MODELLING OF THE DYNAMICS OF A 40 MM GUN AND AMMUNITION SYSTEM DURING FIRING

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Contents

- Introduction to gun dynamics
- Case Telescoped Ammunition System
- Purpose of the study
- Model description
- Experimental study
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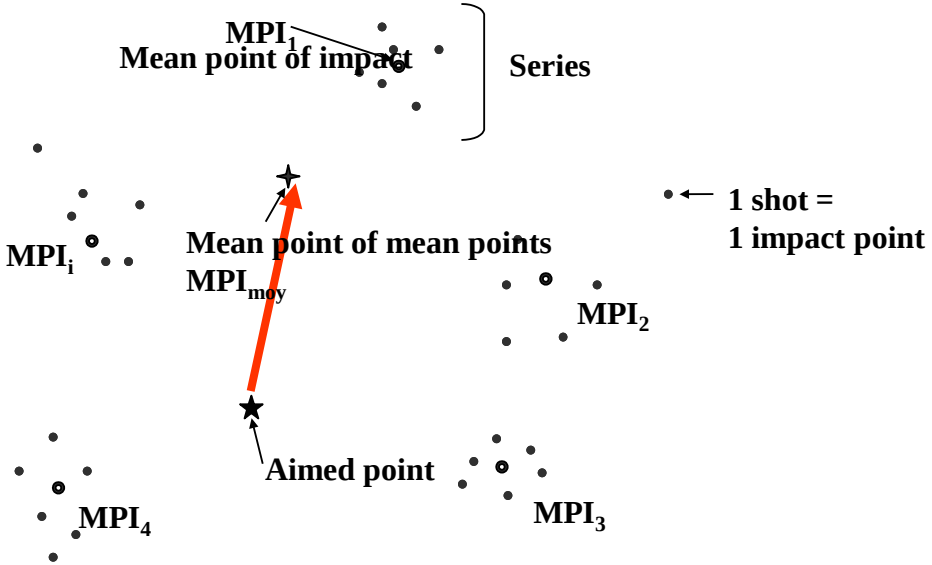
The problem of accuracy

- For tank ammunition, accuracy is a crucial efficiency factor.



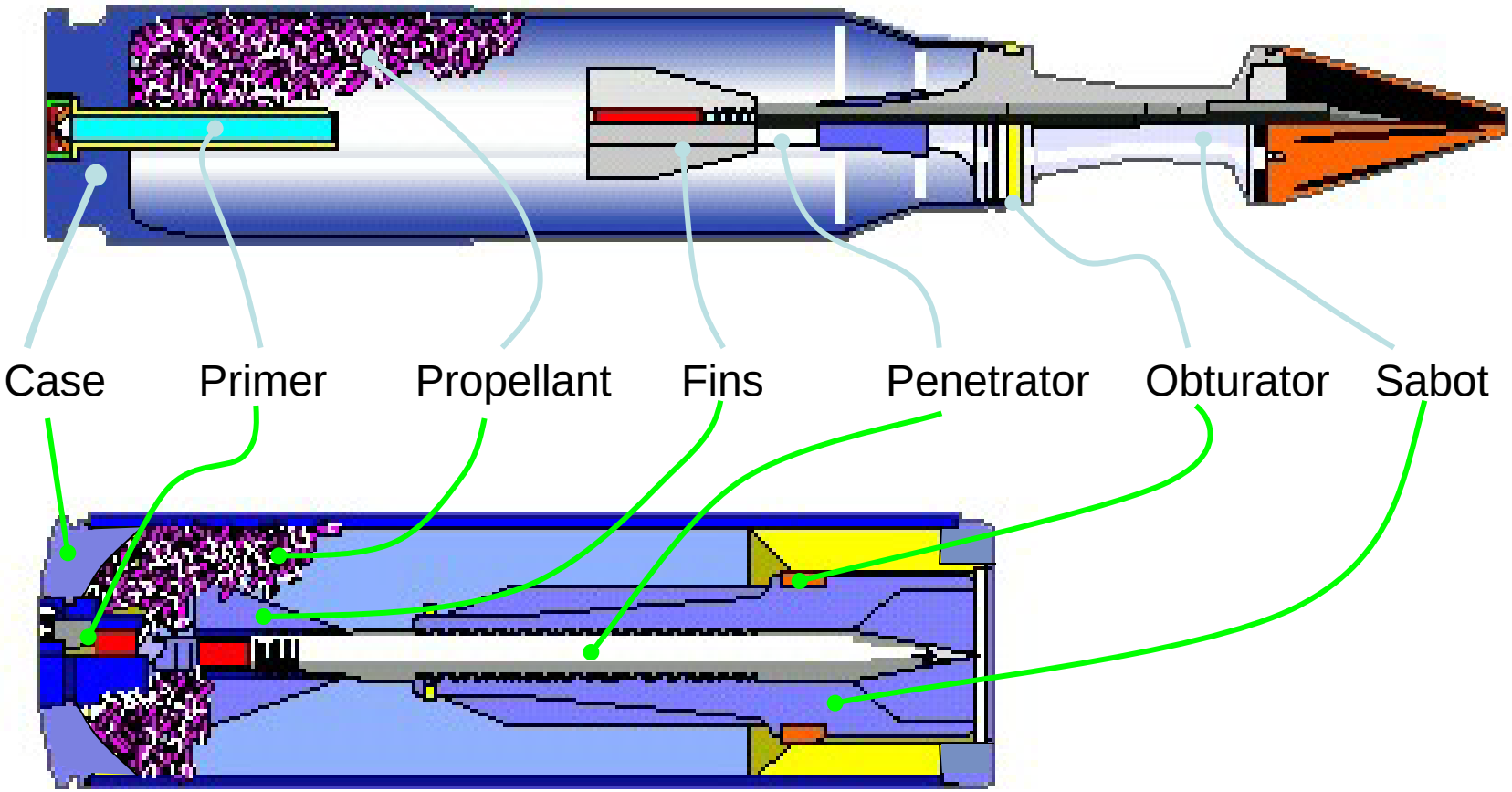
- Accuracy is a function of the perturbations applied on the projectile during :
  - Free-flight : wind, air density, etc
  - In-bore travel : Gun/Ammunition interactions

