

# MEASUREMENT AND SIMULATION OF SMALL ARMS MUZZLE BLAST

Martijn van der Voort (presenter)

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# Introduction

- Traumatic Brain Injury (TBI) due to repetitive exposure to small-arms muzzle blast
- Associated with health issues (cognitive problems, headaches, anxiety, ...)
- First step to investigate and prevent: quantify load on the operator
- Reliable and standardized method is currently missing
- Small Arms Blast Exposure System (SABOES): system capable to determine such loads consistently



# Introduction

- SABOES was developed by TNO between 2023 and 2024
  - Sponsor: IWTSD
- SABOES was tested and validated
  - For various small caliber weapon systems
  - Labs at TNO, Dutch MoD (KCW&M 't Harde) and DRDC Canada
- Work was presented including a paper at MABS 27
  - Military Aspects of Blast and Shock (October 2025)
  - Current presentation follows that paper
- System has now been delivered/ordered by a number of clients

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**IWTSD**

Irregular Warfare Technical  
Support Directorate

27th International Symposium on Military Aspects of Blast and Shock  
MABS27, France, 2025

## MEASUREMENT AND SIMULATION OF SMALL ARMS MUZZLE BLAST

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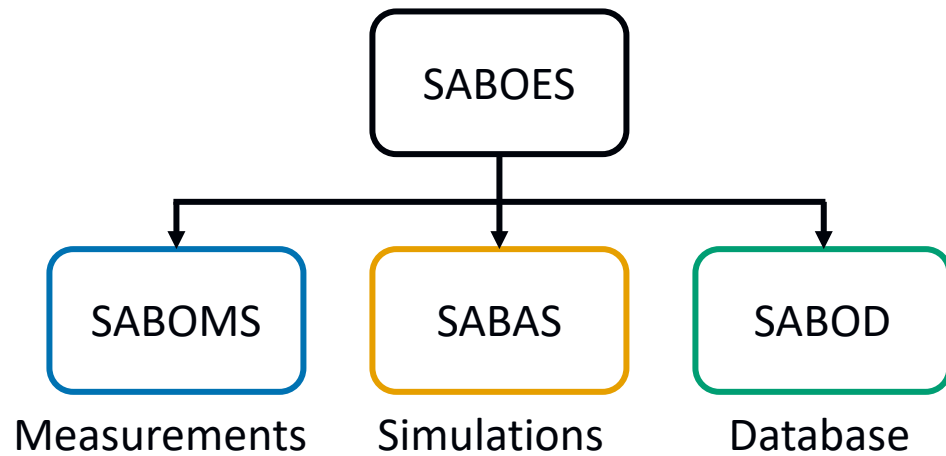
Ypenburgse Boslaan 2, 2496 ZA, Den Haag, The Netherlands;

<sup>2</sup>DRDC Valcartier Research Centre, 2459 de la Bravoure Road, Québec, Canada



# System Overview

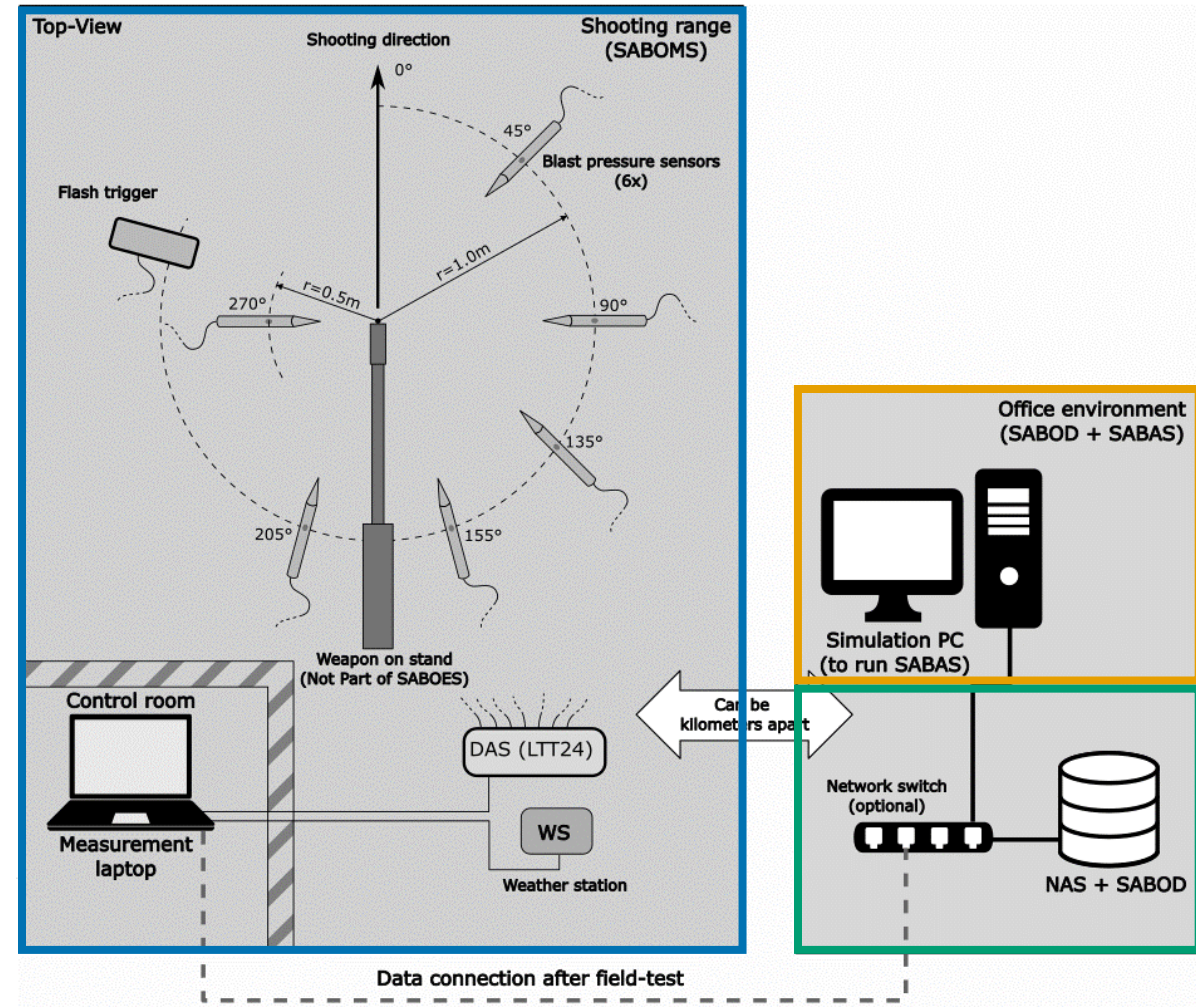
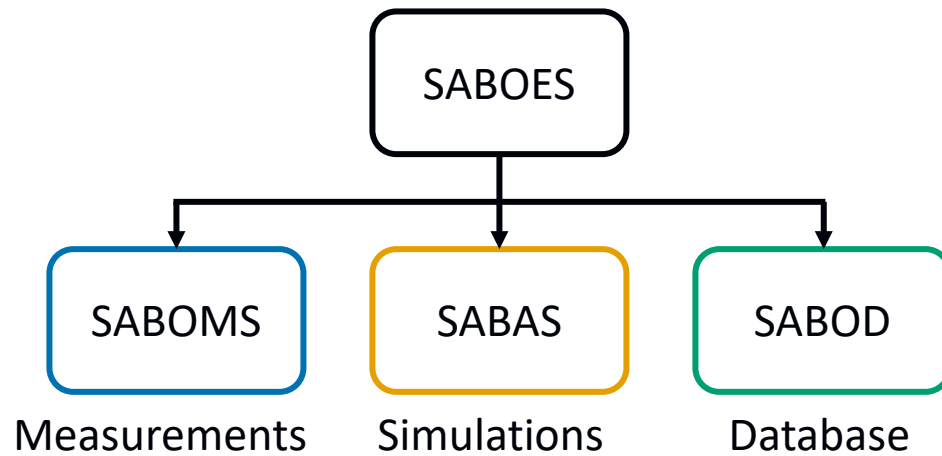
- **S**mall **A**rms **B**last **O**verpressure **E**xposure **S**ystem
  - SAB Overpressure Measurement System
  - SAB Apollo Simulator
  - SAB Overpressure Database





