

# High-g Shock Testing

## Generation and Measurement of Long Duration High-g Acceleration Profiles

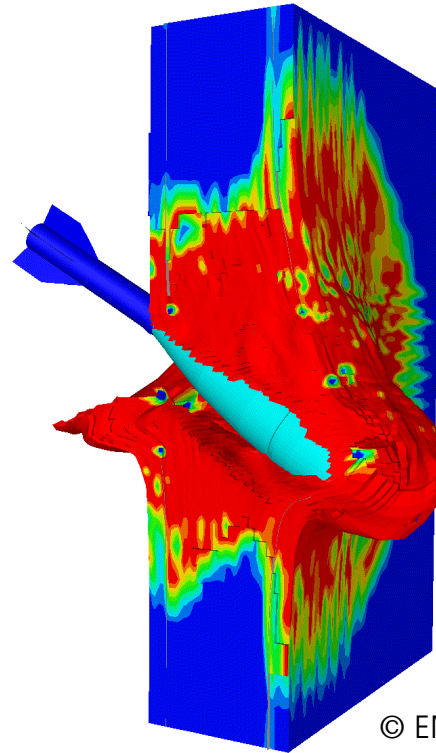
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**23.02.2026 Nuremberg**

# 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



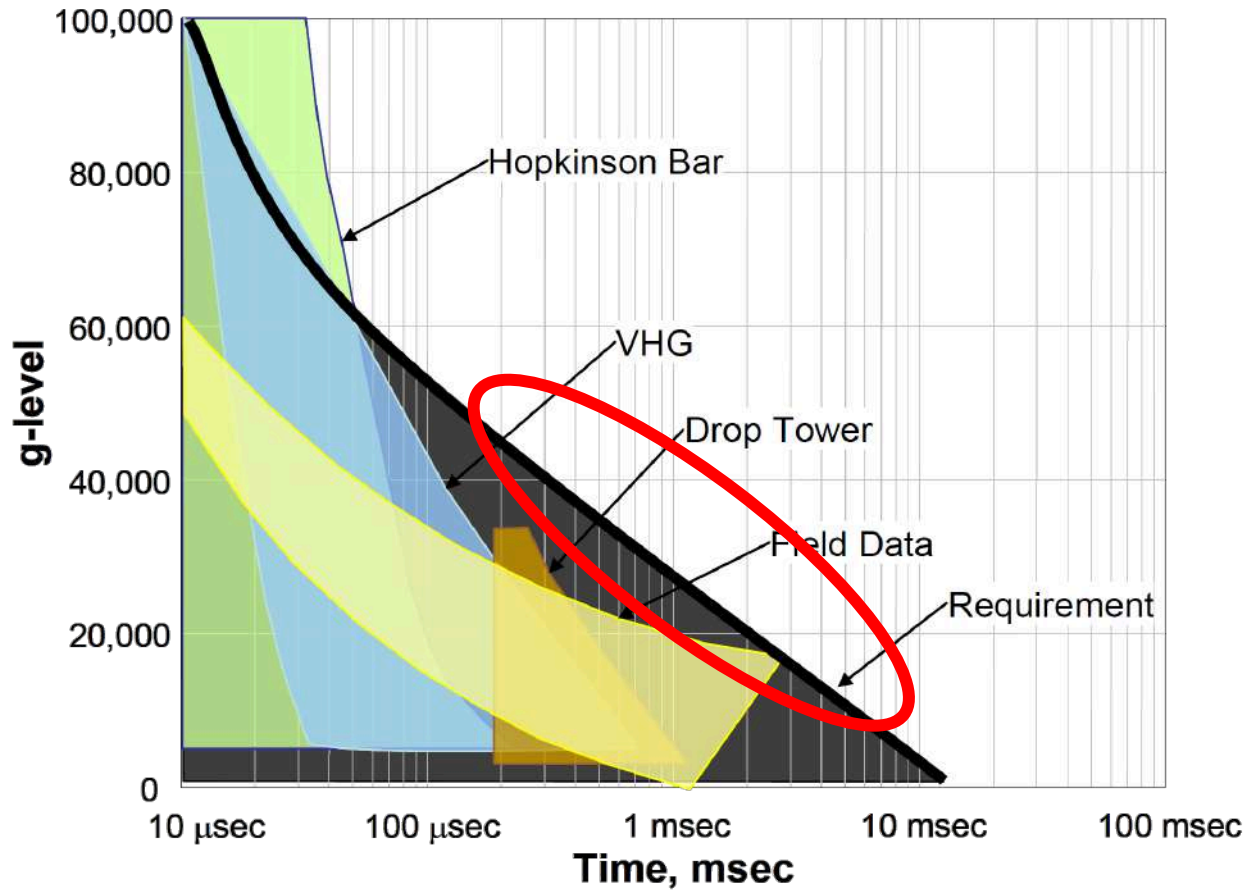
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image: wikipedia



