
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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Salt Lake City, May 26th 2011

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

“g-rec”

- Summary

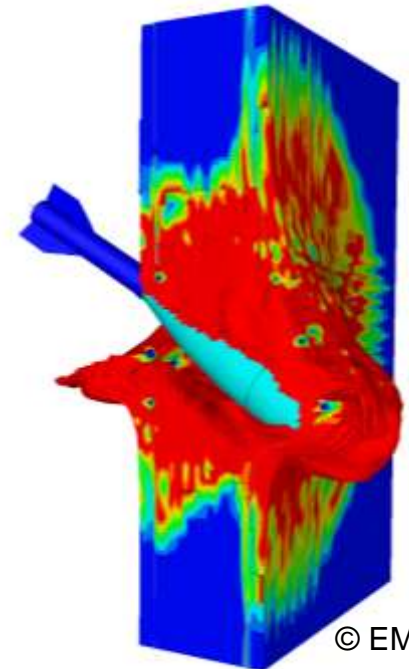
Motivation

Smart Weapons with Penetration Capability

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

⇒ need for reliable, cheap high-g-test methodology

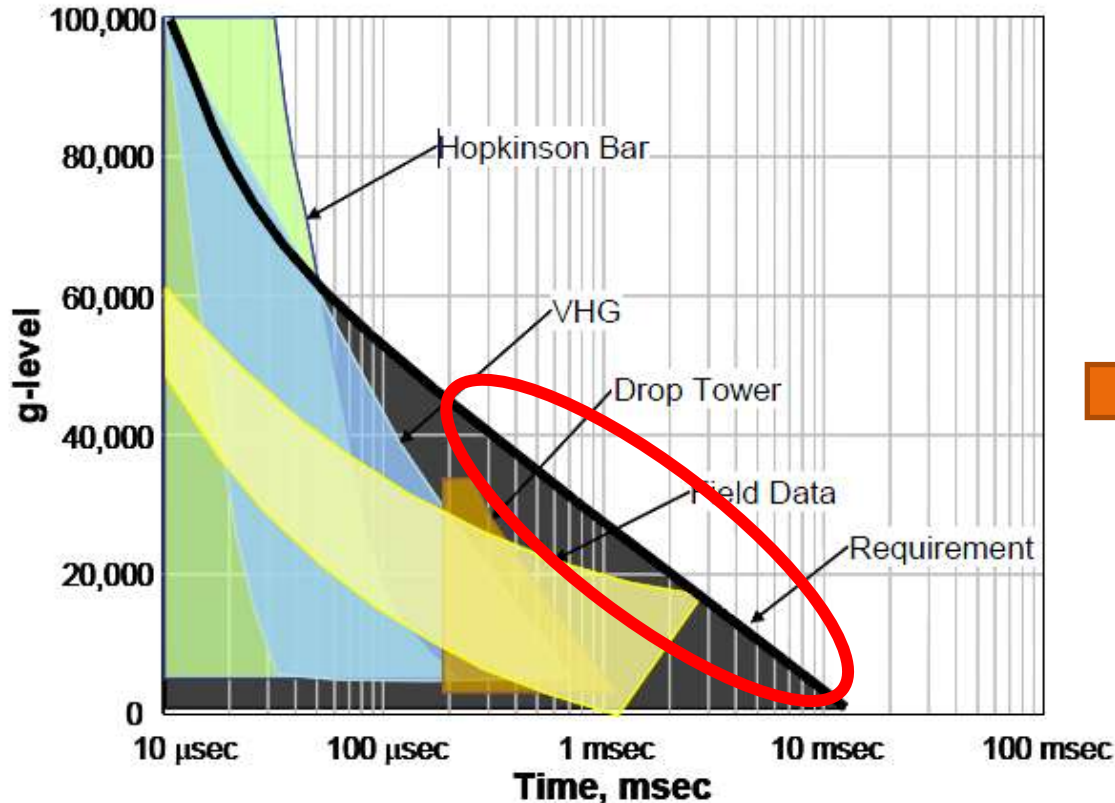
image: wikipedia



Required Test Methodologies for Sub-Scale Survivability Test

Fuze-Conference 2010:

D. Hayles, DTRA : Notional Shock Spectrum



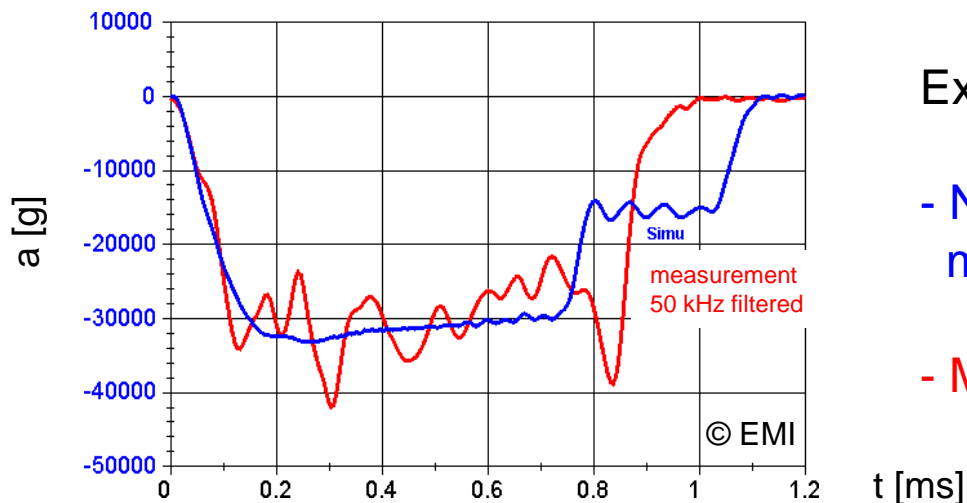
technical requirement:

$$V_{0, DUT} > 100 \text{ m/s}$$

Photo Courtesy of AFRL/RWMF

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 μ s

- Numerical prediction:
movement of center of gravity

- Measurement inside sample holder

* PDV: Photonic Doppler Velocimetry

EMI Defined-Long-Duration (DLD) Shock Test

■ Current R&D-setup:

- $m_{(\text{Device Under Test})}$ up to 200 g
- $\varnothing < 34$ mm,
- $l = 100$ mm

} scalable to higher values

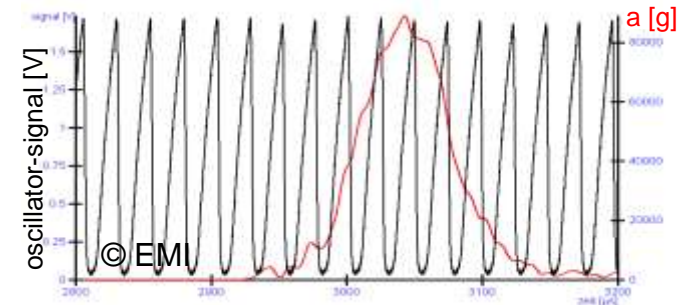
- If needed: Device under Test electrically connected
- Low temperature experiments (-46 °C) possible
- Modest cost
- Extension to spinning systems is under way



