to EM fields
- Precision timing for initiation (e.g. aimable warheads)
- Very reliable
- No need for out-of line of charge



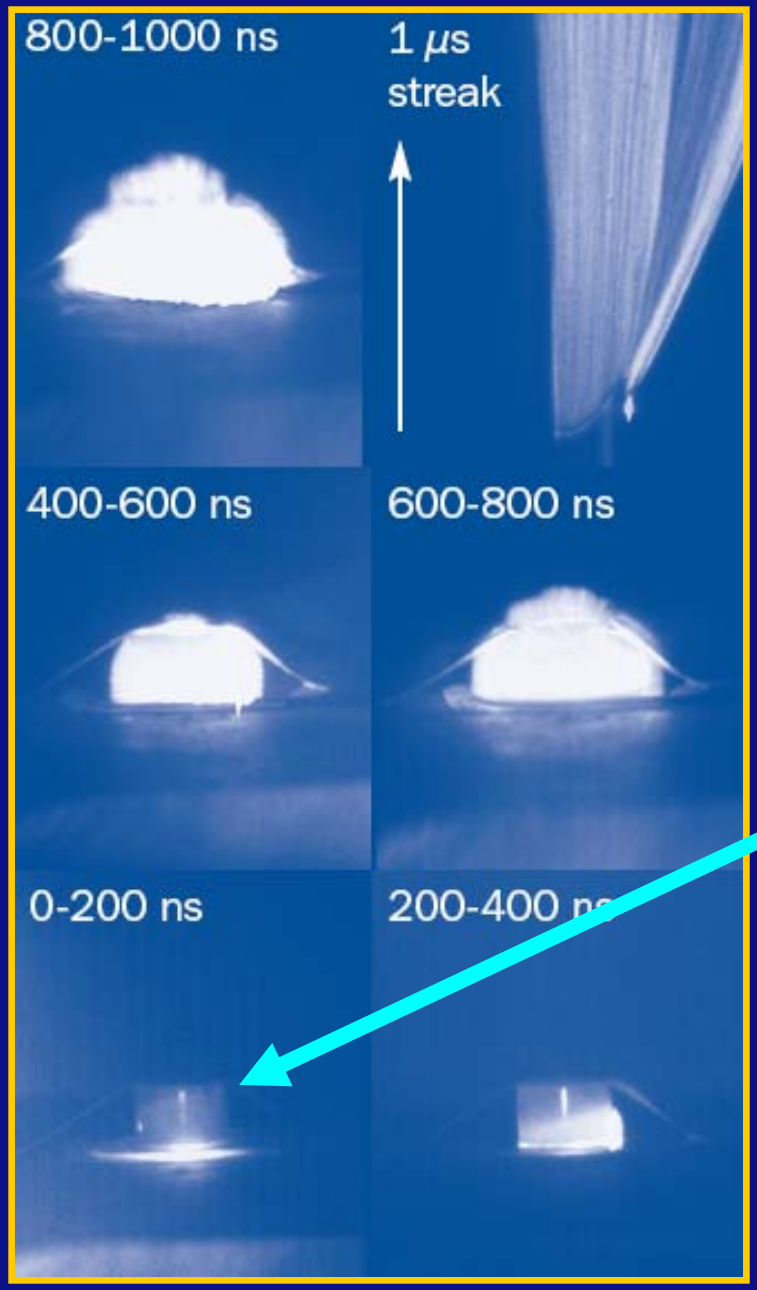
MEMs EFI: What you need

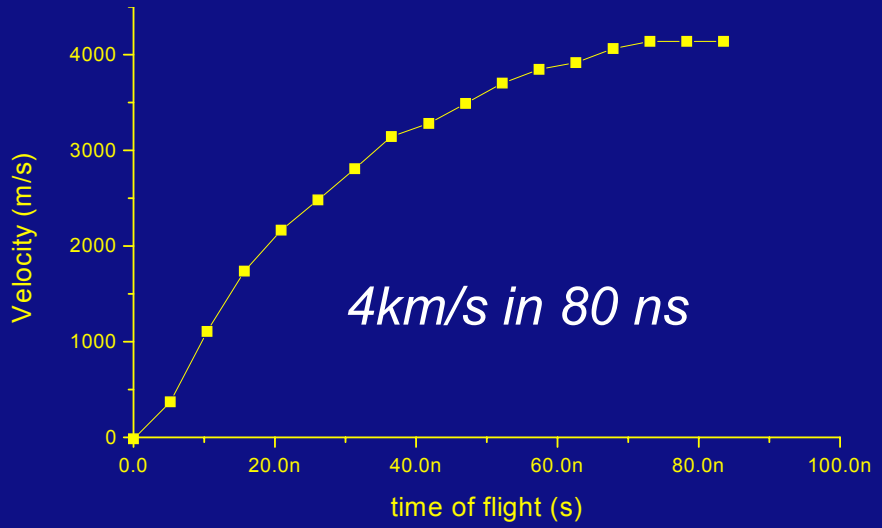
- Proper circuit with COTS components
  - Small high voltage power supply (several kV and kA)
  - Solid state Switching device
- Appropriate dimensions en properties of:
  - Exploding foil
  - Flyer plate
  - Strip-line
  - Barrel
- Pressed HNS-IV crystals at the right density

