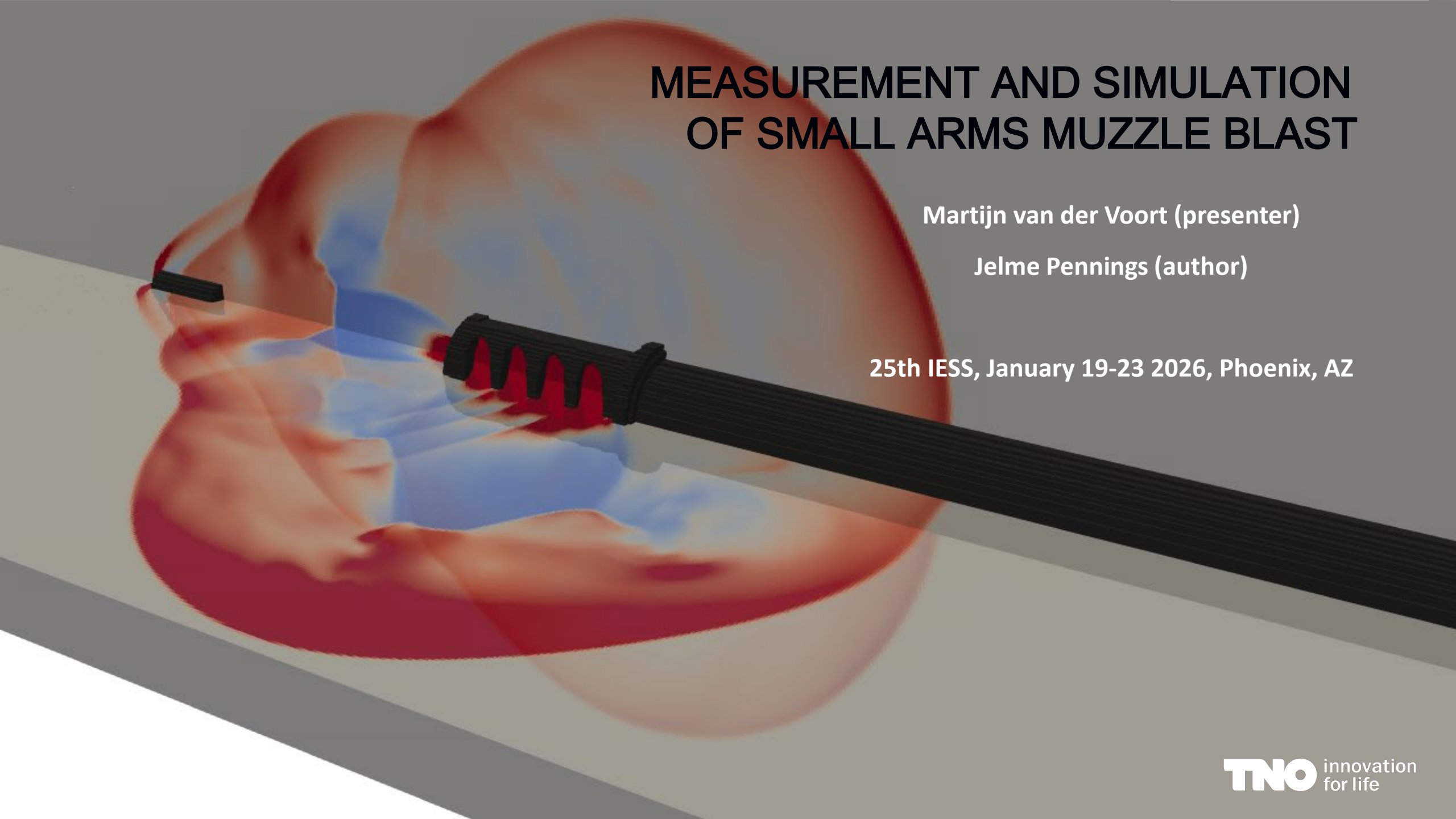


MEASUREMENT AND SIMULATION OF SMALL ARMS MUZZLE BLAST

Martijn van der Voort (presenter)

Jelme Pennings (author)

25th IESS, January 19-23 2026, Phoenix, AZ

TNO innovation for life

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

IWTSD
Irregular Warfare Technical Support Directorate

- 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

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

MEASUREMENT AND SIMULATION OF SMALL ARMS MUZZLE BLAST

J.K. Pennings[1], J. Verreault[1], R.M. van de Kasteele[1], E.P. Veldhuis[1], M.M. van der Voort[1], T.A.T. Westerhof[1], S. Ouellet[2], G. St. Onge[2]

[1]TNO, Personal Protection and Explosives Safety, Ypenburgse Boslaan 2, 2496 ZA, Den Haag, The Netherlands;
[2]DRDC Valcartier Research Centre, 2459 de la Bravoure Road, Québec, Canada

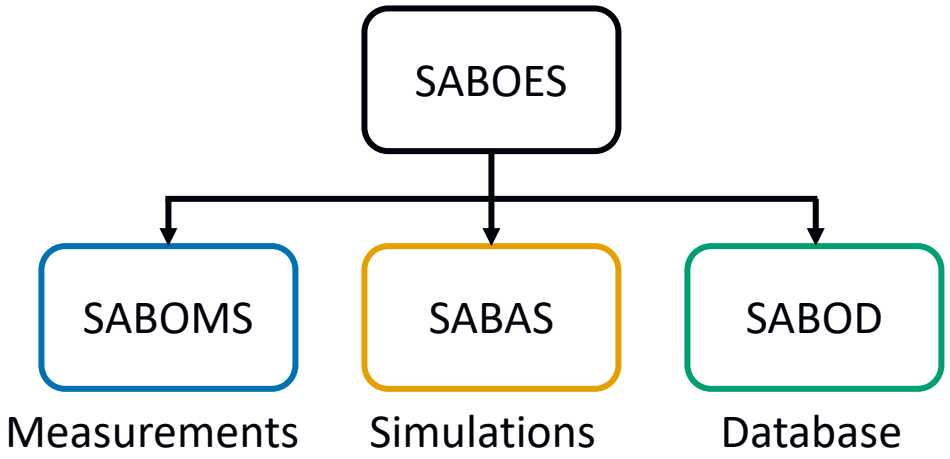
MABS
Military Aspects of Blast and Shock

- System has now been delivered/ordered by a number of clients

This research has been conducted in a project funded by the Irregular Warfare Support Technical Directorate (IWTSD). Financial support by IWTSD does not constitute an express or implied endorsement of the results or conclusions of the project by either IWTSD or the U.S. Department of Defense.

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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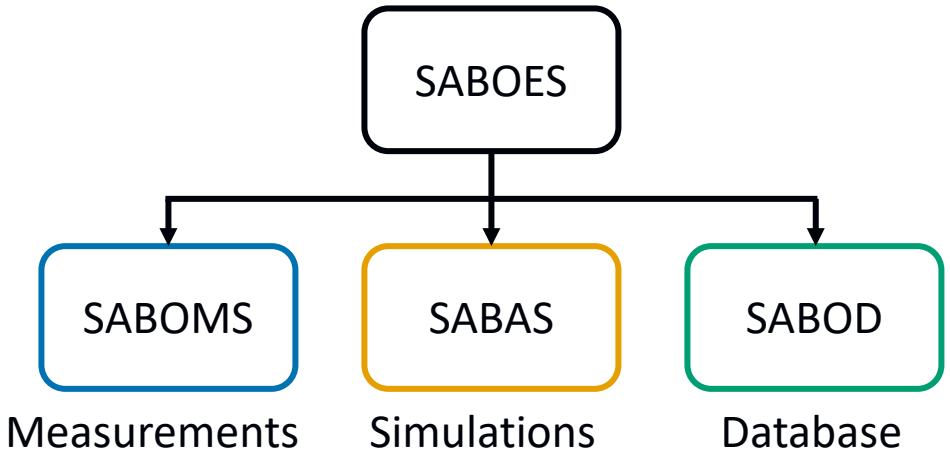