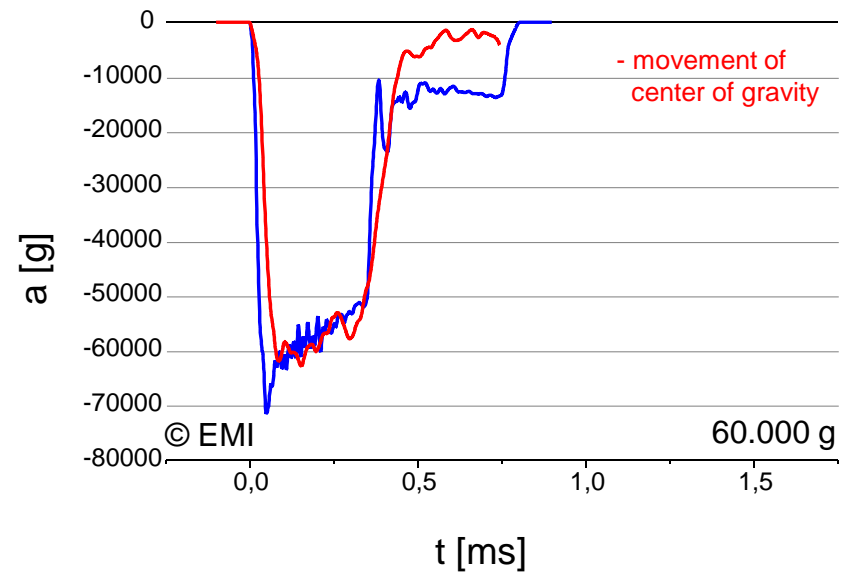
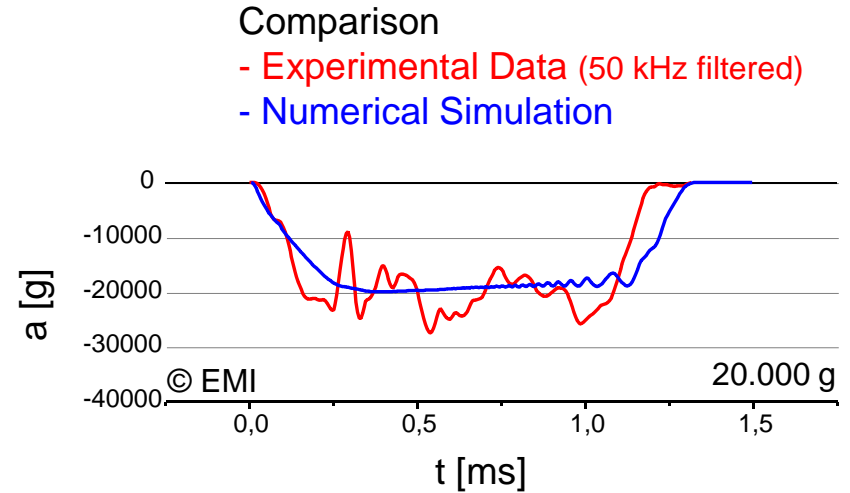
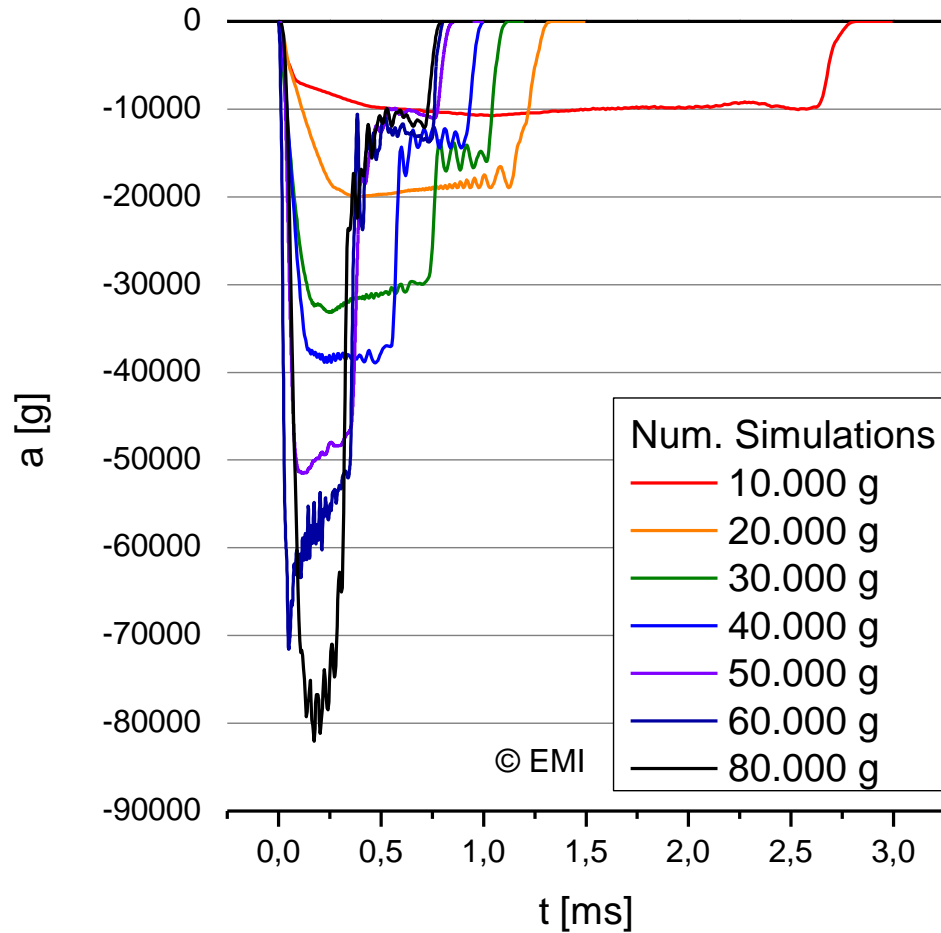
Exemplary sample holder



