Novel techniques for improved munitions development

44th annual Gun and Missile system conference

TNO | Knowledge for business

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Overview

- Introduction

- I Propellants and
- II Ignition of LOVA propellants
- III Multi-mode warheads and
- IV EFI systems

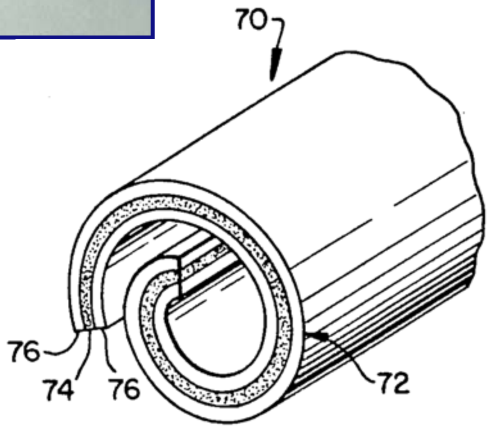
- Summary

Introduction

- Modern Military operations put high requirements on Munitions
- IM requirements (comparable performance)
- be inexpensive,
- Better performance (e.g. extended range munitions),
- decreased barrel erosion,
- temperature independent performance,
- Multi-mode or scalable functionality for MOUT intervention
- reliable (# UXO's) and
- have a long lifetime

I Propellants

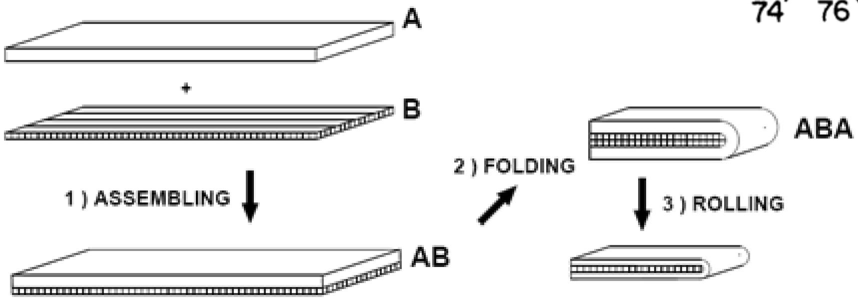
- Less Sensitive,
- more performance,
- decreased barrel erosion and
- temperature independent



- Solution: Co-layered propellants

- Advantage: improvement of gun performance by enlargement of the impulse on the projectile

- Manufacture:



- Disadvantage:
  - Difficult
  - Time-consuming

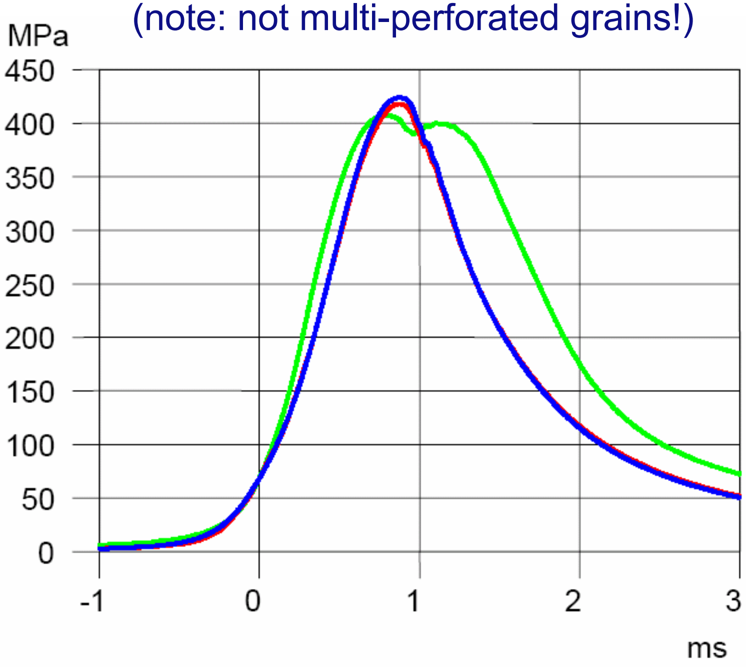
- **TNO's approach: co-extrusion**

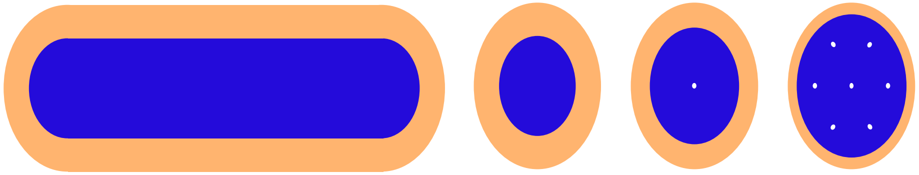
Co-layered propellants

(some) Advantages

- Increased performance
- Decreased erosivity of high energy propellants
- Increased ignition behaviour (e.g. LOVA propellants)
- A wide variation in geometries-> implying a larger number of possible applications

Ritter, ICT 2007
(note: not multi-perforated grains!)