# Motivation

## Required Test Methodologies for Sub-Scale Survivability Test



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

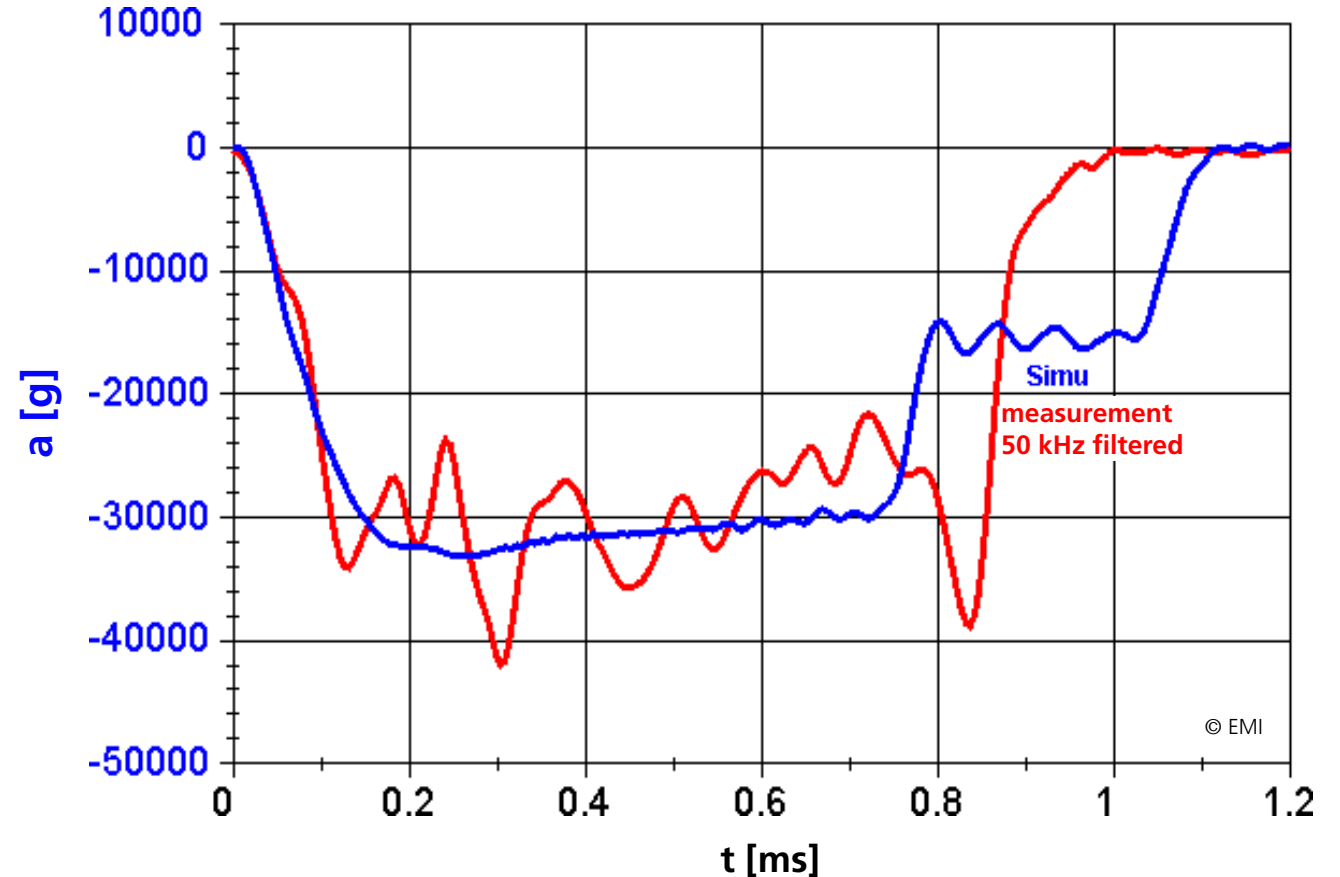
Fuze-Conference 2010:  
D. Hayles, DTRA : Notional Shock Spectrum

# EMI Defined-Long-Duration (DLD) Shock Test

## Basic principle

- 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  $\mu$ s



Numerical prediction: movement of center of gravity

Measurement inside sample holder

\* PDV: Photonic Doppler Velocimetry

# EMI Defined-Long-Duration (DLD) Shock Test

## Exemplary tests

- Exemplary R&D-setup:
    - $m_{\text{Device Under Test}}$  up to 200 g
    - $\varnothing < 34$  mm,
    - $l = 100$  mm
  - If needed: Device under Test electrically connected
  - Low temperature experiments (-46 °C) possible
  - Modest cost per test
- } scalable to higher values



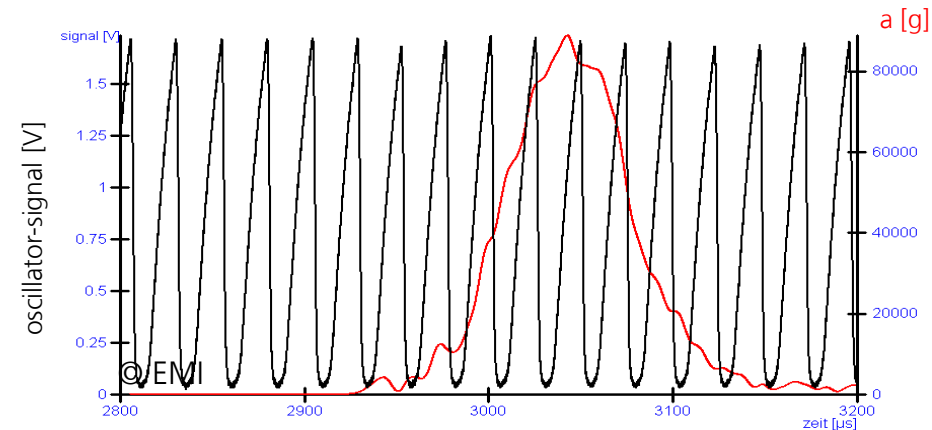
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Exemplary sample holder

Example:

