55th Annual Fuze Conference
Fuzing‘s Evolving Role in Smart Weapons

Generation and Measurement of Long Duration High-g Acceleration Profiles

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OUTLINE

- Introduction
  - Need for Test Methods
- Generation of Long Duration Transients
  - EMI Defined-Long-Duration Shock Test
- Application
  - Choice and Test of Electronic Components
- Measurement of Long Duration High g-Acceleration Profiles
  - Penetration of Concrete
- Summary

Motivation
Smart Weapons with Penetration Capability

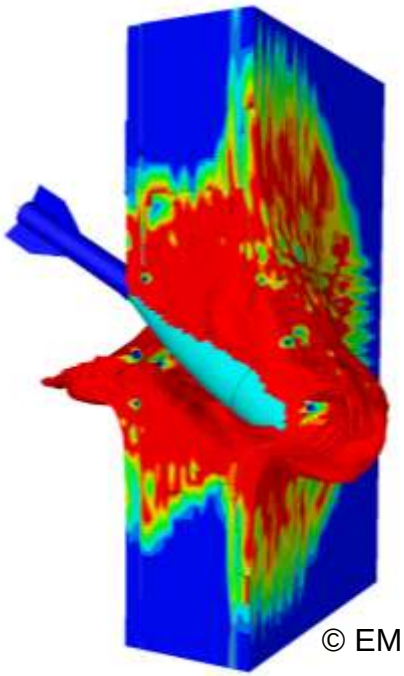
- High-g hardened fuzing
  - Large warheads
  - Upcoming: Smaller calibers as for precision guided munitions with moderate effect $a_{max} > 100{,}000$ g

  $\Rightarrow$ the smaller the ammunition, the bigger the acceleration

- No manufacturers specifications available for electronic parts for high-g-regime
- Inexplicable system failures in the field

$\Rightarrow$ need for reliable, cheap high-g-test methodology

image: wikipedia



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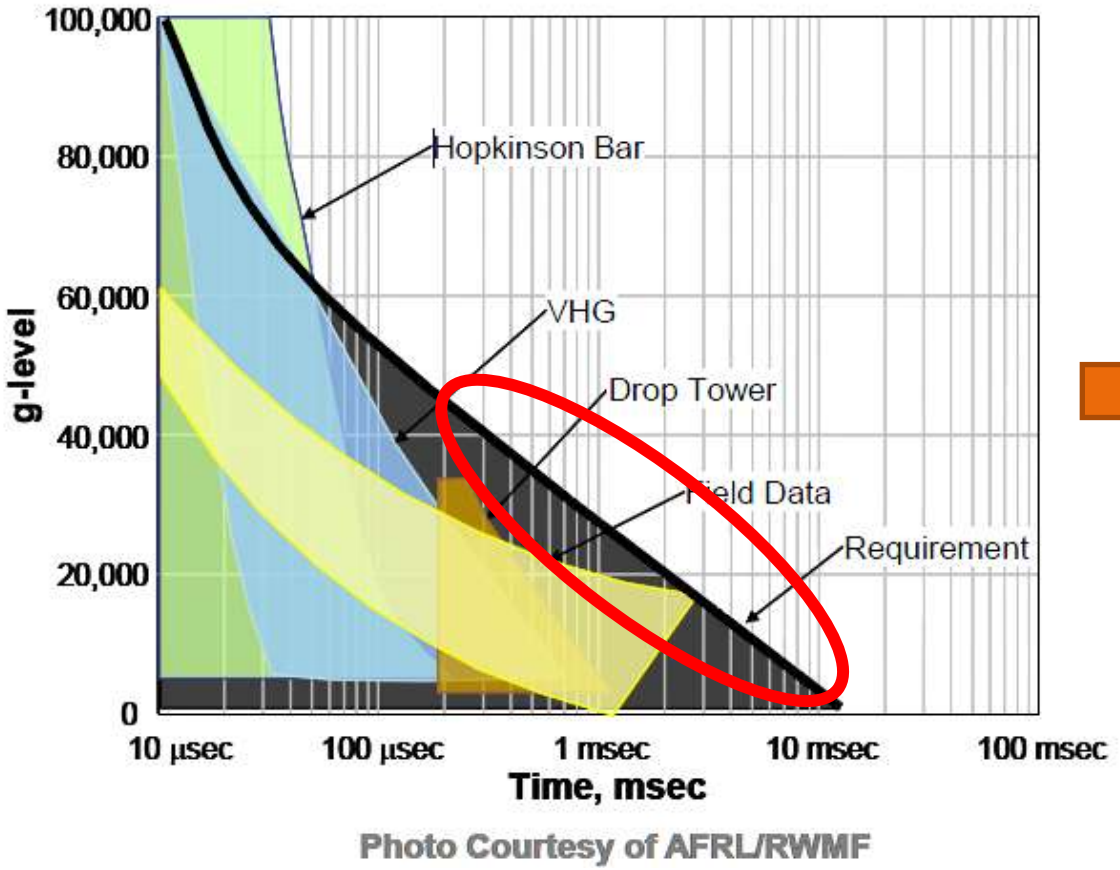
Required Test Methodologies for Sub-Scale Survivability Test