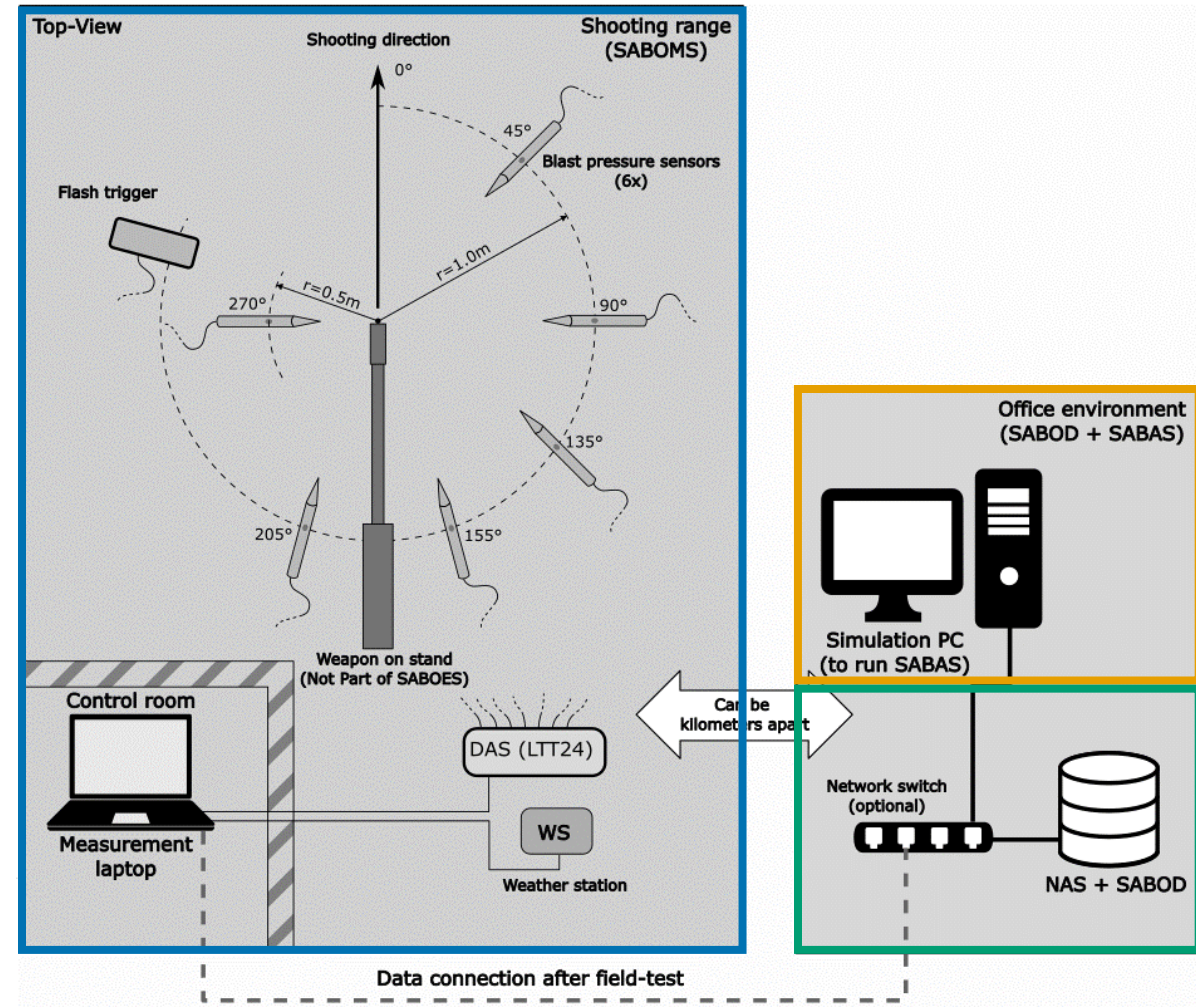
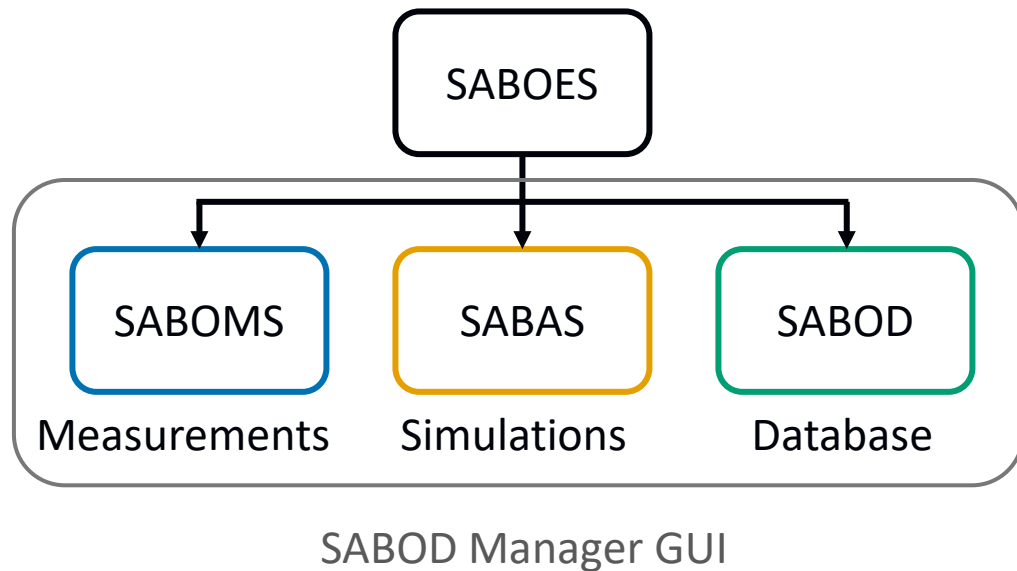
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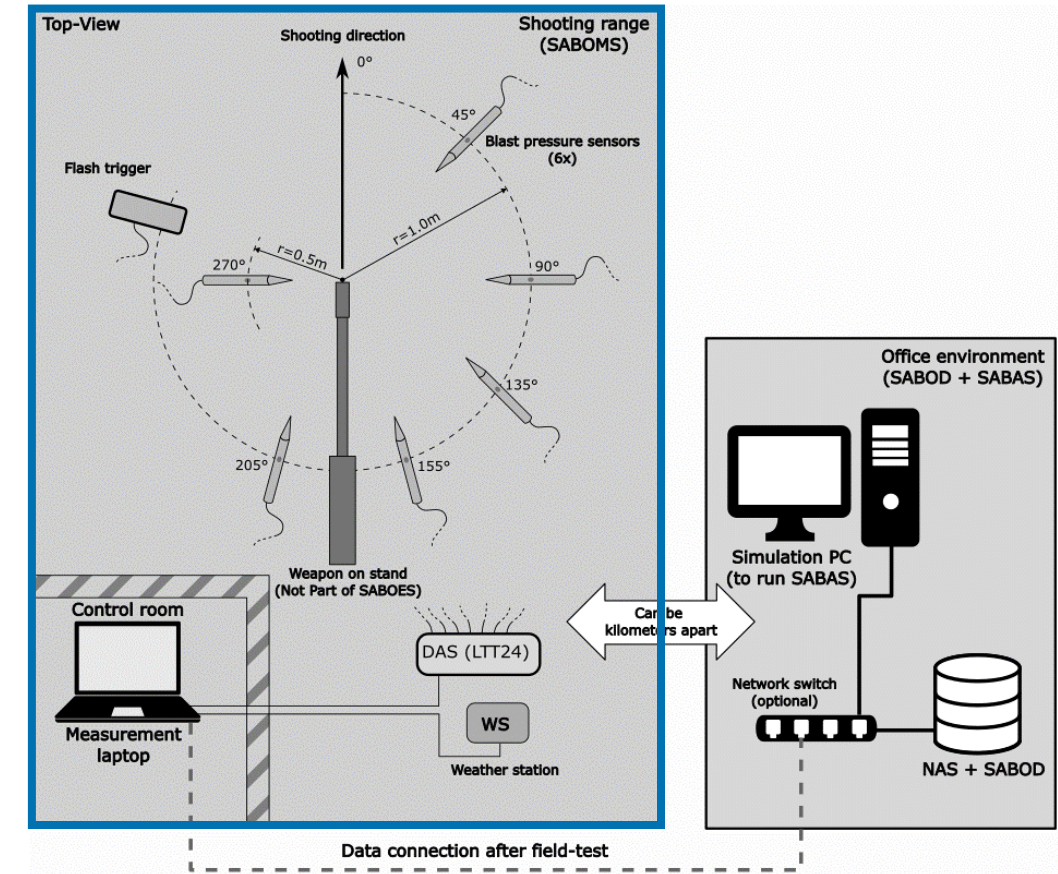
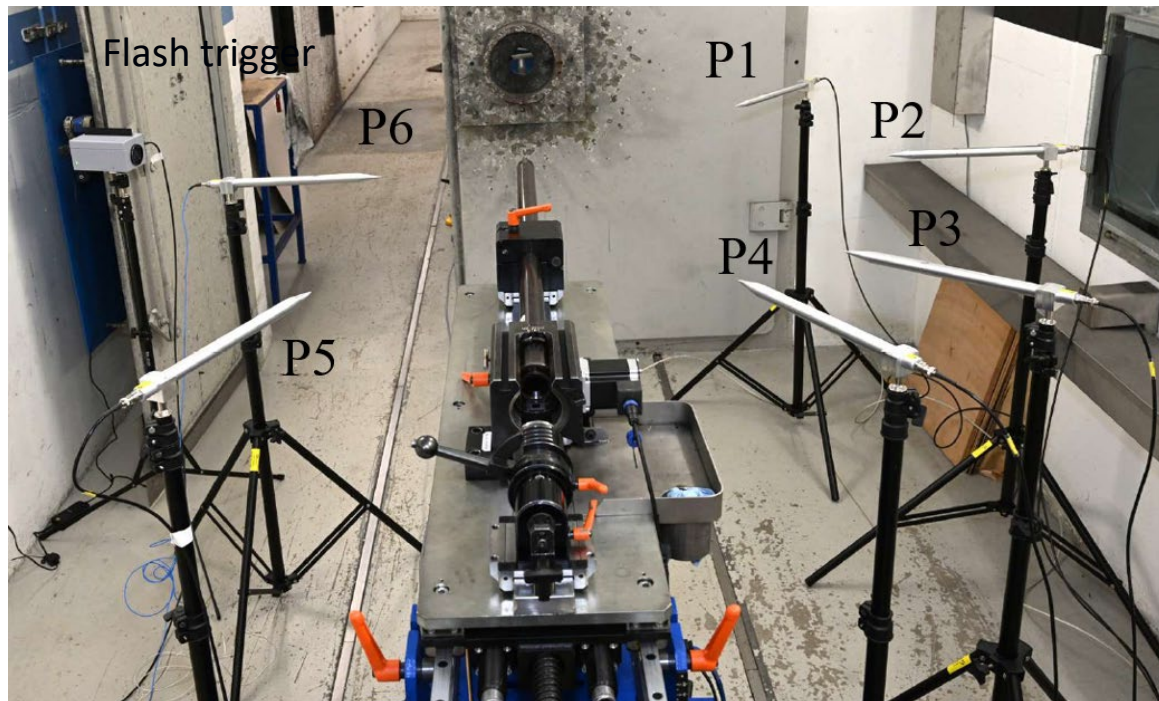
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# Measurement Subsystem ( SABOMS )