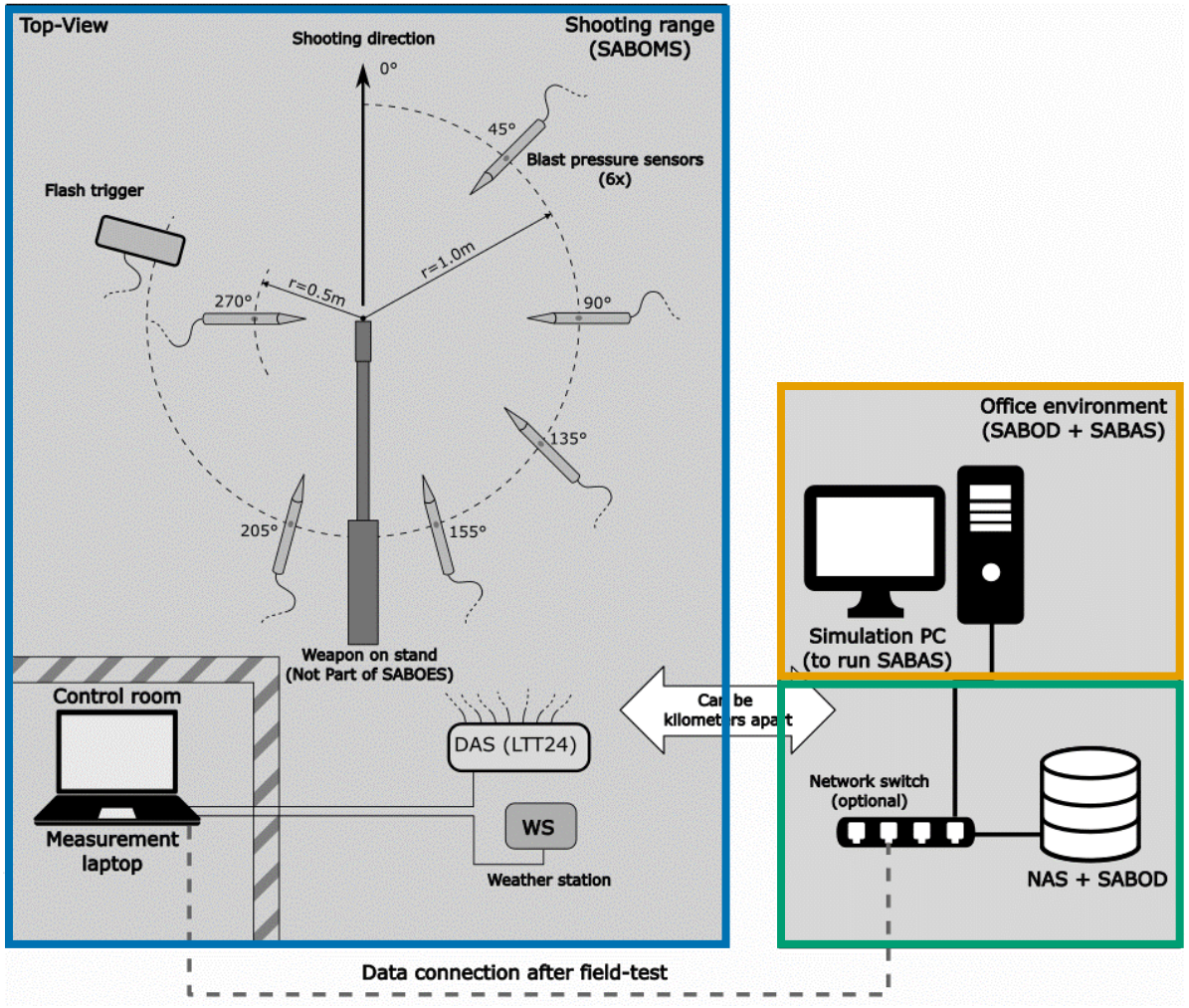

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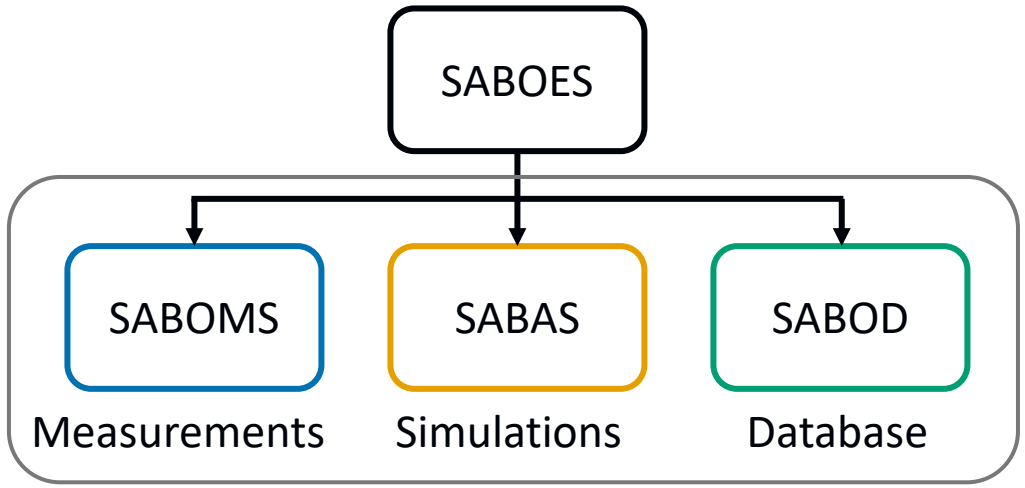
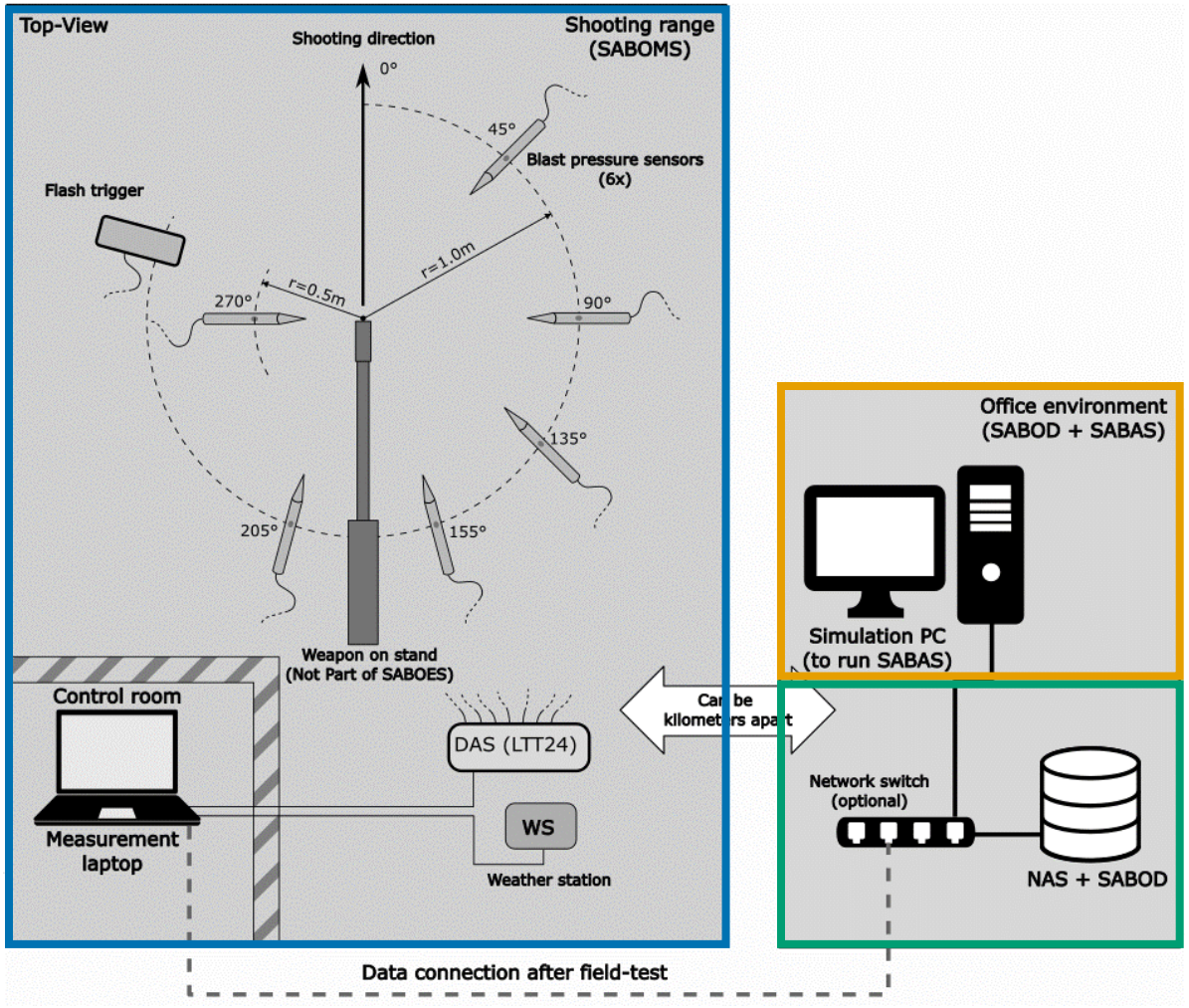
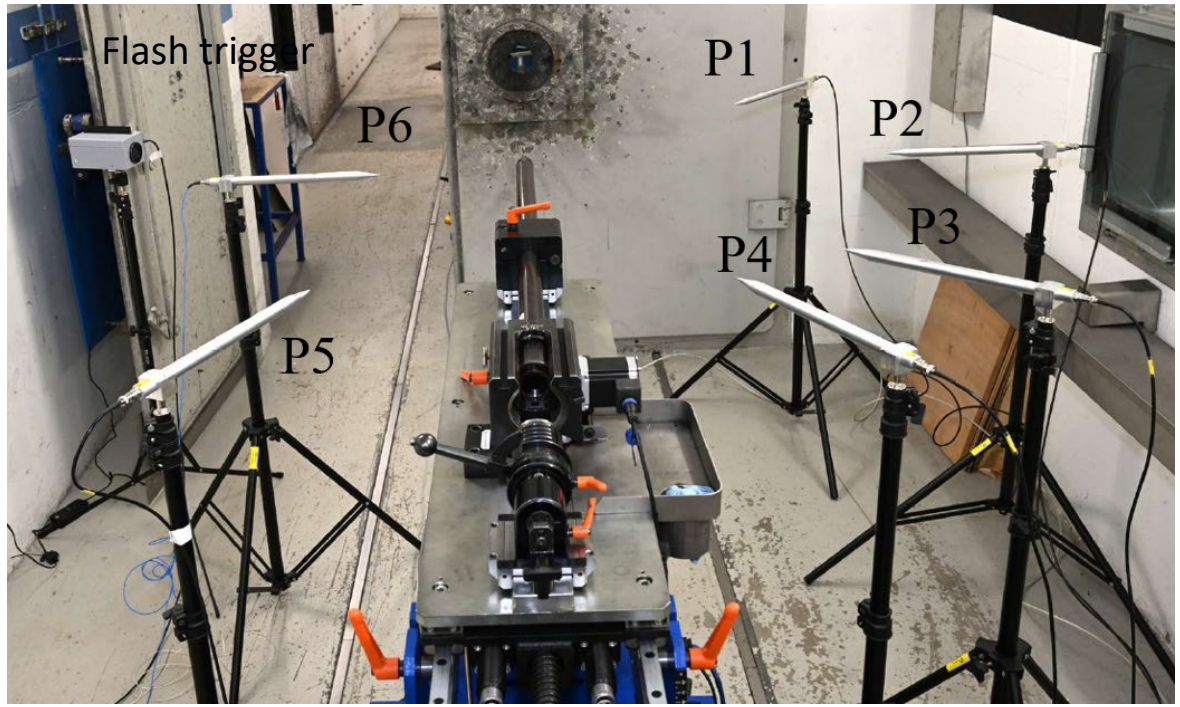