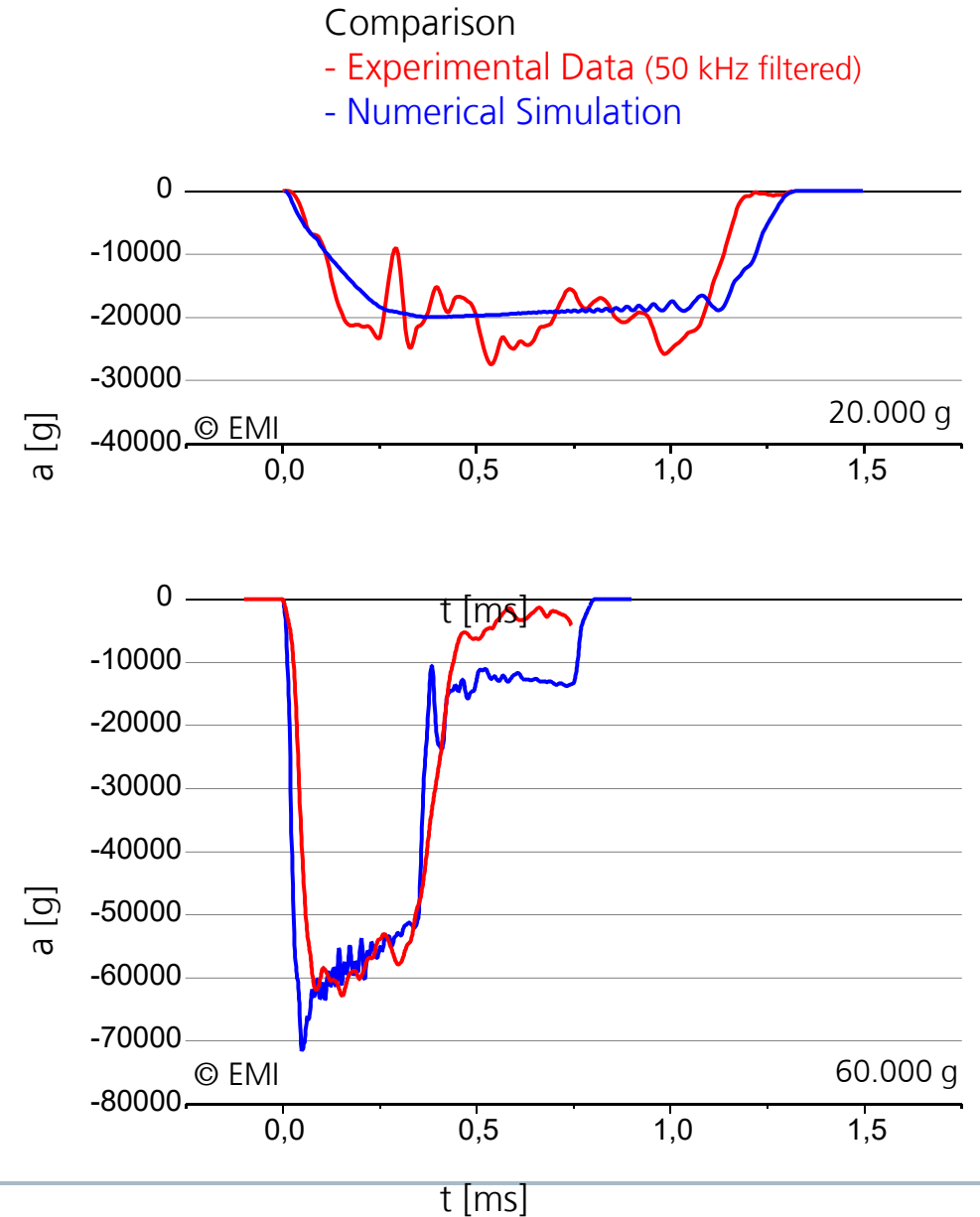
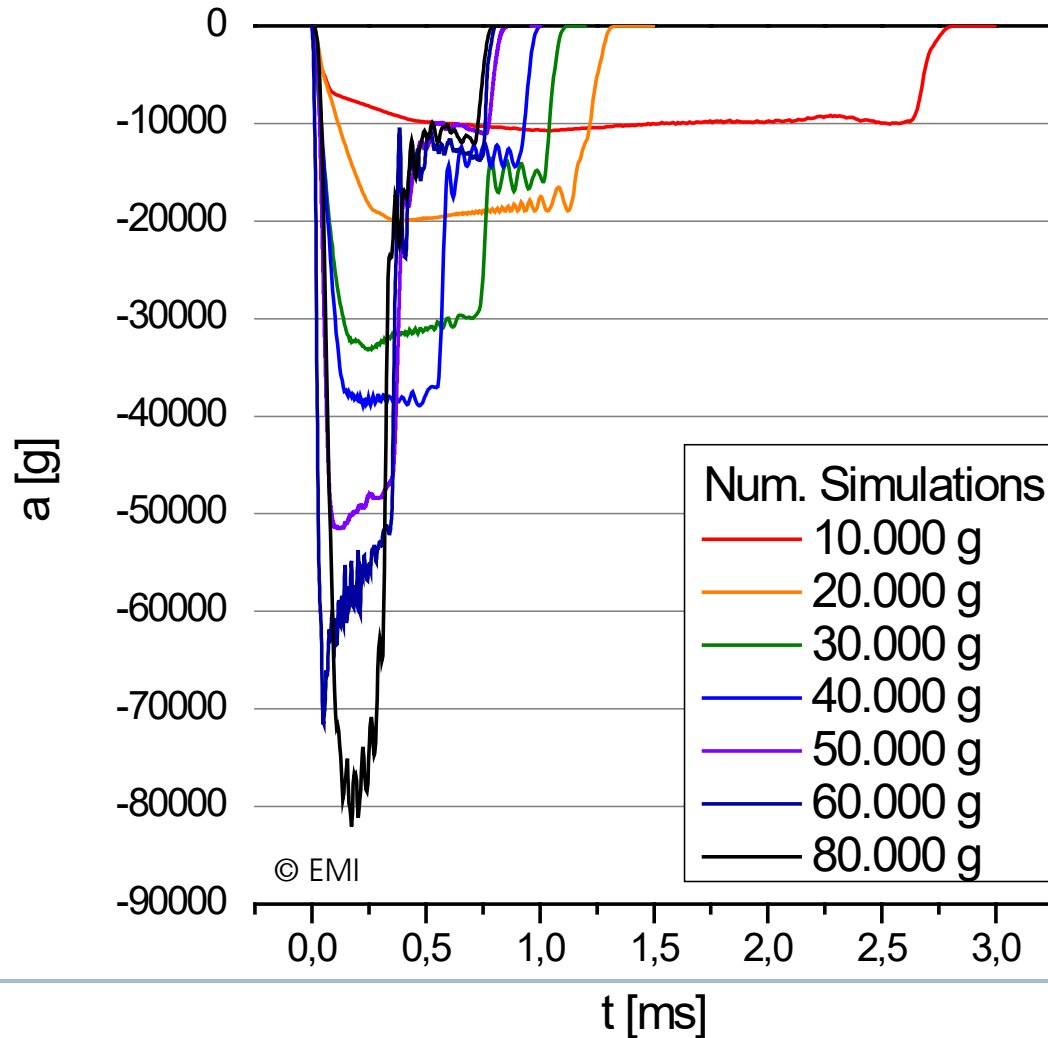
80.000 g