- Weapon to be placed on a stand
- Pre-defined blast pencil locations w.r.t. muzzle end
- Flash trigger for  $t = 0$
- Validation data for SABAS



# Simulation Subsystem ( **SABAS** )

## Why simulations?

1. Access to field data at arbitrary locations instead of at a limited amount of measurement locations
2. Visualization of the flow field for gaining insights in the muzzle blast propagation
3. Simulate scenarios which are a (small) variation to validated (tested) scenarios
4. Allowing the possibility to obtain the reflected pressure on the (simplified) head of the operator



# Simulation Subsystem ( **SABAS** )

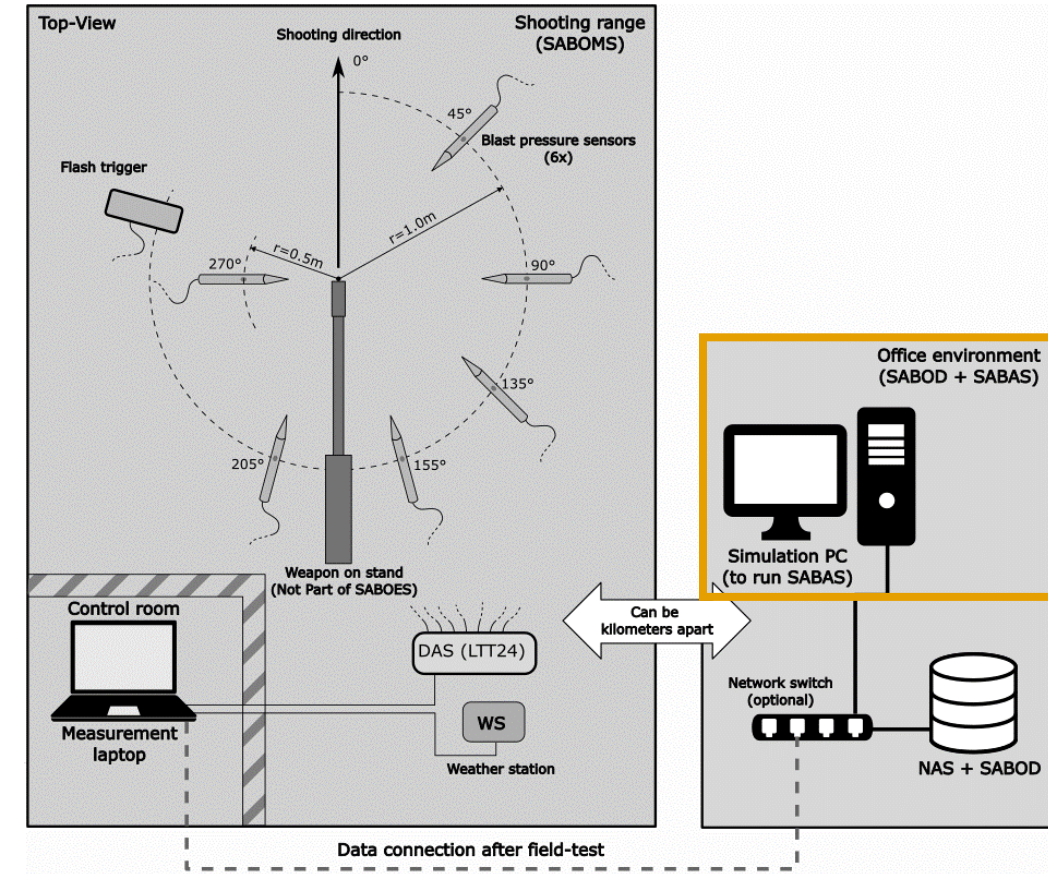
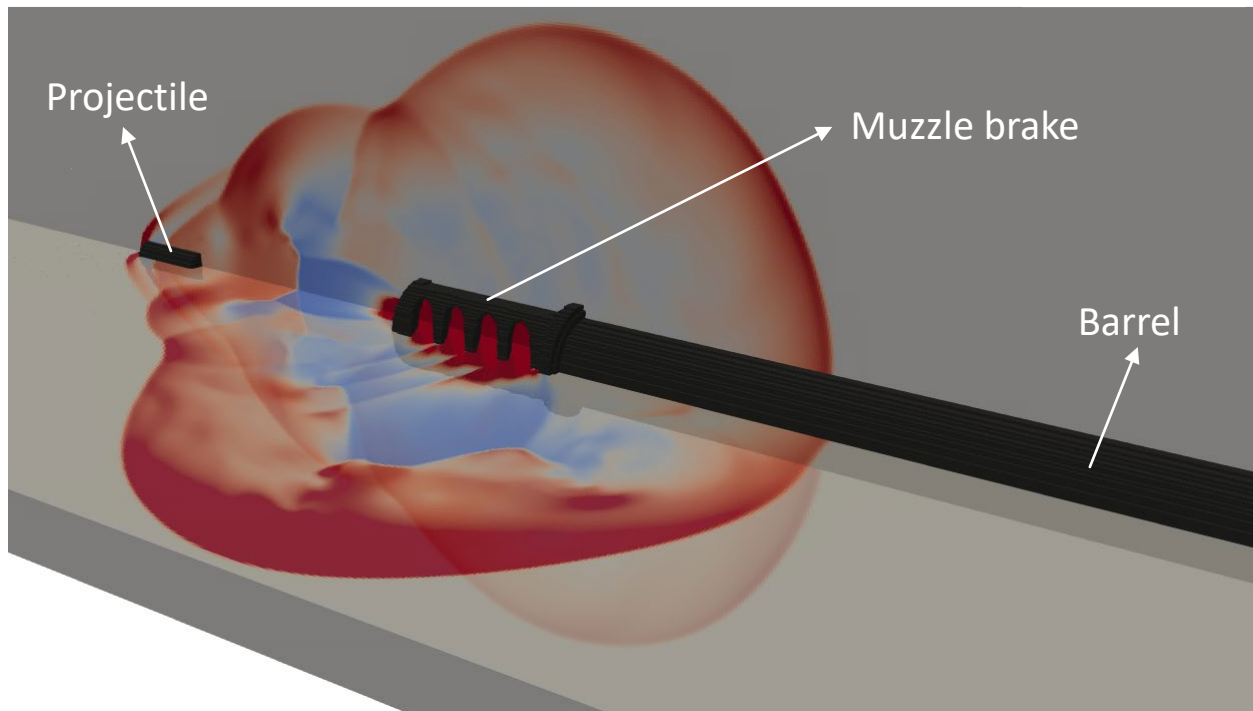
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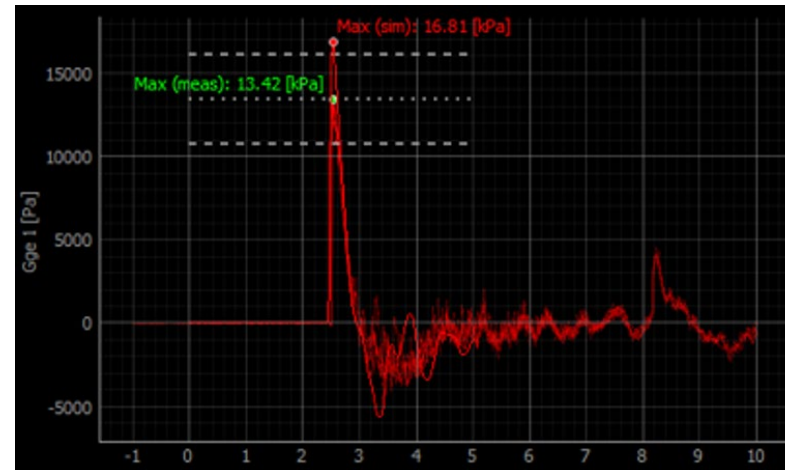
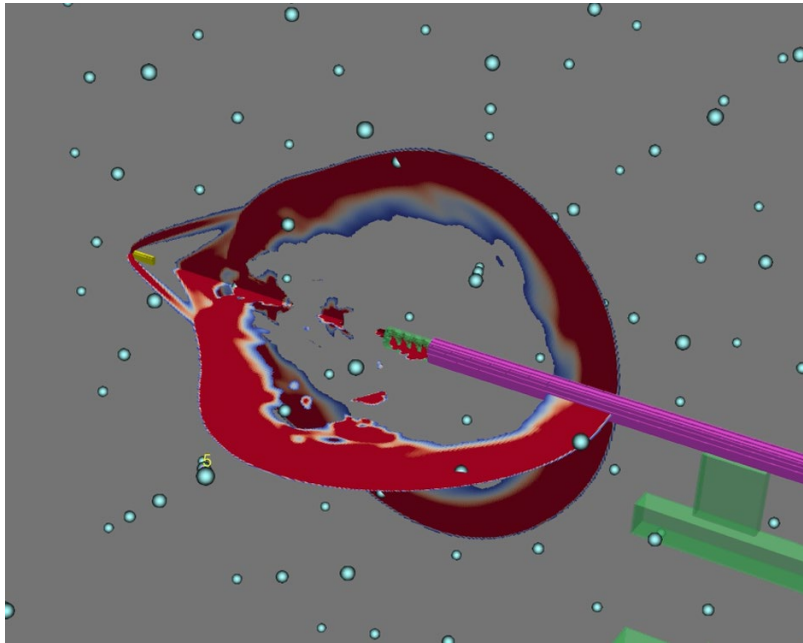
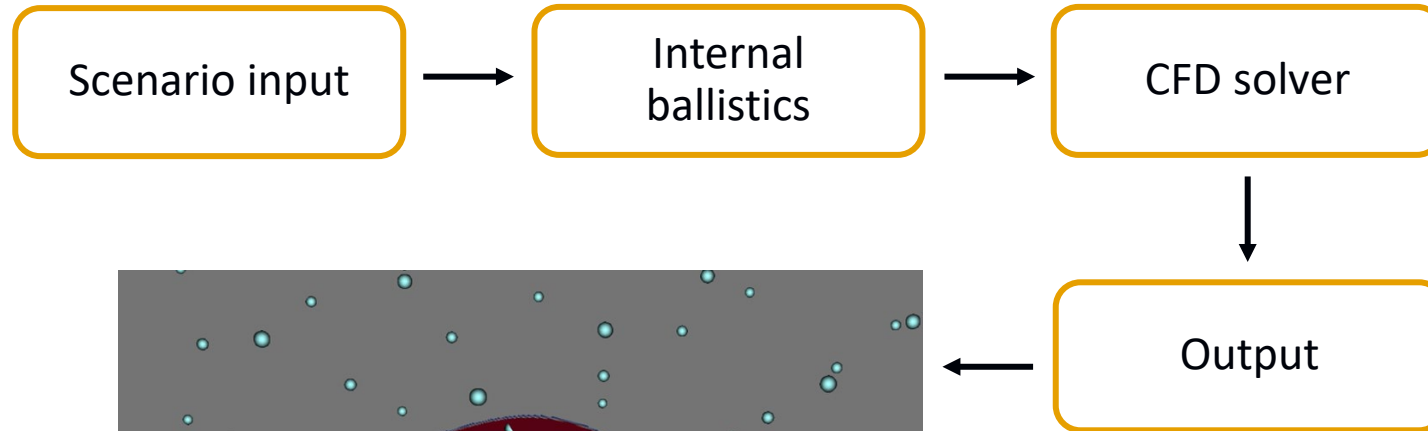
Provided simulation results are validated (SABOMS)!