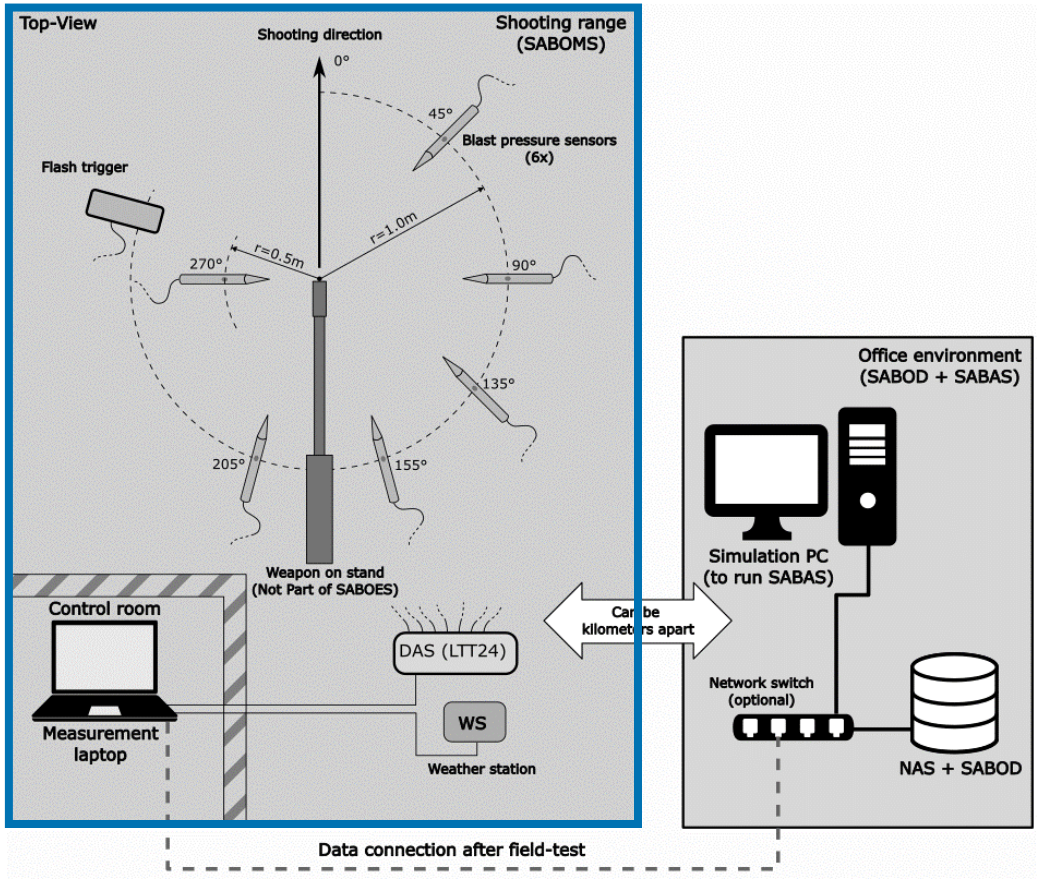
SABOD Manager GUI



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

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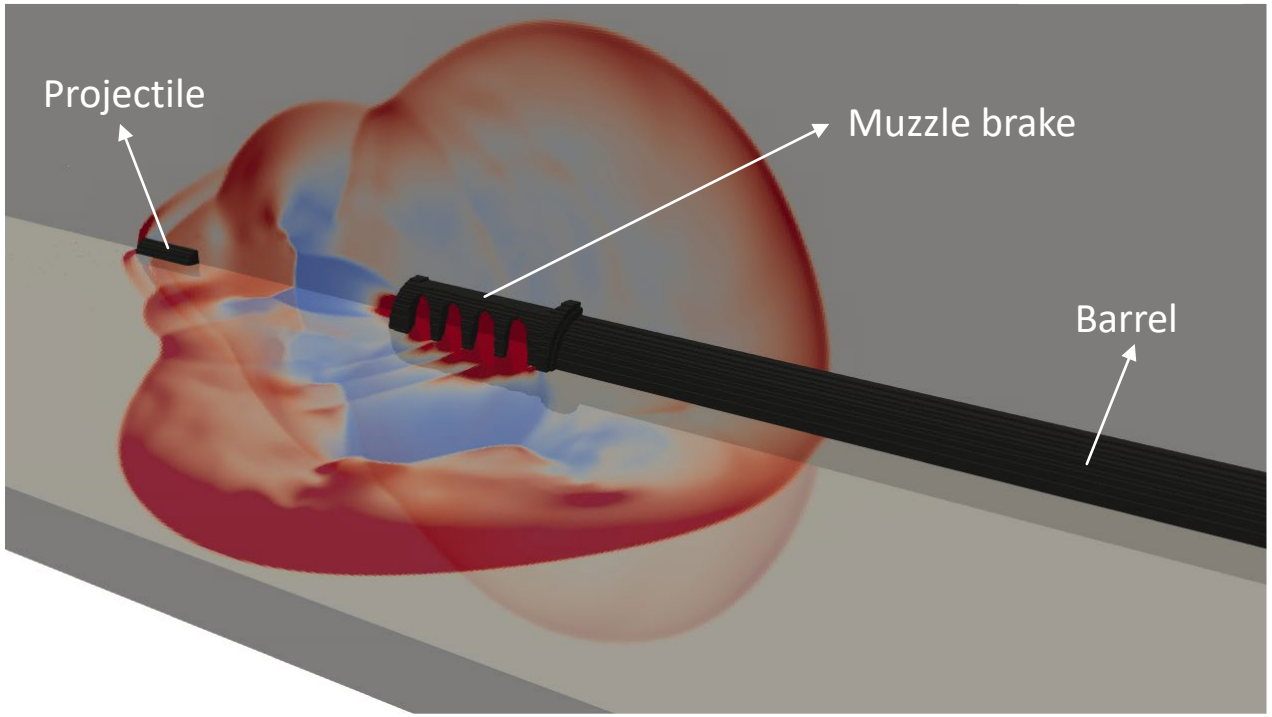
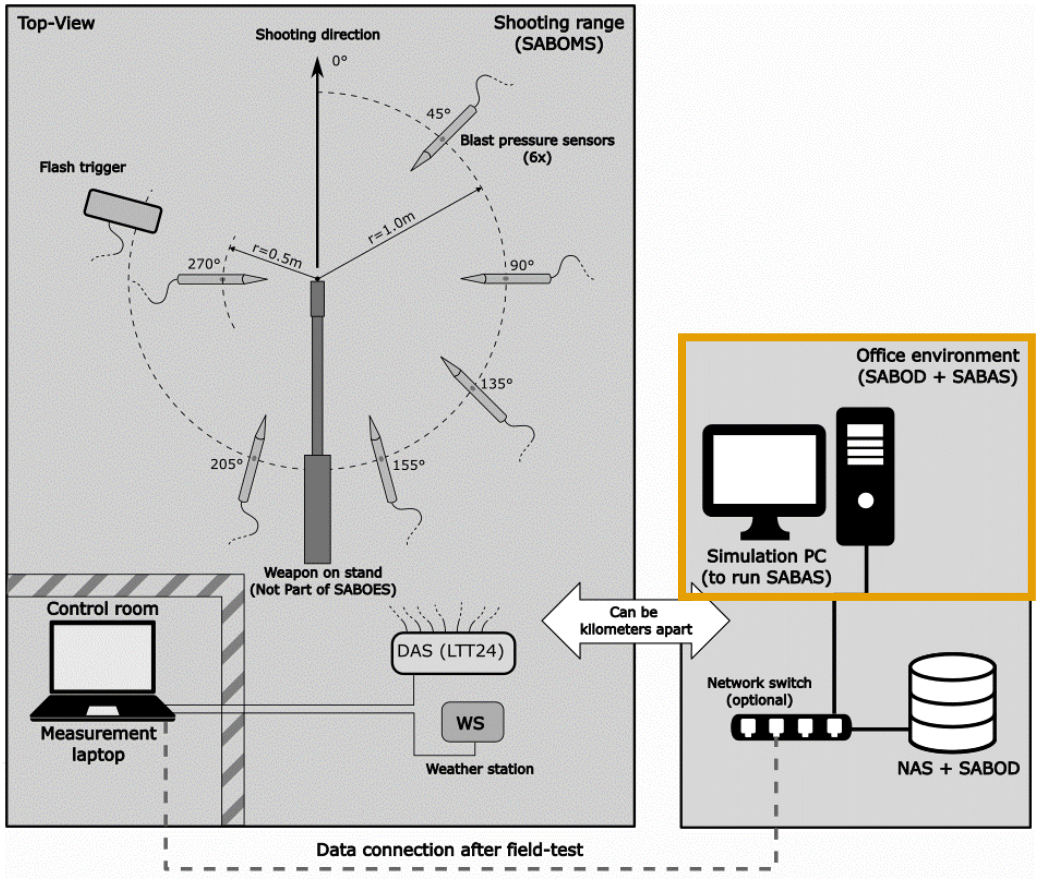
Provided simulation results are validated (SABOMS)!