oscillator test



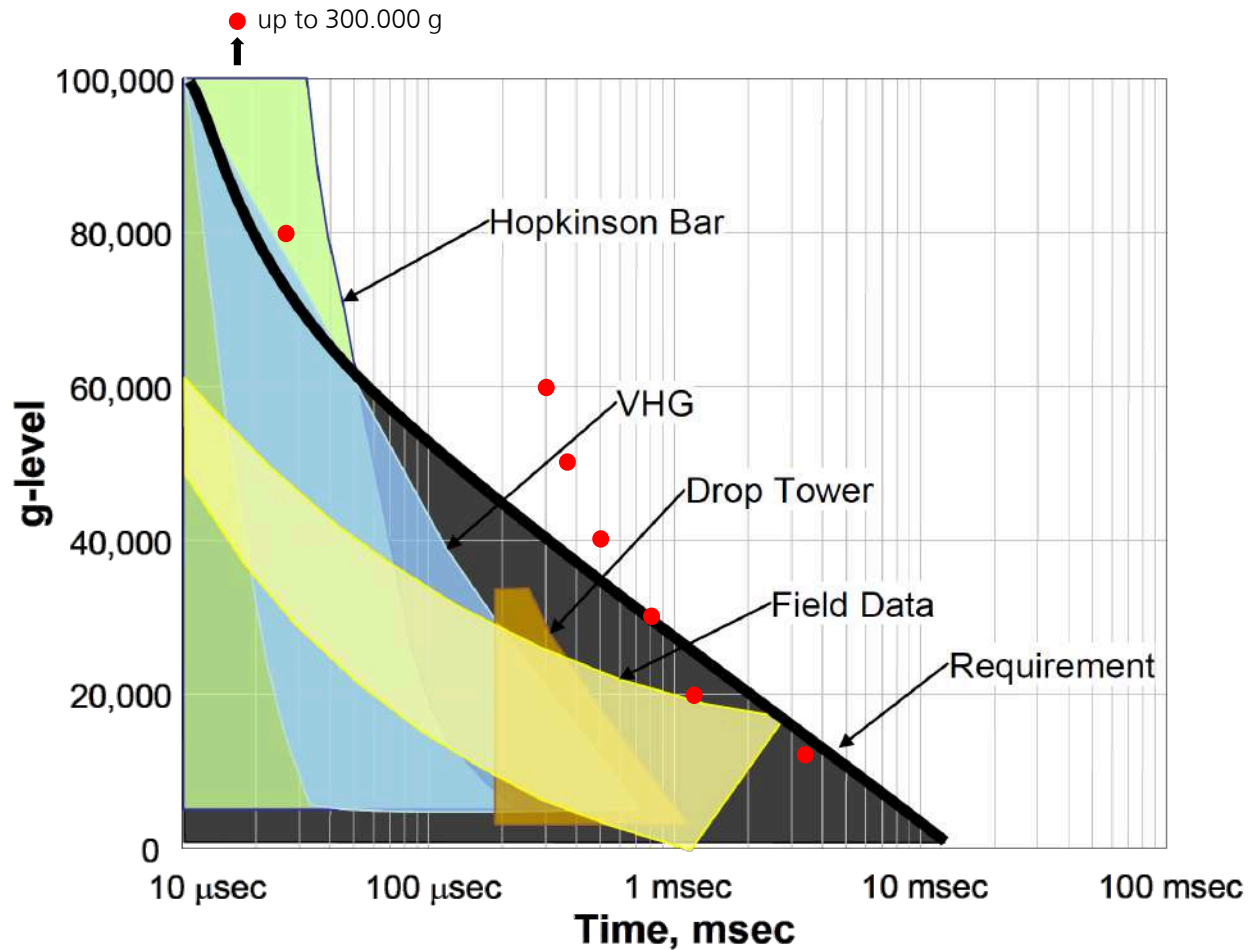
# EMI Defined-Long-Duration (DLD) Shock Test

Range of application



# EMI Defined-Long-Duration (DLD) Shock Test

Range of application



## 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)	
120.000 g	0.120 ms	(exp)	} different setup
200.000 g	0.100 ms	(exp)	
300.000 g	0.070 ms	(sim)	

Experiments validated by

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

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

# EMI Defined-Long-Duration (DLD) Shock Test

Application: Choice and Test of Electronic Components

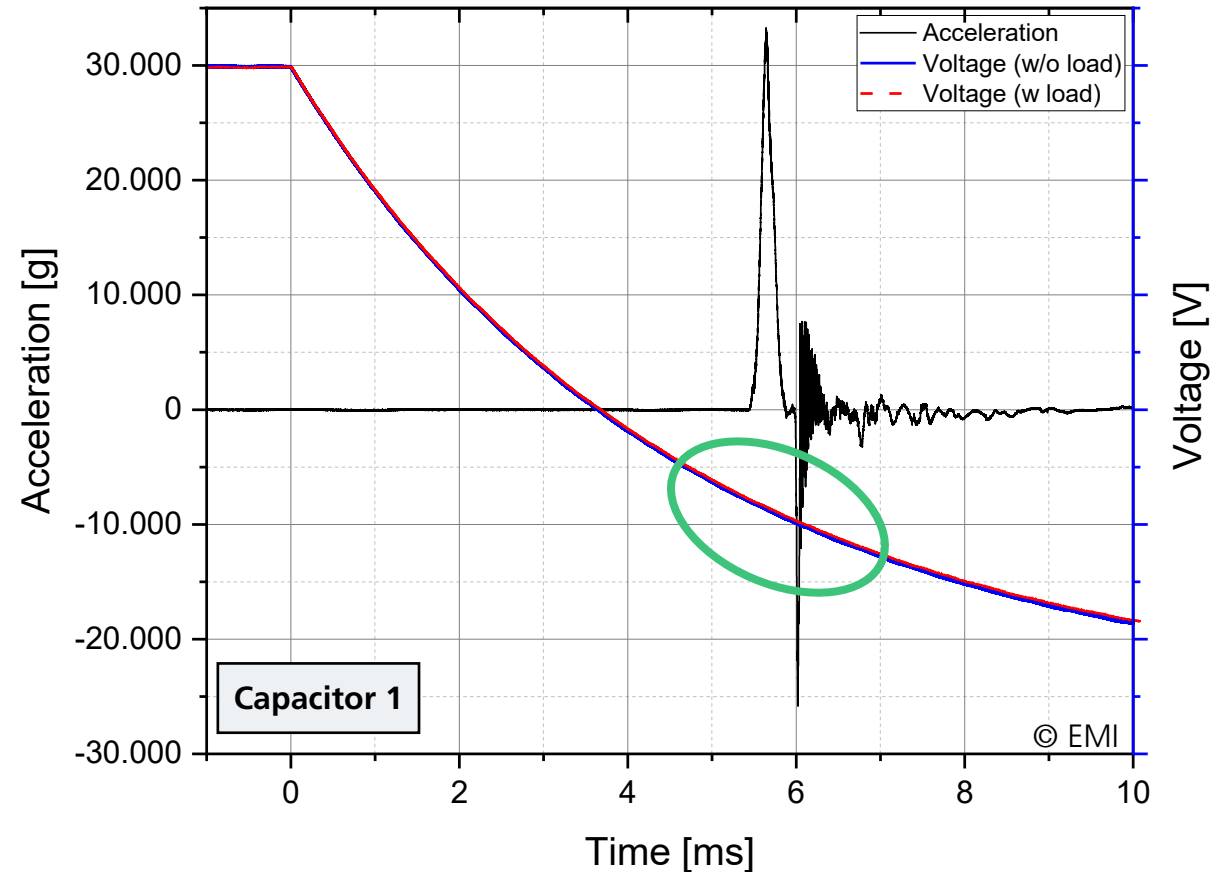
## Device behavior upon high-g-loads:

- 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



# EMI Defined-Long-Duration (DLD) Shock Test

Application: Choice and Test of Electronic Components

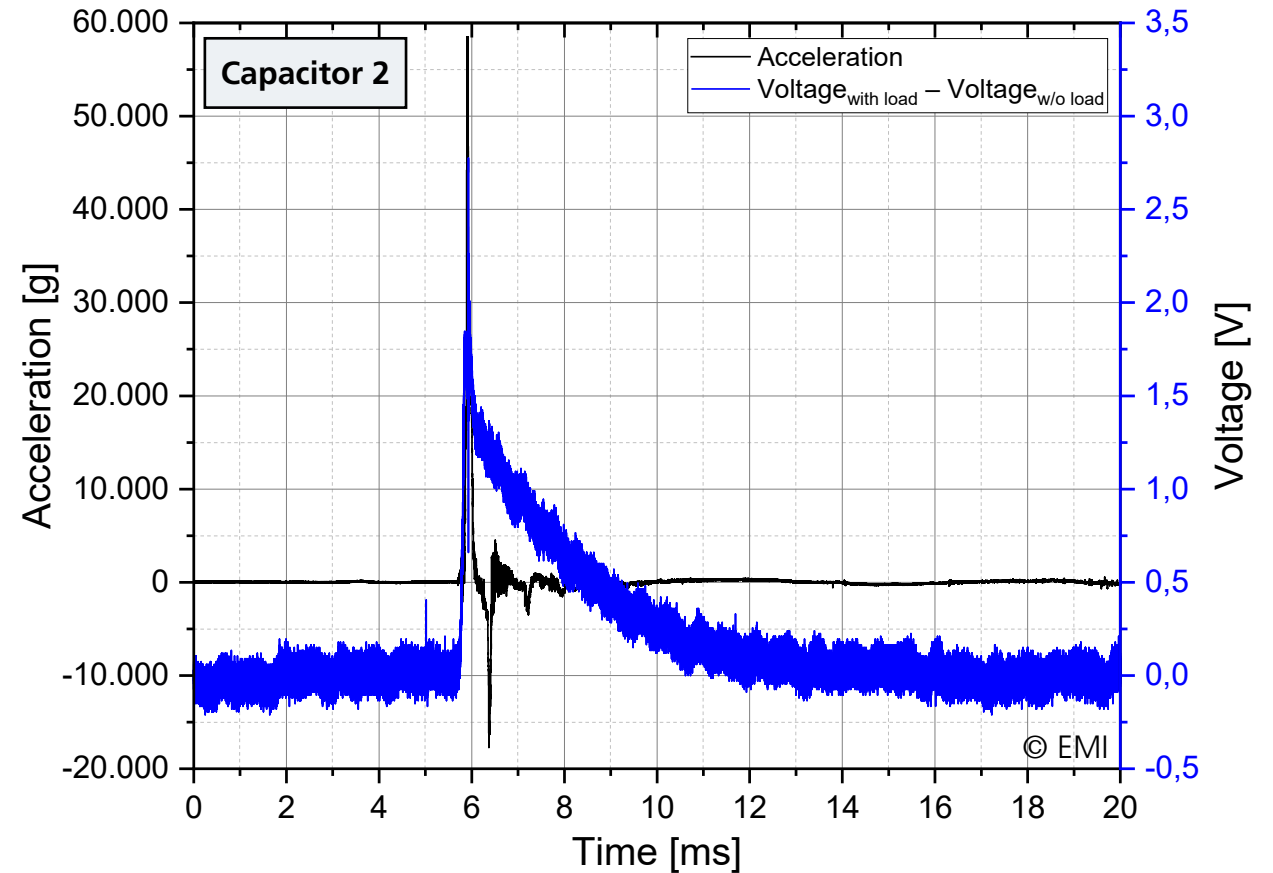
## Device behavior upon high-g-loads:

- 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

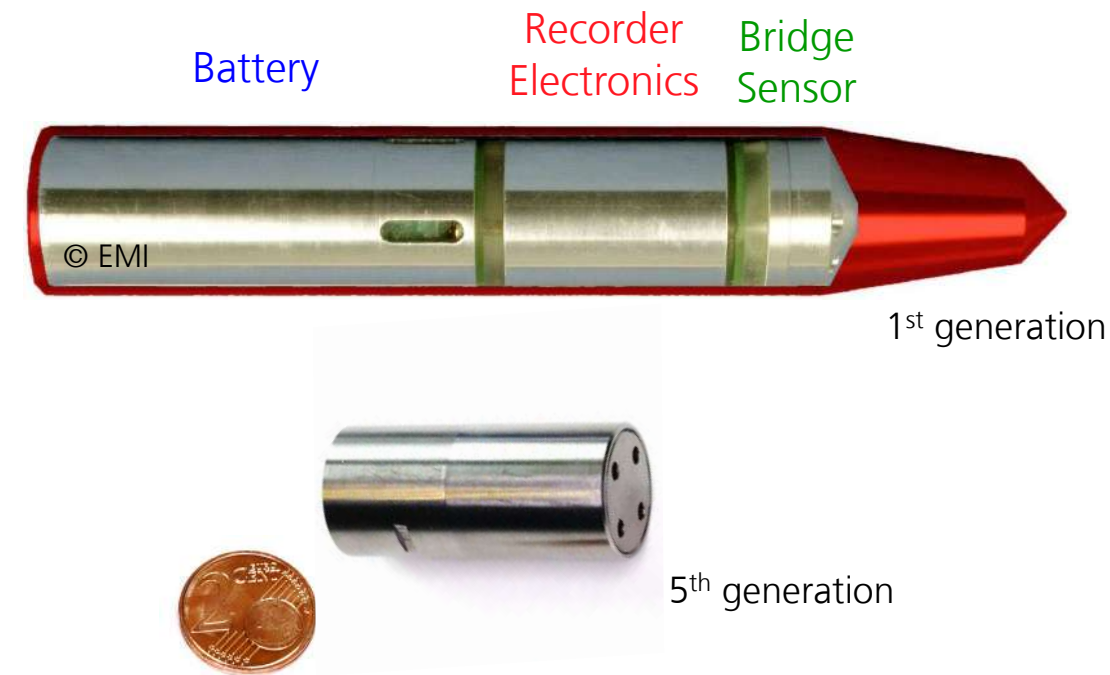
## Measurement of Long Duration High-g Acceleration Profiles

### Concept:

- Autonomous digital data recorder with shock accelerometer
- Resistant to high accelerations and decelerations
- Digital readout of measurement data after projectile recovery

### Technical Data:

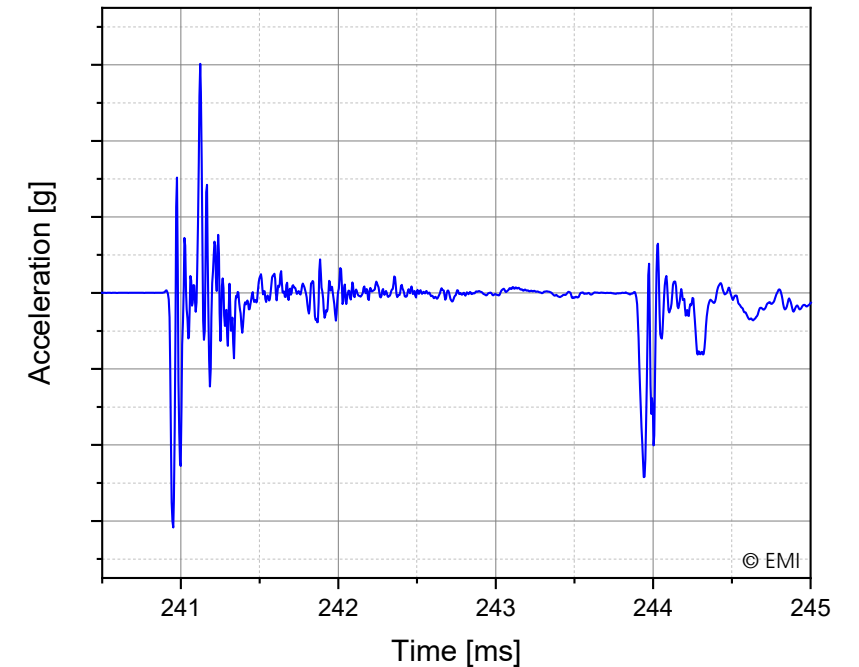
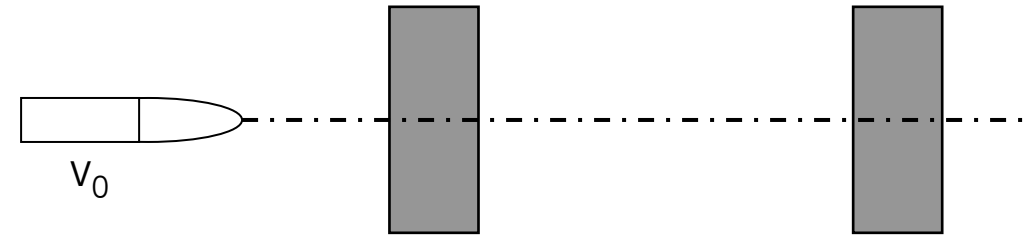
- 1<sup>st</sup> channel: acceleration, optional 2<sup>nd</sup> channel for generic external signals
- 12-bit resolution
- Shock proof > 80,000 g
- Spin proof > 1000 Hz
- Programmable acquisition rate (up to 200 kS/s), trigger level and pre-trigger



# 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 elastic during impact conditions
- Stand alone data recorder for harsh environments
- Measurement tool for fuze and electronic systems during impact
- Investigation of interior dynamic of penetrators
  - Study of mechanical wave propagation and resonances
  - Damage mechanisms, ...



