Improving knowledge of tactical rocket motor response under Insensitive Munitions threats

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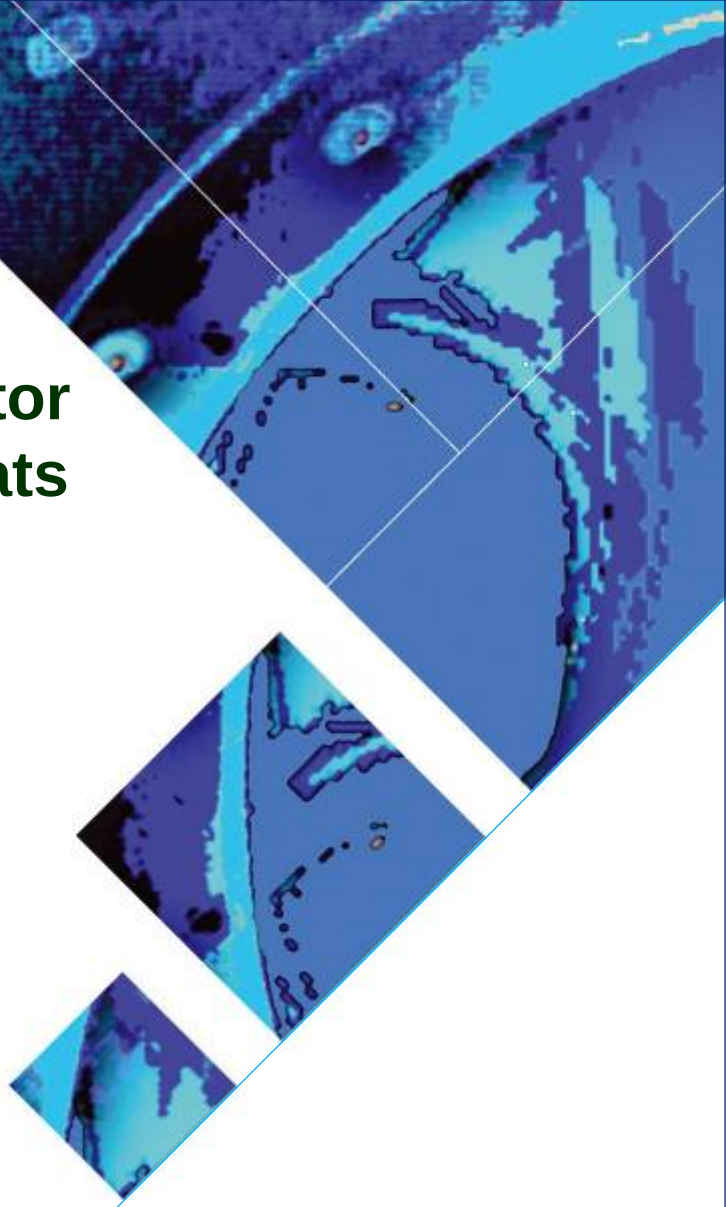