# Simulation Subsystem ( **SABAS** )

- CFD based simulation tool (directly coupled to Rigid Body Solver for projectile)
- Powered by the Apollo Blastsimulator
- Requires minimal user-intervention
- Readily available input parameters



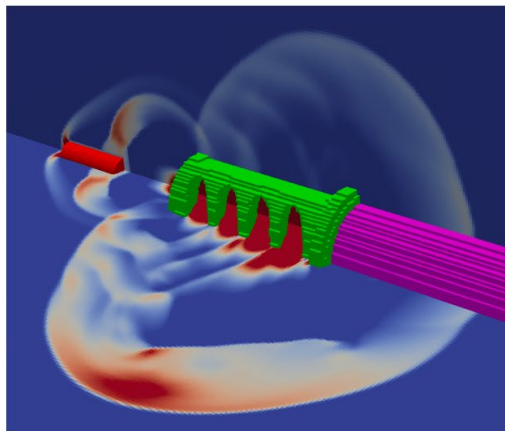
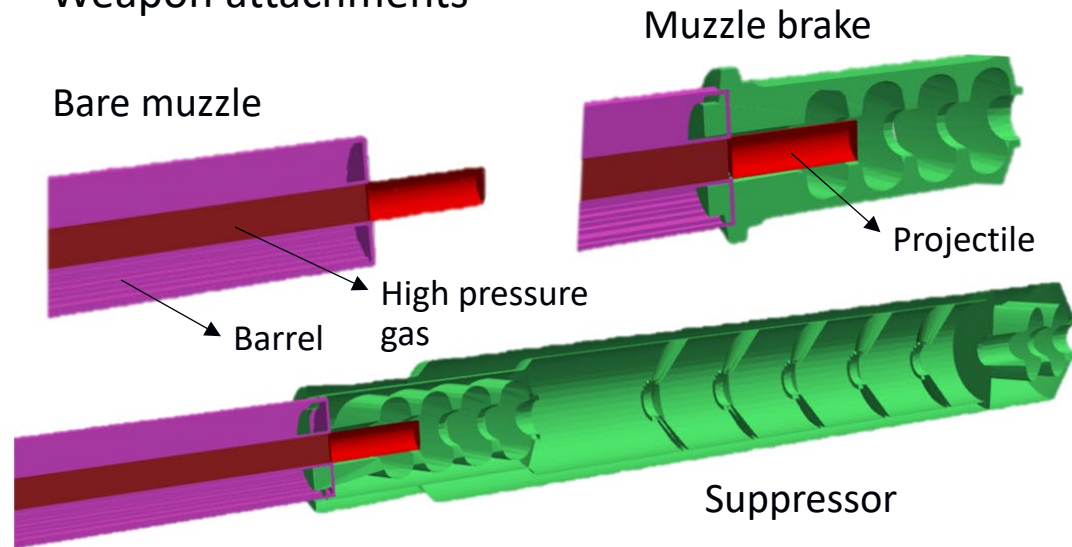
# Simulation Subsystem ( **SABAS** )



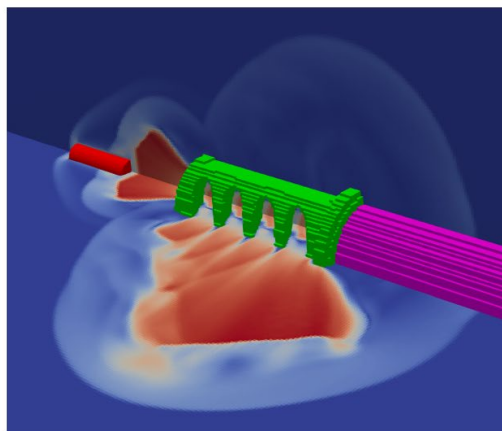


# Simulation Subsystem ( **SABAS** )

- Weapon attachments



Pressure

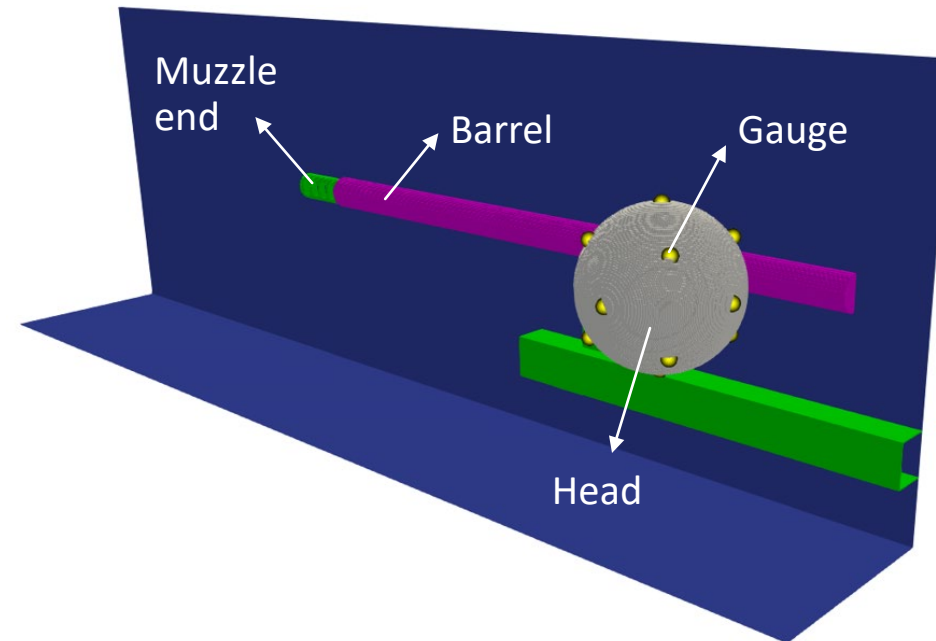
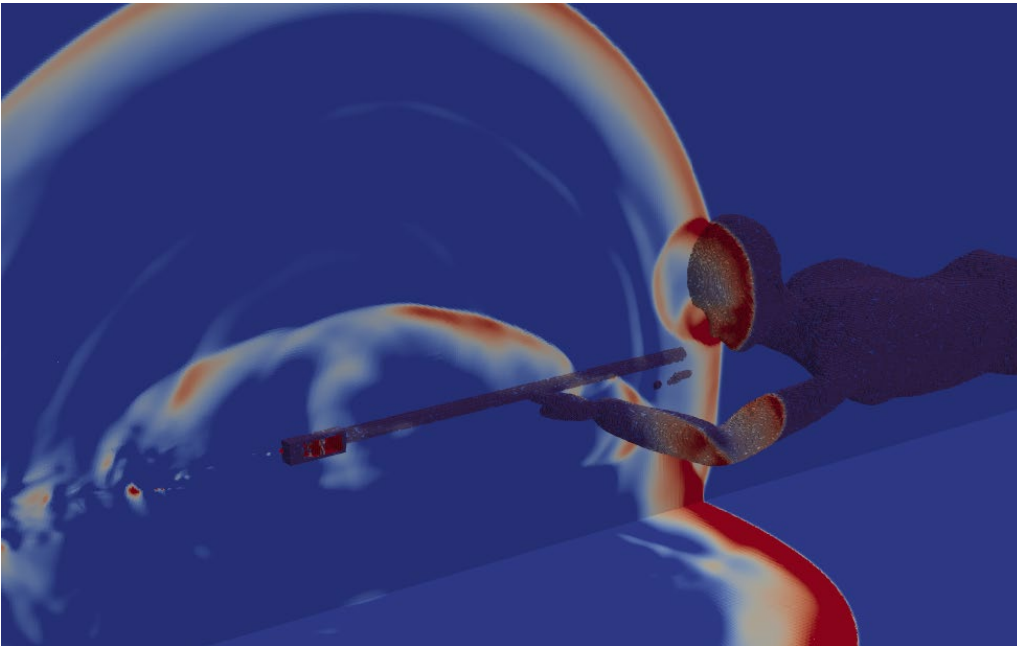