Gun Dynamics

- Nexter Munitions set up a modelling methodology to study the gun/ammunition interactions in calibre 120 mm (LS-Dyna european conference 2001)
- CTA International, Producer of the 40 mm CTWS weapon system, in cooperation with the Institut PRISME launched a PHD Thesis on the influence of the ammunition design on the consistency.
- As a part of this thesis, work was contracted to Nexter Munitions on a finite element model of the gun/ammunition interaction.
- In parallel, CTA International, in collaboration with Nexter Munitions electronics lab, developped a projectile instrumentation methodology in order to record the ammunition behaviour during its in-bore travel.
- This paper deals with the FE Model set-up, and the comparison of the results obtained with experimental mesurements

What is a Case Telescoped Ammunition

"Traditionnal" Ammunition



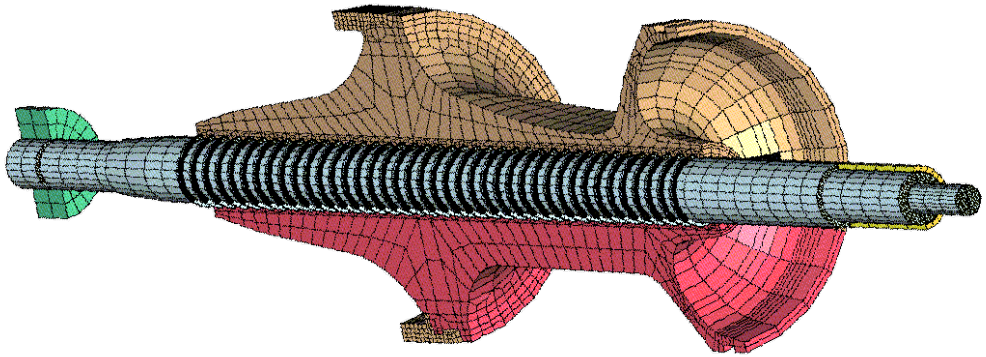
CTA-International Case Telescoped Ammunition

Why a Case Telescoped Ammunition System?

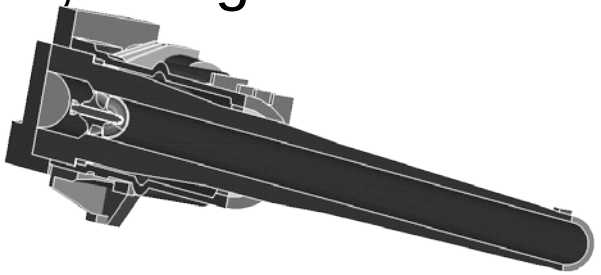
- Larger volume for propellant yields better performances
  - More energy available
- Cylindrical ‘Tin can’ shape makes storage and transportation easier
  - Bulk volume reduction of 30%
- Ammunition feeding & loading in gun chamber is achieved without connectors (links) between two neighbouring rounds, preventing jamming.

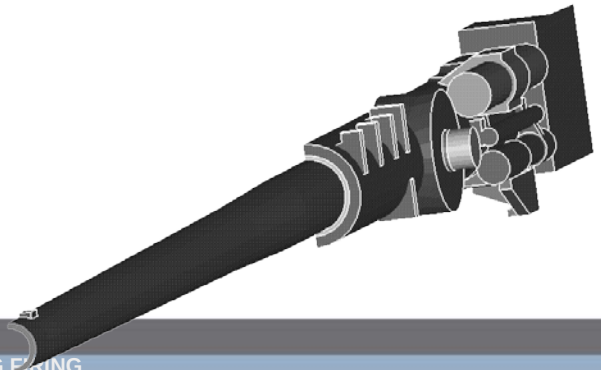
40 mm Gun/Ammunition System Model

- Based on the 120 mm model, built in 2001 including a fully functionnal projectile :
  - Realistic interface between rod and sabot
  - Projectile pushed forward by the means of the sabot
  - Sabot discard at muzzle exit
  - Pressure applied on the barrel wall, along with the projectile progression.