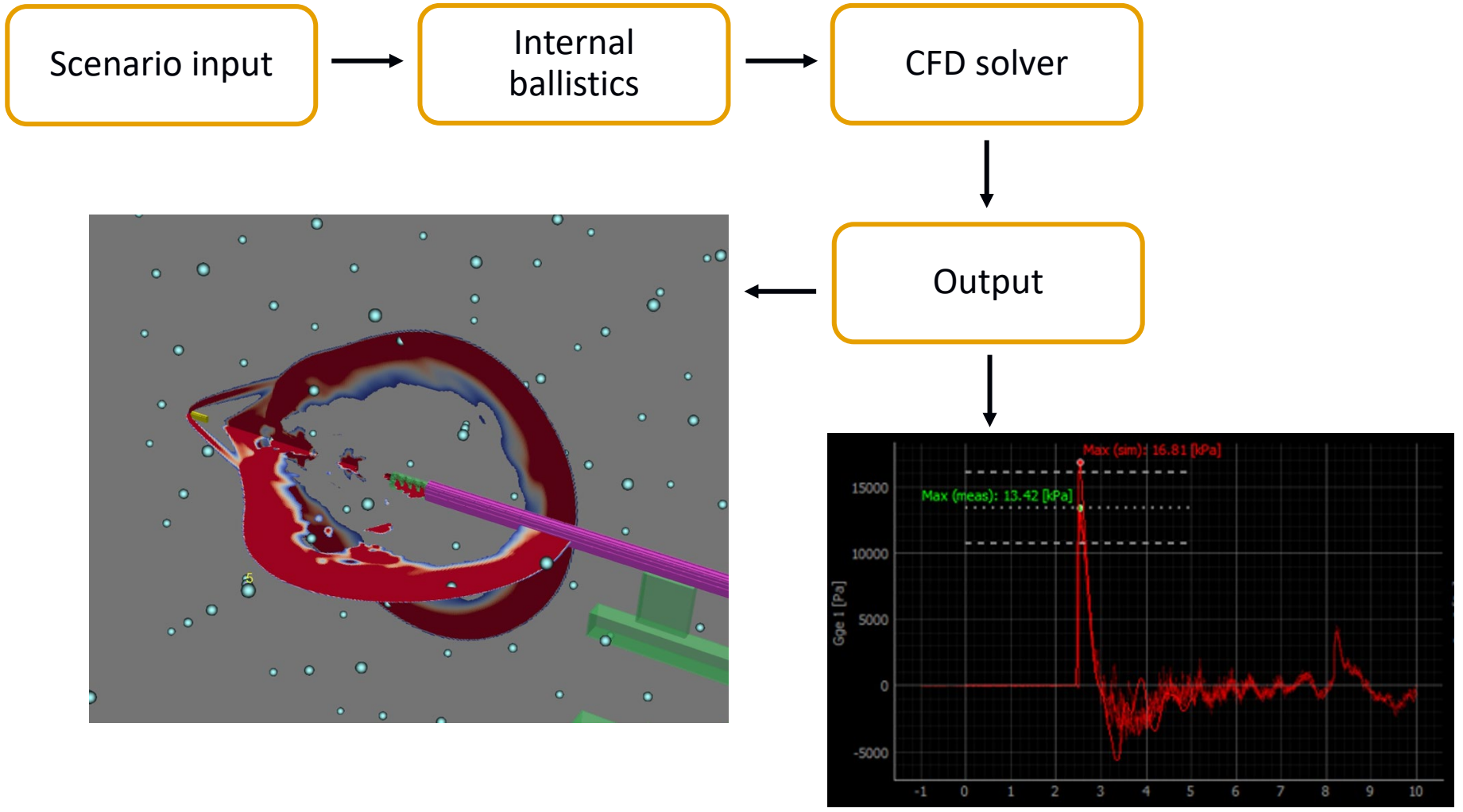
Simulation Subsystem (SABAS)

- 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



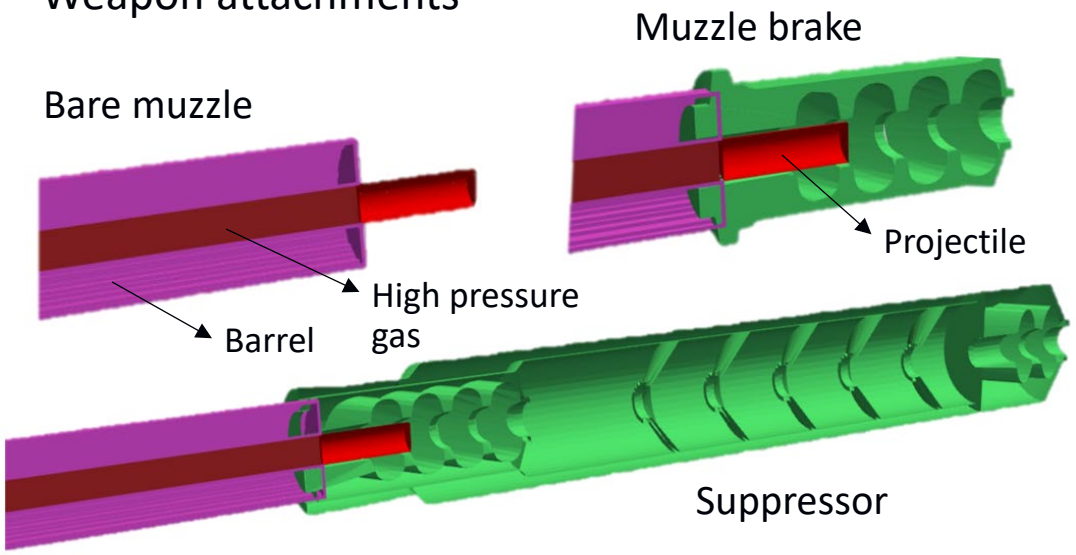


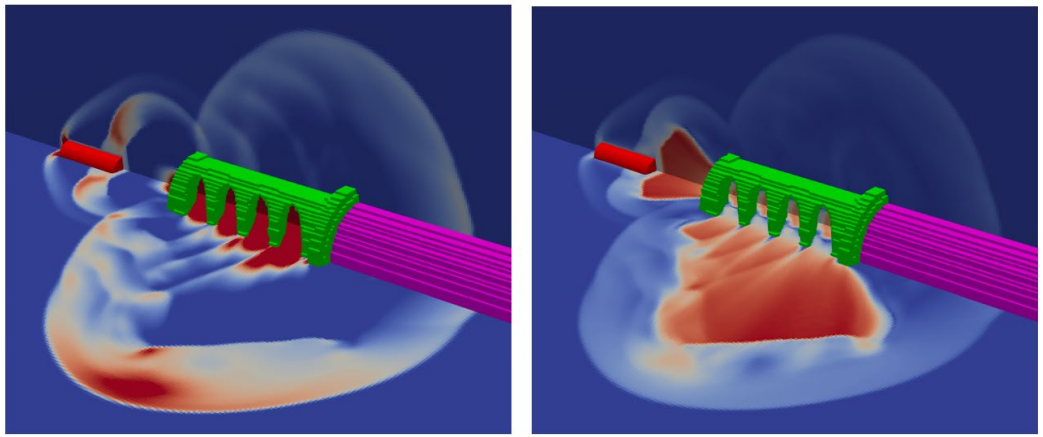
Simulation Subsystem (SABAS)



Simulation Subsystem (SABAS)

- Weapon attachments



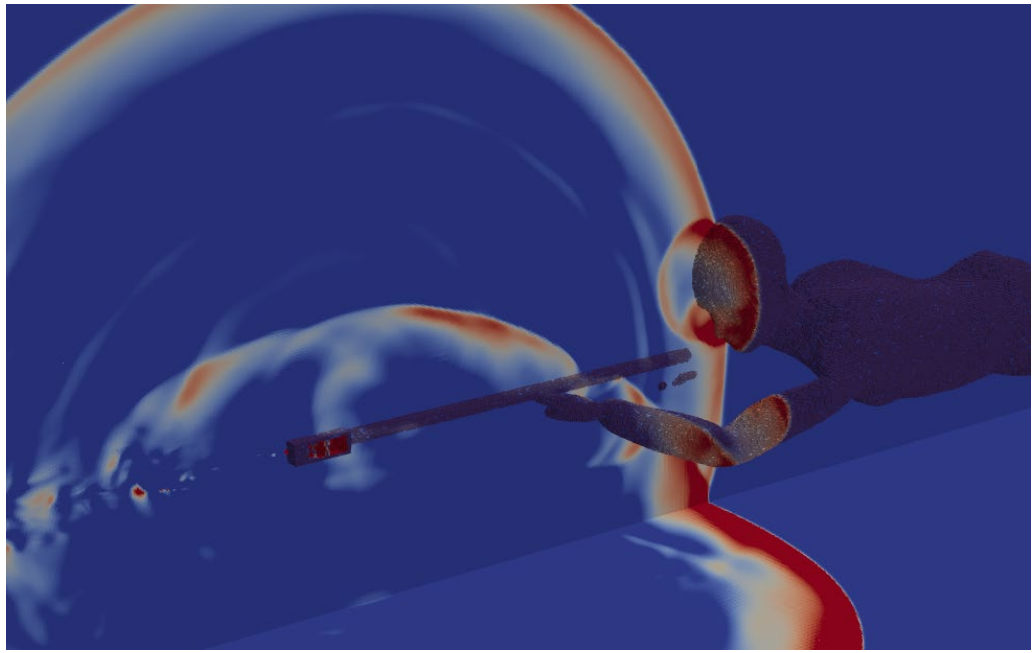


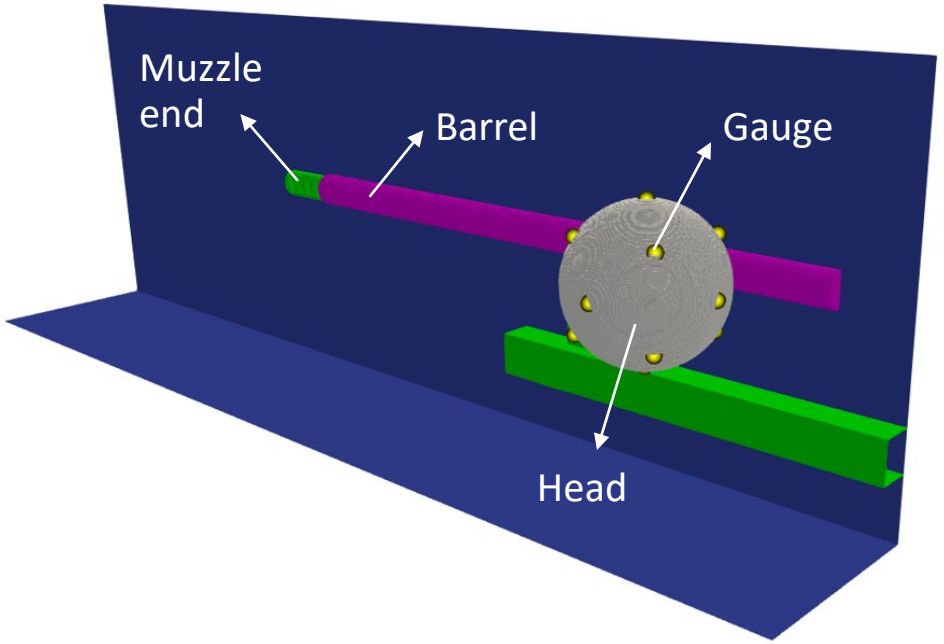
Pressure

Velocity

Simulation Subsystem (SABAS)