Fuze-Conference 2010:
D. Hayles, DTRA : Notional Shock Spectrum



technical requirement:
$v_{0,\ DUT} > 100$ m/s

EMI Defined-Long-Duration (DLD) Shock Test

- High initial velocity of actuator

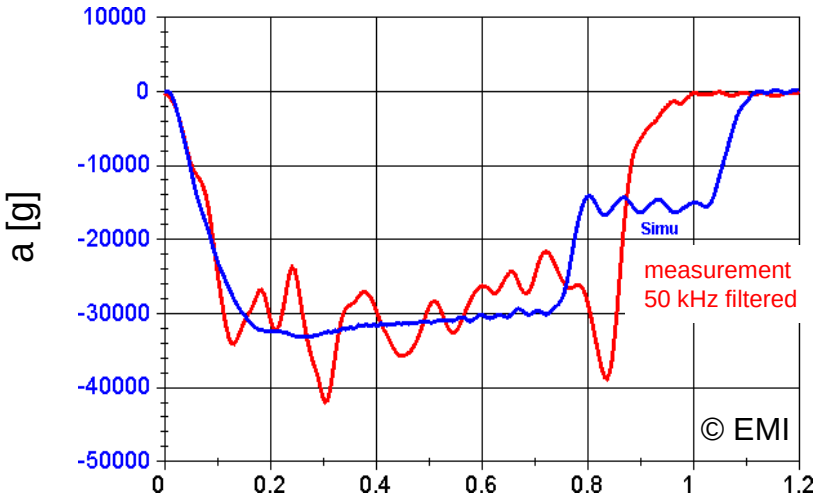
  ⇒ long duration *and* high amplitude load profiles

- Numerically tailored compression body

  ⇒ quantitative load profile estimation

  ⇒ new load regimes reproducible accessible

- Experimental validation by g-rec or PDV* measurements



Example: 30.000 g, 800 µs

- Numerical prediction:
  movement of center of gravity

- Measurement inside sample holder

* PDV: Photonic Doppler Velocimetry

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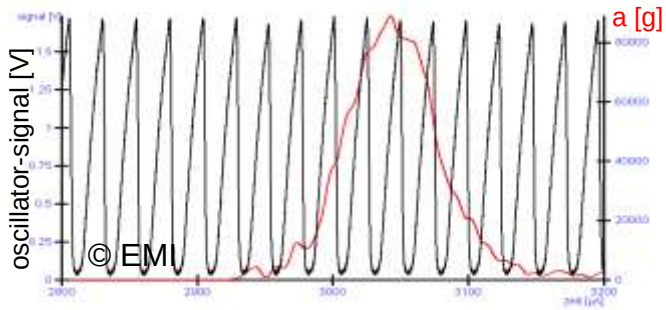
EMI Defined-Long-Duration (DLD) Shock Test

- Current R&D-setup:
  - $m_{(Device\ Under\ Test)}$ up to 200 g
  - ø < 34 mm,
  - l = 100 mm