Performance of an optimised EFI-circuit

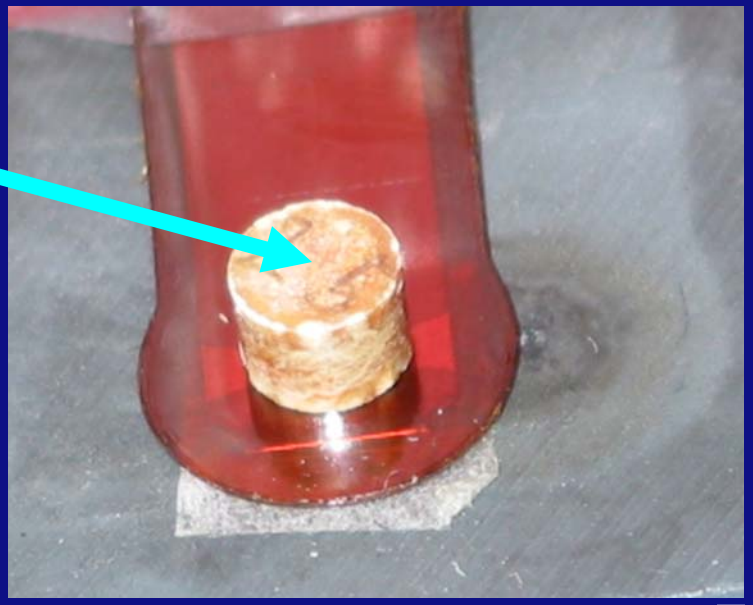


Ignition train: MEMs EFI





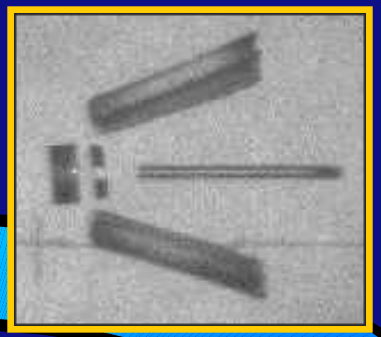
HNS-IV



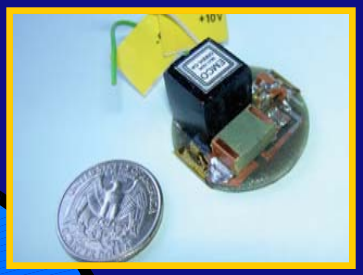
Overview

Propellant

Flight



Ignition train



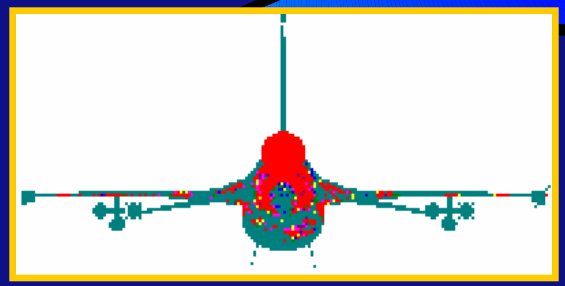
Ignition propellant

Lifetime prediction

Surveillance

Performance

IM Warhead

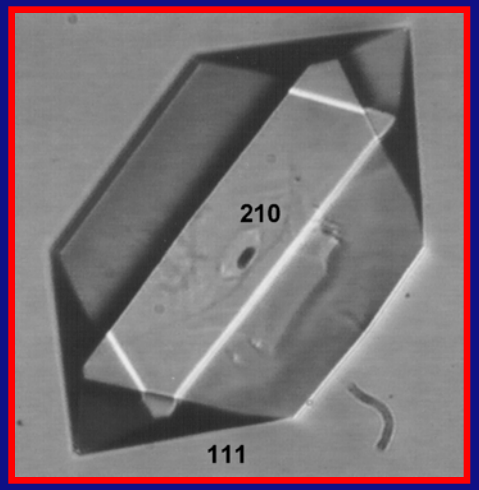


Effectiveness

Hit

Warhead: recrystallisation to obtain the next generation of explosives