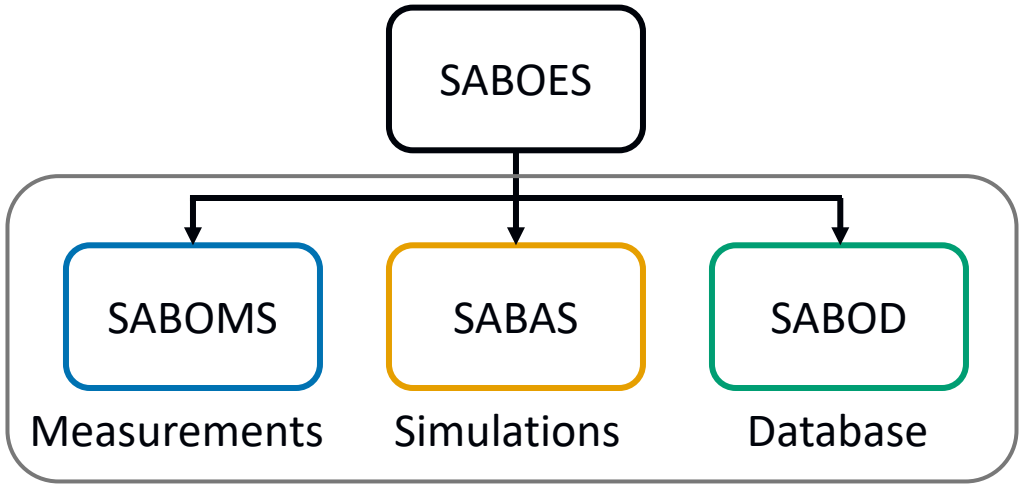
- Gauges at head of operator
  - Directly measure pressure applied to the head
  - Accounting for reflections and blast propagation around the head