} scalable to higher values

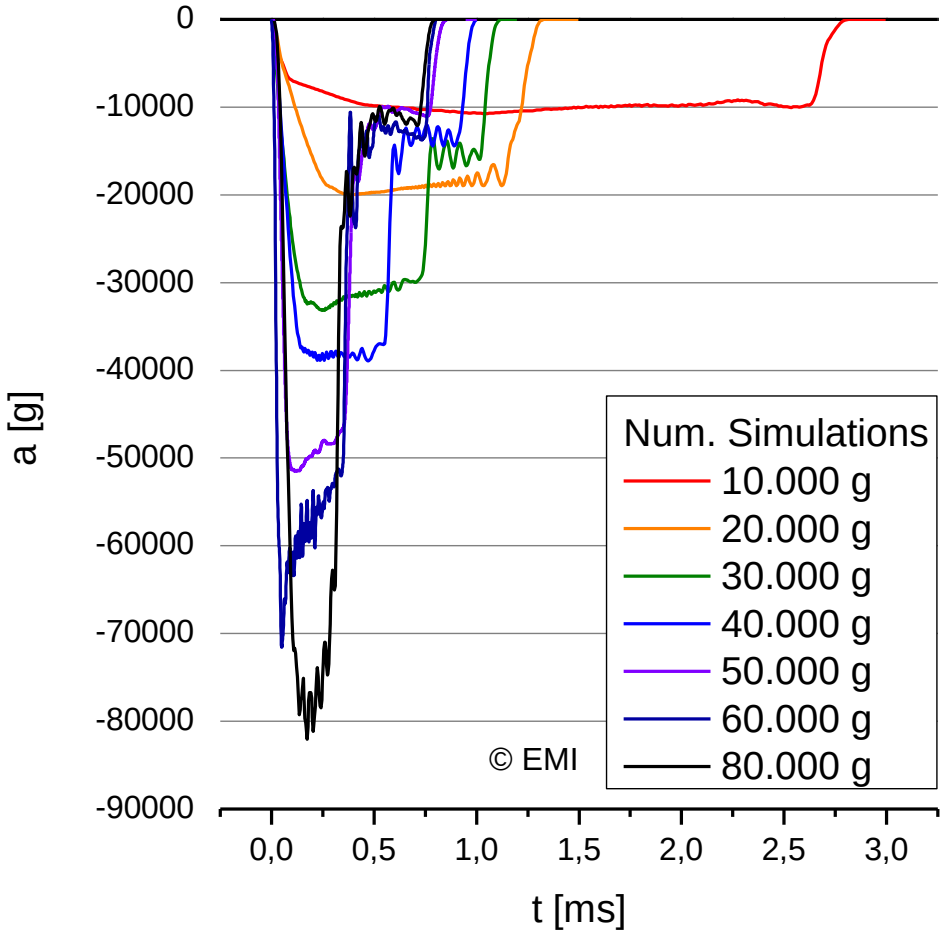
- If needed: Device under Test electrically connected
- Low temperature experiments (-46 °C) possible
- Modest cost
- Extension to spinning systems is under way