Roxel Propulsion systems

ariane GROUP

DGA

AGENDA

- **INTRODUCTION**
- **IM ADVANCED RESEARCH PROGRAMME APTE**
- **FRENCH IM TACTICAL SRM DATABASE**
- **NEW GLOBAL IM PROTOCOL FOR TACTICAL SRM FAILURE MODE ANALYSIS**
- **TEST PLAN OUTCOME OVERVIEW**
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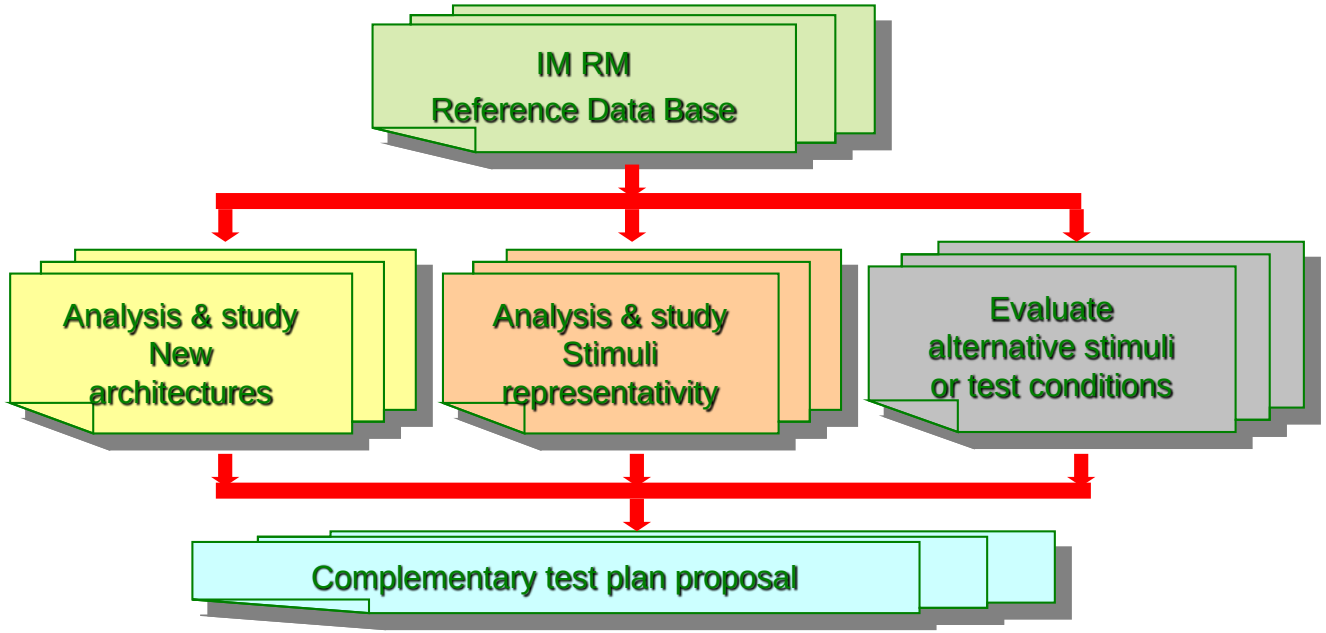
  - **Alternative stimuli (BI)**
  - **New architecture (FH)**
  - **Lesson learned : Test Set-up influence (BI)**
- **CONCLUSION**

IM ADVANCED RESEARCH PROGRAMME APTE

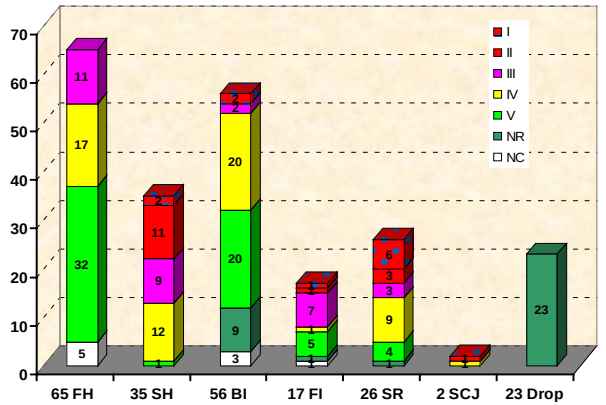
- Over last 10 years, French MOD funded the Advanced Research Programme “APTE” (Tactical Propulsion Improvement).
- Advanced Research Programme conducted by French Rocket Motor manufacturers ROXEL and ARIANEGROUP.
- The IM part of the programme was devoted to:
  - Search the best IM compromise for solid rocket motor hardware,
  - Analysis of the standard stimuli representativeness and results interpretation,
  - Evaluate the impact of alternative stimuli or test conditions



FRENCH IM TACTICAL SRM DATABASE

- A database has been populated with more than 220 different test results conducted on Solid Rocket Motors (SRM) and mock-ups in France since the 80's, and is continuously populated with new results.

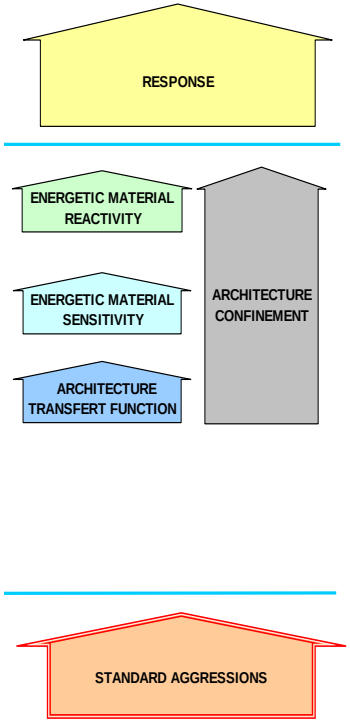
- Characteristics of the tested objects are :
  - Diameter up to 350 mm
  - Metallic, composite and hybrid cases
  - All propellants and igniters types
  - Propellant mass up to 200 kg
- Tests characteristics, compliance or not with corresponding STANAG test procedure
- Tests Results with main measurements and hazard classification (reaction level)
- Database contents :
  - 65 Fast Heating tests (FH)
  - 35 Slow Heating tests (SH)
  - 56 Bullet Impact tests (BI)
  - 17 Fragment Impact tests (FI)
  - 2 Shape charge jet tests (SCJ)
  - 26 Sympathetic Reaction tests (SR)
  - 23 Drop tests