Velocity



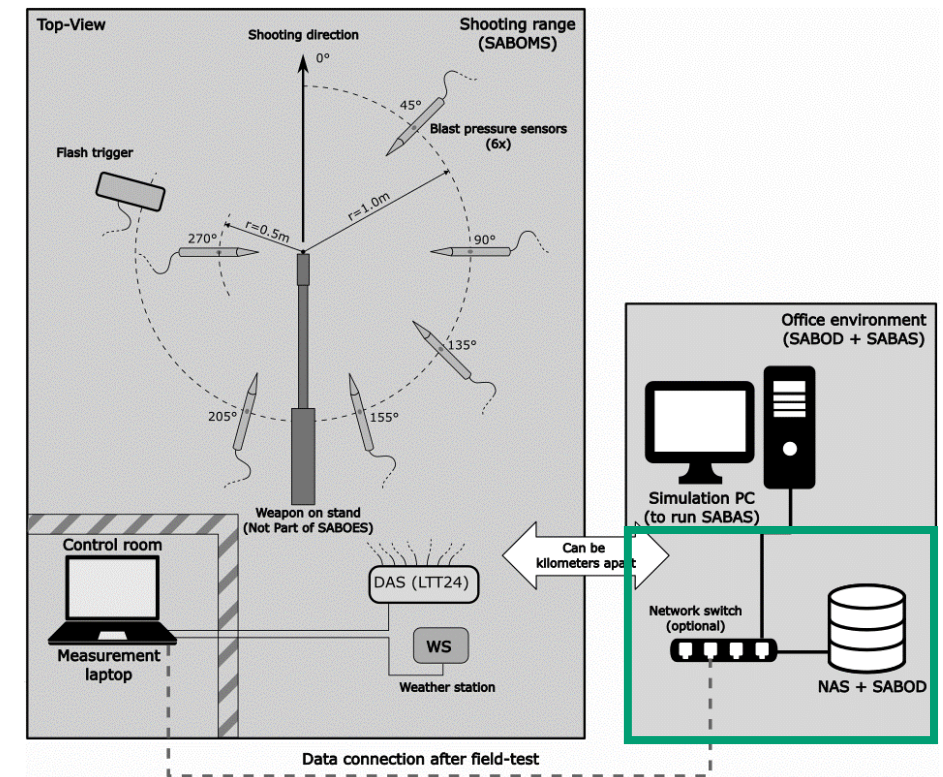
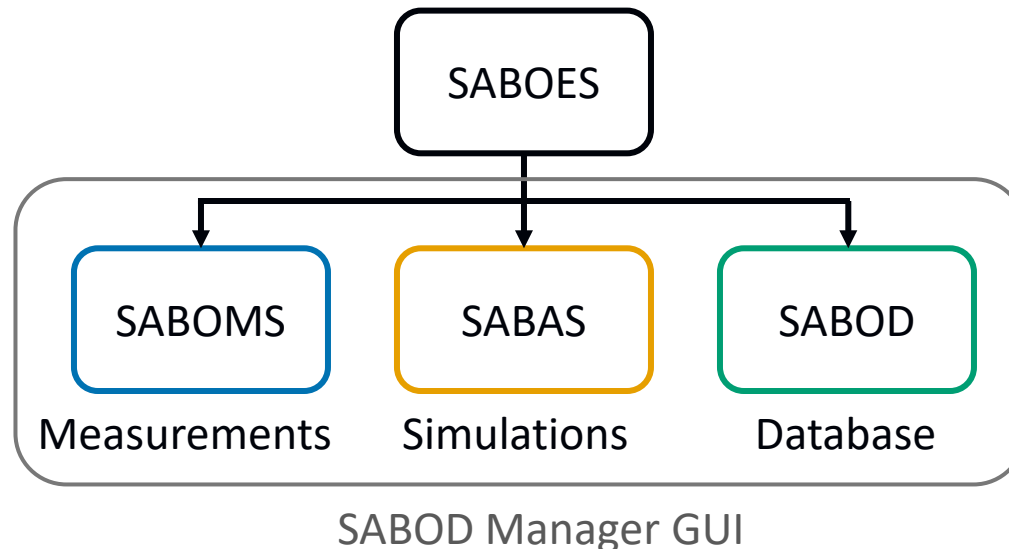
# Simulation Subsystem ( **SABAS** )

- Gauges at head of operator
  - Directly measure pressure applied to the head
  - Accounting for reflections and blast propagation around the head



# Database Subsystem ( **SABOD** ) + SABOD Manager GUI

- Database for archiving data from both SABOMS and SABAS
- Network Attached Storage (NAS)
- All subsystems connected through the SABOD Manager GUI
- Functionalities of GUI:
  - Enabling storing data from SABOMS and SABAS
  - Browse and plot stored data
  - Running SABAS simulations





# Database Subsystem ( **SABOD** ) + SABOD Manager GUI

- Home screen of the SABOD Manager GUI

**SABOD Manager**

Menu Tools Options Help

**Connection Options**

SABOD Root Folder:  Set SABOD Root Folder & Connect to SABOD

☐ Create New SABOD Database and Folder Structure if it Does Not Exist

Add / Load Weapon, Caliber, Ammunition | Set Sensor Configuration | SABOMS, Run Measurement | SABAS, Run Simulation

**Lock-in: Weapon & Caliber & Ammunition**

Lock-in: Weapon, Caliber & Ammunition

**Weapon Details**

**Weapon**

Presets:

Name:

Type: Assault Rifle

Barrel Length [mm]:

**Barrel Attachment**

Name:

Type: None

**Caliber**

Presets:

Name:

Diameter [mm]: 0.00

☐ **Optional Details**

Item Group:

Description:

Alt. Name:

**Ammunition**

Presets:

**Cartridge**

Name:

**Projectile**

Name:

Type: Full Metal Jacket (FMJ)

Mass [gram]: 0.00

Diameter [mm]: 0.00

**Case**

Length [mm]: 0.00

Diameter [mm]: 0.00

**Propellant**

Mass [gram]: 0.00

☐ **Enable Pre Insert Weapons, Caliber & Ammunition to Database**

Enabling This Allows the User to Add a Weapon and Caliber Record, or Ammunition Record Directly to the Database. This is Useful for Filling up the Database and Reuse the Combinations Later

Warning: These Records Are Not Linked to a Measurement or Simulation and Will Not be Visible in the Database Inspector.

☐ **Advanced: Add Weapon & Caliber to Database**

Add Weapon With Linked Caliber Record

☐ **Advanced: Add Ammunition Record to Database**

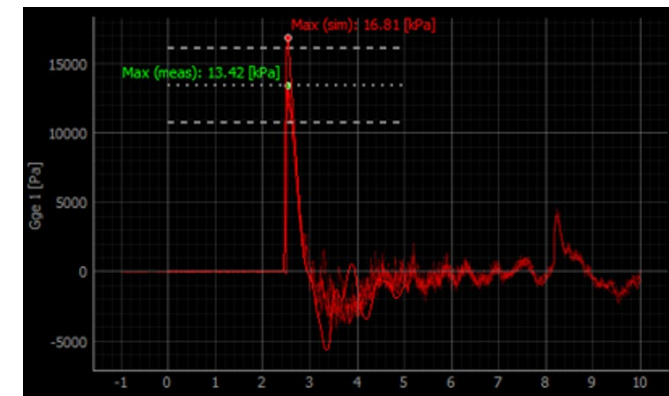
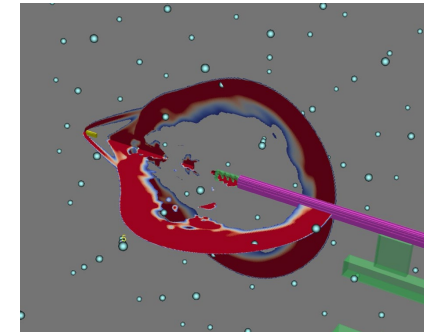
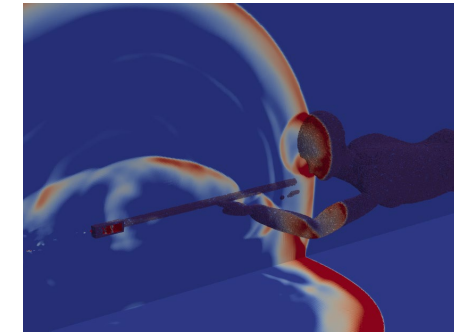
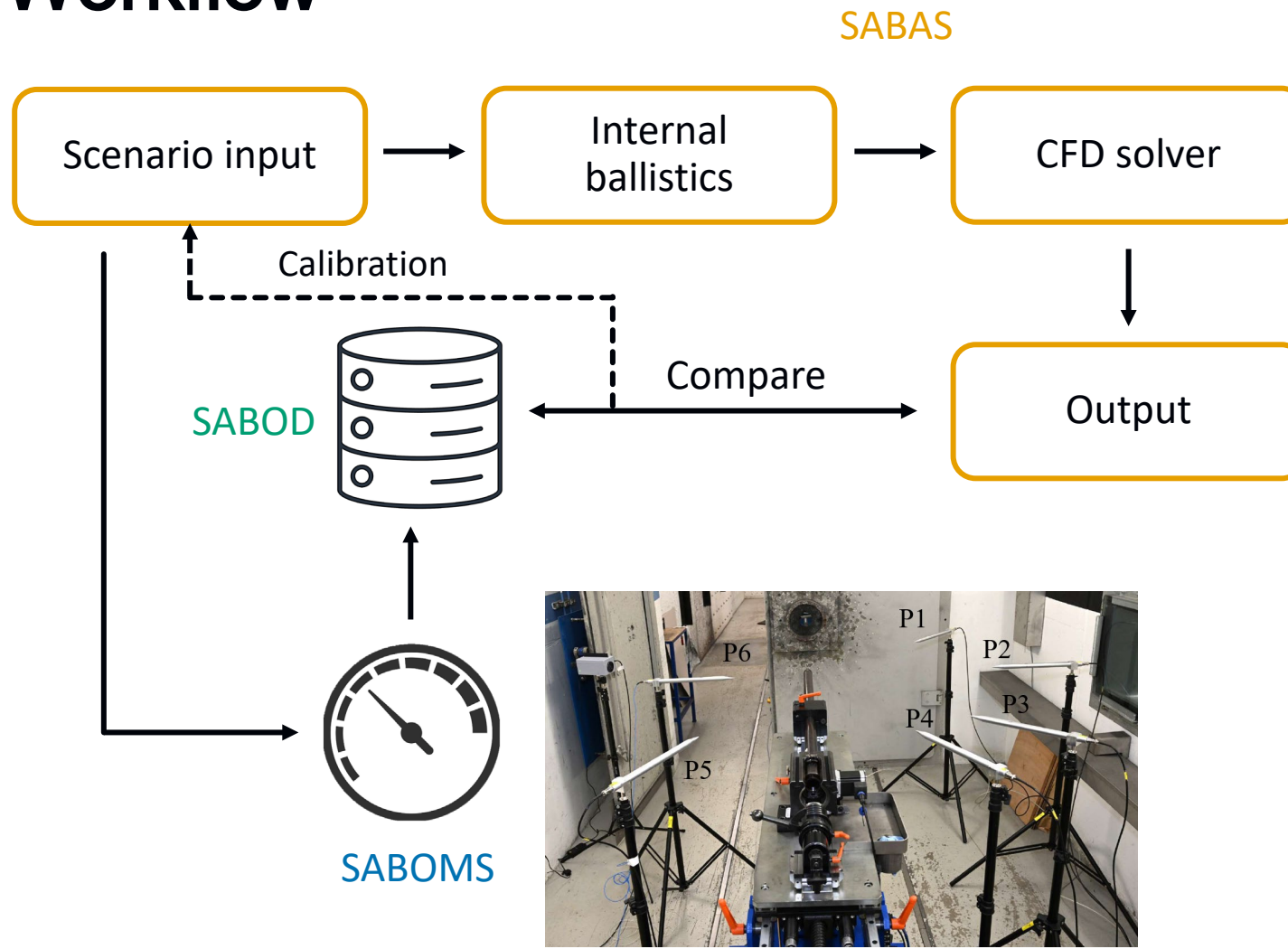
Add Ammunition Record