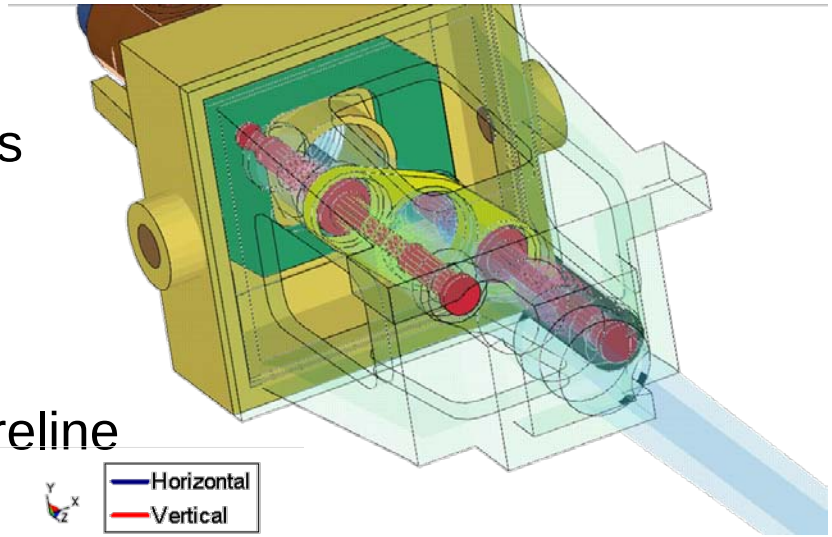
120 mm APFSDS model

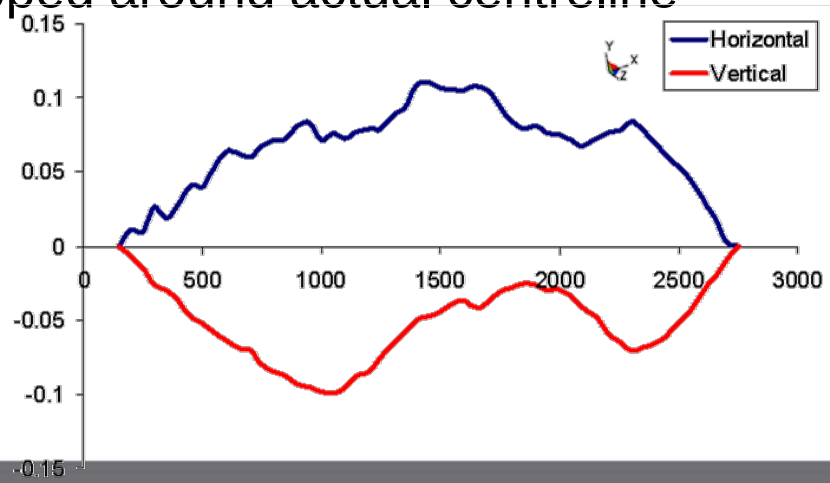




40 mm Gun/Ammunition System Model

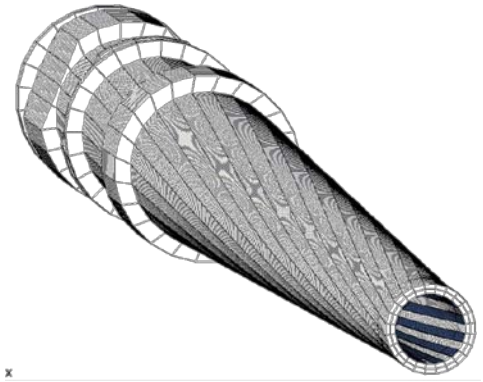
- Accurate modelling of the experiments configuration
- Faithful geometric description of weapon components including:
  - Rotating chamber
  - Recoil system body and springs
  - Trunnions pins
  - Bearings
- Barrel mapped around actual centreline

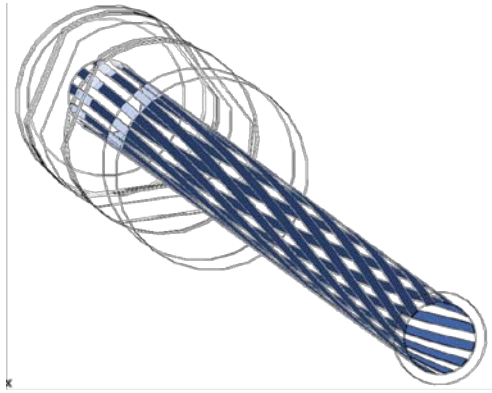




40 mm Gun/Ammunition System Model

- Full 3D model necessary
- Rifling modelled by a mesh twist, according to the rifling law.
- In order to transmit the rifling torque to the projectile, rifling grooves are modelled





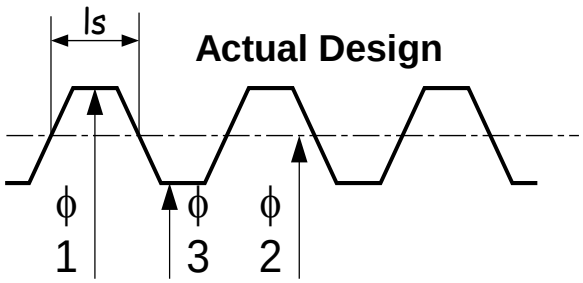
- As the engraving involves too much plastic strain in the obturator, the latter is "pre-rifled" i.e. is meshed with grooves.
- In order to simulate the actual spin rate of the projectile due to the friction of the slipping obturator, the rifling law is modified to give a final projectile spin-rate of around 25% of the full-spin rate, and the obturator is fixed to the sabot

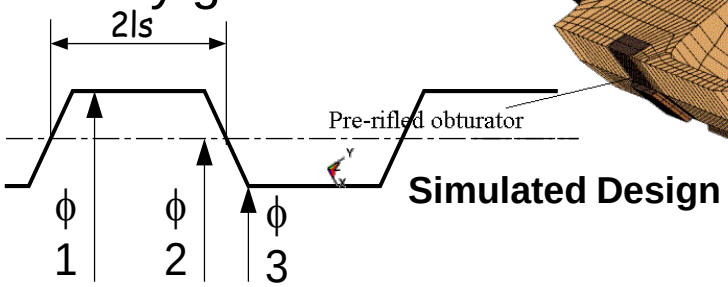
40 mm Gun/Ammunition System Model

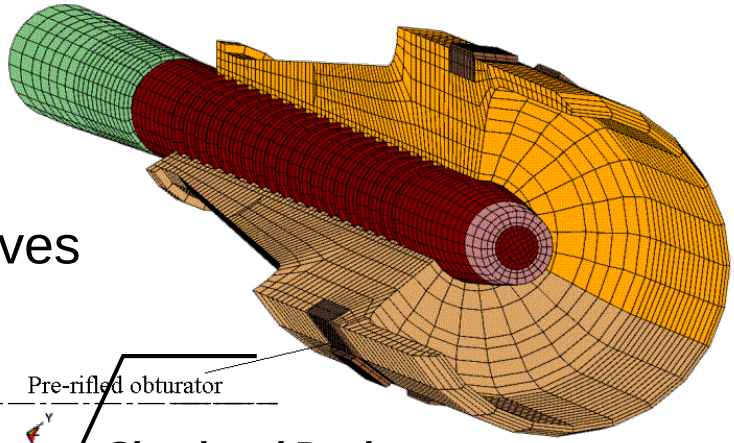
High level of details in the projectile model

Sabot petals behave individually

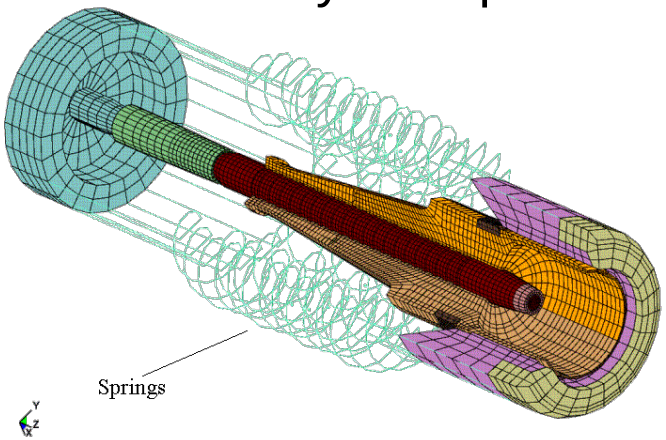
Sabot-Penetrator interface simulated by grooves