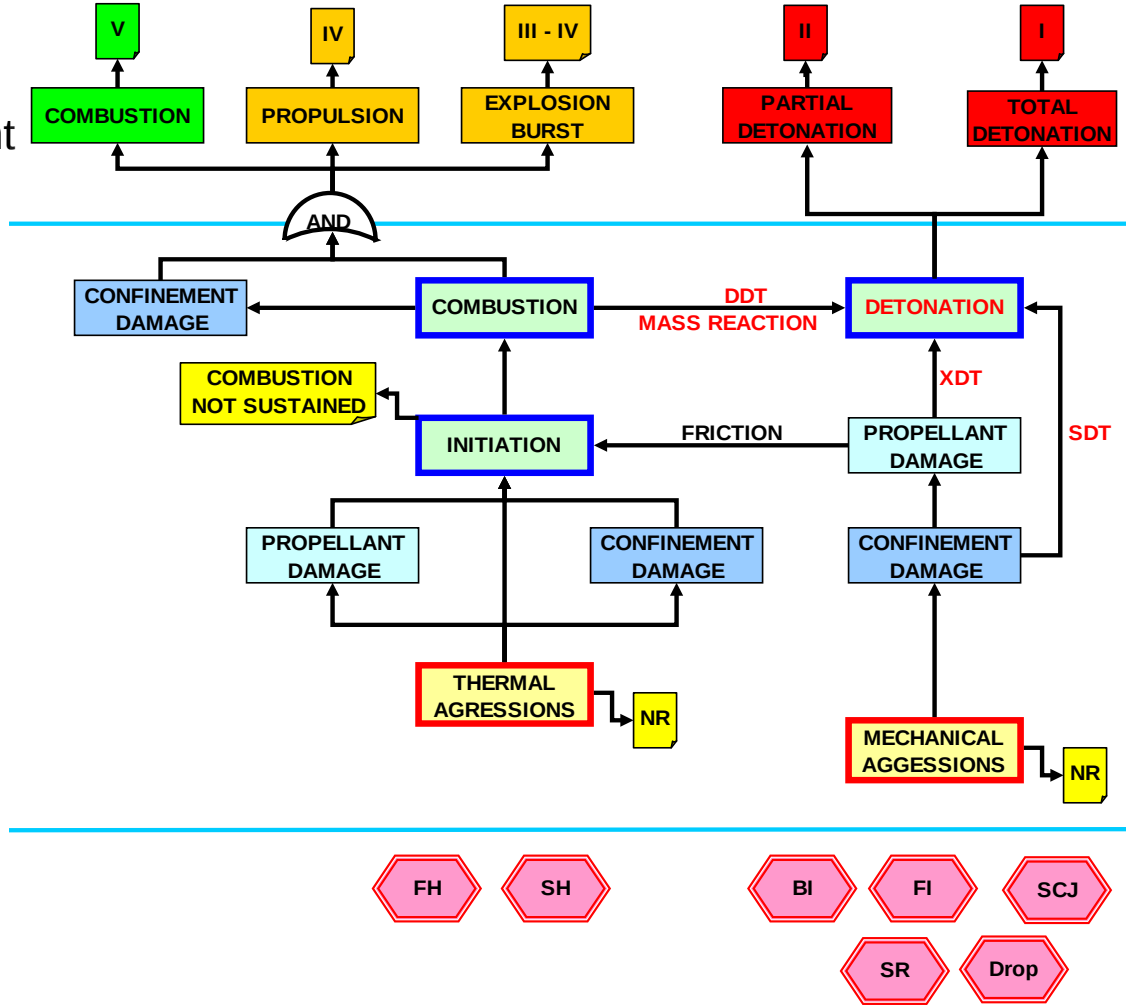


→ **Identification of deficiencies and gaps in the technology and knowledge**

NEW GLOBAL IM PROTOCOL FOR TACTICAL SRM FAILURE MODE ANALYSIS

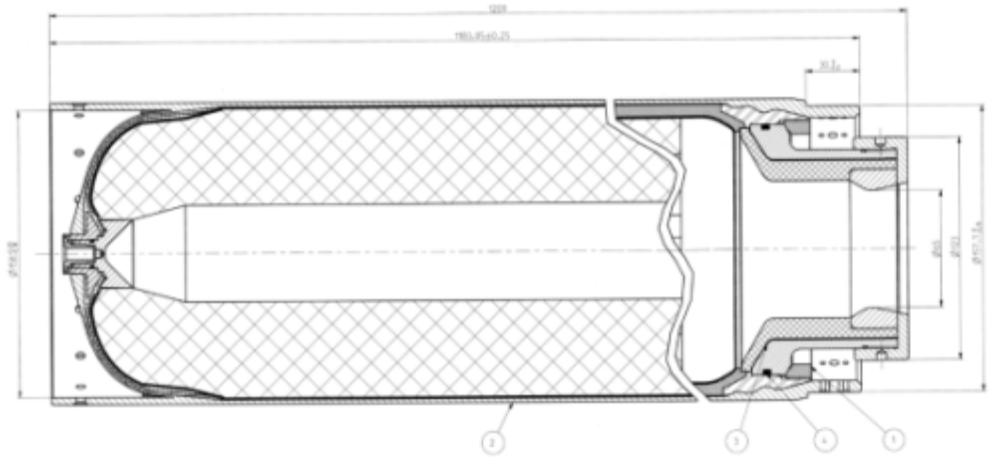
- New protocol is based on AOP39 ones but :
  - dedicated for tactical Solid Rocket Motors (SRM)
  - applicable for all stimuli
- SRM architecture effects are detailed :
  - SRM materials design and confinement
  - Propellant sensitivity an reactivity
  - Stimuli





TEST PLAN OUTCOME OVERVIEW : Test conditions (BI)

- **Effect of the temperature on SRM response to BI agression:**
  - Three temperature evaluated : Ambiant, -40°C, +70°C
- **Specimen tested :**