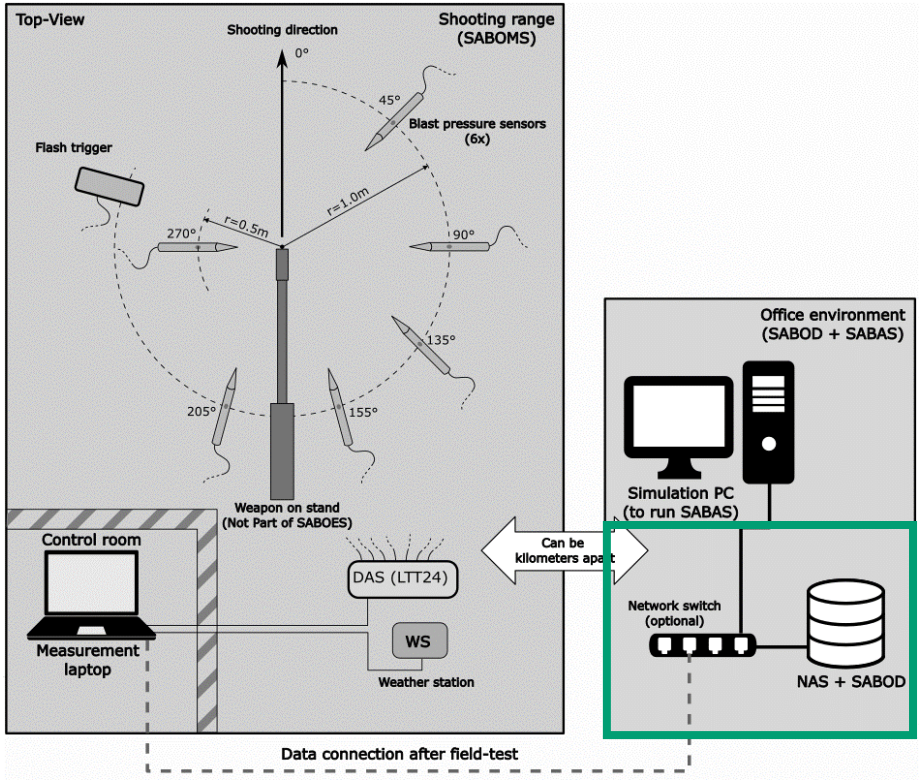


Database Subsystem (SABOD) + SABOD Manager GUI

- 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

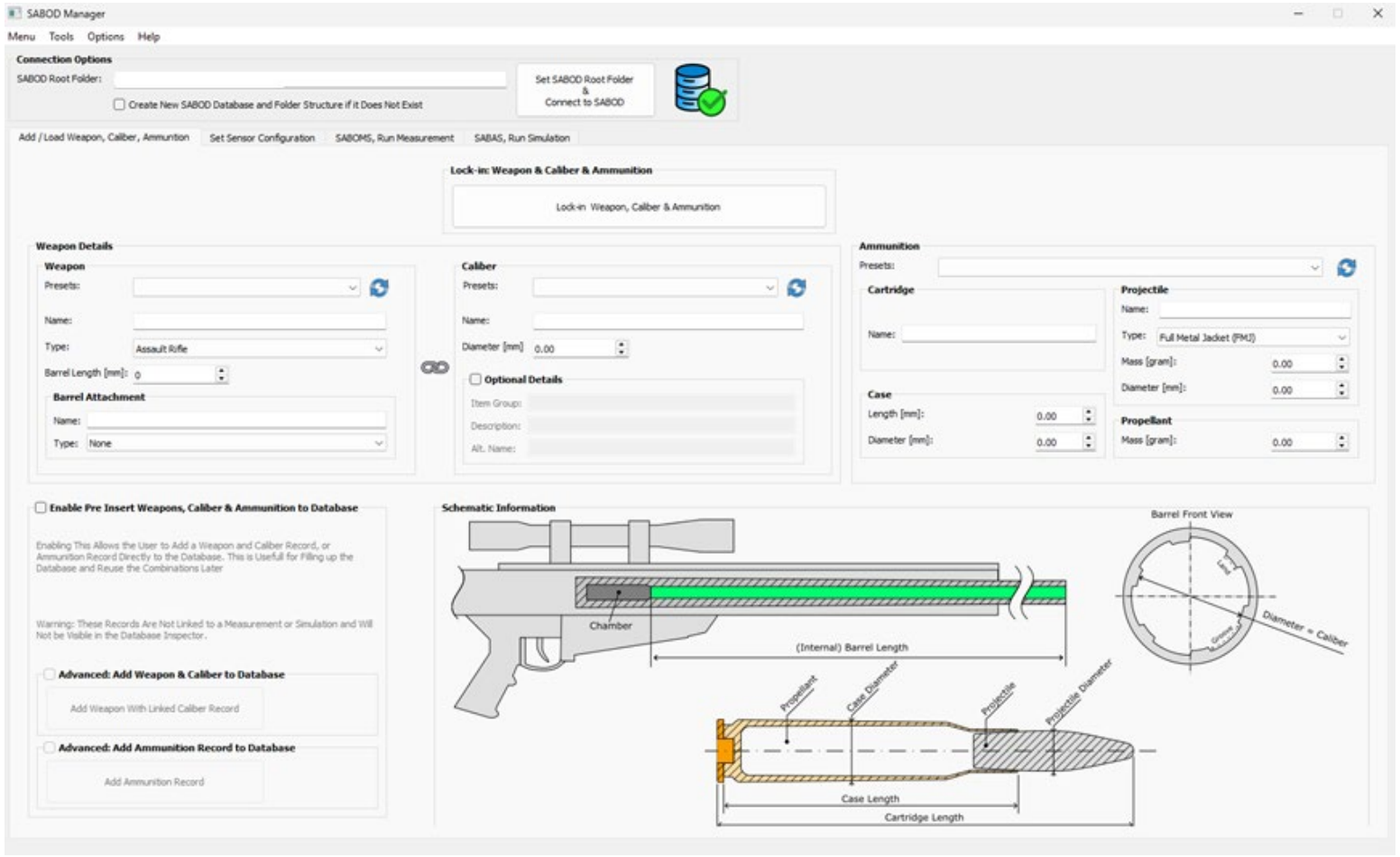


SABOD Manager GUI

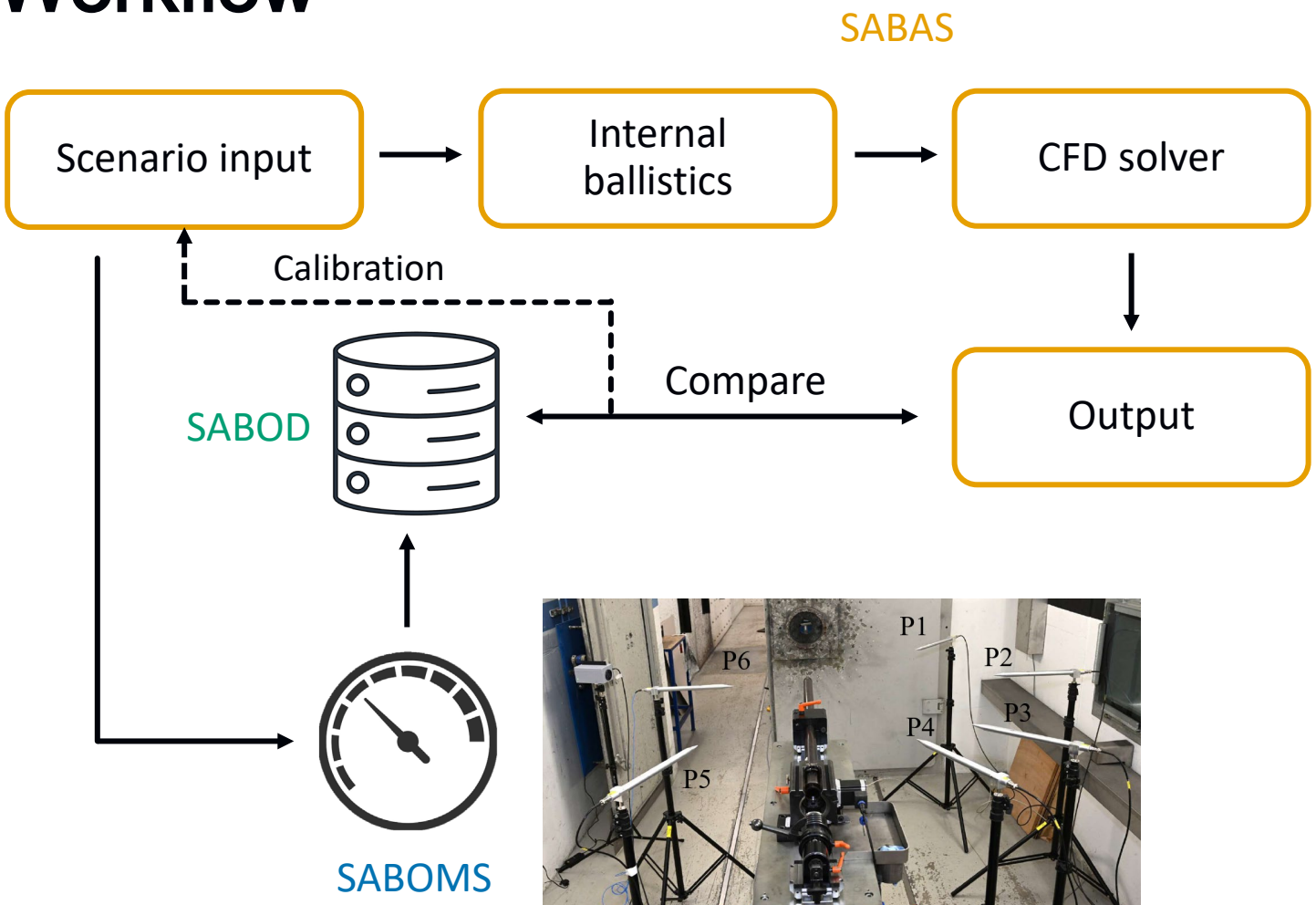


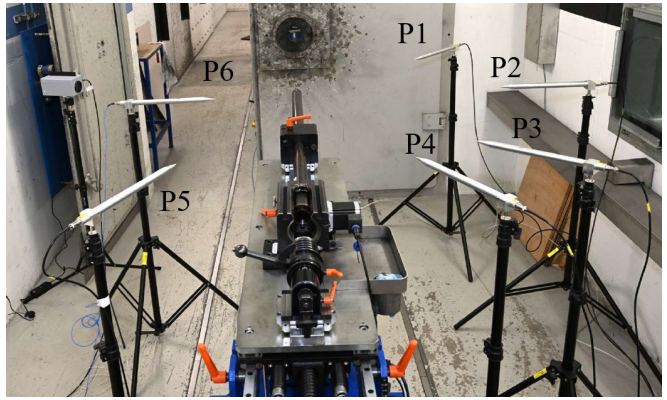
Database Subsystem (SABOD) + SABOD Manager GUI