RS-RDX

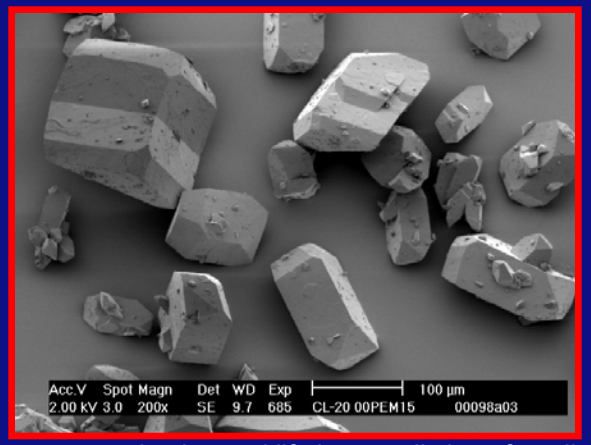


Insensitive crystals for HE Warheads

HNF

Insensitive crystals for rocket propellants

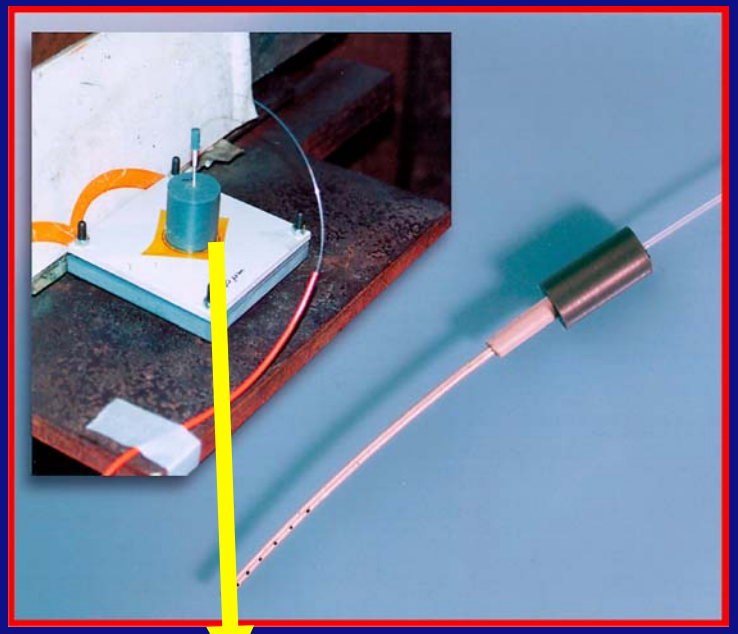
CL-20

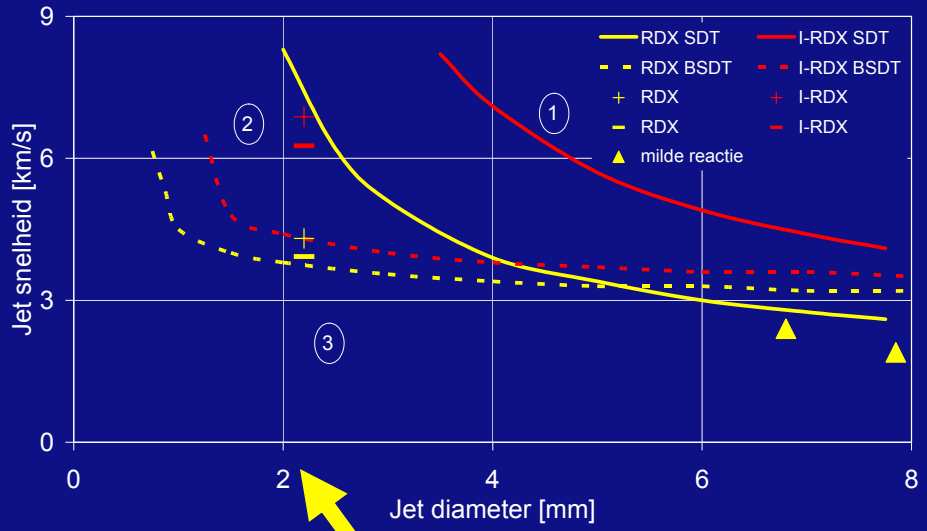


HNS-IV

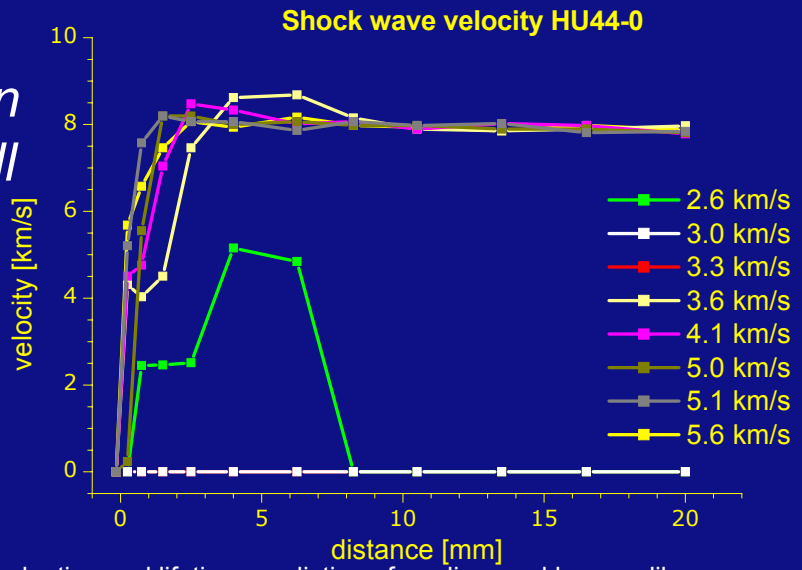
Insensitive crystals for Booster Explosives

Warhead: characterisation of explosives

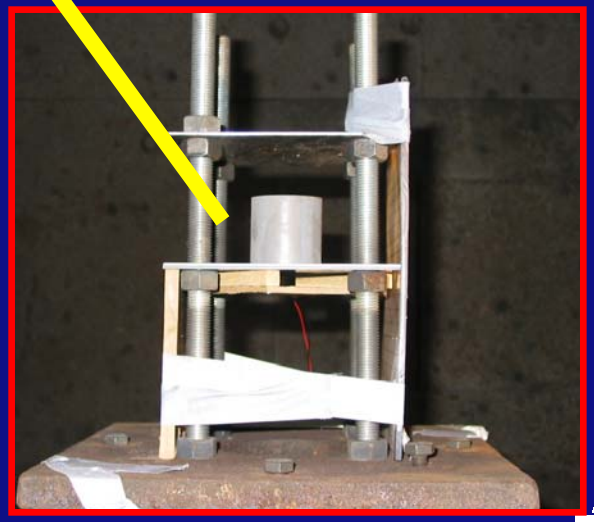




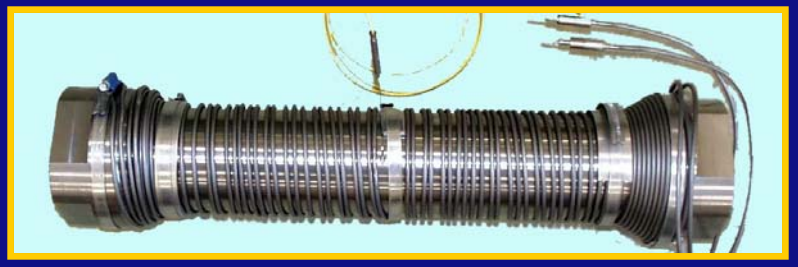
Shock initiation testing of small samples