Exemplary sample holder

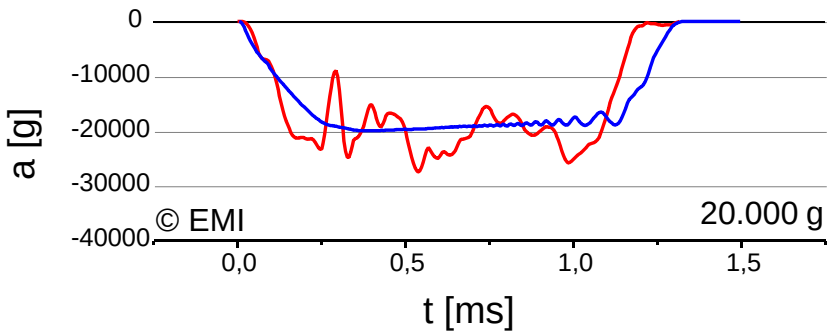


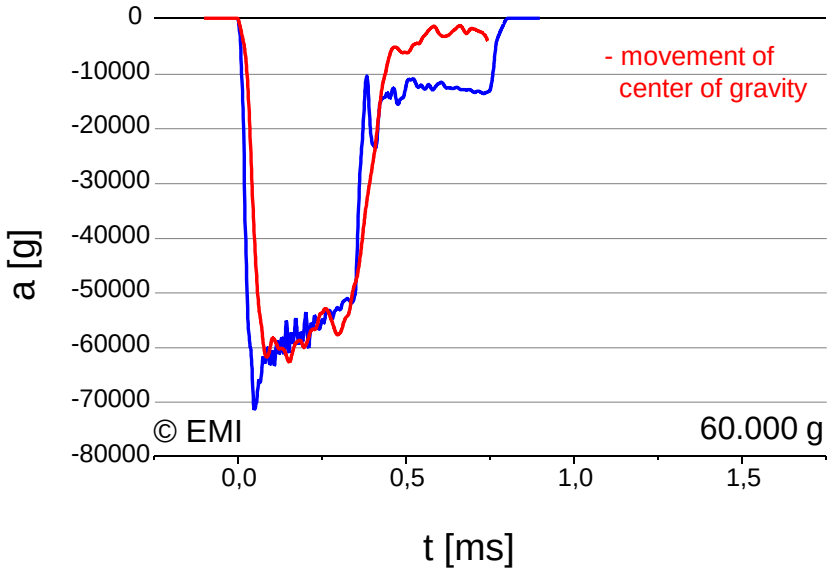
Example: 80.000 g oscillator-Test

EMI - DLD - Shock Test



Comparison
- Experimental Data (50 kHz filtered)
- Numerical Simulation





EMI - DLD - Shock Test

Experimental Results

D. Hayles, DTRA, Fuze Conference 2010

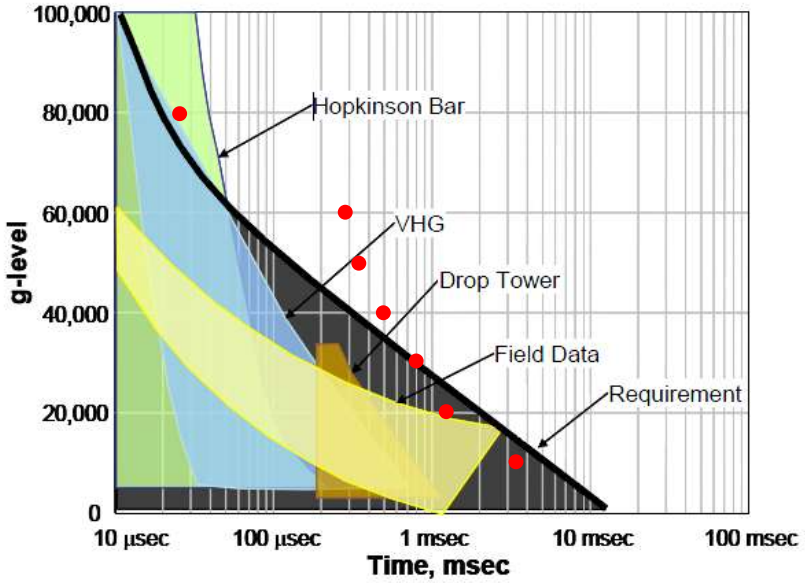


Photo Courtesy of AFRL/RWMF

Experiments were conducted in cooperation with industry partners and used for product development.

EMI-DLD-Experiments

10.000 g	3.300 ms	(exp)
20.000 g	1.250 ms	(exp)
30.000 g	0.800 ms	(exp)
40.000 g	0.520 ms	(exp)
50.000 g	0.350 ms	(sim)
60.000 g	0.310 ms	(exp)
80.000 g	0.025 ms	(exp)
	0.300 ms	(sim)

Experiments validated by

- exp — acceleration measurement or Photonic Doppler Velocimetry
- sim — numerical Simulation *and* high-speed Video

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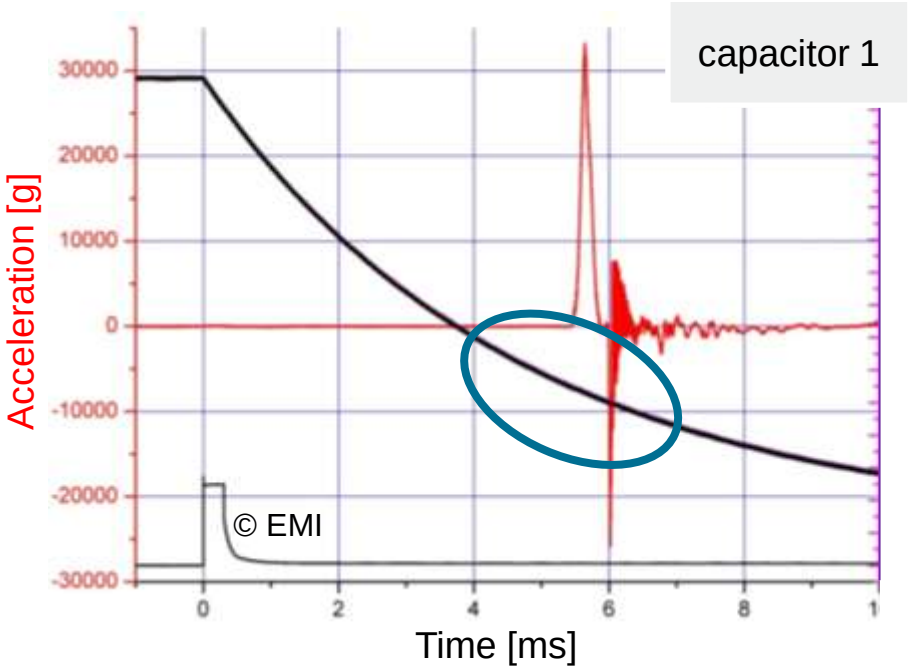
Application
Choice and Test of Electronic Devices