**Schematic Information**

Diagram illustrating the components and dimensions of a rifle and a cartridge:

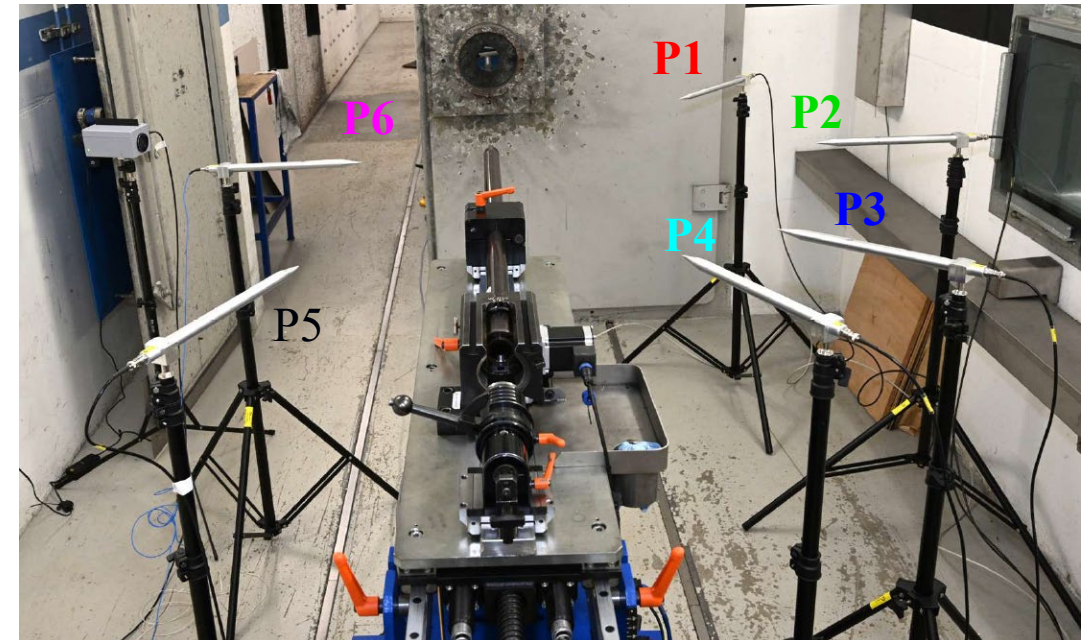
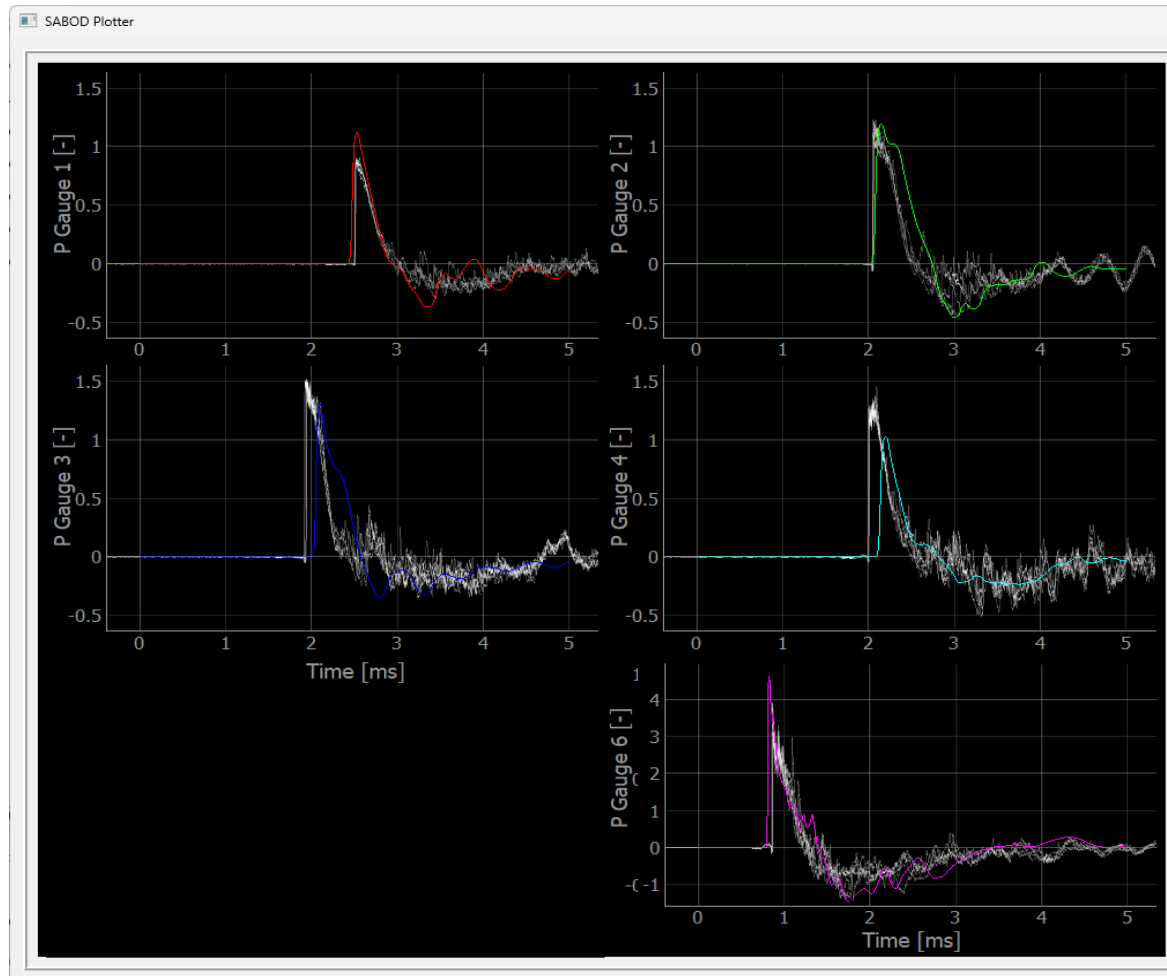
- Rifle Diagram:** Shows the internal barrel length and the chamber.
- Cartridge Diagram:** Shows the case length, cartridge length, case diameter, propellant, projectile, and projectile diameter.
- Barrel Front View:** Shows the diameter of the barrel, which is equal to the caliber.