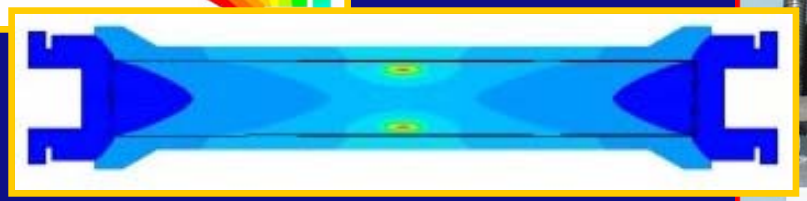


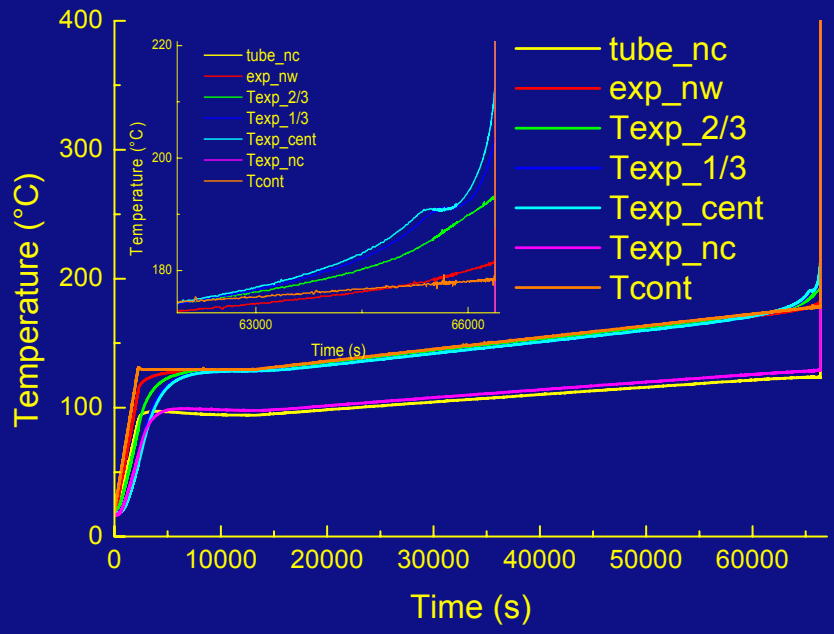
Shaped charge testing and simulation (PBXN109)