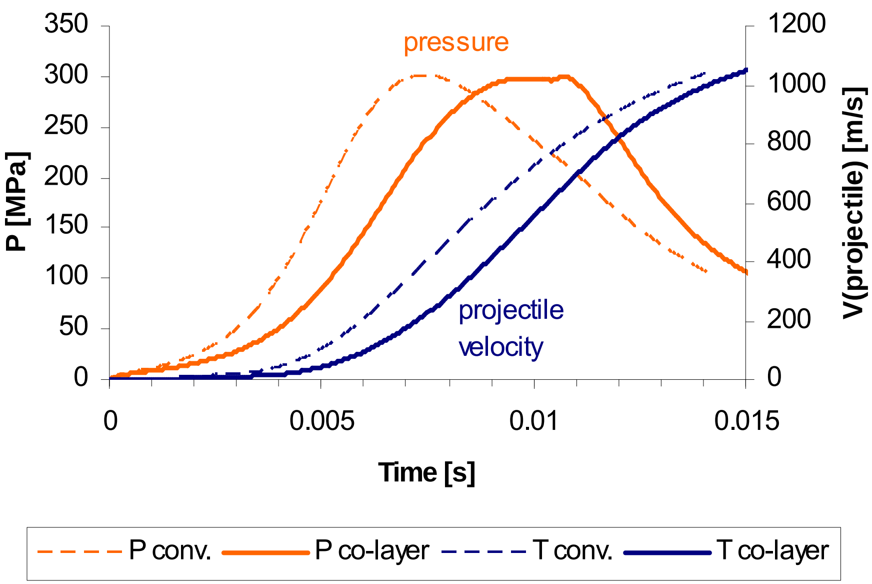


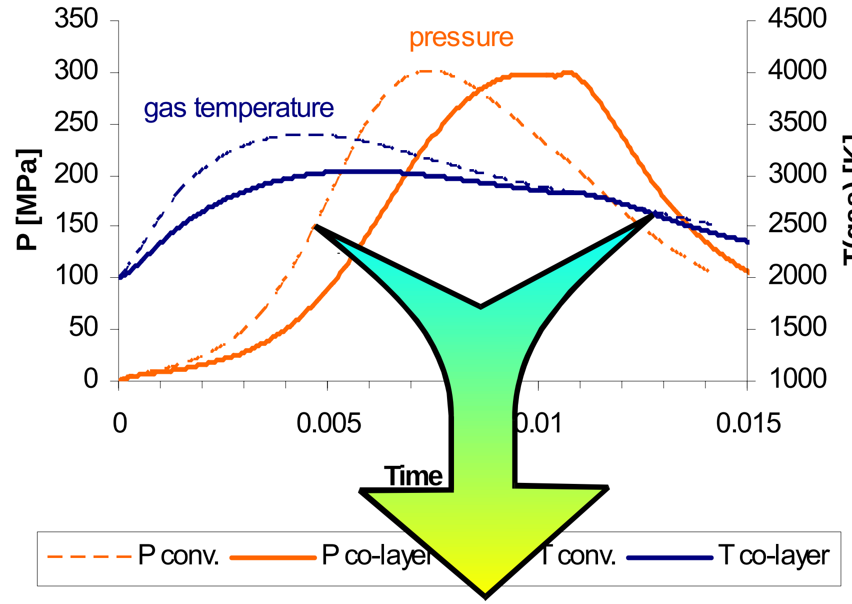


Performance: Co-layer vs. Conventional

- Examples of simulated performance effects

2 propellants: 7-perf; T_f(core) = 3515 K; T_f(layer) = 2900 K
factor burning rates = **2**



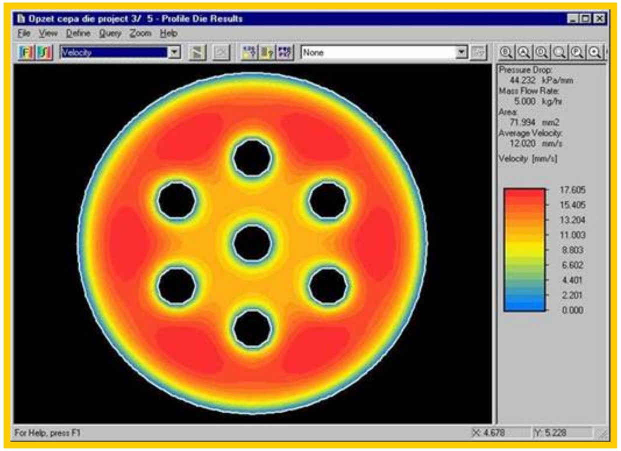


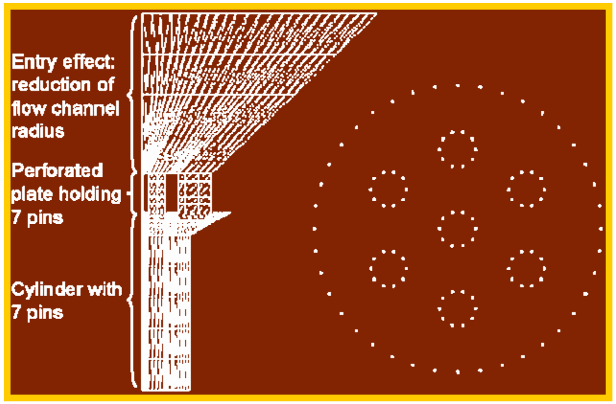
→ T_{max} = 3040 K
= 3385 K without 'cool' outer layer

Barrel lifetime increase ≈ factor 2

Results of Co-extrusion of co-layered propellants at TNO

- Improved die-design using special simulation software in 2007 (applying available knowledge from polymer processing)
- Die is very important for this process





Co-extruded LOVA propellant

Co-extruded DB propellant

Results of Co-extrusion of co-layered propellants at TNO

Bond integrity at high pressures:

→ Closed vessel tests with DB single-perforated co-extruded grains

- Manufacturing:
  - Excellent distribution of both layers
  - Excellent bonding
  - Also at high pressure (260 MPa)