# Application: Concrete Penetration

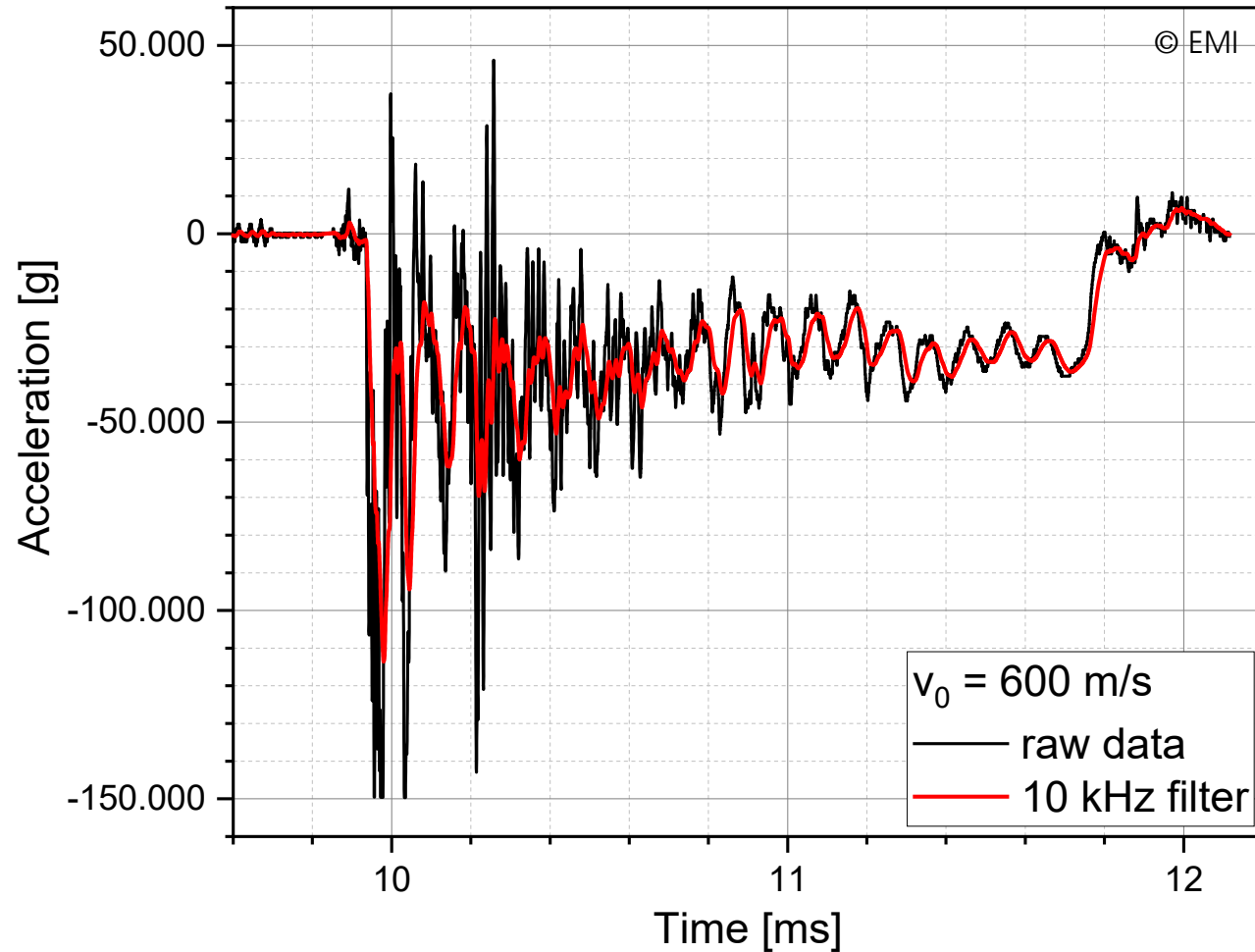
## Measurement of Long Duration High-g Acceleration Profiles