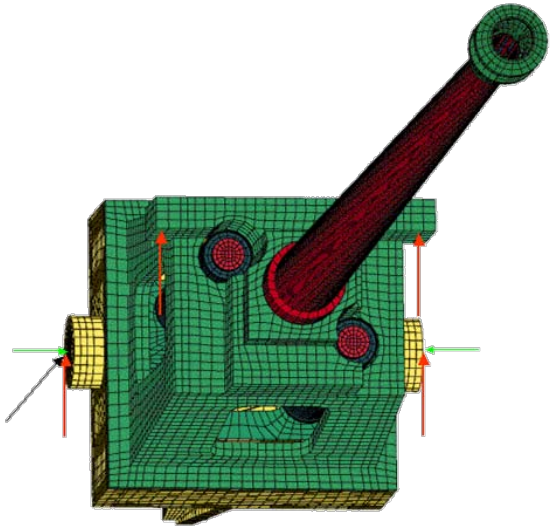


Axial stiffness of the case modelled by an equivalent spring stiffness

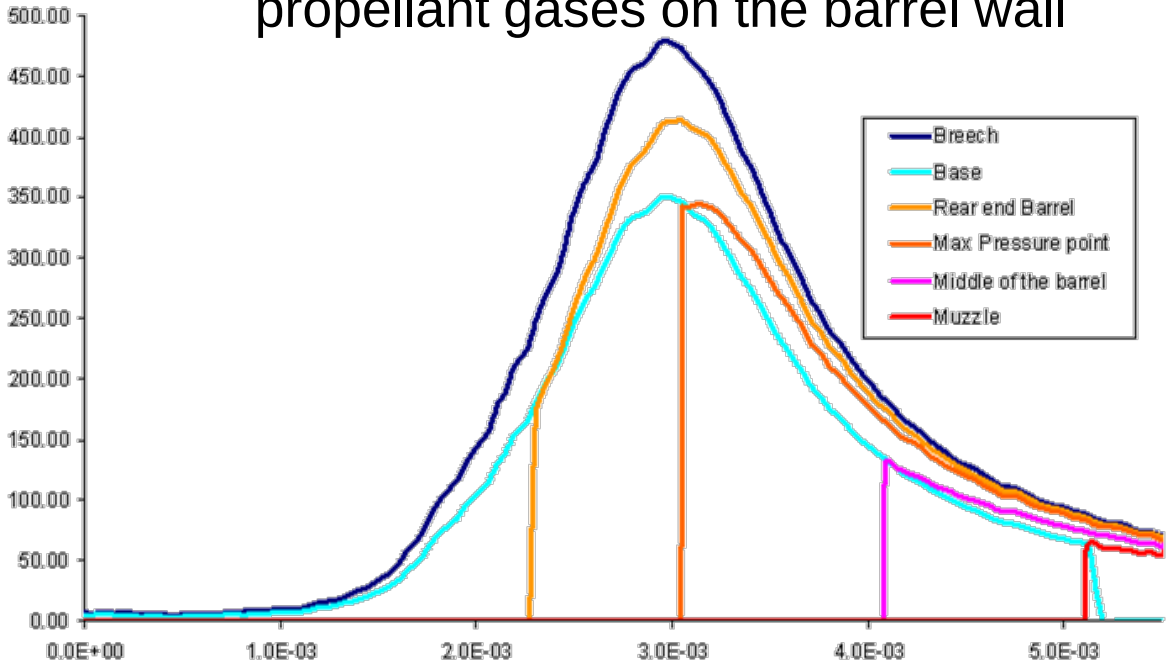


40 mm Gun/Ammunition System Model

- Boundary conditions

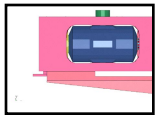
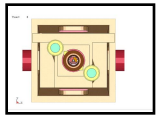
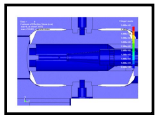


- Loads :
  - Base pressure on the projectile
  - Breech pressure in the chamber
  - One pressure curve per element slice of the barrel, simulating the action of propellant gases on the barrel wall



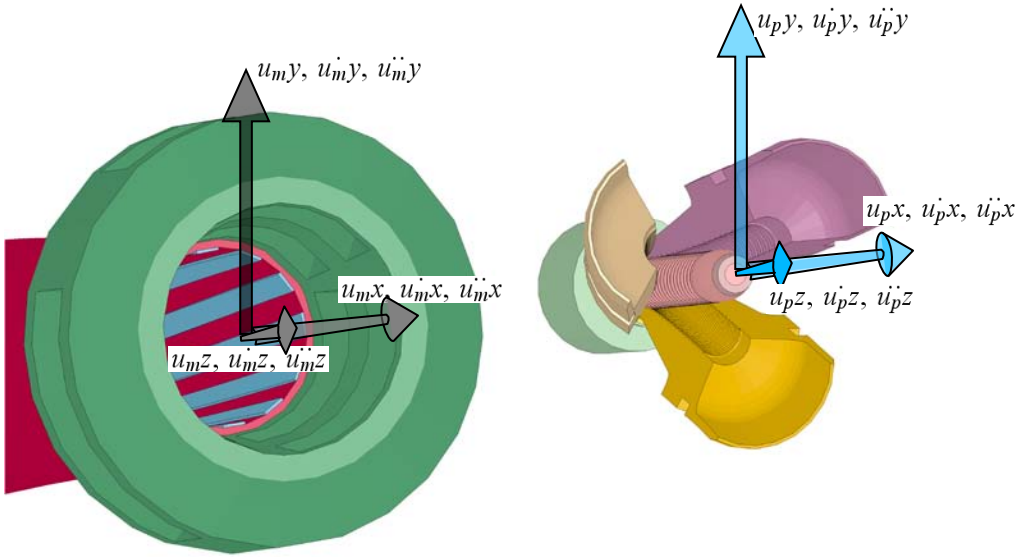
Simulation Sequence

- Modelling with in-house tools plugged to XYZ True-Grid.
  - Pressure curves definition and application
  - Barrel mesh twist and mapping around straightness curve
- Implicit Static Simulation
  - Gravity droop
  - Static contact forces definition
- Explicit dynamic calculation
  - Adjustment of projectile kinematics
  - Synchronisation of barrel loading and projectile axial movement
- Final explicit calculation
- Post-processing, using in-house tools to access all the necessary data from binary history file