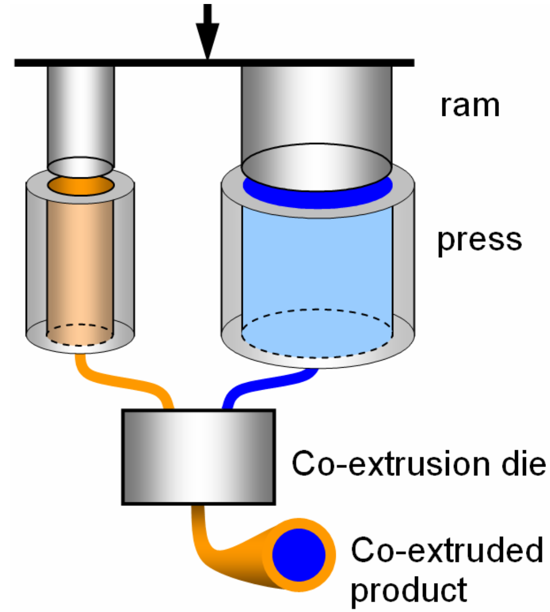
6.8 mm

Future developments

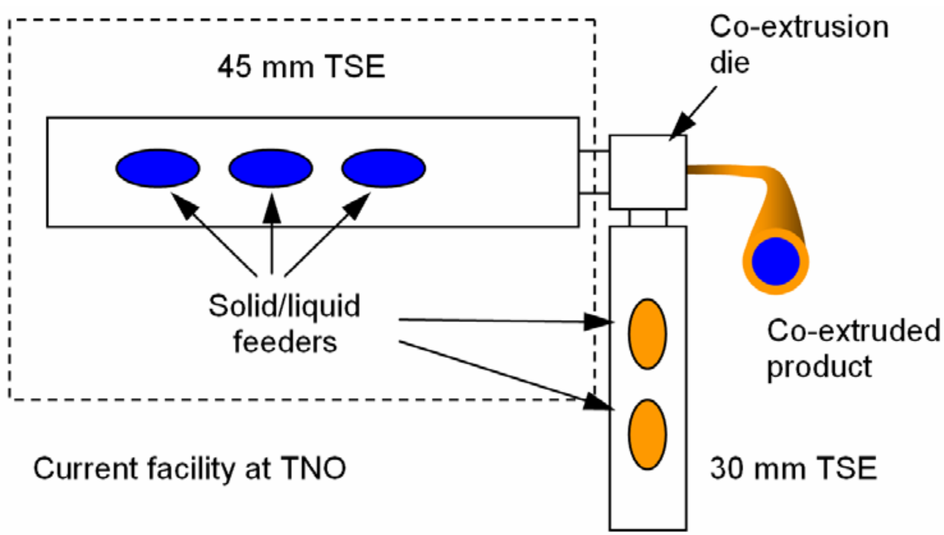
- Double ram press

Alternative ram extrusion set-up

- Well controllable process
- Inner and outer layer can be variable (i.e. composition and size)
- No dramatic change of facilities

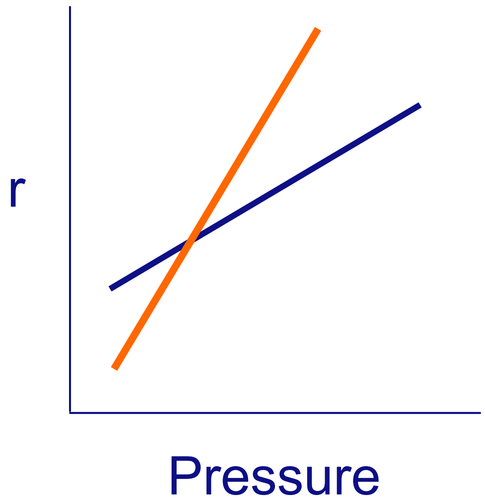


- Continuous co-extrusion (twins-screw extruder)



II Less vulnerable: LOVA propellant-> ignition problem

- LOw Vulnerability propellants
- Burning behaviour (Vieille's law): $r = \beta \times P^{\alpha}$
  - Conventional (NC-based) $\alpha \approx 0.6 - 1.0$
  - 'LOVA' (RDX-based) $\alpha \approx$ **1.0 – 1.4**



- Two-step ignition process:
  - Endothermic pyrolysis of binder
  - Exothermic combustion

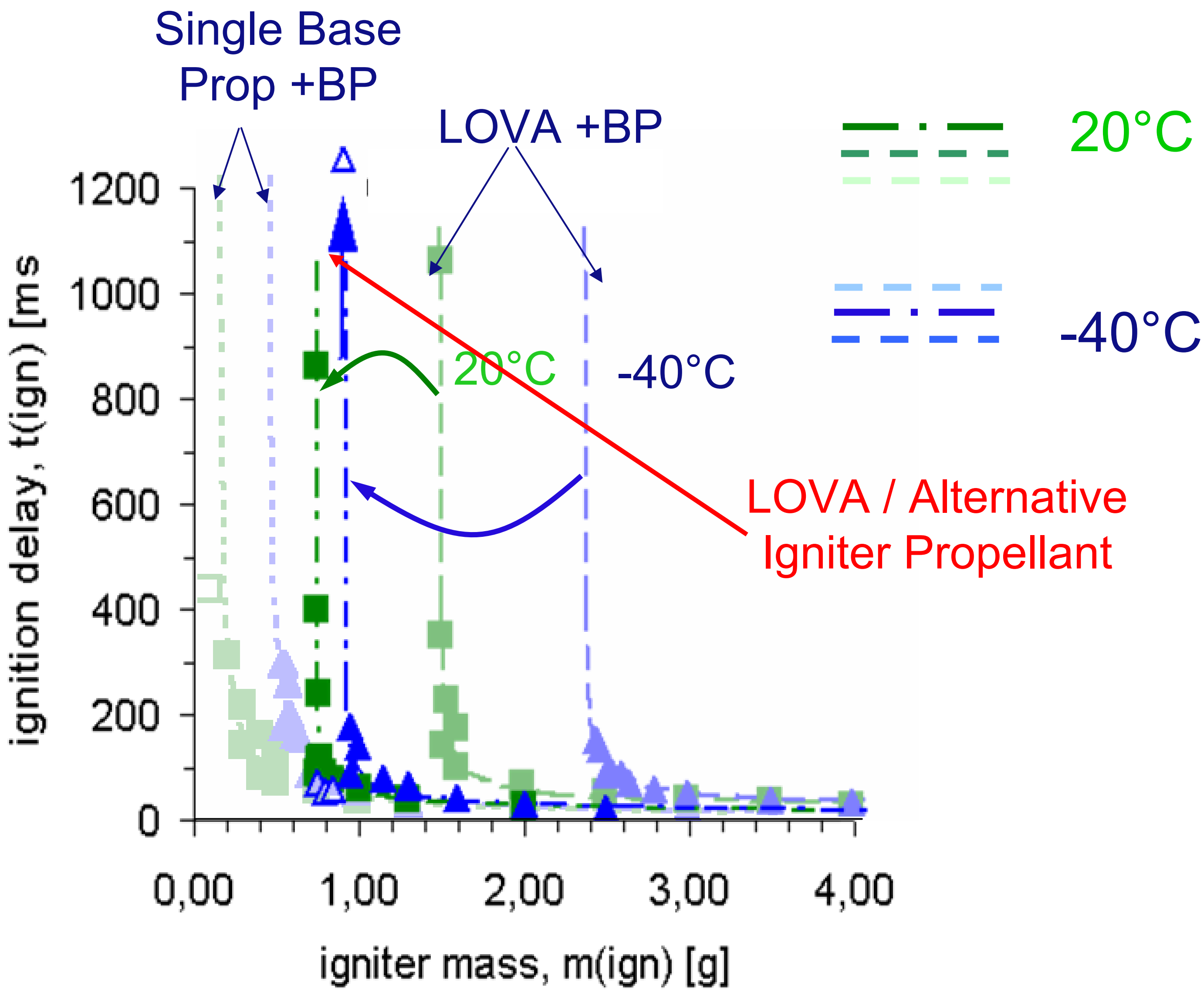
→ ignition phase LOVA's: low pressure → low burning rate → **lengthy and variable ignition delays**