- Penetrator (36 mm) instrumented with g-rec
- Powder gun shot  $v_0 = 600$  m/s



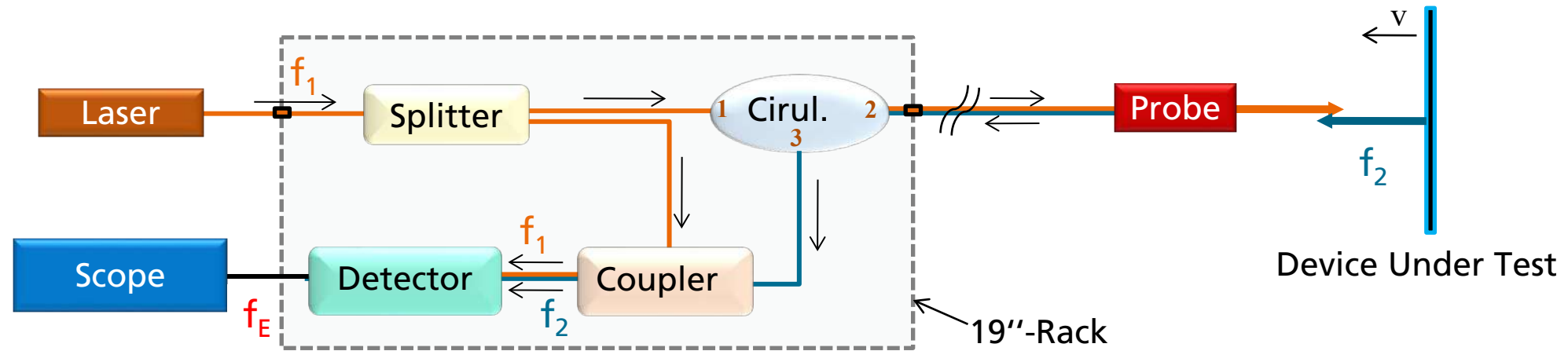
# Application: Concrete Penetration

## Measurement of Long Duration High-g Acceleration Profiles



# Application: Photonic-Doppler-Velocimeter (PDV)

Optical method for measuring velocity profiles  $v(t)$

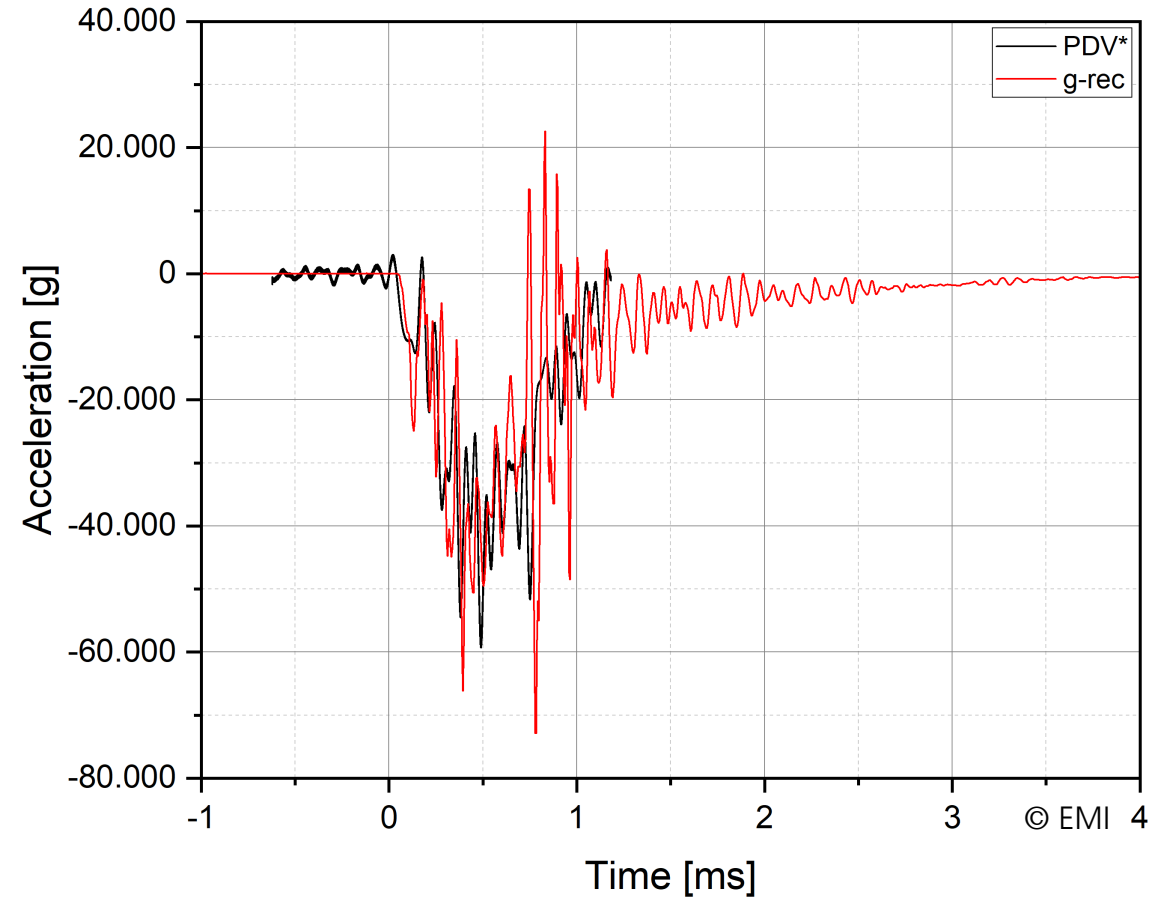
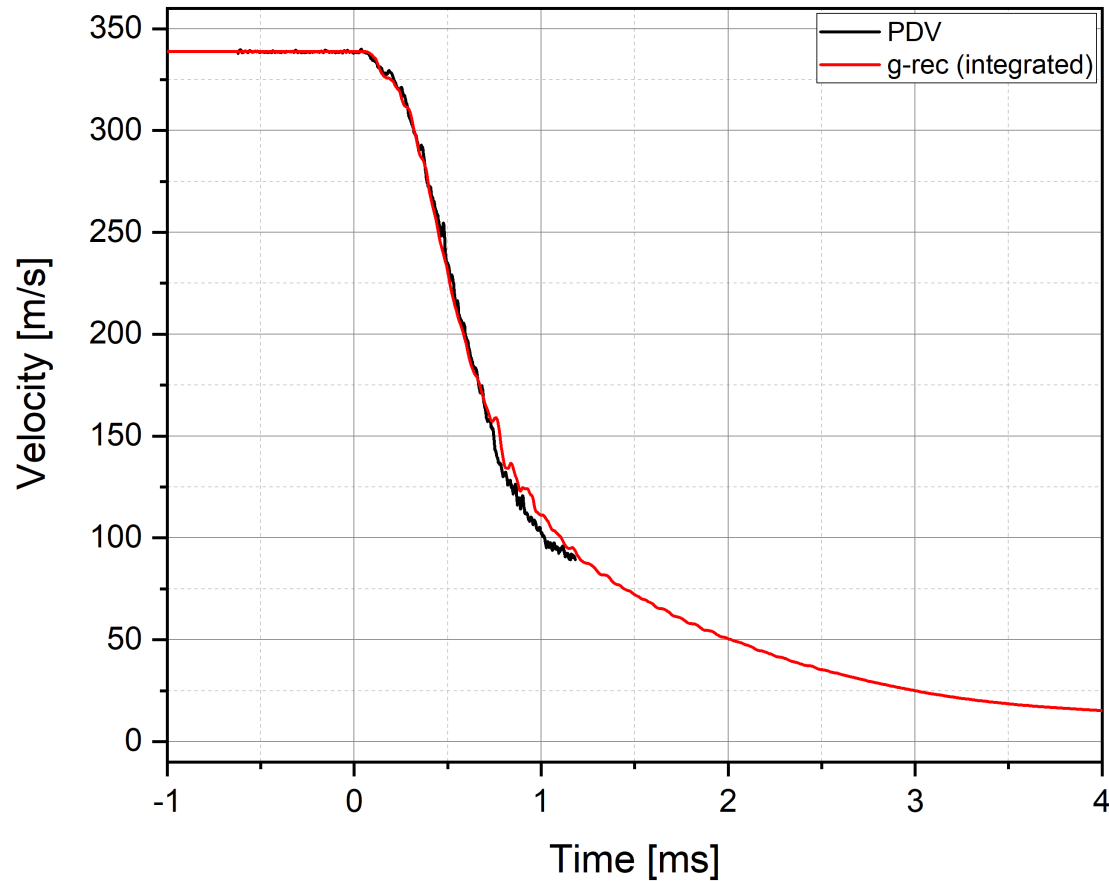


- Continuous measurement of velocity profiles
- Measurement range: cm/s up to 10 km/s without range switching
- Time resolution: several tens of ns
- Portable and robust system (telecommunication components)
- Temporary loss of signal without abort of measurement



# Application: Photonic-Doppler-Velocimeter (PDV)

Optical method for measuring velocity profiles  $v(t)$



# Summary

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- 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
- Measurement of velocity profiles with Photonic-Doppler-Velocimeter (PDV)

# Contact

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