# Workflow



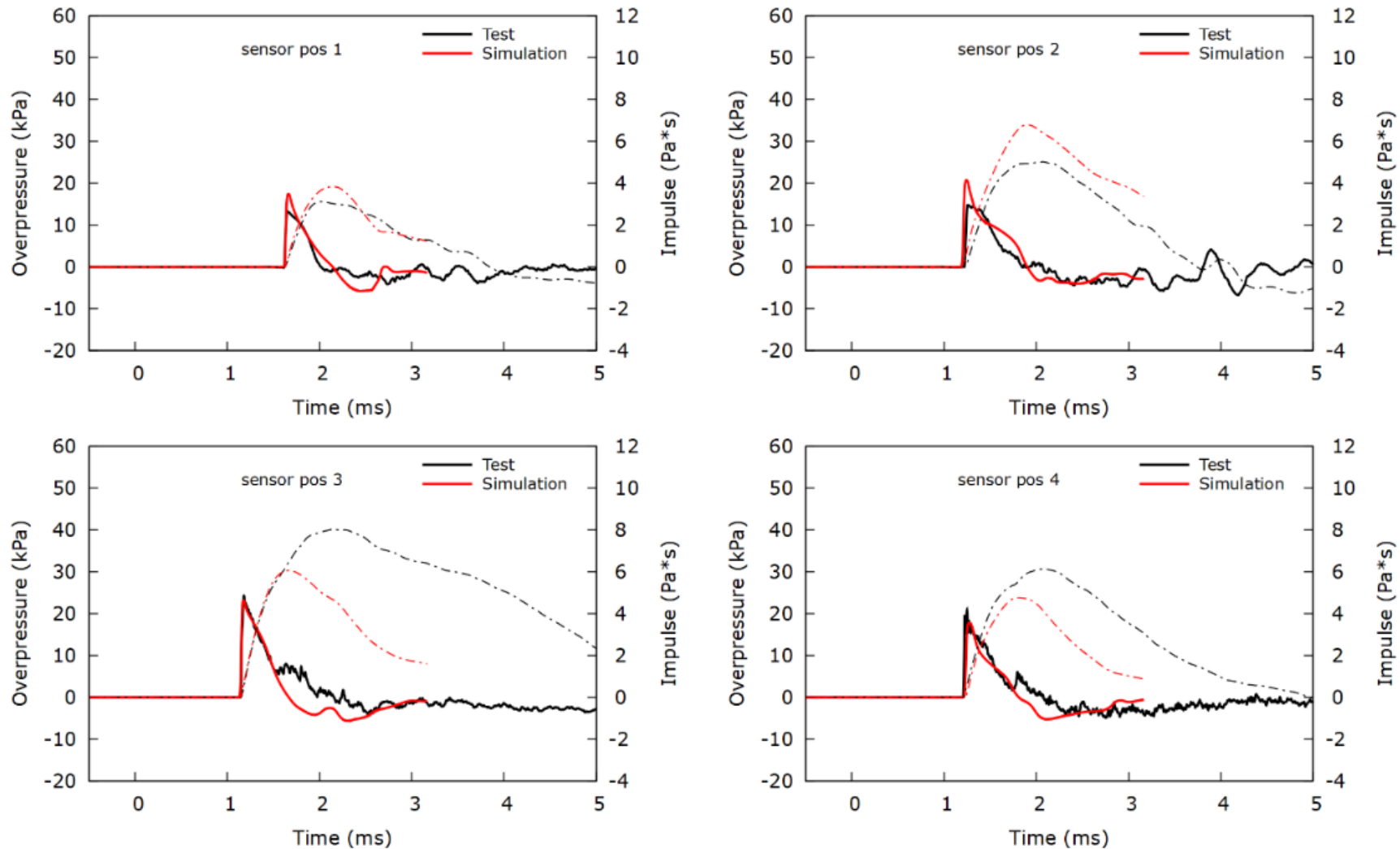
- All controlled from SABOD Manager GUI
- Semi-automatic, user friendly

# Example and Validation of SABAS



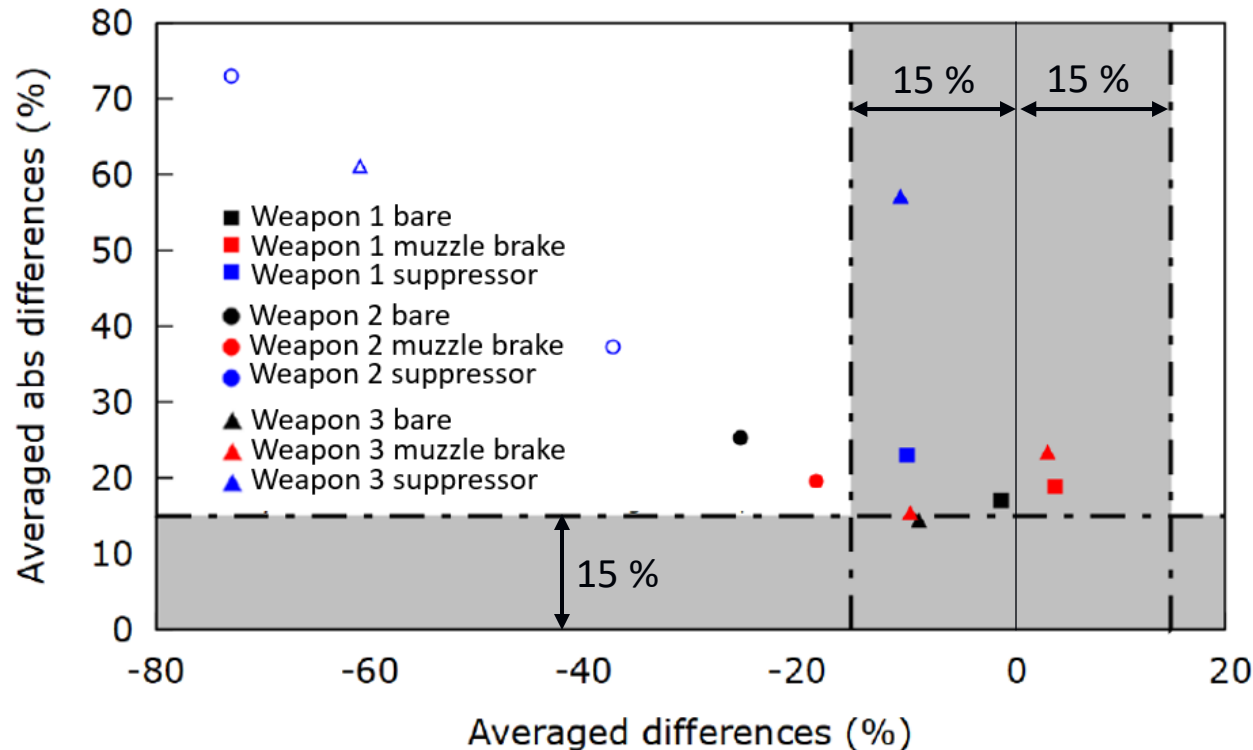


# Example and Validation of SABAS



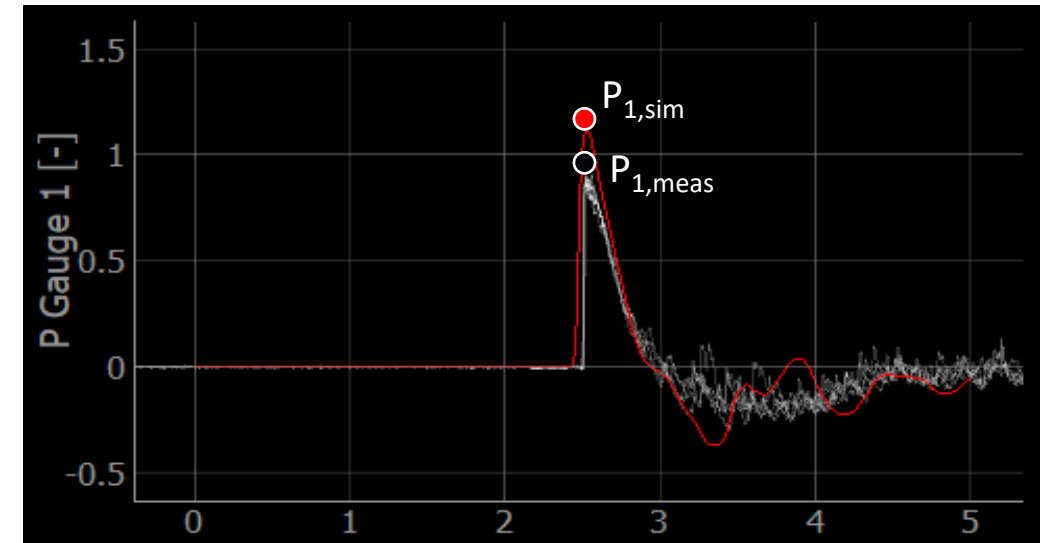
# Example and Validation of SABAS

- So far 9 configurations are considered (3 weapons with each 3 muzzle configurations)
- No calibration was performed
- Open symbols: overpressure below 1 kPa



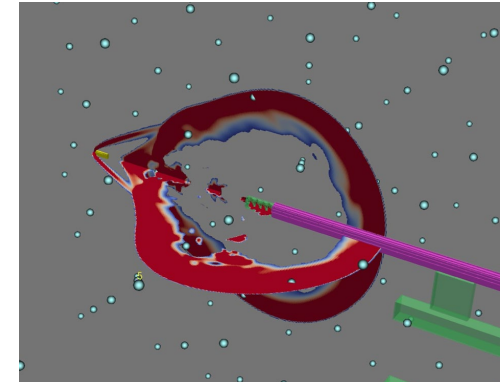
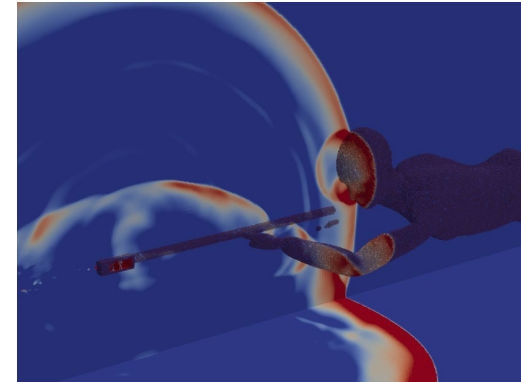
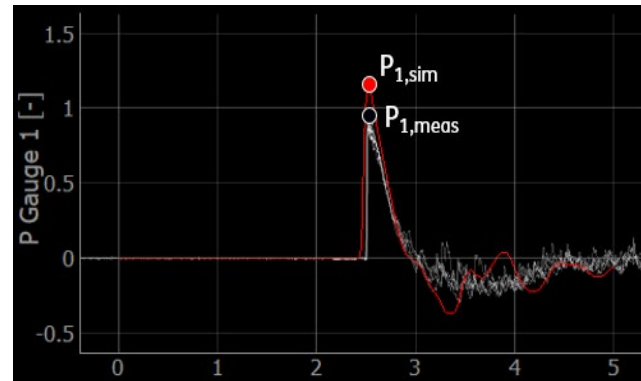
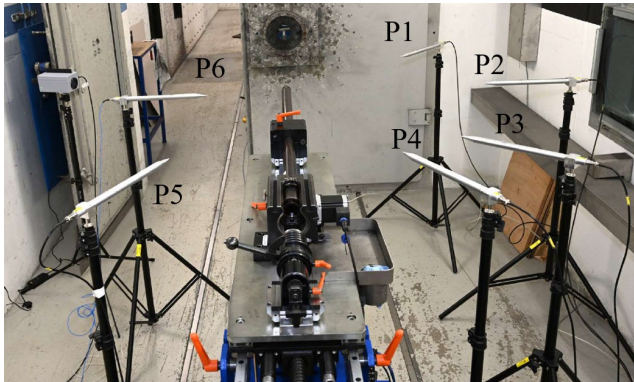
$$\delta = \frac{1}{n} \sum_{i=1}^n \frac{P_{i,sim} - P_{i,meas}}{P_{i,meas}} \cdot 100\%$$

$$\delta_{abs} = \frac{1}{n} \sum_{i=1}^n \left| \frac{P_{i,sim} - P_{i,meas}}{P_{i,meas}} \right| \cdot 100\%$$