Test results – mis-fires

- Mis-fire: insufficient igniter output for ignition of the propellant

- Grain surface melts initially, recovered grains stick together
- Tiny droplets of igniter (BP) combustion products on grain surface

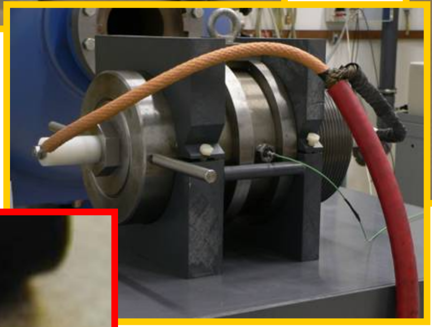
Ignition delays and improved igniter composition



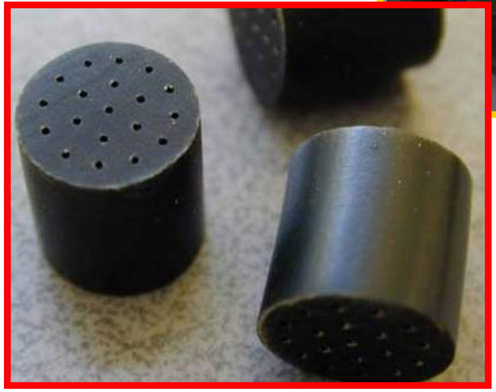
Propellants:
Testing facilities

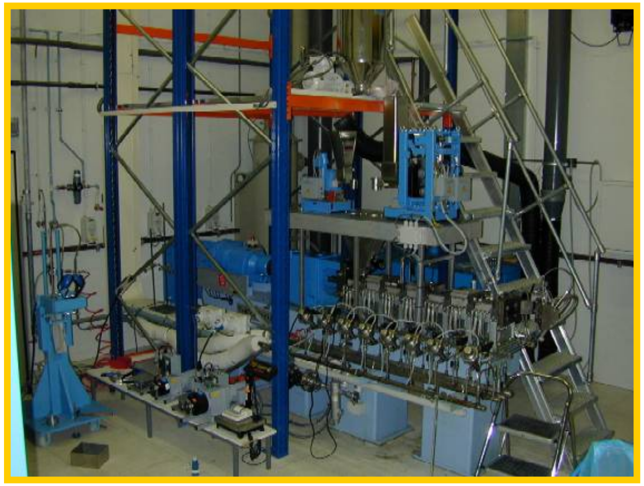
- Closed Vessels
- Erosivity & burning interruption tests
- Gun simulator
- Laboratory Guns
- Plasma ignition





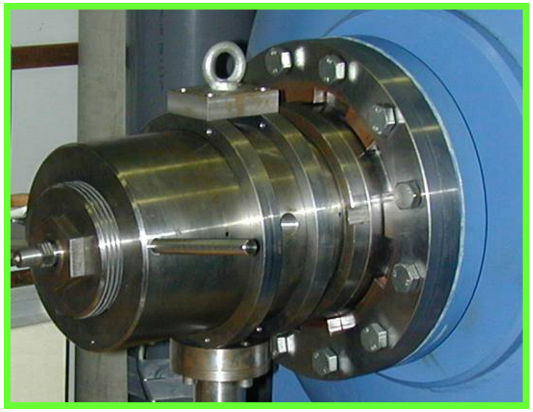
Closed VesselsV's (25 – 700cc)