Device behavior upon high-g-loads:

- Intended function
- Disintegration of the device
- Malfunction only during load

⇒ DLD-Shock-Test with electrical access to relevant device properties during load



Example: Capacitor 1

⇒ intended function

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Application
Choice and Test of Electronic Devices

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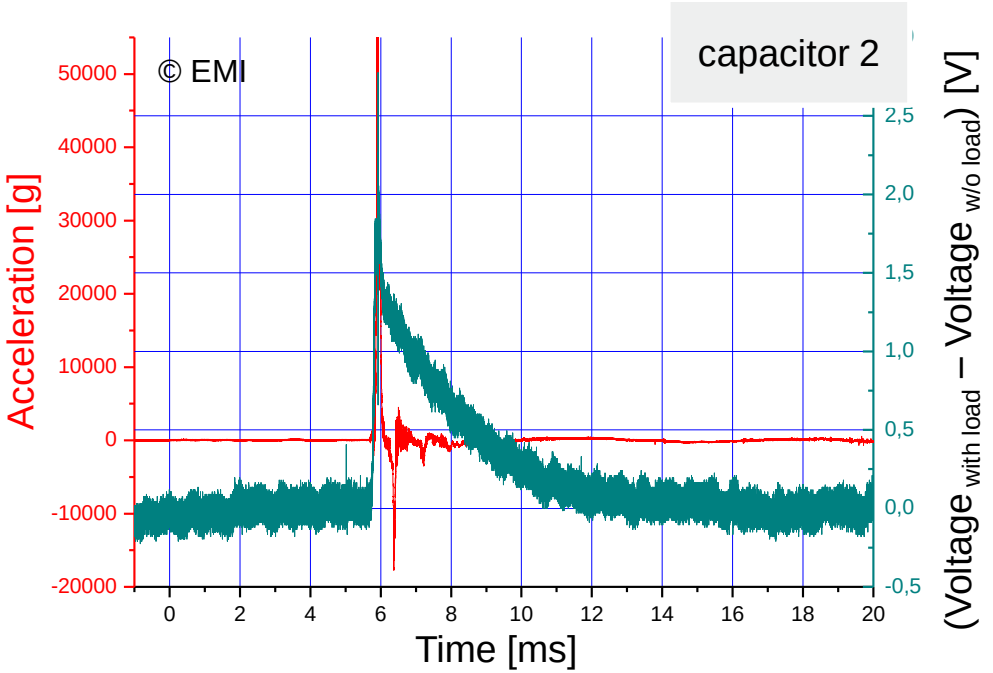


Example: Capacitor 2

- (Reversible) effect only during load !
- Pre- and post-mortem results could be misleading

Approach / solution :

- Usage of different devices, or device technologies
- Improved engineering concepts