Example: 80.000 g oscillator-Test



EMI - DLD - Shock Test



EMI - DLD - Shock Test

Experimental Results

D. Hayles, DTRA, Fuze Conference 2010

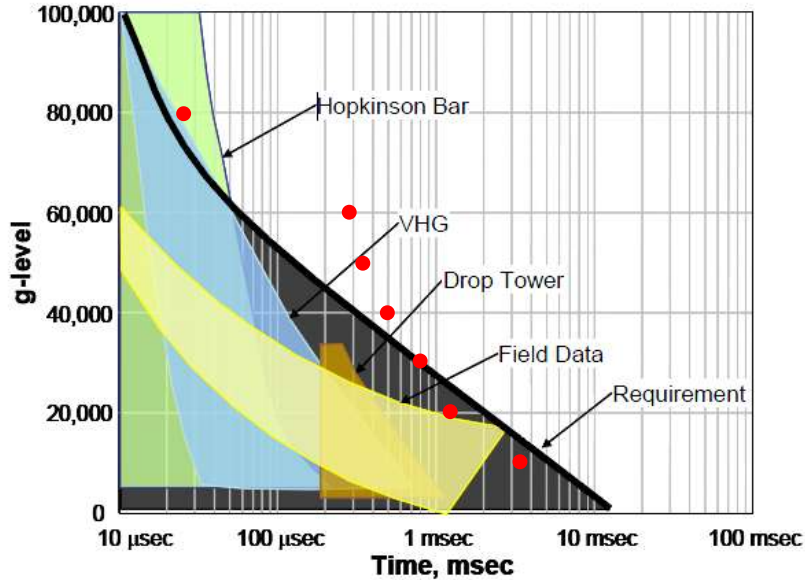


Photo Courtesy of AFRL/RWMF

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

Application

Choice and Test of Electronic Devices