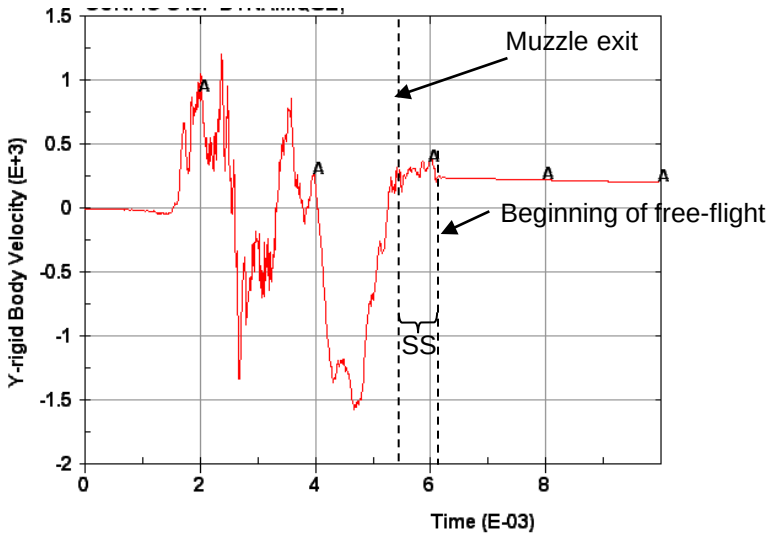
Outputs

- Data delivered by Post-Processing Routine:
  - Muzzle and projectile kinematics
    - Translation
    - Rotations
  - Projectile free-flight initial conditions
  - Projectile deformed geometry
  - Projectile strain on specific points (see experimental study)
  - Barrel expansion on specific locations (see experimental study)



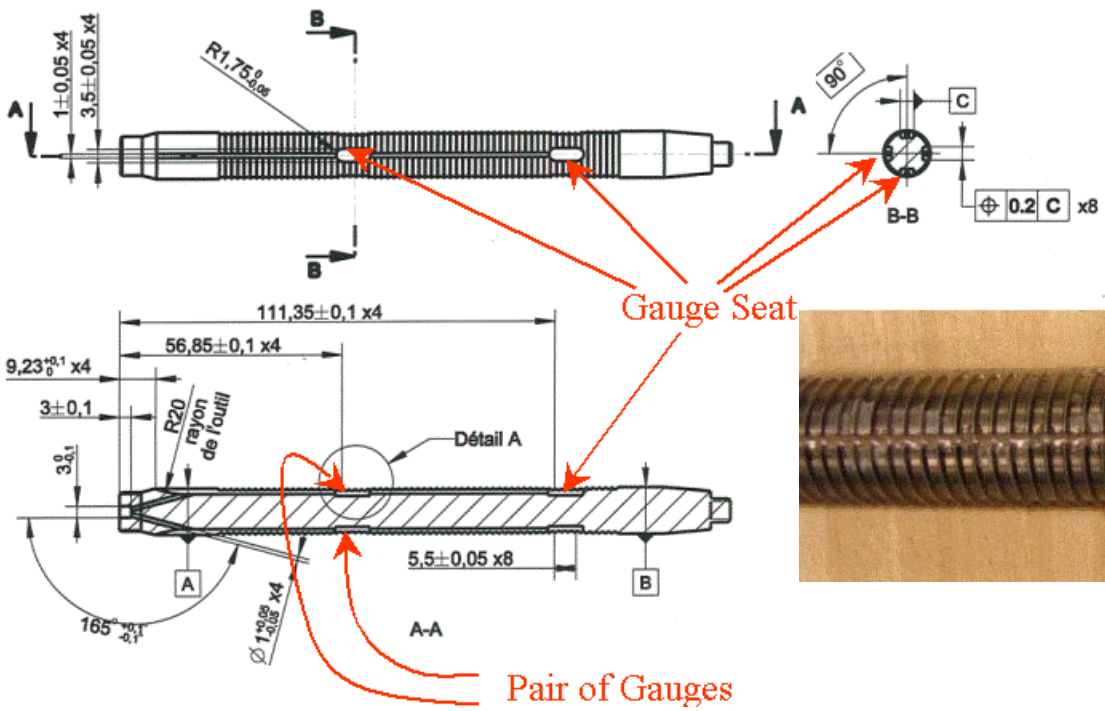
Outputs

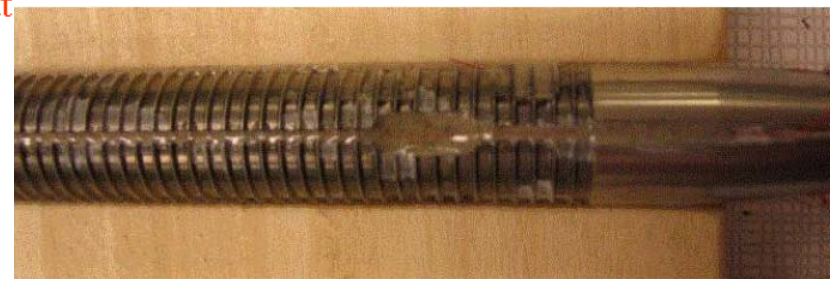
- Muzzle kinematics is obtained by averaging inner wall nodes motion
- Barrel expansion is obtained by averaging outer wall diameter variations
- Penetrator free flight initial conditions are obtained by letting the calculation proceed several milli seconds after muzzle exit in order to :
  - Allow sabot separation to occur
  - Establish free motion
  - Then, kinematics quantities are calculated by evaluation of the slope of the different DoF's evolution.



Experimental Study

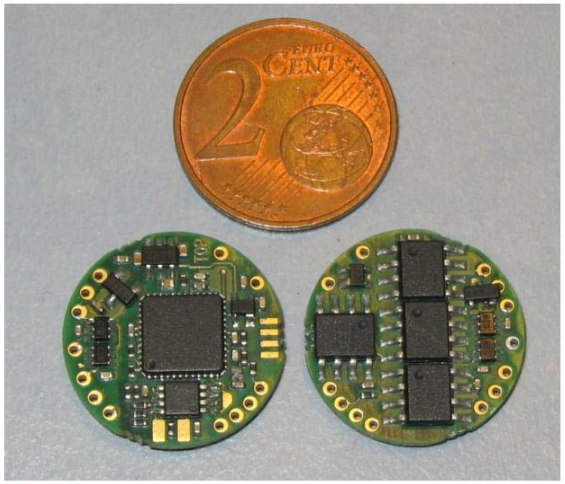
- Purpose : record bending strains in the projectile rod during the in-bore travel, to obtain data for comparison with the simulation results.
- Methodology : instrumentation of the rod, with pairs of strain gauges