45 mm twin-screw extruder

Plasma ignition

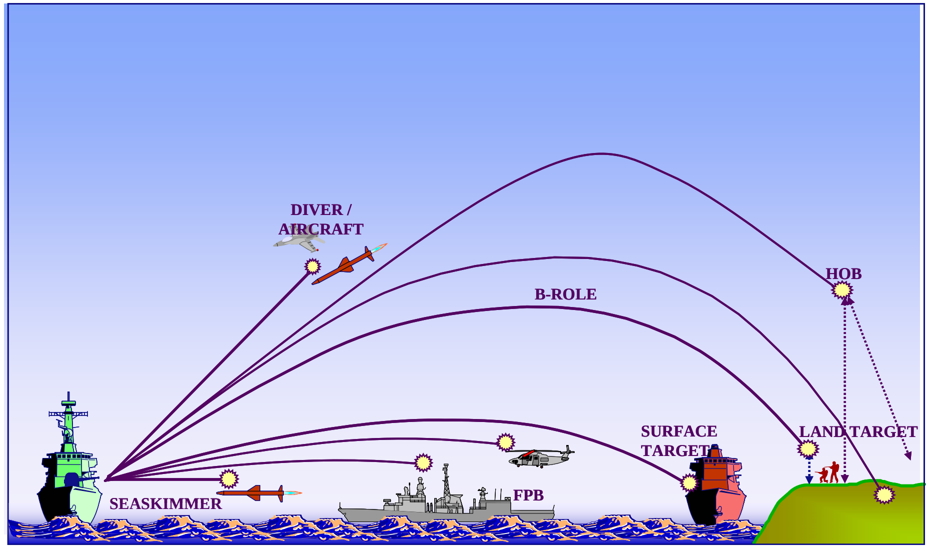


Vented HPCV and catch tank

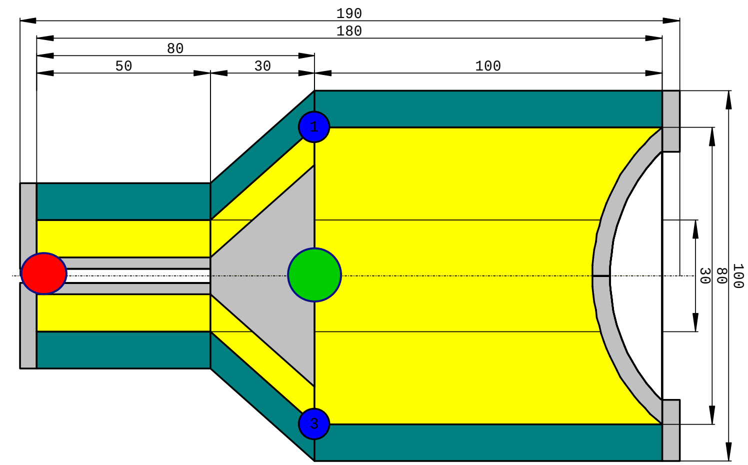
III Multi-mode warheads

- Solutions:
  - Programmable fuzes
  - Warhead design
  - Complex ignition systems

- The MEDEA programmable fuze is intended for use against (see Figure):
  - Fast patrol boats FIAC
  - High diver missiles
  - Sea skimming missiles
  - Fixed wing aircraft
  - Rotary wing aircraft
  - Surface vessels



Multi-mode warheads: e.g. EFP



- Changing location of ignition
  - EFP mode
  - Streched EFP
  - Fragments
  - Aimable warhead

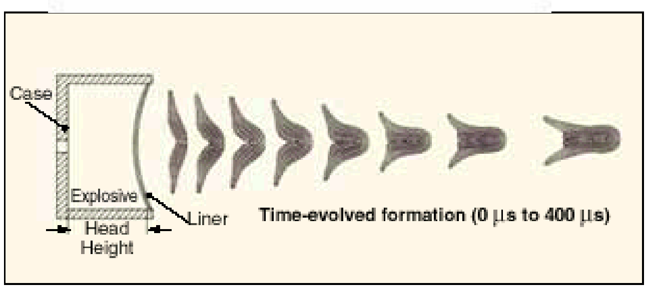
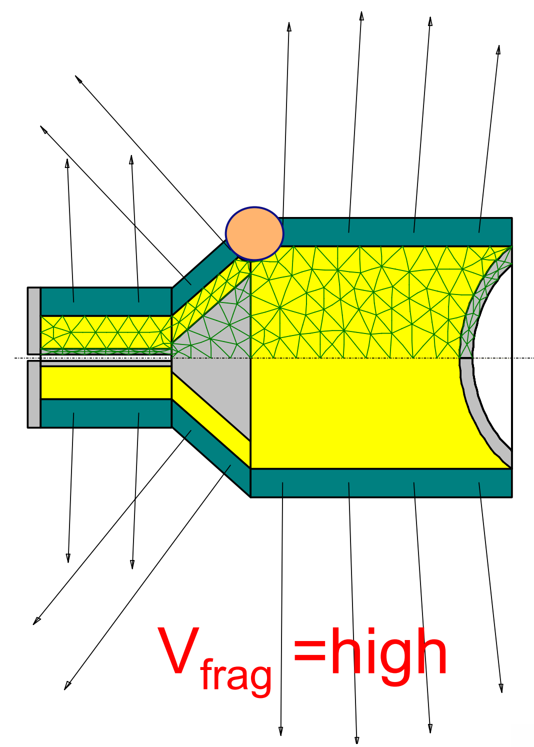
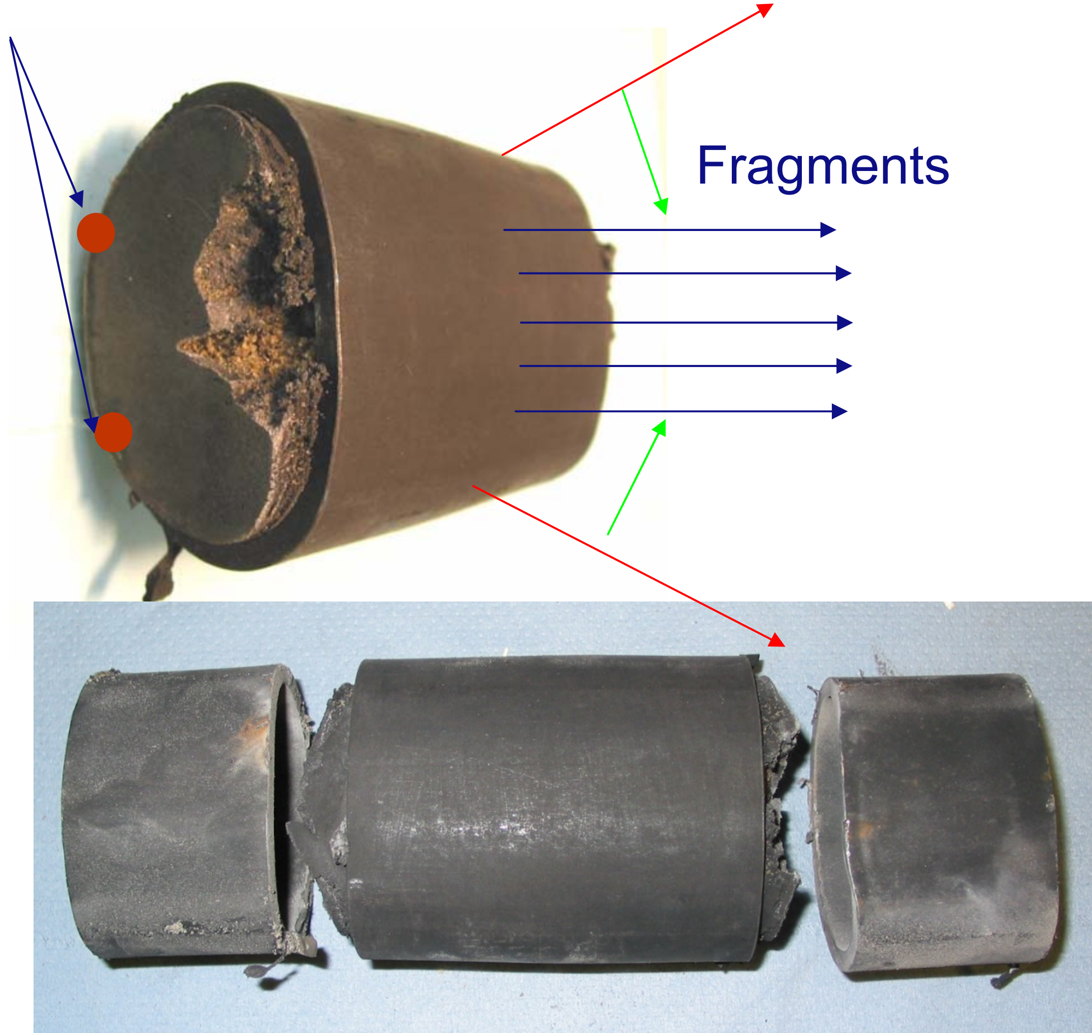