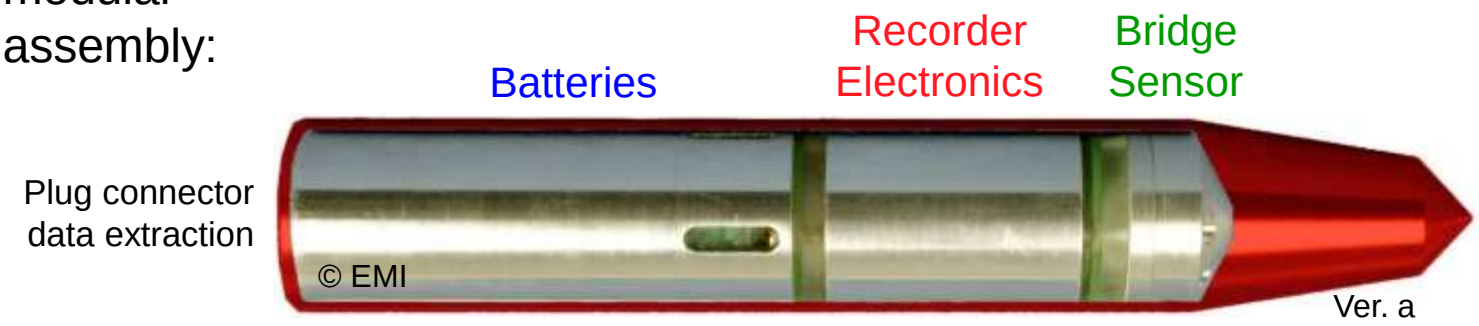
Application g-rec

Measurement of Long Duration High-g Acceleration Profiles

Concept

- Autonomous digital data recorder with shock accelerometer
- Resistant to high accelerations and decelerations (> 100,000 g, Ver. a)
- PC based data retrieval after projectile recovery

modular assembly:



2 versions: a) hard-wired version ø = 26 mm, l = 155 mm

b) programmable, based on microcontroller ø = 23 mm, l = 80 mm

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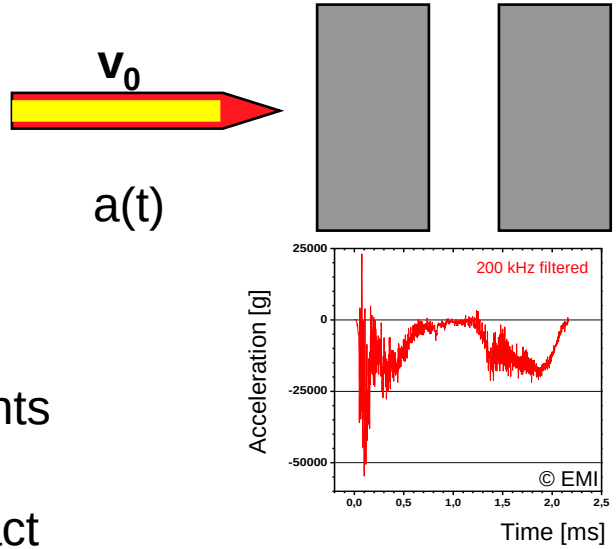
Application

g-rec

Measurement of Long Duration High-g Acceleration Profiles

- Investigation of penetration processes
  - Movement of the center of gravity
  - Characterization of mechanical properties of HE during impact conditions
- Stand alone data recorder for harsh environments
- Measurement tool for fuze systems during impact
- Investigation of interior dynamic of penetrators
  - Study of mechanical wave propagation and resonances
  - Damage mechanisms, …