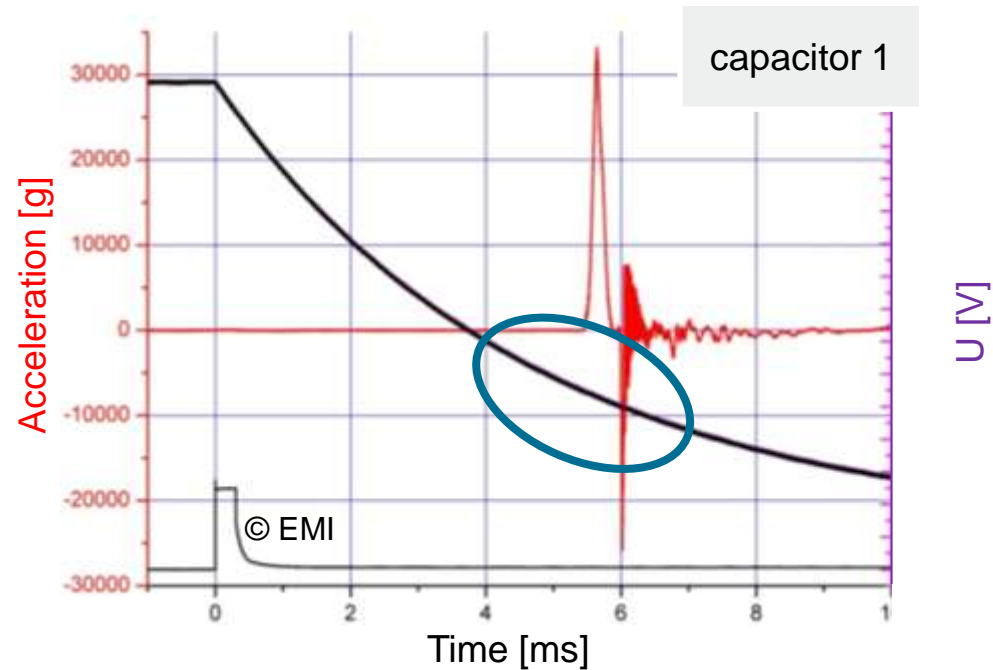
Device behavior upon high-g-loads:

- 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



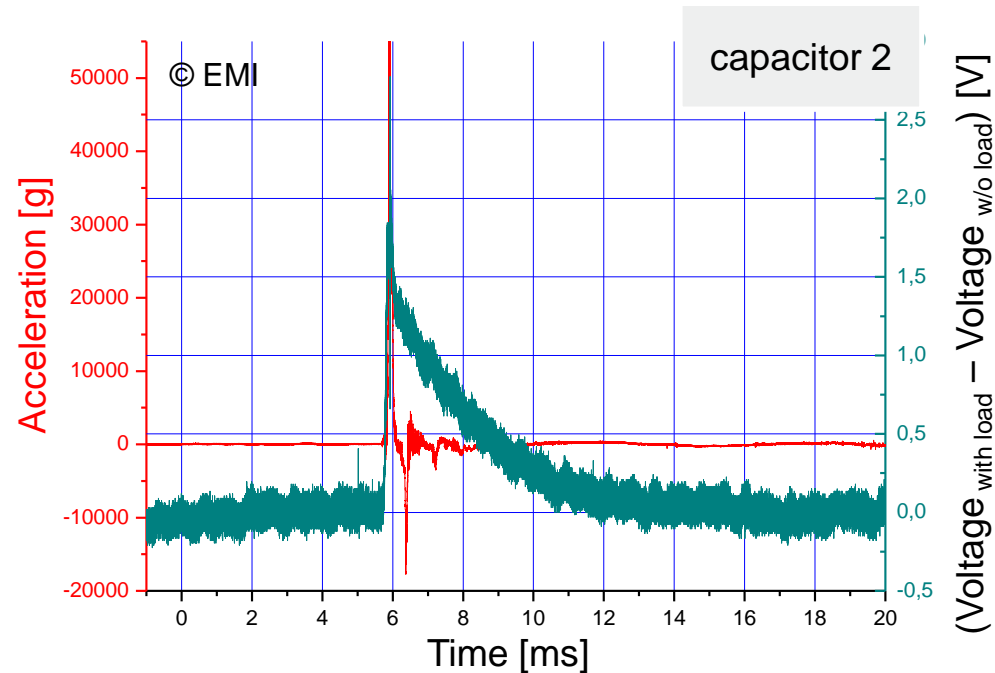
Application

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 2

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

Approach / solution :