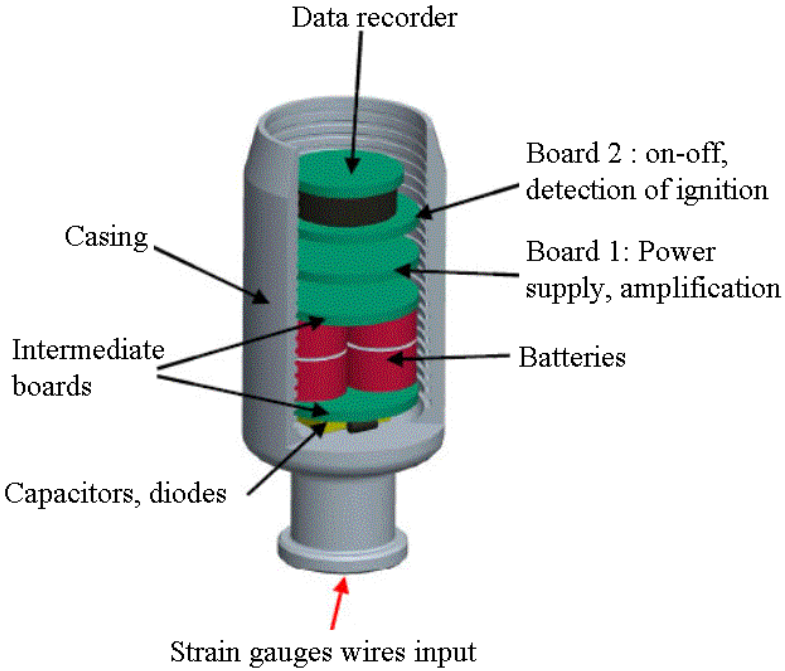




Experimental Study

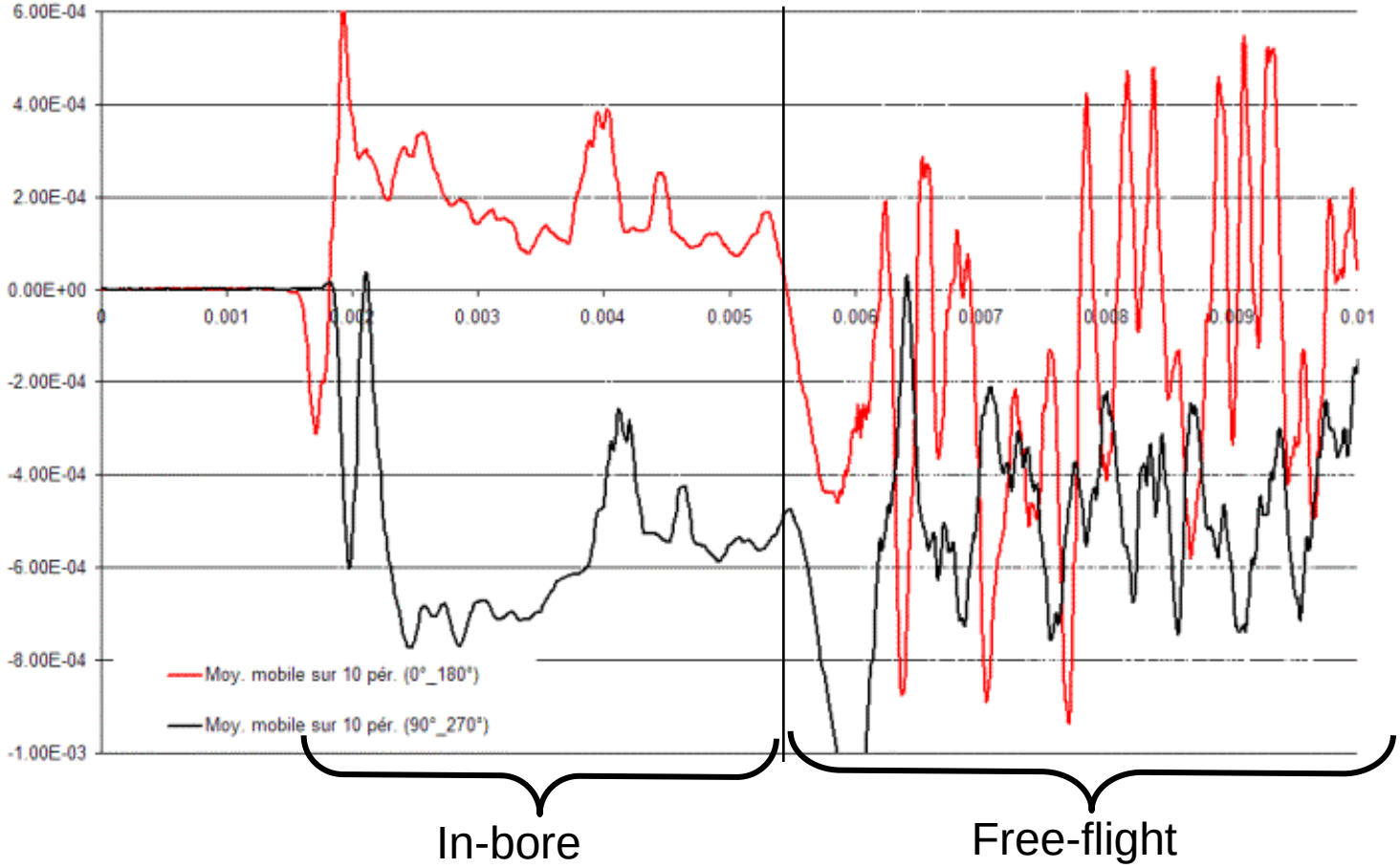
- Gauges signal recorded with Nexter Munitions data recorder, embedded in projectile flare which replaces the standard fin unit.