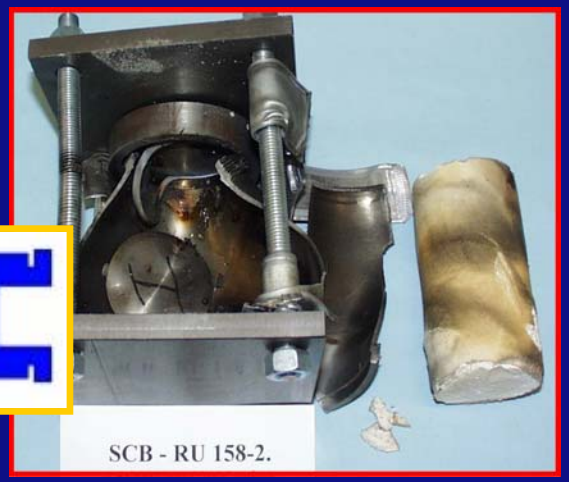


Warhead: Understanding the behaviour of explosives and IM



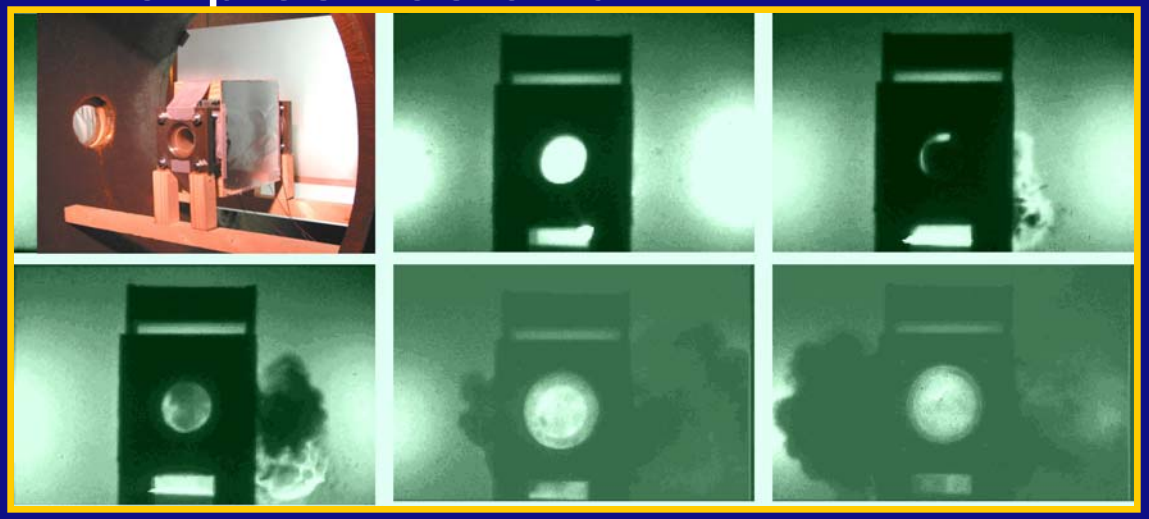




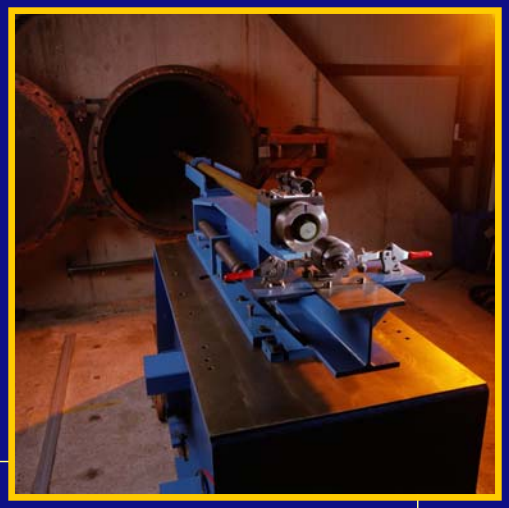


Cook-off testing and Simulation

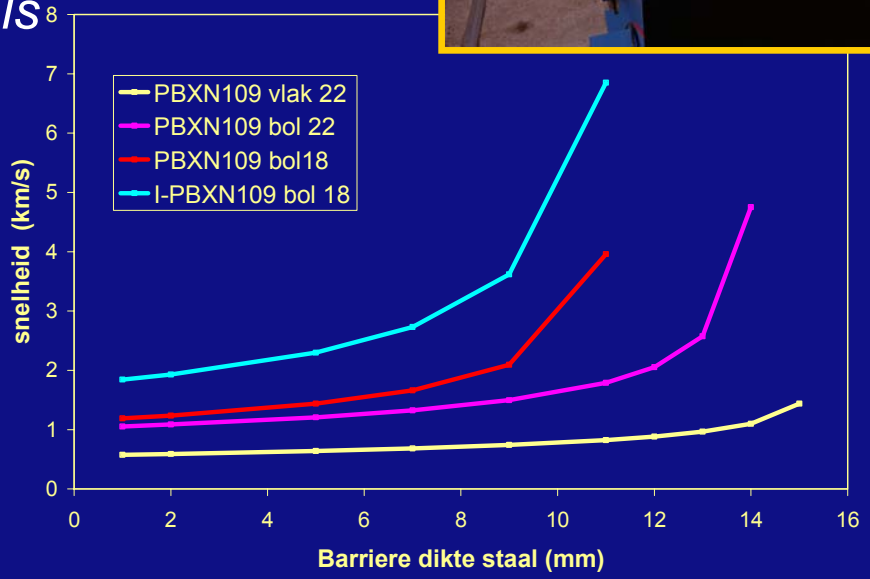
Warhead: Understanding the behaviour of explosives and IM



Bullet/Fragment testing and simulation



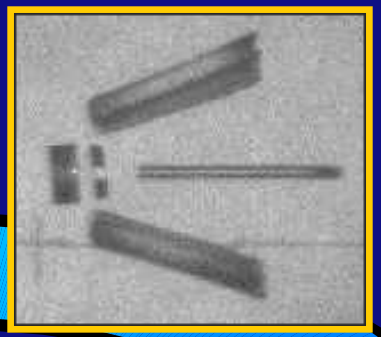
The responses of a confined materials after the impact of a fragment.



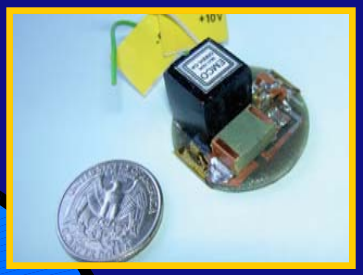
Overview

Propellant

Flight



Ignition train



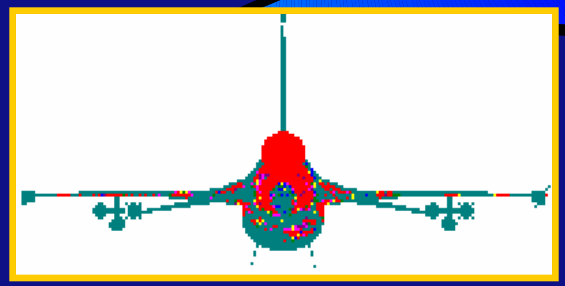
Ignition propellant

Lifetime prediction

Surveillance

Performance

IM Warhead



Effectiveness

Hit

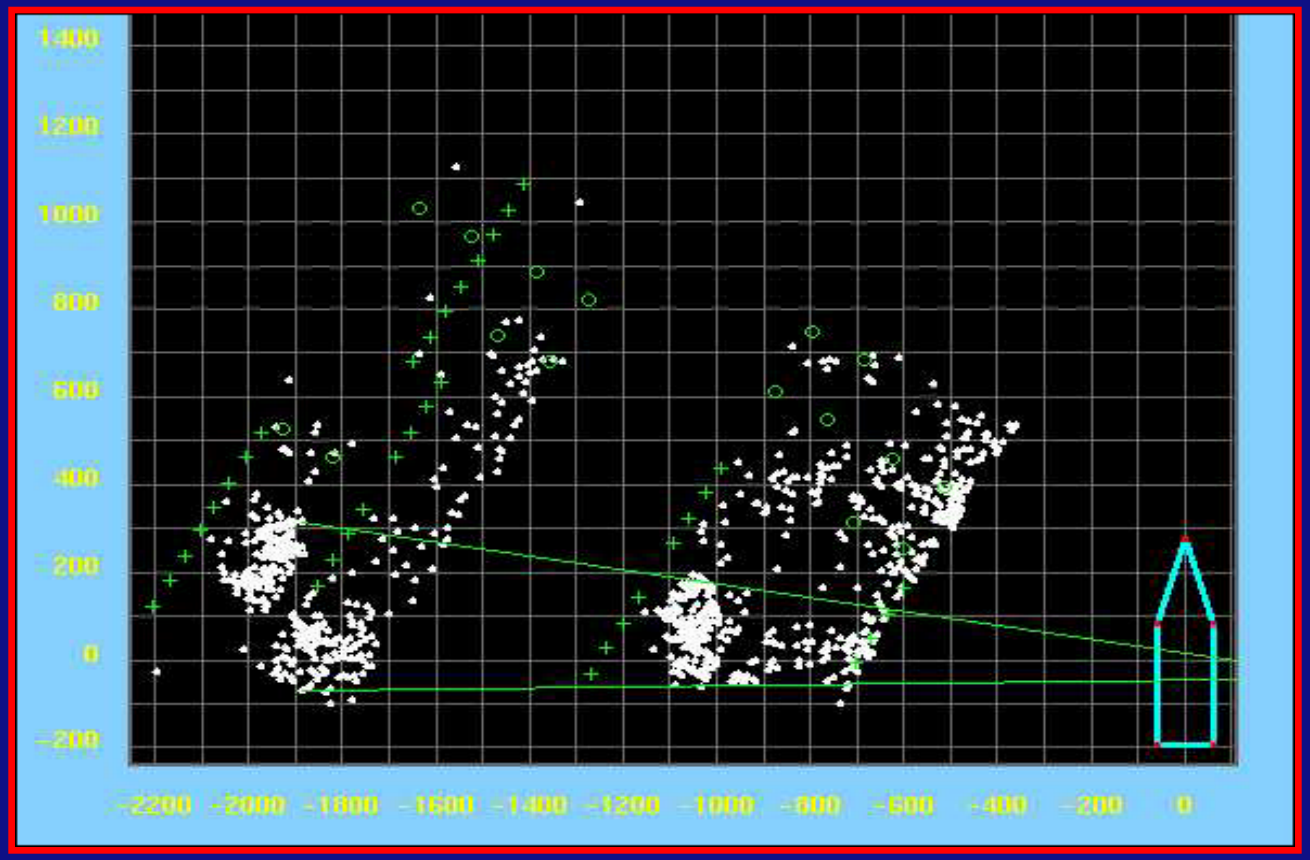
Effectiveness: Fragmenting ammunition testing