# Conclusions SABOES system

- The SABOES system is:
  - Able to systematically quantify muzzle blast exposure from small arm weapons
  - Availability of both experimental and simulation data in a convenient database
  - Capable of simulating the muzzle blast of all scenarios with reasonable accuracy (without calibration)
  - Applicable to arbitrary small-arms weapons and in a wide variety of environments
  - Easy to use

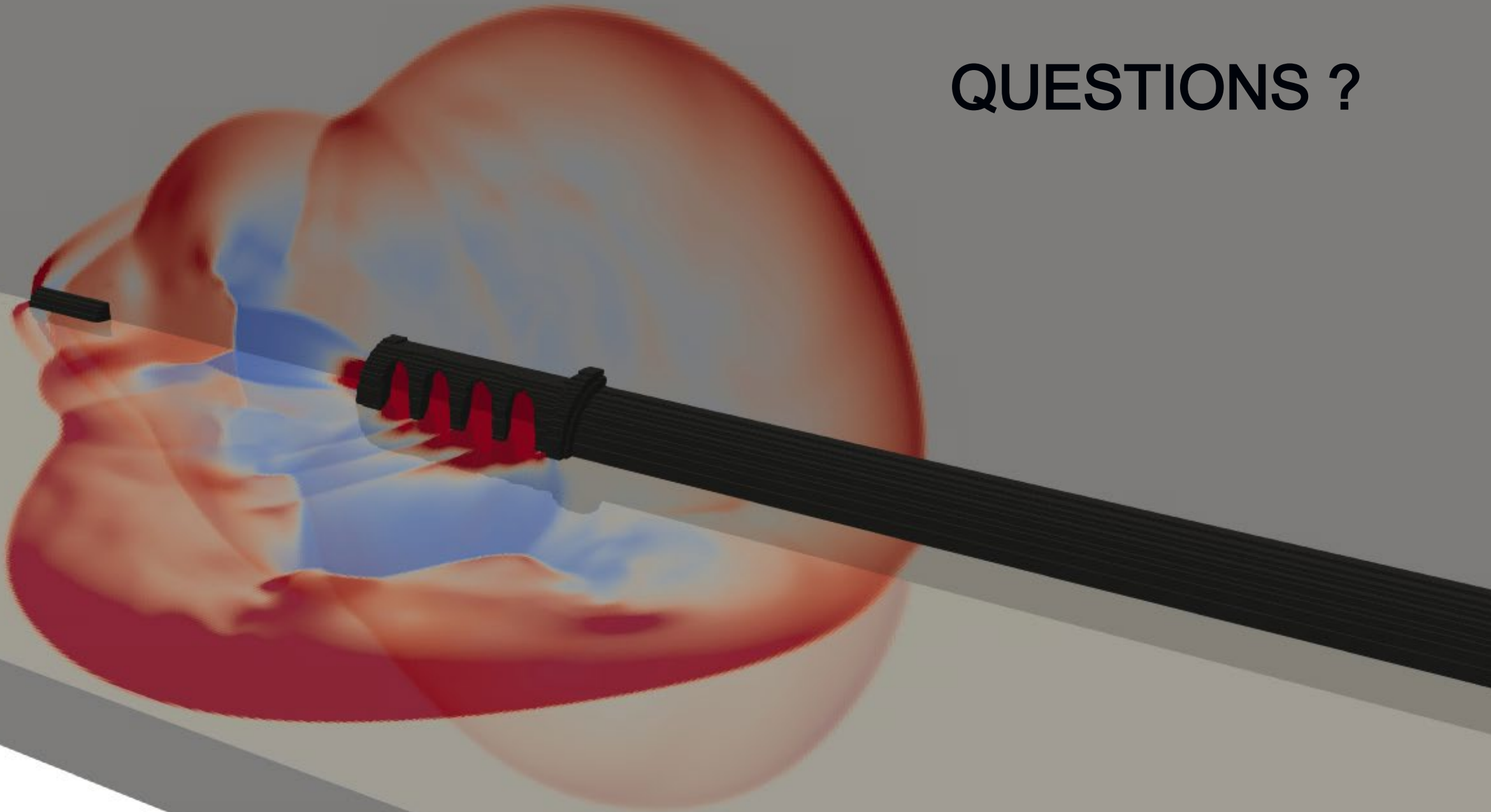




# Future work

- Test if system is applicable to larger caliber weapons
- Explore possibilities for standardization to quantify blast load on operator
- Potential to correlate exposure blast loads and exposure frequency to injury

QUESTIONS ?



# Simulation Subsystem ( **SABAS** )

- Basic input parameters

## Barrel

- Internal length
- Internal diameter

## Cartridge

- Case length
- Case diameter

## Internal ballistics

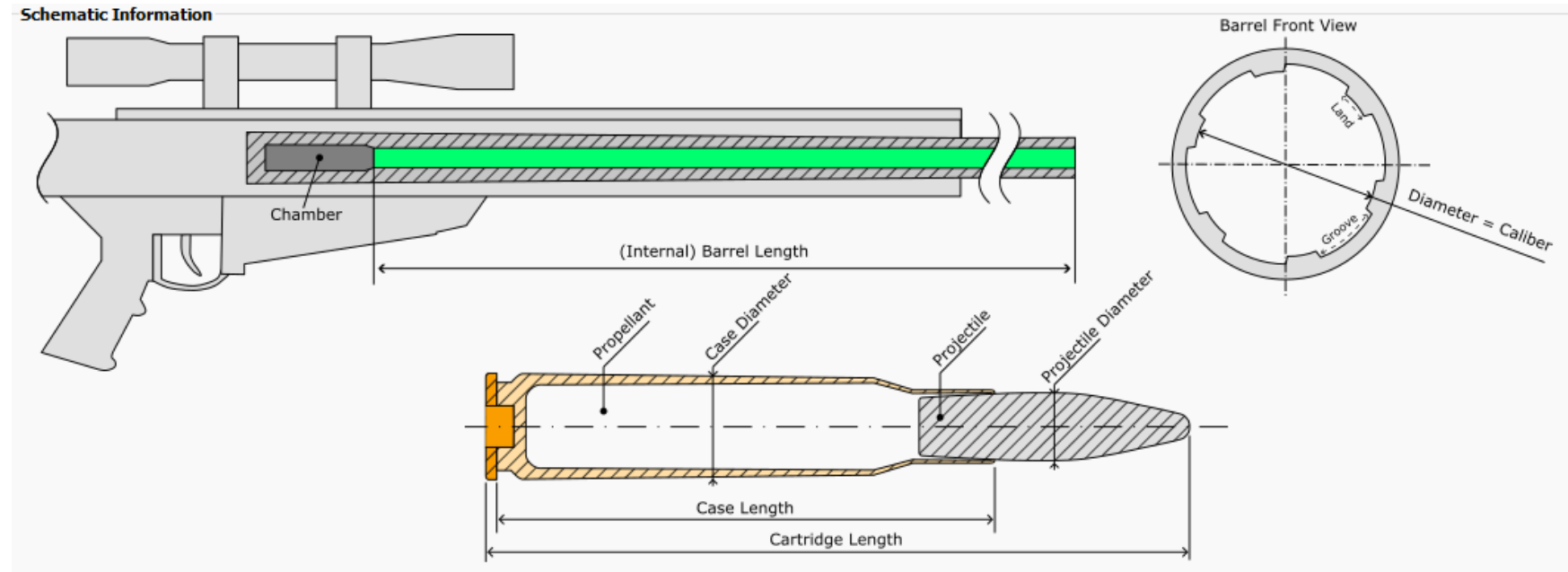
- Propellant mass
- Peak internal pressure

## Projectile

- Projectile mass
- Muzzle velocity

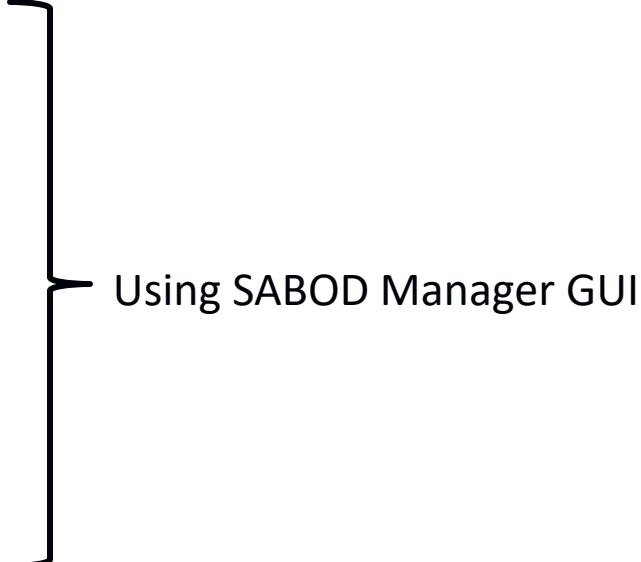
## Weapon position

- Height
- Elevation





# SABOES Workflow

1. Determine scenario (weapon, attachment, environment, etc.)
  2. Perform measurements (typically 5 shots)
  3. Transfer measurement data to SABOD
  4. Import scenario parameters to SABAS
  5. Run SABAS analysis
  6. Transfer simulation data to SABOD
  7. Compare measurement and simulation data
  8. Perform calibration procedure + compare again
  9. Perform variation on validated simulation
- 
- Using SABOD Manager GUI