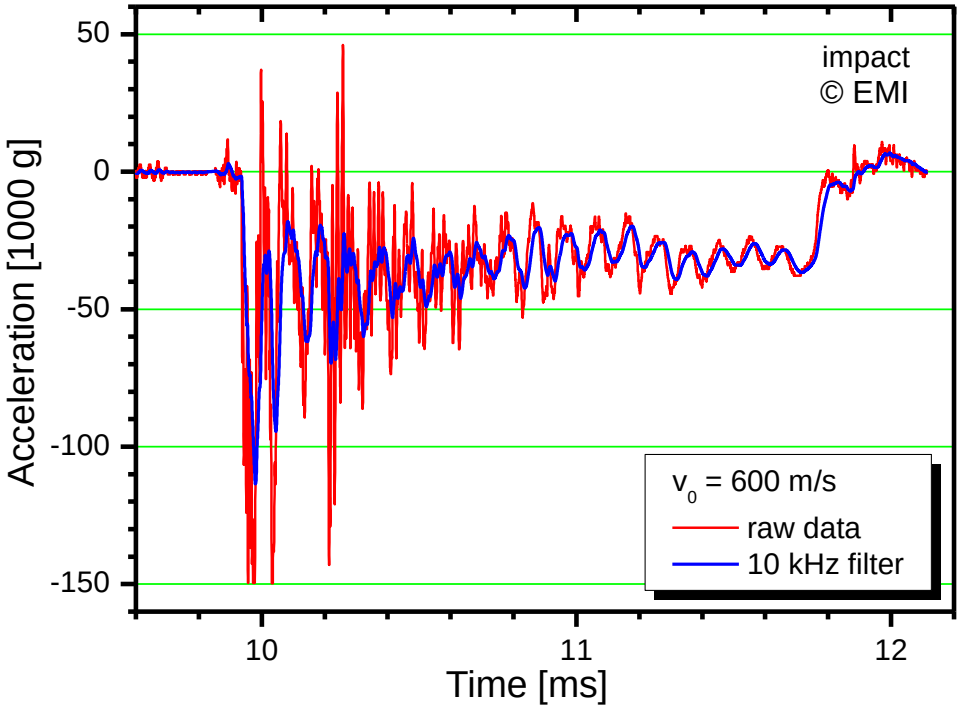
Ver. b
ø = 23 mm

Application Concrete Penetration
Measurement of Long Duration High-g Acceleration Profiles

36 mm - penetrator equipped with g-rec:
Gun launch (powder cannon) v_0 = 600 m/s

Application Concrete Penetration

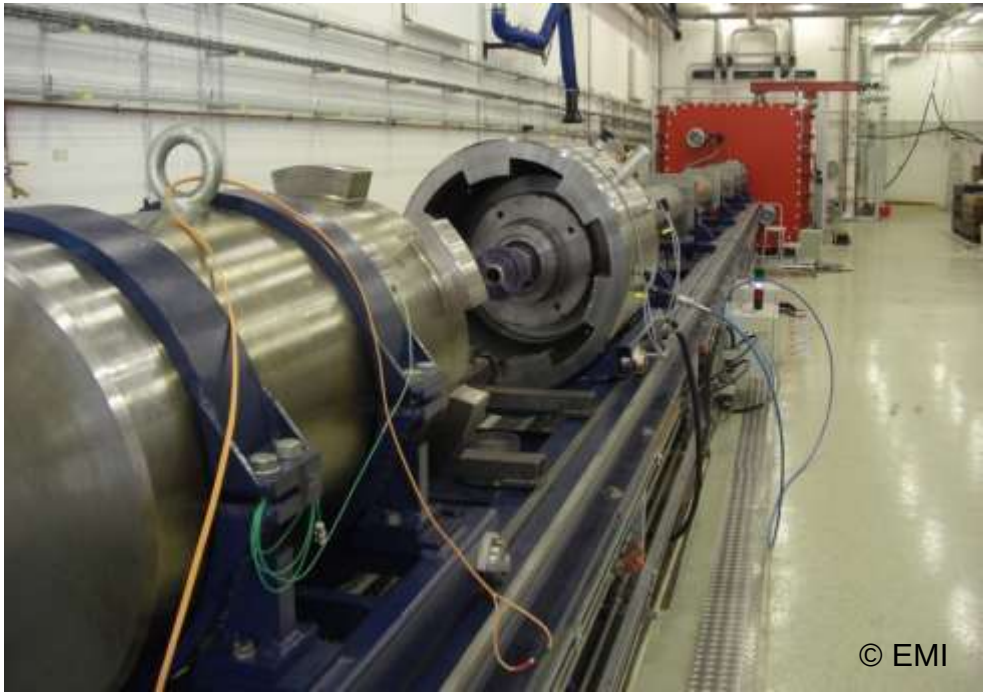
Measurement of Long Duration High-g Acceleration Profiles



Application Concrete Penetration
Measurement of Long Duration High-g Acceleration Profiles