- 60 m range for HE ≤ 76 mm
- 200 m range for KE ≤ 40 mm
- Bunker for ≤ 25 kg TNT

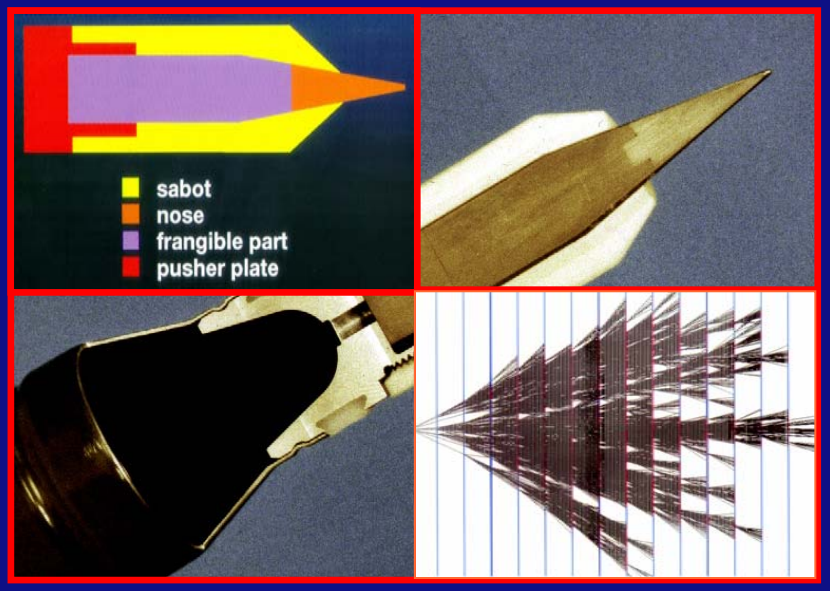
- Fragment cloud analysis method
  - Rotational symmetry
  - Cylinder with windows
  - Cardboard soft recovery
  - X-ray shadowgraphs
  - Image processing

Effectiveness: Fragmenting ammunition testing

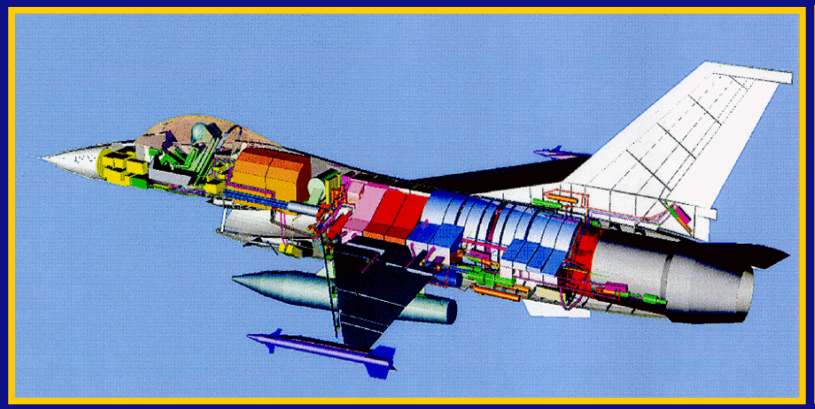
- Fragment distribution
  - Spatial
  - Velocity
  - Mass
  - Energy