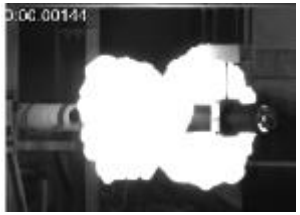


- **Main characteristics :**
  - Composite carbon fibre case (external diameter : 160 mm / Length: 1209 mm)
  - High Burning Rate Propellant (Finocyl shape / about 30 Kg)

TEST PLAN OUTCOME OVERVIEW : Test conditions (BI)

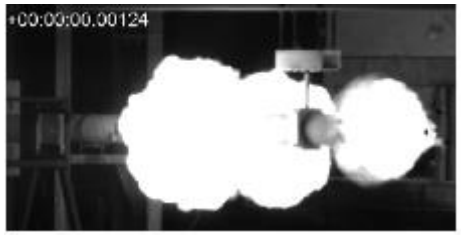
➢ BI Tests results :

- Test conditions : 20°C, Bullet impact velocity = 843 m/s



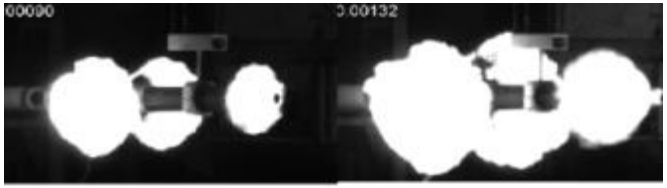
→ **Type IVp** (Fragments < 15 m but rear end total displacement > 15 m)

- Test conditions : -40°C, Bullet impact velocity 838 m/s




→ **Type III** (Fragments and burning propellant up to 110 m)

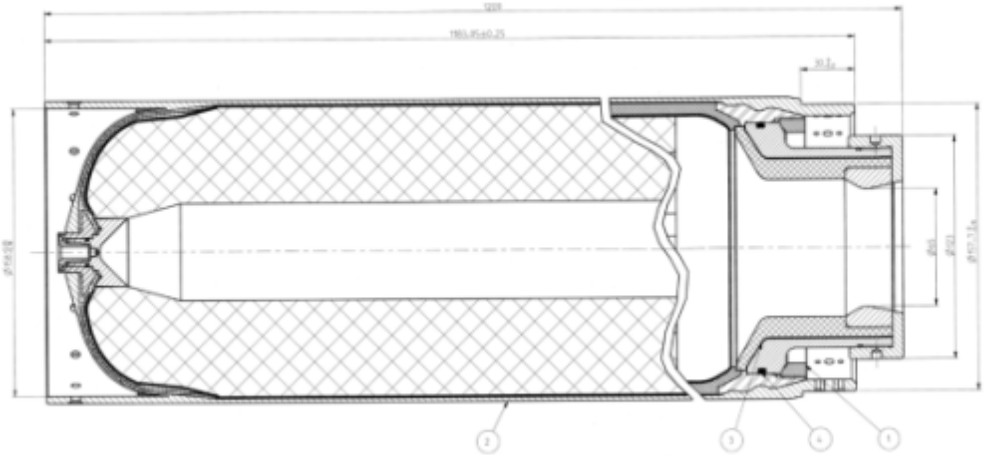
- Test conditions : 70°C, Bullet impact velocity 830 m/s