Figure 1. Formation of an EFP warhead

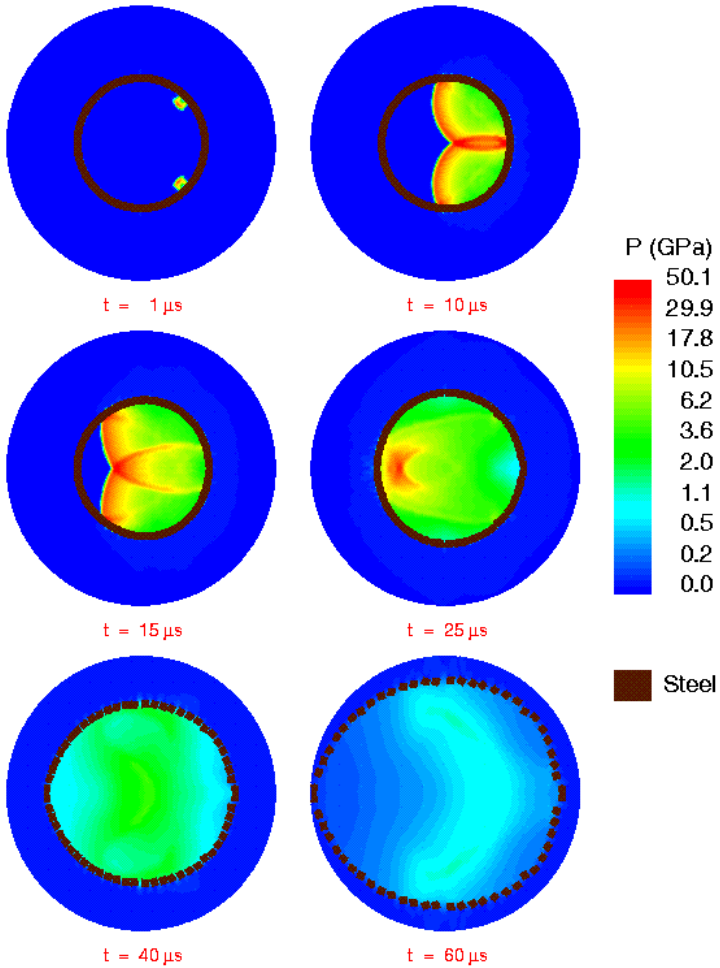


Forming of warhead (aimable)

- 3 mm plastic explosive, buffer: 1 layer rubber (PBXN-109)
- After forming: ignition



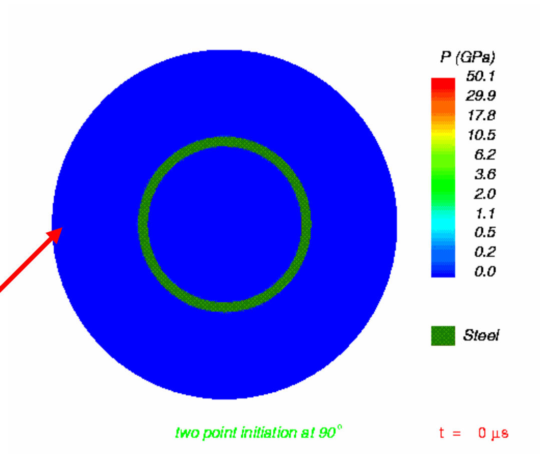
Aimable warheads: 2-Point initiation vs single