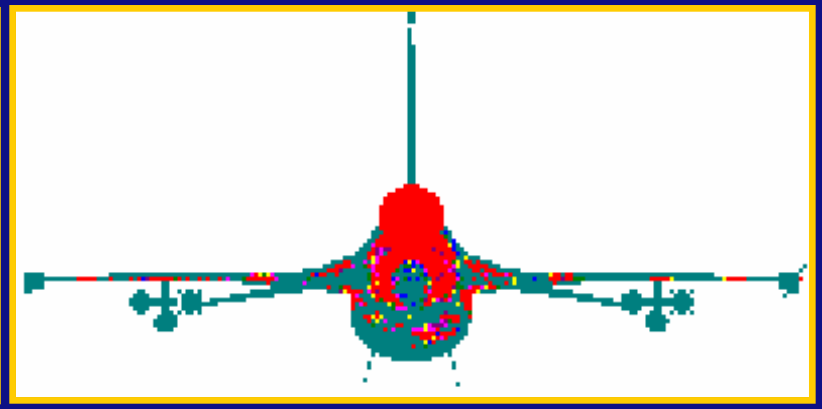


Effectiveness: Munition Lethality/Platform Vulnerability



Terminal ballistics experiments & simulations



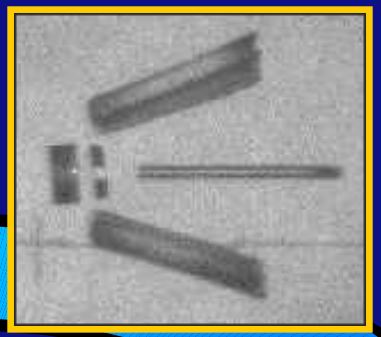


Lethality / vulnerability simulations

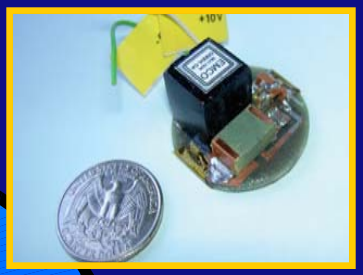
Overview

Propellant

Flight



Ignition train



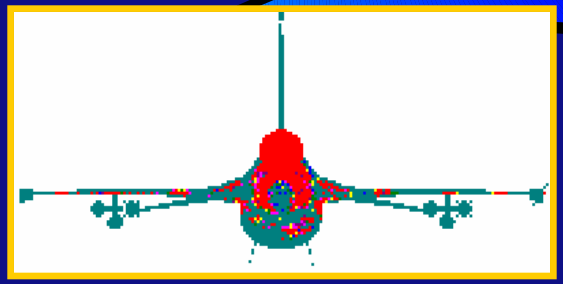
Ignition propellant

IM Warhead

Lifetime prediction

Surveillance

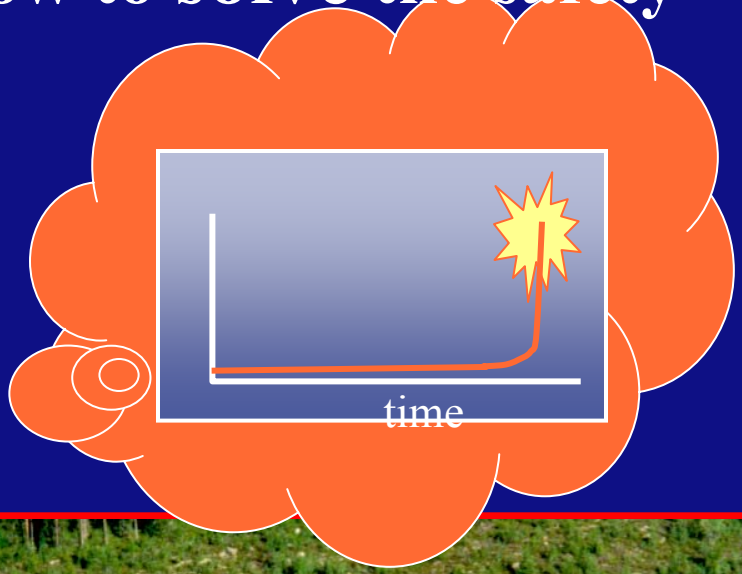
Performance



Effectiveness

Hit

Lifetime prediction: How to solve the safety problem?



Accident with propelling charges

Lifetime prediction: Ageing of missile

US AIM-7 Sparrow incidents
(1997 & 1999)

US MK-58 Mod 2 motor
investigation

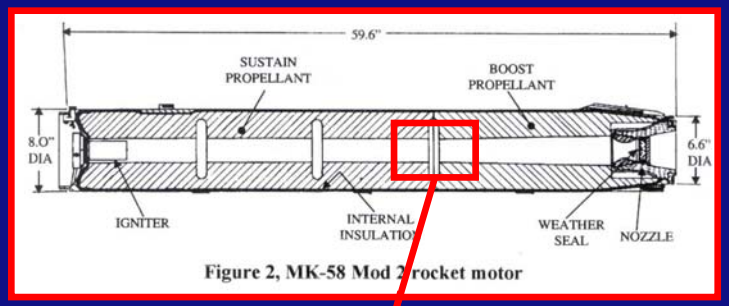
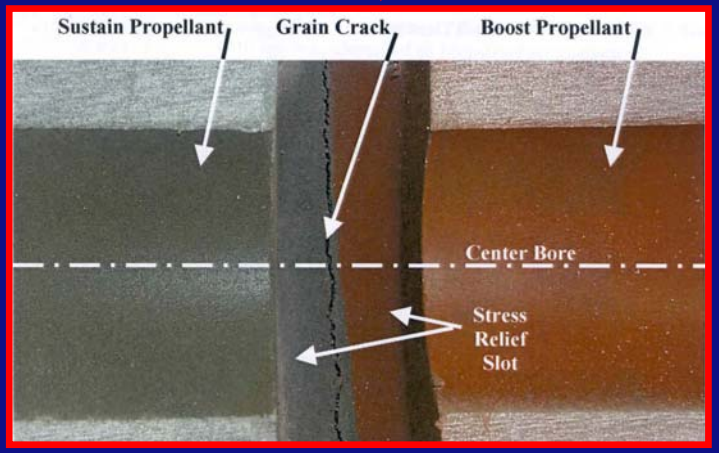
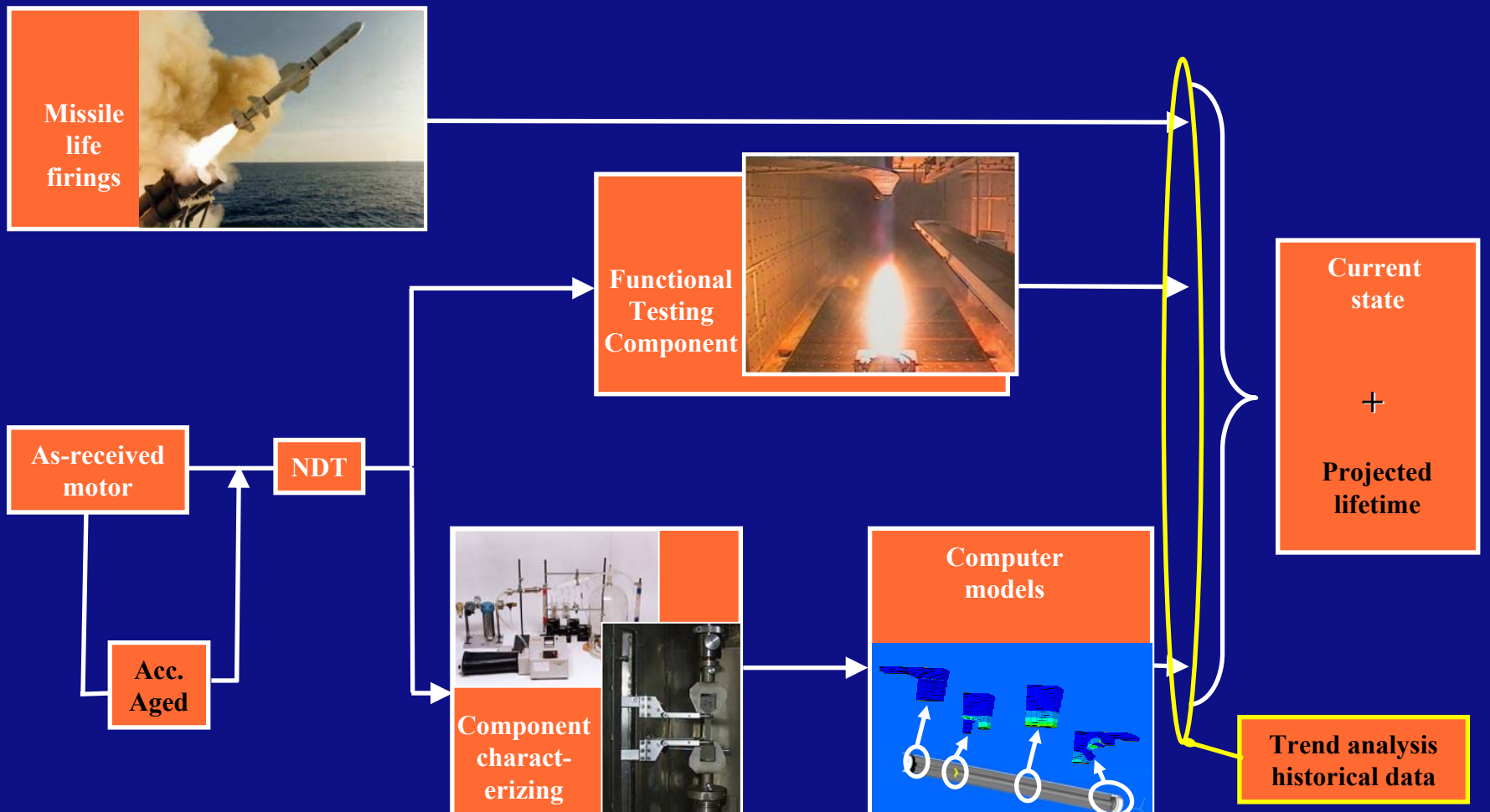