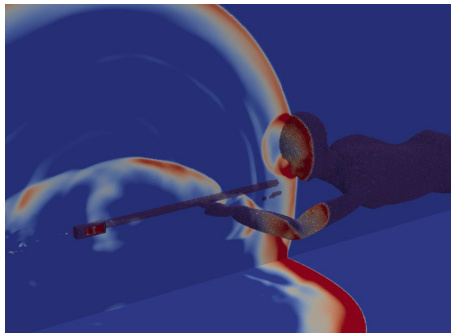
- Home screen of the SABOD Manager GUI

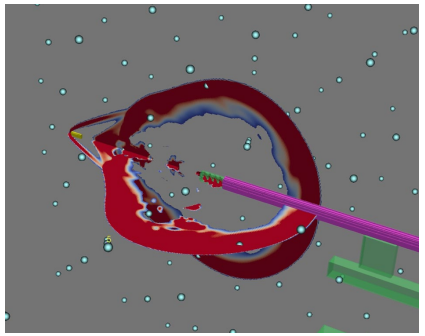


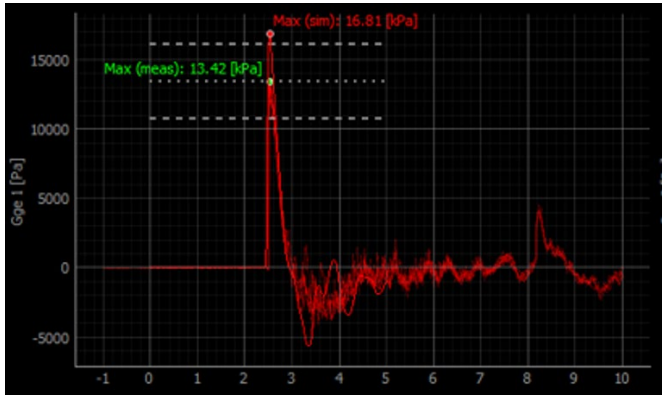
Workflow





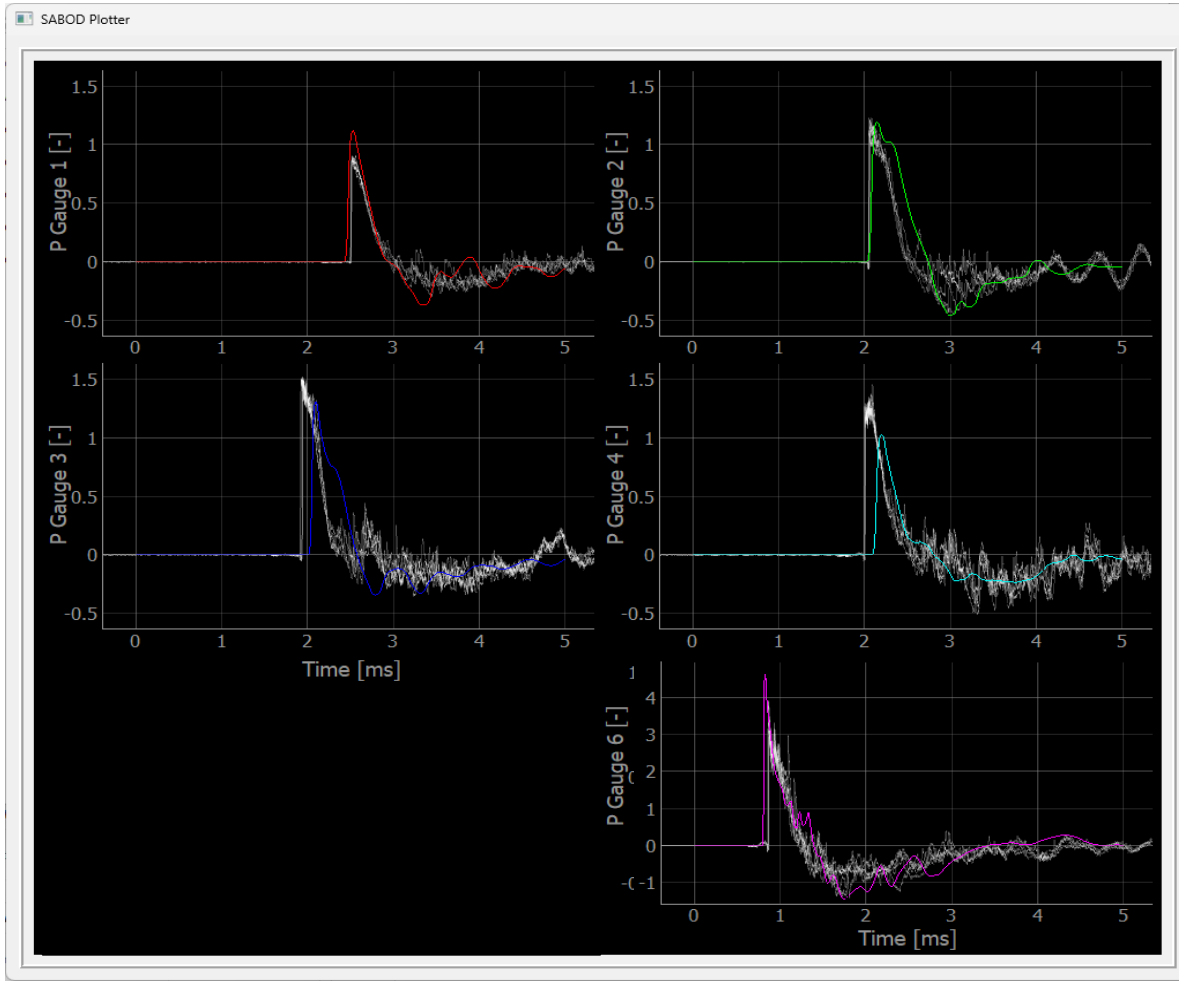


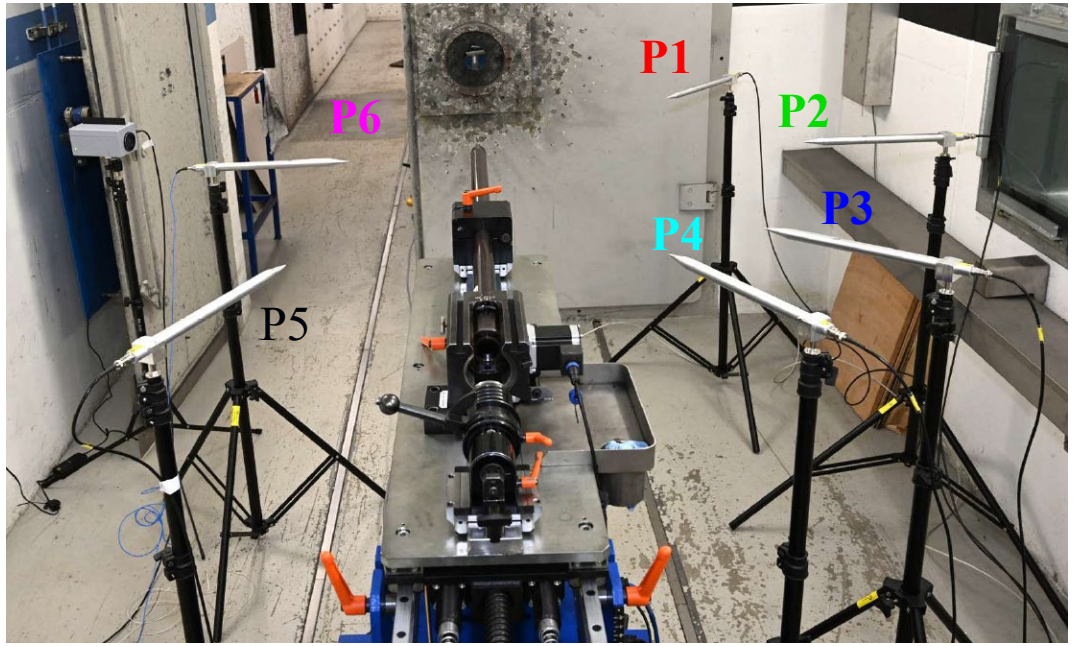




- All controlled from SABOD Manager GUI
- Semi-automatic, user friendly

Example and Validation of SABAS





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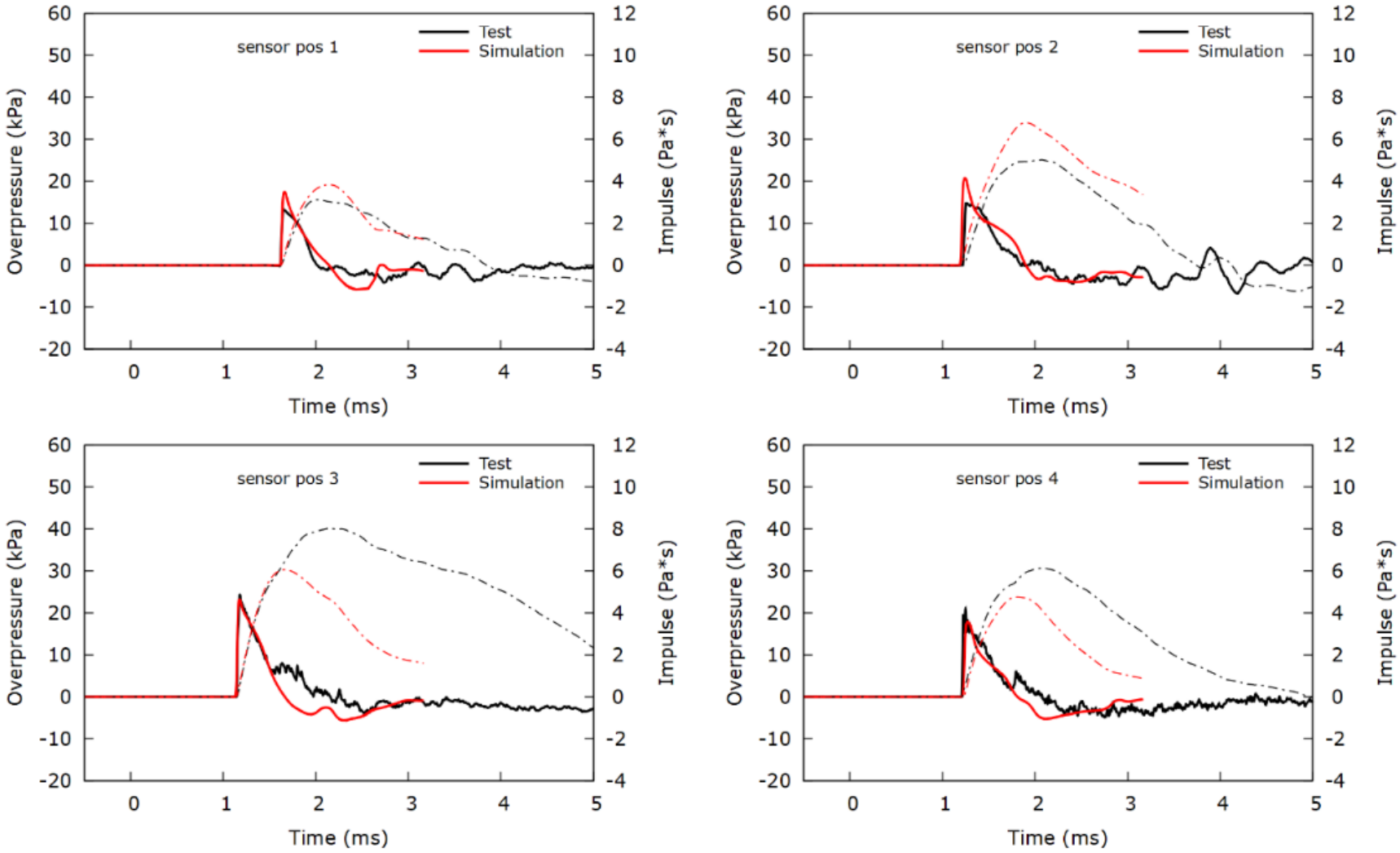
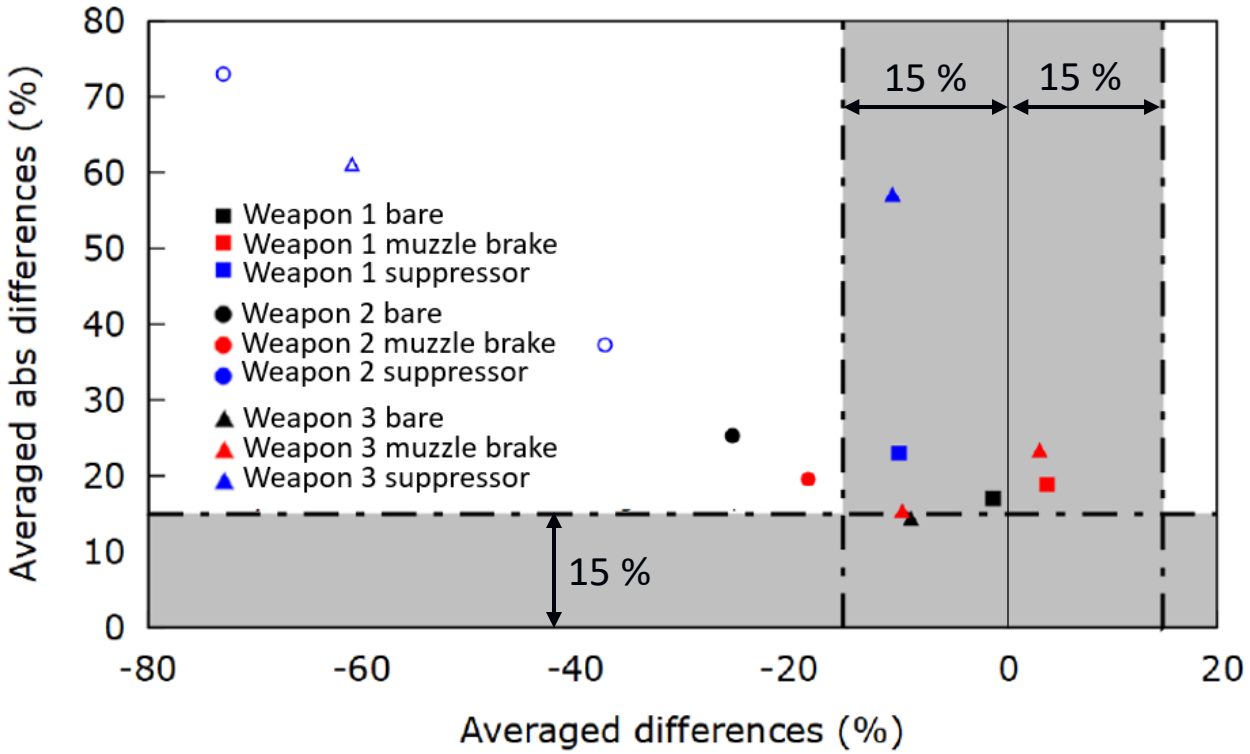


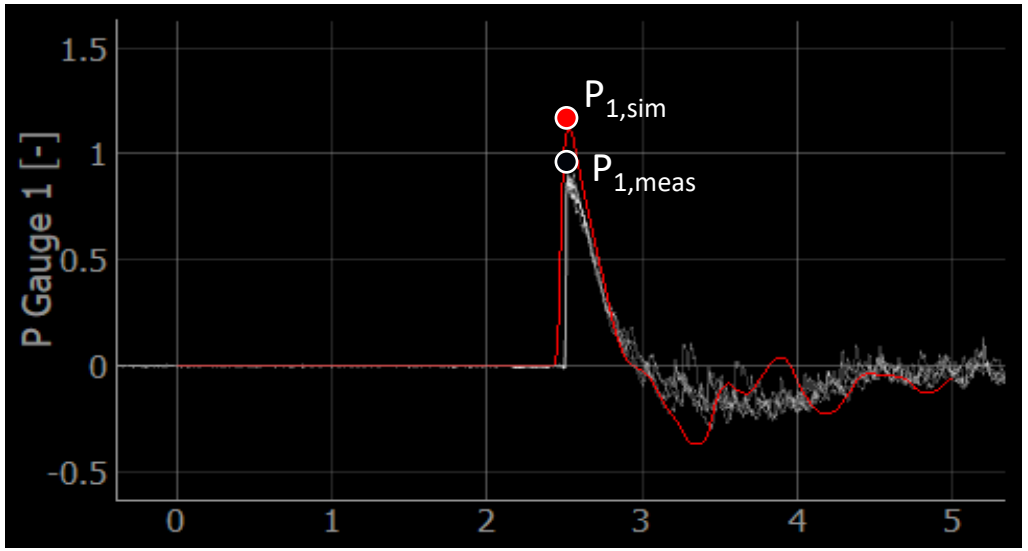
Example and Validation of SABAS

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

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

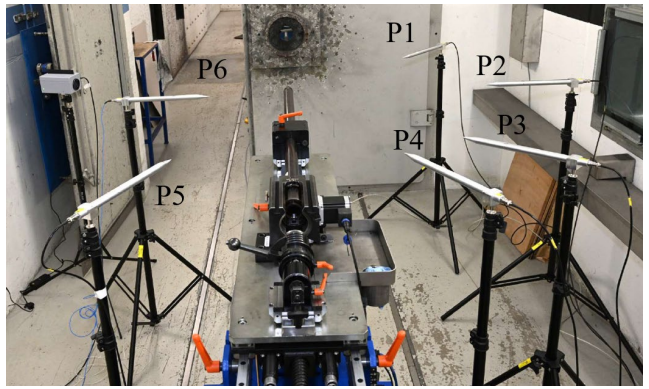
$$\delta_{abs} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{P_{i,sim}-P_{i,meas}}{P_{i,meas}}\right|\cdot 100\%$$