Experiments with 60 mm projectiles

Projectile and sabot,
projectile: cal. 60 mm



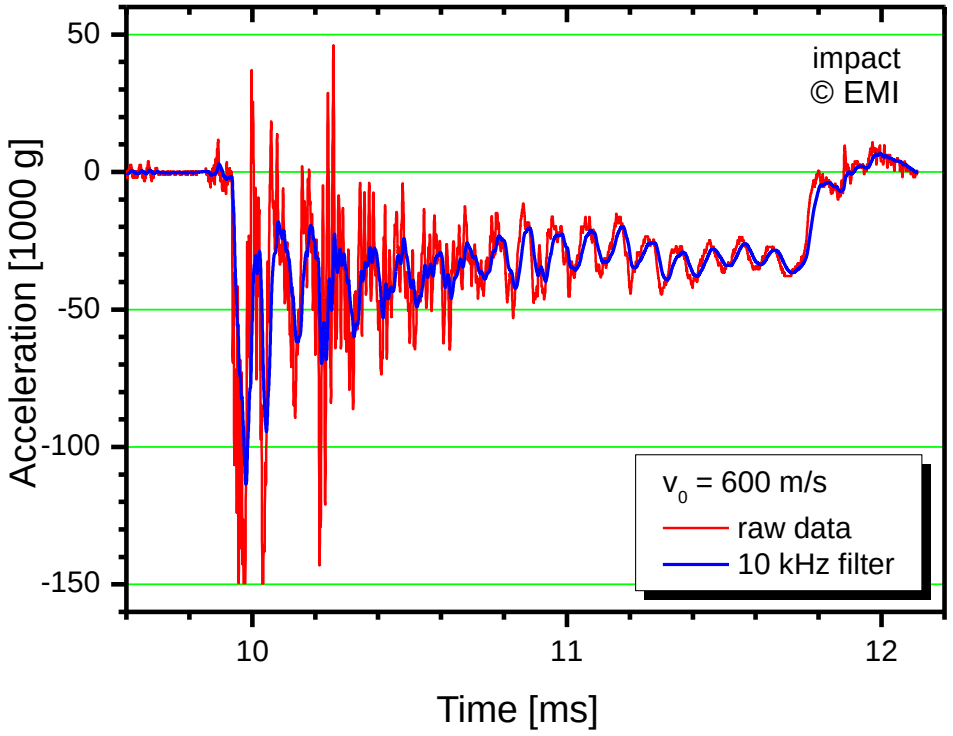
150 mm-Facility,
Ernst-Mach-Institute, Germany

Application Concrete Penetration

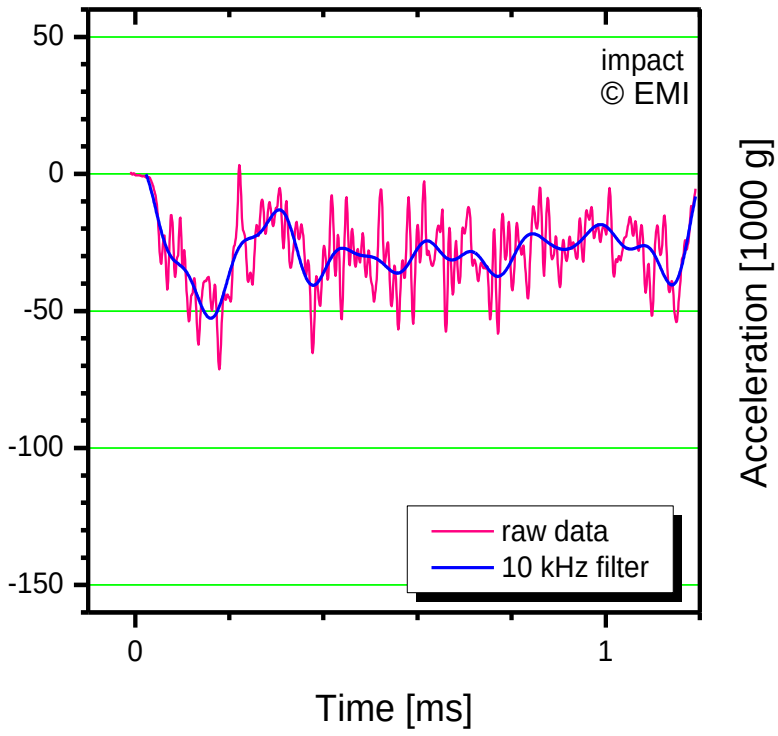
Measurement of Long Duration High-g Acceleration Profiles

Interpretation after experiment, no real time processing.

caliber: 36 mm



caliber: 60 mm



$\Rightarrow a_{max,\ 36\ mm}$ more than two times higher than $a_{max,\ 60\ mm}$

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Summary

- EMI-DLD-Shock Test
  - Powerful test-method that covers interesting high-g-load and long duration pulse regime
  - Reproducible lab-test at moderate costs
- Application of DLD-Shock Test: behavior of capacitors during high-g-load
- Measurement of long duration shock pulses with autonomous data recorder
  - g-rec: versatile and robust measurement-tool
  - Medium caliber concrete penetration at high velocities

    $\Rightarrow$ the smaller the ammunition, the bigger the acceleration

Thank you for your Attention!

Questions?

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