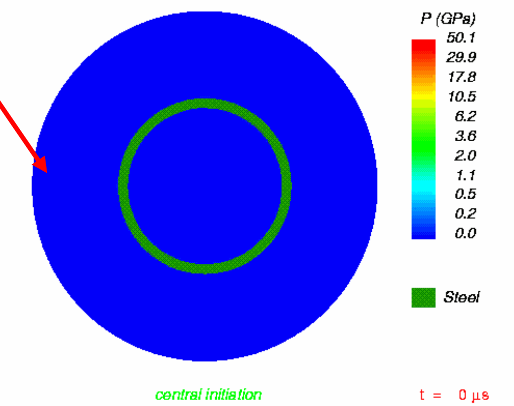
two point initiation at 90°

V_{max}= 2700 m/s

Fragment velocity



V_{max}= 2000 m/s



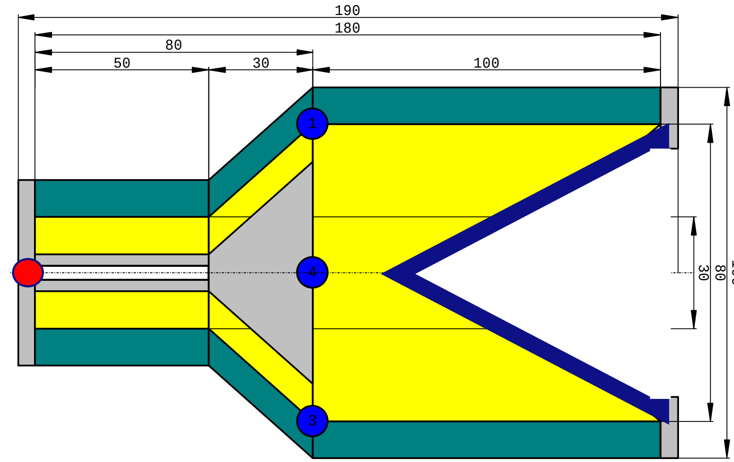
Multi-mode warheads: e.g. SC

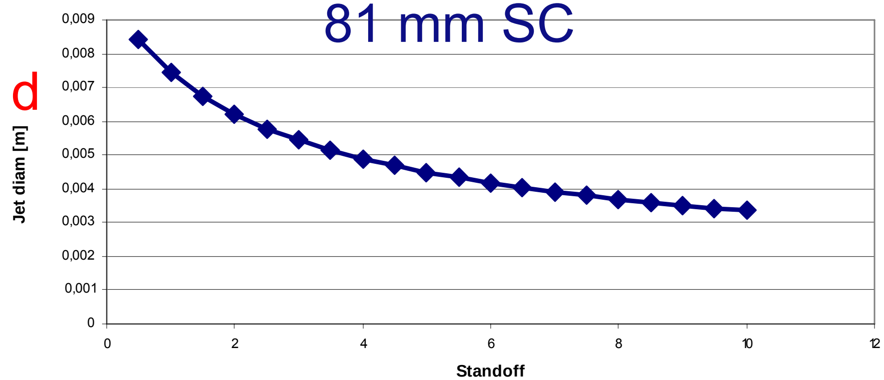
- Shaped Charge or
- EOD Shaped Charge

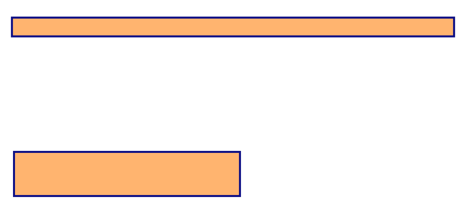
- Initiation of Explosives
- v^2d=constant [Held criteria]
- V= velocity of tip and d = diameter of jet (V in km/s and d in mm)

- PBXN109: 49 BSDT
- I-PBXN109: 92 BSDT

- For penetration: long jet -> small diameter
- For EOD: v^2d max. so short stand-off -> large diameter
- Timing of igniter
- But timing is crucial; Solution:



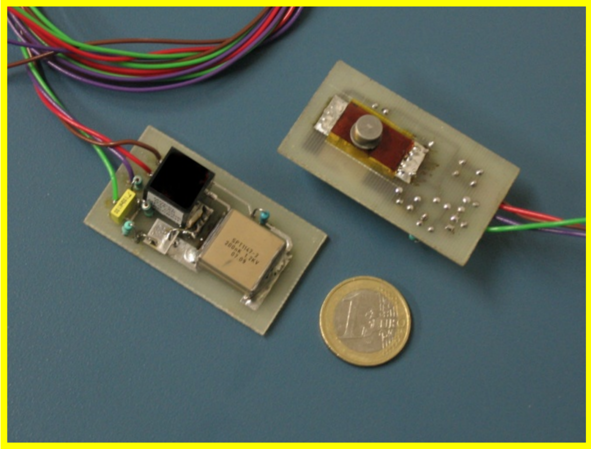




EFI Igniter

IV Why an EFI system

- An EFI is intrinsically safer than standard initiators (no primary explosive)
- More reliable (So, no UXO's)
- Works much faster < microseconds (µs)
- Can be smaller (near future)
- Is compliant with new STANAG (4560) regulations
- New opportunities (tandem charges, aim able warheads etc.)