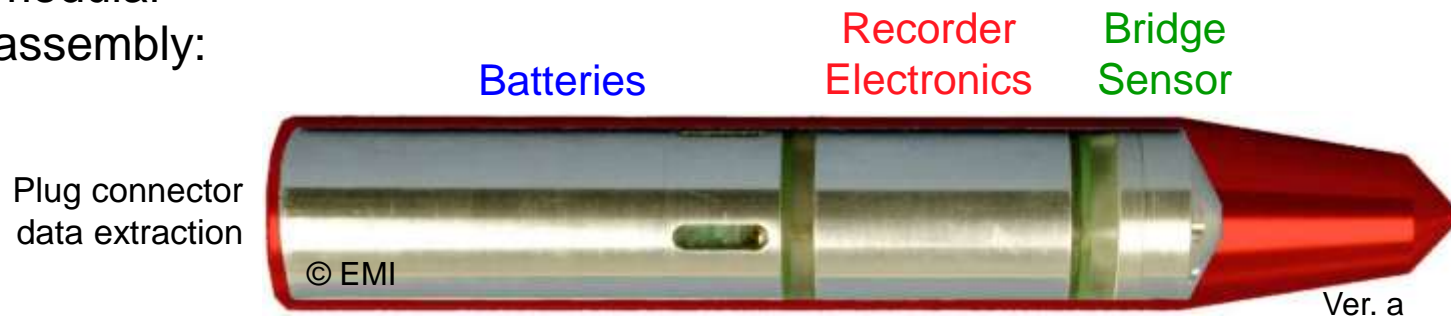
- Usage of different devices, or device technologies
- Improved engineering concepts

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

$\varnothing = 26 \text{ mm}$, $l = 155 \text{ mm}$

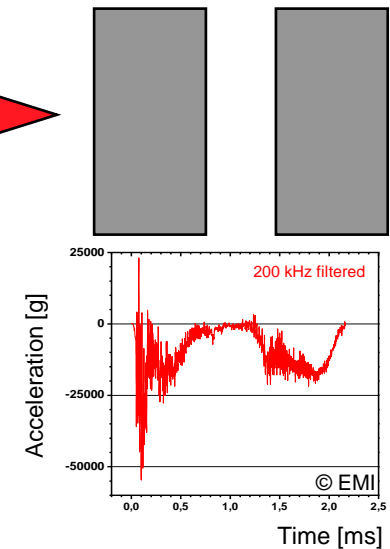
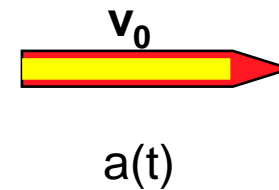
b) programmable, based on microcontroller

$\varnothing = 23 \text{ mm}$, $l = 80 \text{ mm}$

Application

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, ...



Application

Measurement of Long Duration High-g Acceleration Profiles

Concrete Penetration

36 mm - penetrator equipped with g-rec:

Gun launch (powder cannon)