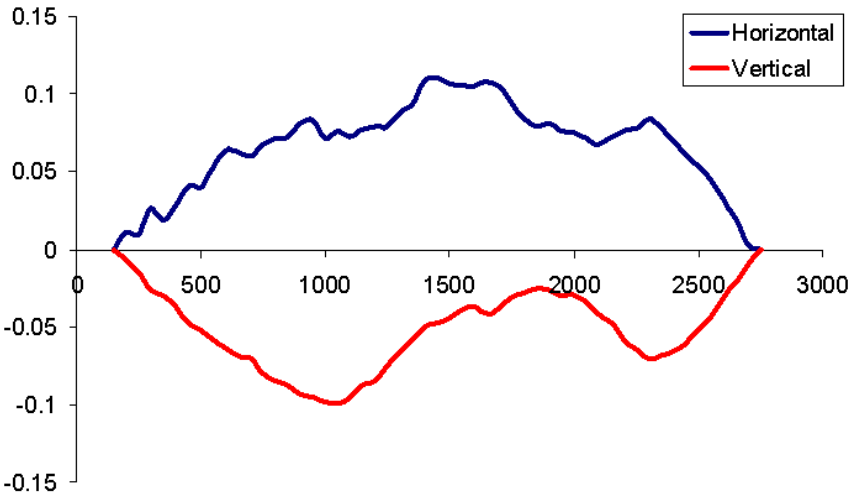
Experimental Study

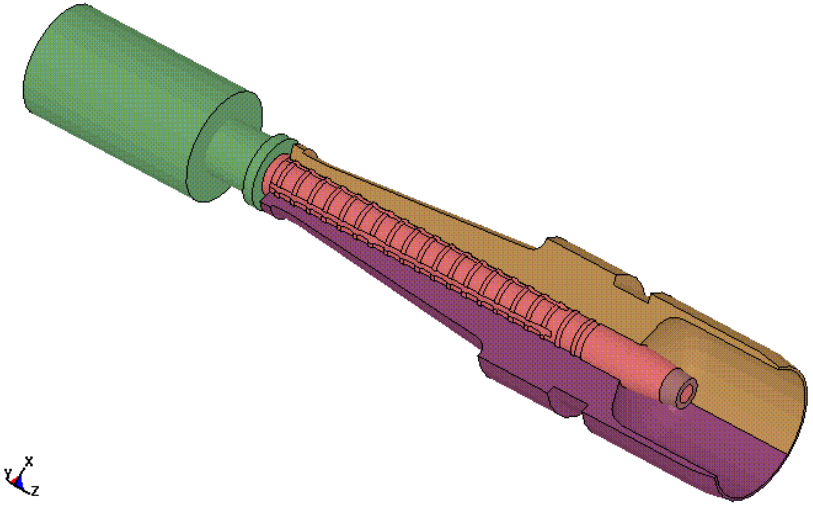
- Best results obtained with firing #6 : 1320 m/s, 80.000 G’
- Front Gauge pairs, strains=f(t) (m/m,s)



Model Calibration

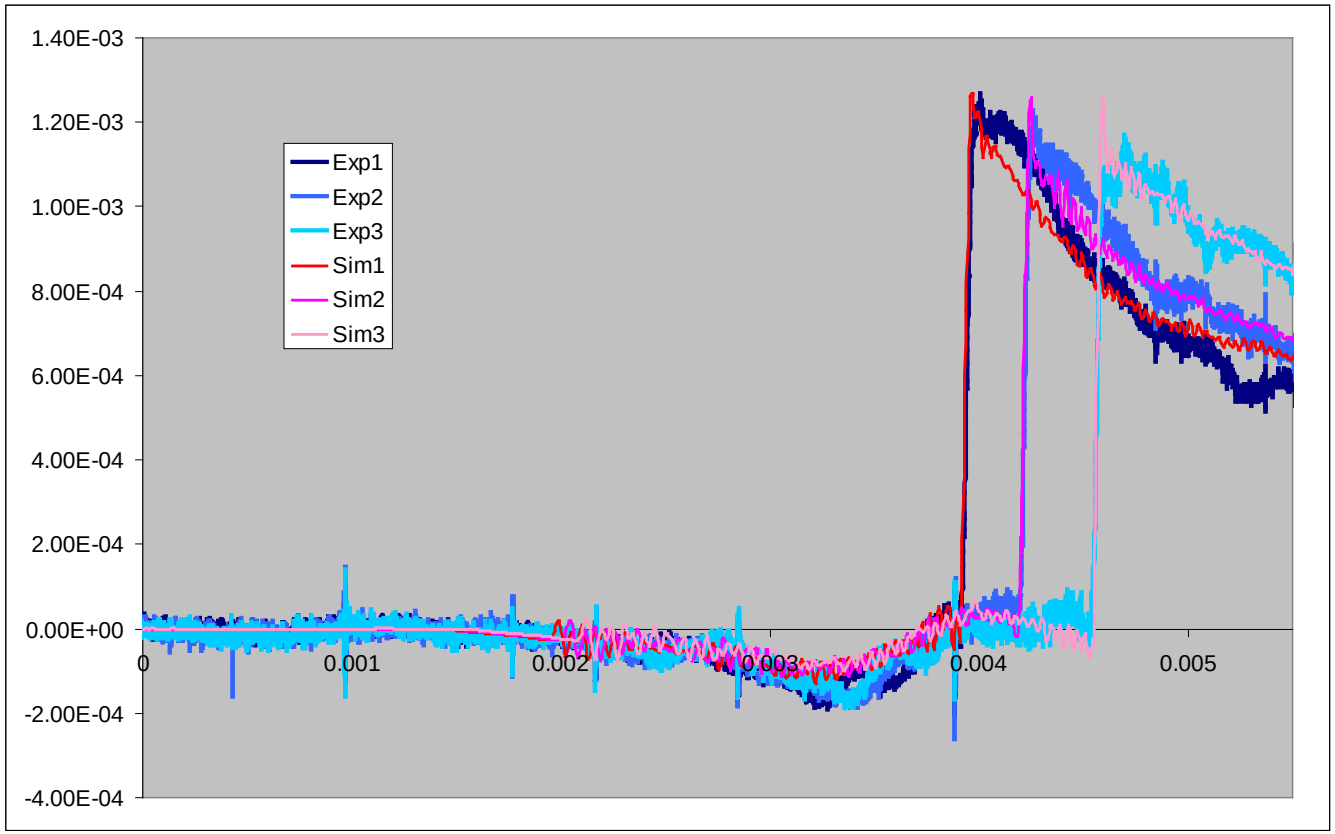
- Methodology : modelling of firing #6, with same conditions, ie:
  - barrel straightness,
  - Instrumented penetrator
  - flare
  - projectile weight, breech pressure and muzzle velocity