Figure 2, MK-58 Mod 2 rocket motor

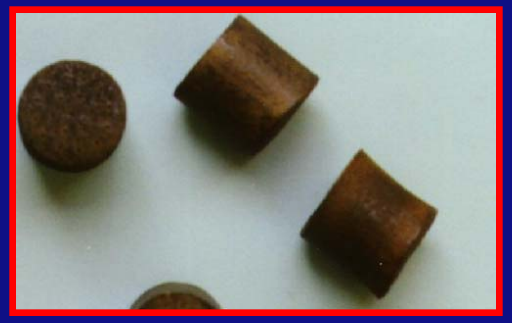


Source: paper P. Huisveld AVT-RTO-089, 2002 Aalborg

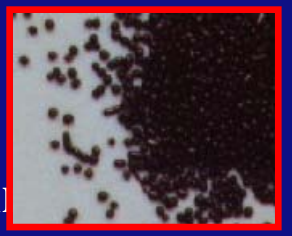
Lifetime prediction: Element “toolbox” for missiles



Surveillance of gun propellants



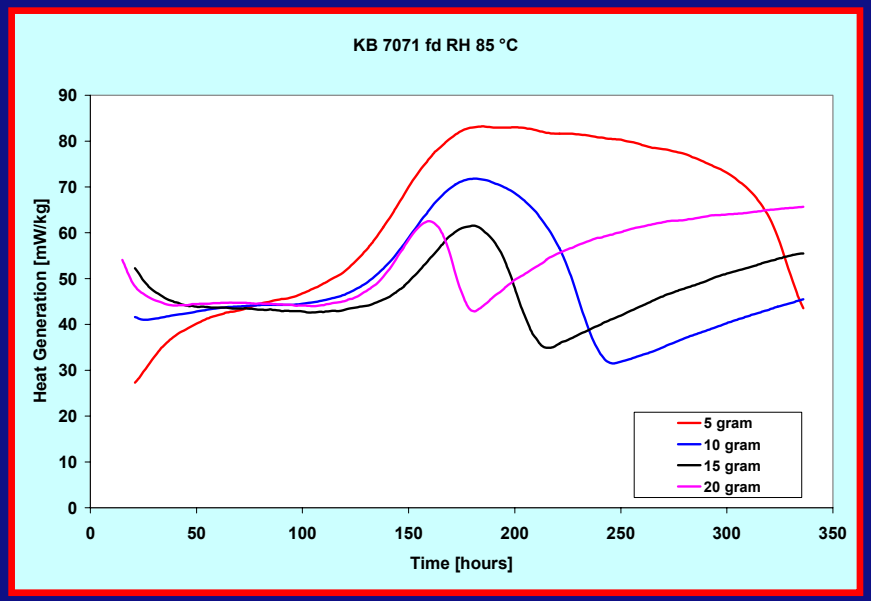
Range of 5 sample vessels covers the whole range of propellant grains



No pre-treatment of grai necessary

Surveillance of gun propellants

- Heat flow Calorimetry (HFC) with full size grains
- Heat generation in time as function of loading density of vessel
- →Munition like testing



Lifetime production and surveillance: Products

- Lifetime studies (Toolbox)
- Surveillance methodology for gun propellants (realistic comparison to ammunition situation, including
    - Equipment
    - Tailor made training programme
    - Tailor made munition management system
    - Guarantee and spare parts

Summary

- TNO Defence, security and safety is an independent organisation and a strategic partner for the Dutch Ministry of defence
- We also use our accumulated expertise for foreign governments and for defence related industries.

- R&D → development → prototyping → pre-production → production → in service, of munition: TNO has the expertise for Effective and Insensitive Munitions development.
- But also the expertise for lifetime predictions and surveillance of propellants.

- Combination of experimental facilities, theoretical knowledge/expertise and model/computer codes makes TNO a qualified partner for your future munitions development.