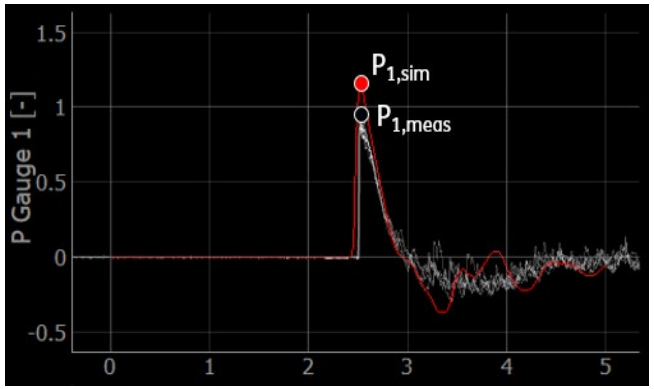


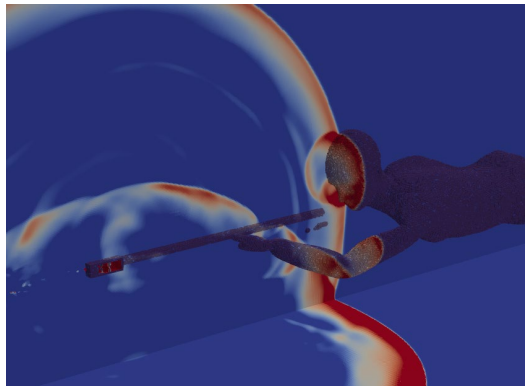


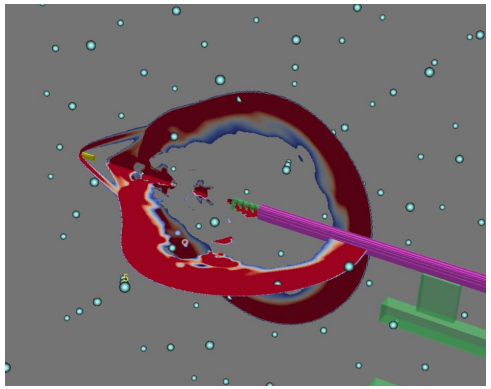
Conclusions SABOES system

- 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





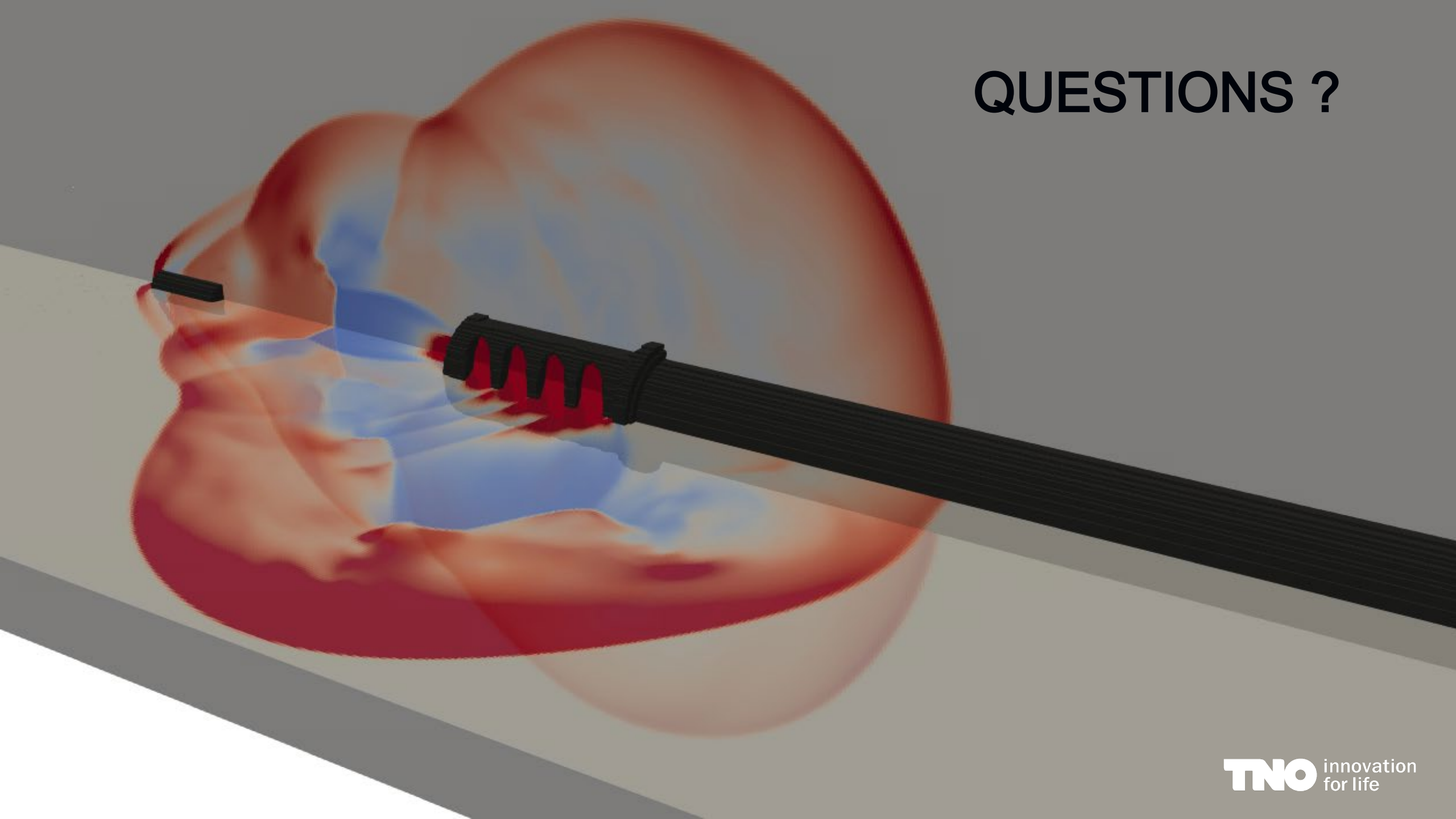




Future work

- 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 ?



TNO innovation for life

Simulation Subsystem (SABAS)

- Basic input parameters

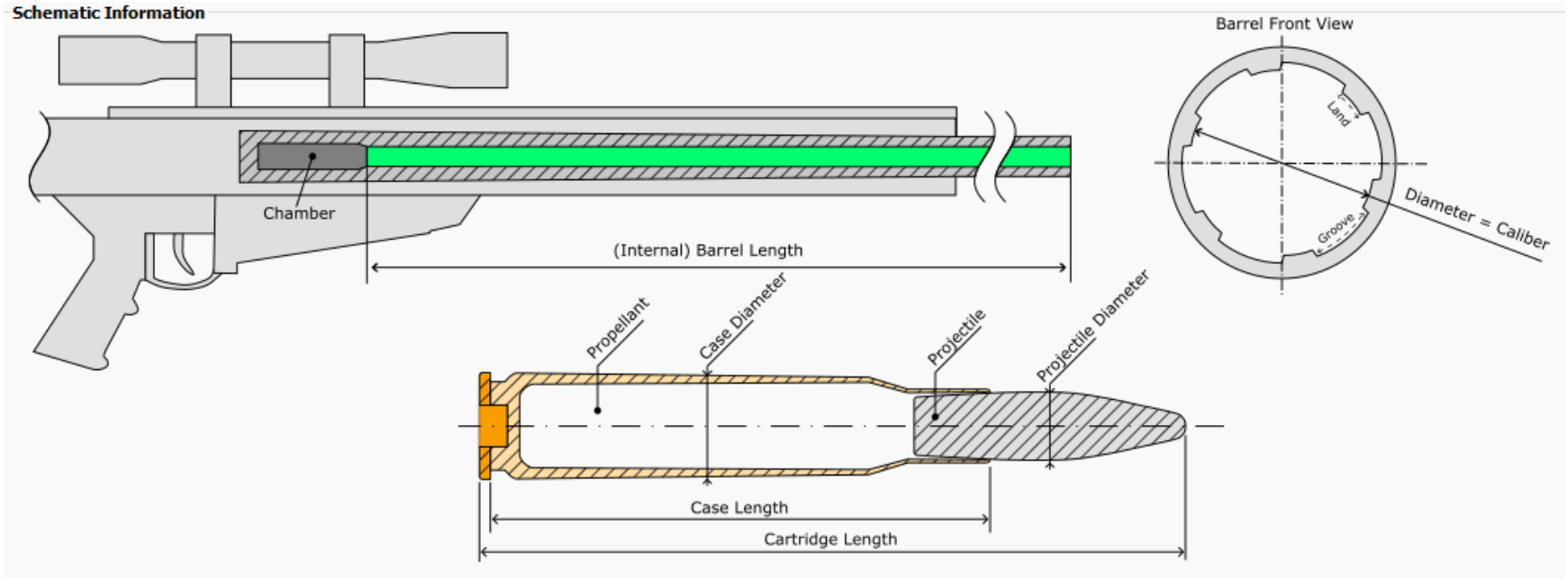
Barrel
- Internal length
- Internal diameter

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