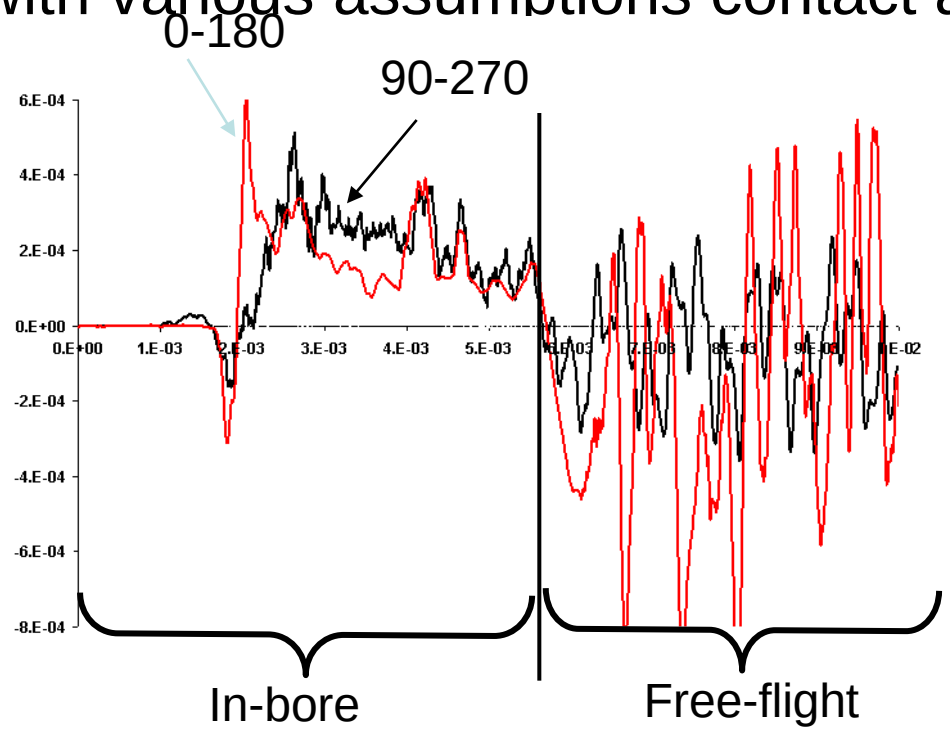
Model Calibration

- Barrel expansion
  - Barrel instrumented with strain gauges pairs on several locations
  - Comparison of experimental and simulation results shows the consistency of moving pressure front modelling



Model Calibration

- Comparison of simulation results with experimental results, with various assumptions contact and friction conditior



Key :

Config 19

Between sabot petals : surface-to-surface, by parts, no friction

Between penetrator and sabot : surface-to-surface, by segments sets, static friction of 0.1

Experiment

Model Calibration

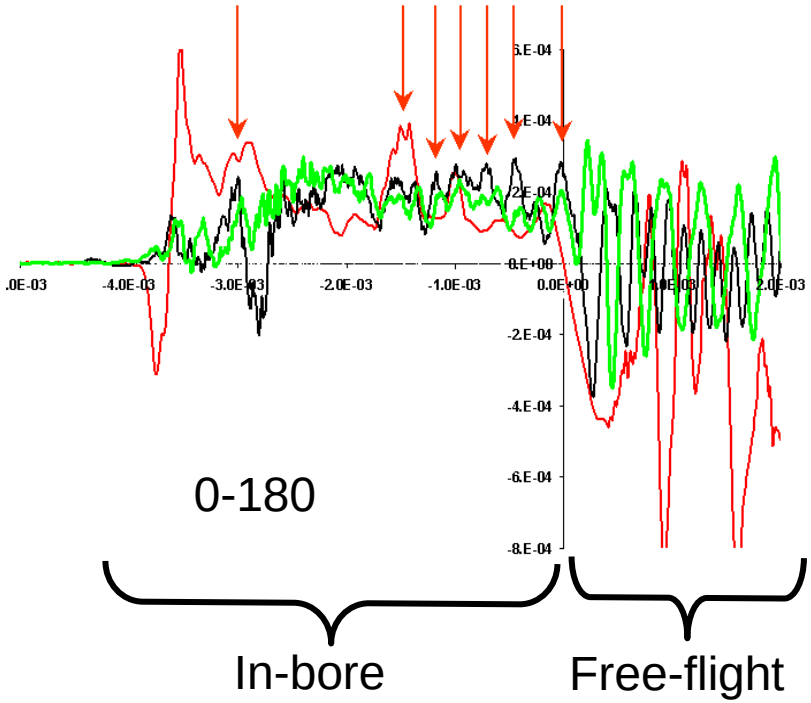
Key :

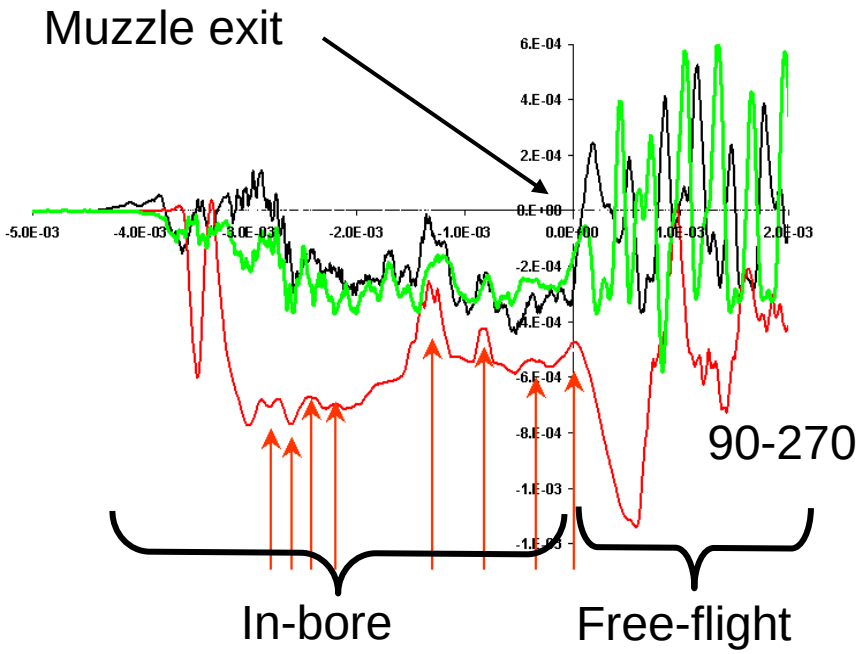
Config 30 :

- Between sabot petals : surface-to-surface, by parts, no friction
- Between penetrator and sabot : surface-to-surface, by segments sets, static friction of 0.05

Config 47 :

- Between sabot petals : surface-to-surface, by parts, static friction of 0.1
- Between penetrator and sabot : surface-to-surface, by parts, static friction of 0.05
- Experiments





Conclusions

- Parallel progress of numerical and experimental techniques nowadays enables very complex fields of investigation, with very promising results.
- Nevertheless, some work remains to be done in order to
  - Make the experimental techniques more reliable
    - More exploitable firings
    - Reliability of recorded data
  - Improve the match between calculation and firings
    - Investigate the current discrepancies
    - Find out if origin of discrepancies lie in a lack of understanding of the physics, or in a limitation of the numerical techniques