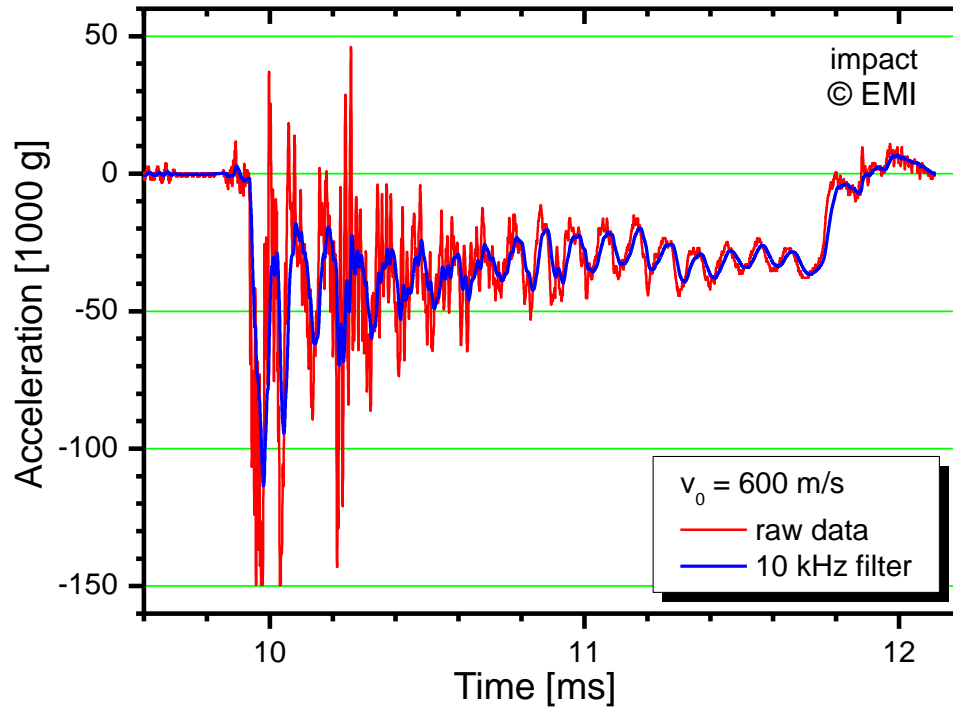
$$v_0 = 600 \text{ m/s}$$



Application

Concrete Penetration

Measurement of Long Duration High-g Acceleration Profiles



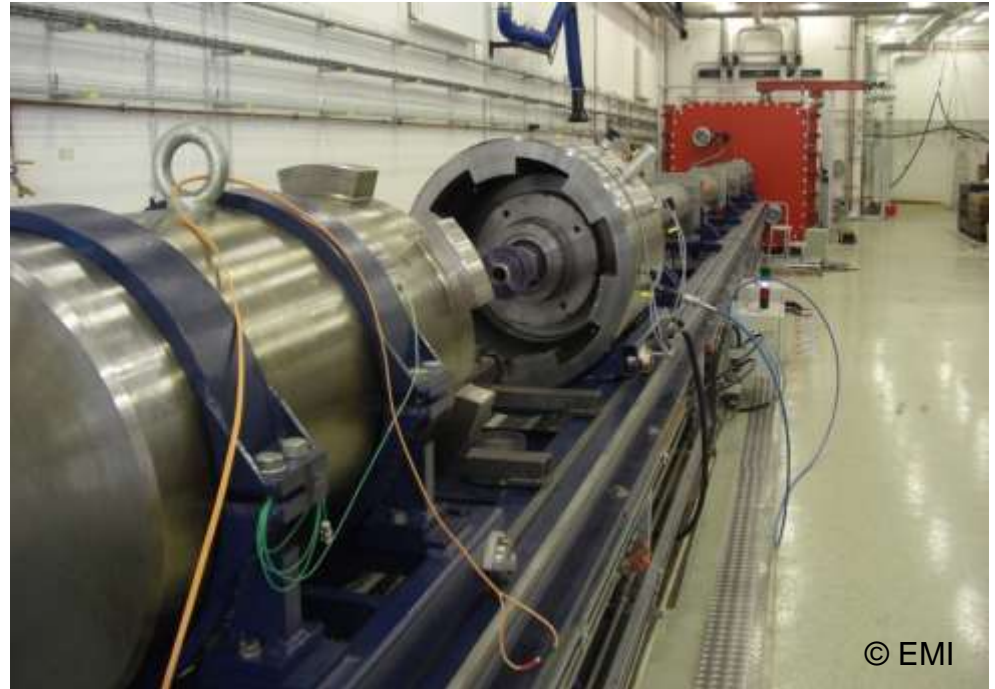
Application Concrete Penetration Measurement of Long Duration High-g Acceleration Profiles