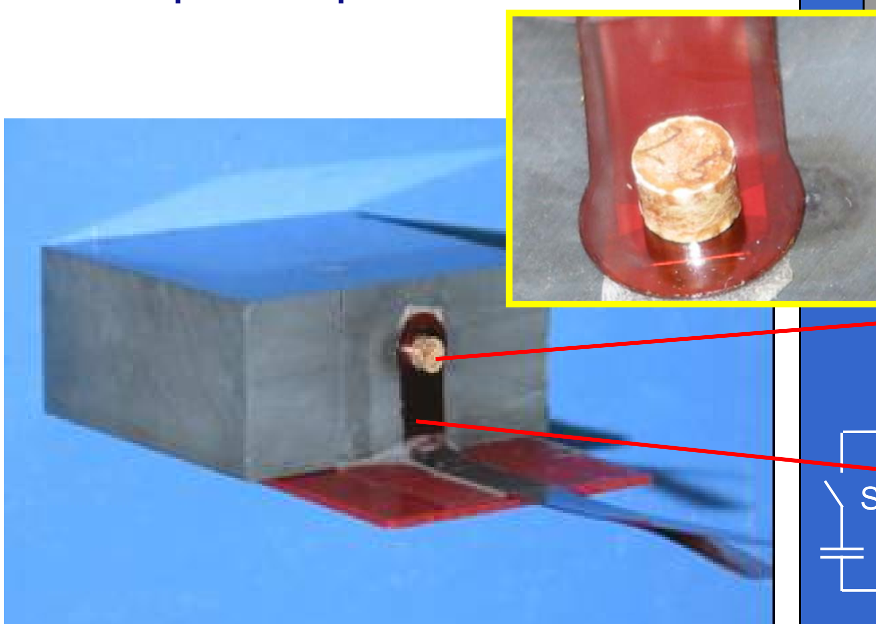


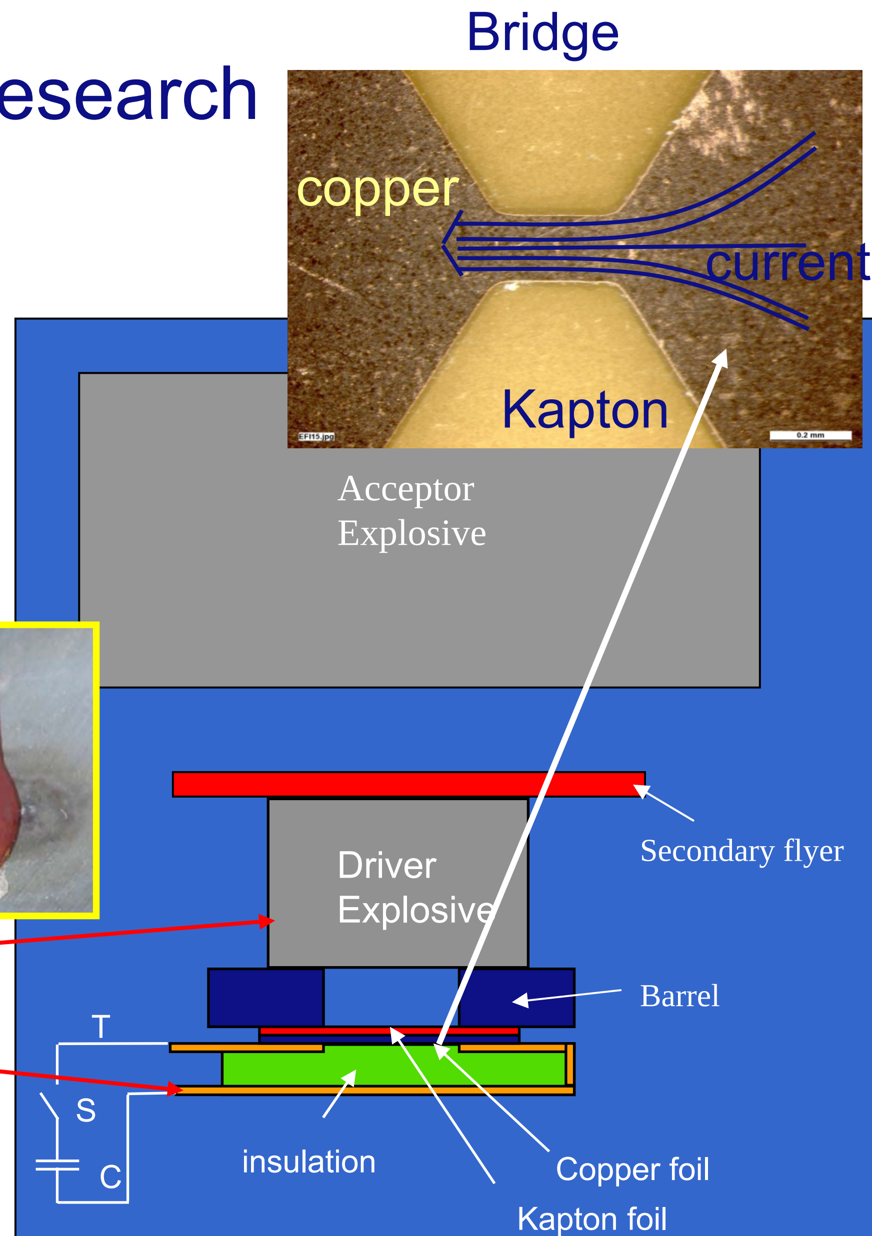
- Disadvantage : More expensive (at the moment)

- Future: Micro Chip EFI (McEFI) → inexpensive

Exploding Foil Initiator Research

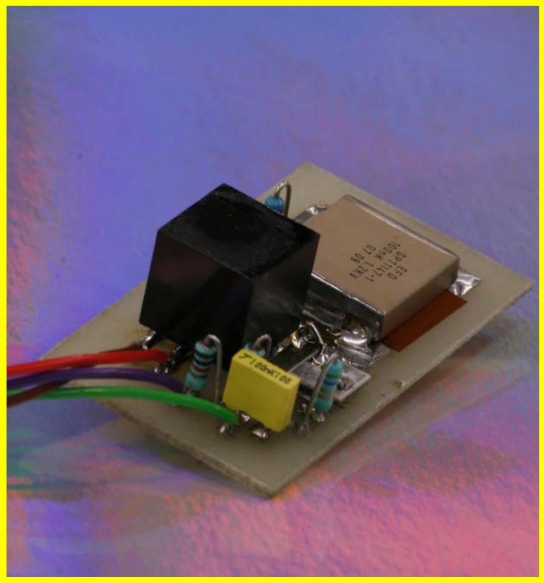
- Exploding foil
- Electrical circuit
- Velocity of the flyer
- Driver Explosive
- Secondary flyer
- Acceptor explosive





Conclusions mini EFI and Mc EFI development platform

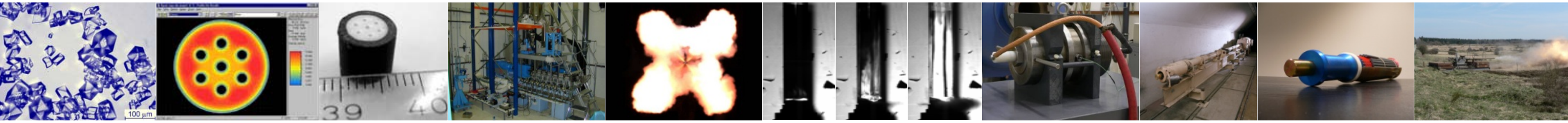
- A very efficient electrical circuit (η = 50 → 90%)
- Mini-EFI Works at Voltage < 1300 Volt (Solid state switch)
- With “of the shelf components” small IM compliant EFI-detonators can be built (~8cm^3 including High Voltage-supply)
- Secondary flyers makes the detonation train more reliable (in case of set-back)



- Successful initiation of TATB and RDX with several types of flyer materials
- Combining the EFI with the ESAD with Micro Chip technology can make a small and cost effective unit
- Solution for complex ignition system (multi-mode warheads)

Summary

- Modern Military operations put high requirements on Munitions
- Innovation in munitions' development can give the answer, examples:
  - Co-layer propellants (co-extrusion)
  - Ignition of LOVA propellant
  - Multi-mode warheads and programmable Fuzes
- Technical solutions can help to address the challenges for your future munition developments



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