Experiments with 60 mm projectiles



© EMI

Projectile and sabot,
projectile: cal. 60 mm



© EMI

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

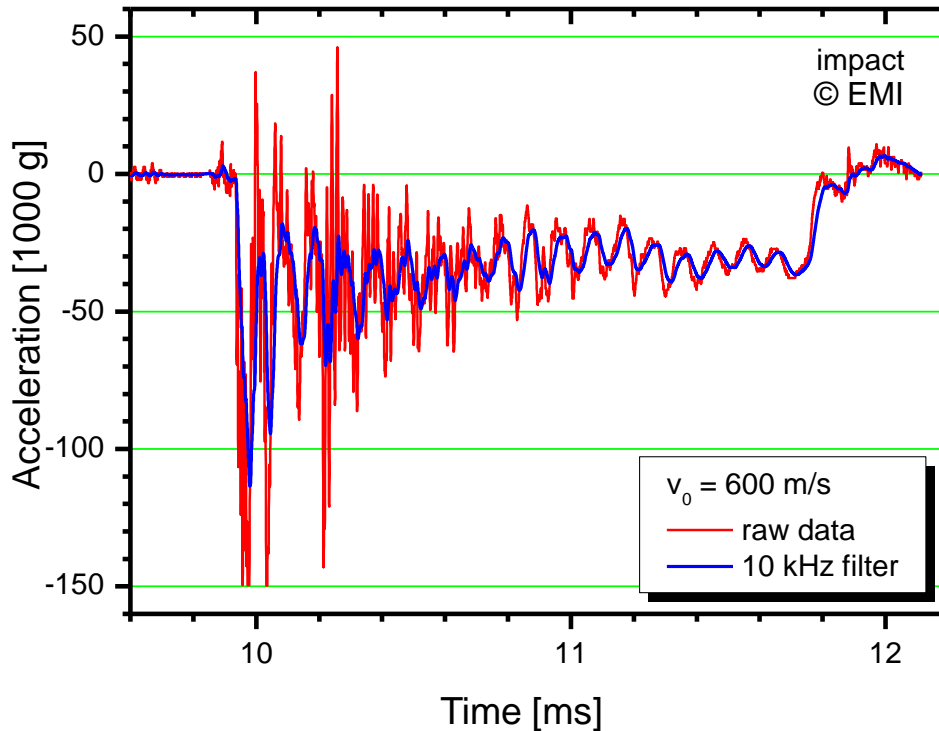
Application

Measurement of Long Duration High-g Acceleration Profiles

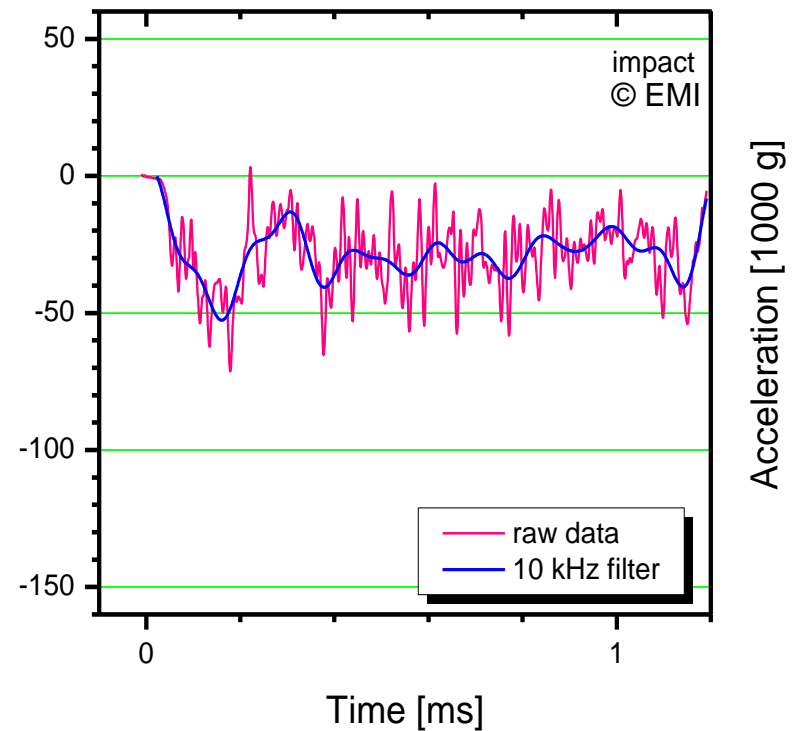
Concrete Penetration

Interpretation after experiment, no real time processing.

caliber: 36 mm



caliber: 60 mm



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

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
 - ⇒ the smaller the ammunition, the bigger the acceleration

Thank you for your Attention!

Questions?

This work was funded by the
Federal Office for Defence Technology and Procurement BWB
(Bundesamt für Wehrtechnik und Beschaffung)

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