→ **Type IVp** (Fragment < 15 m but rear end total displacement > 15 m)

TEST PLAN OUTCOME OVERVIEW : Alternative stimuli (BI)

- **Alternative stimuli :** Explosive armor percing 12,7 mm Bullet
- **Specimen tested :**

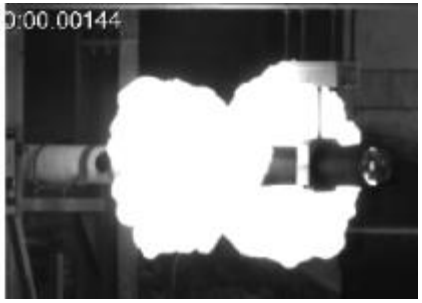


- **Main characteristics :**
  - Composite carbon fibre case (external diameter : 160 mm / Length: 1209 mm)
  - High Burning Rate Propellant (Finocyl shape / about 30 Kg)

TEST PLAN OUTCOME OVERVIEW : Alternative stimuli (BI)

➢ BI Tests results :

- Test conditions : 12.7 mm AP Bullet at 843 m/s (Reference)




→ **Type IVp** (Fragments < 15 m but rear end total displacement > 15 m)

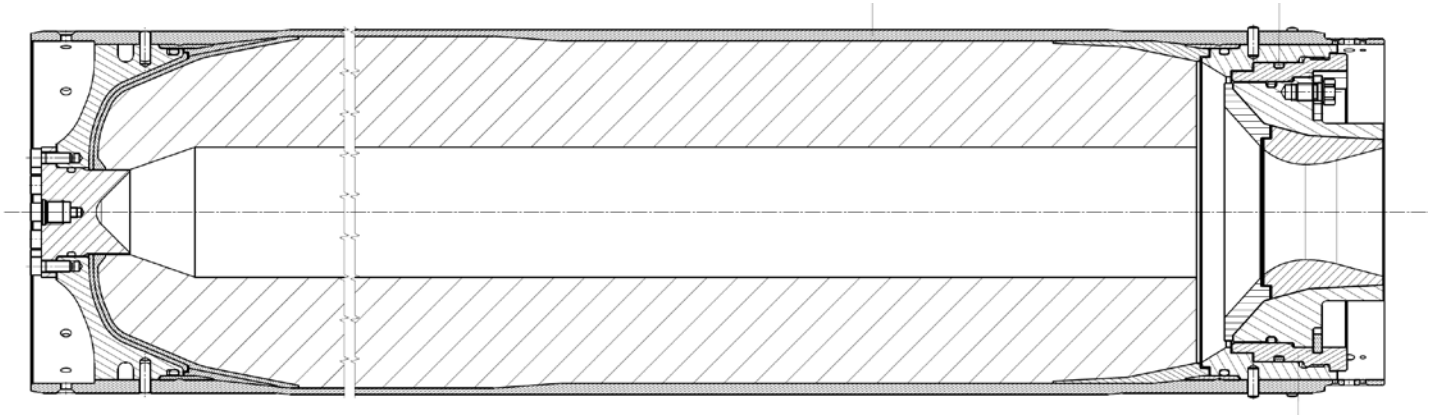
- Test conditions : 12,7 mm explosive AP Bullet at 863 m/s (Alternative)

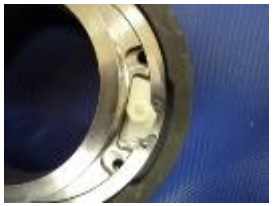

→ **Type IVp/III** (Rear end moved and stopped at 43 m , burning propellant up to 200 m)

TEST PLAN OUTCOME OVERVIEW : New Architecture (FH)

- **New architecture :**
  - Optimised confinement release to FCO agression

- **Specimen tested**





- **Main characteristics :**
  - Composite kevlar/carbon/Kevlar fibre case with 180°C resin **(**external diameter : 165 mm / Length: 1200 mm)
  - Passive venting rear end
  - IM advanced propellant (30 Kg)

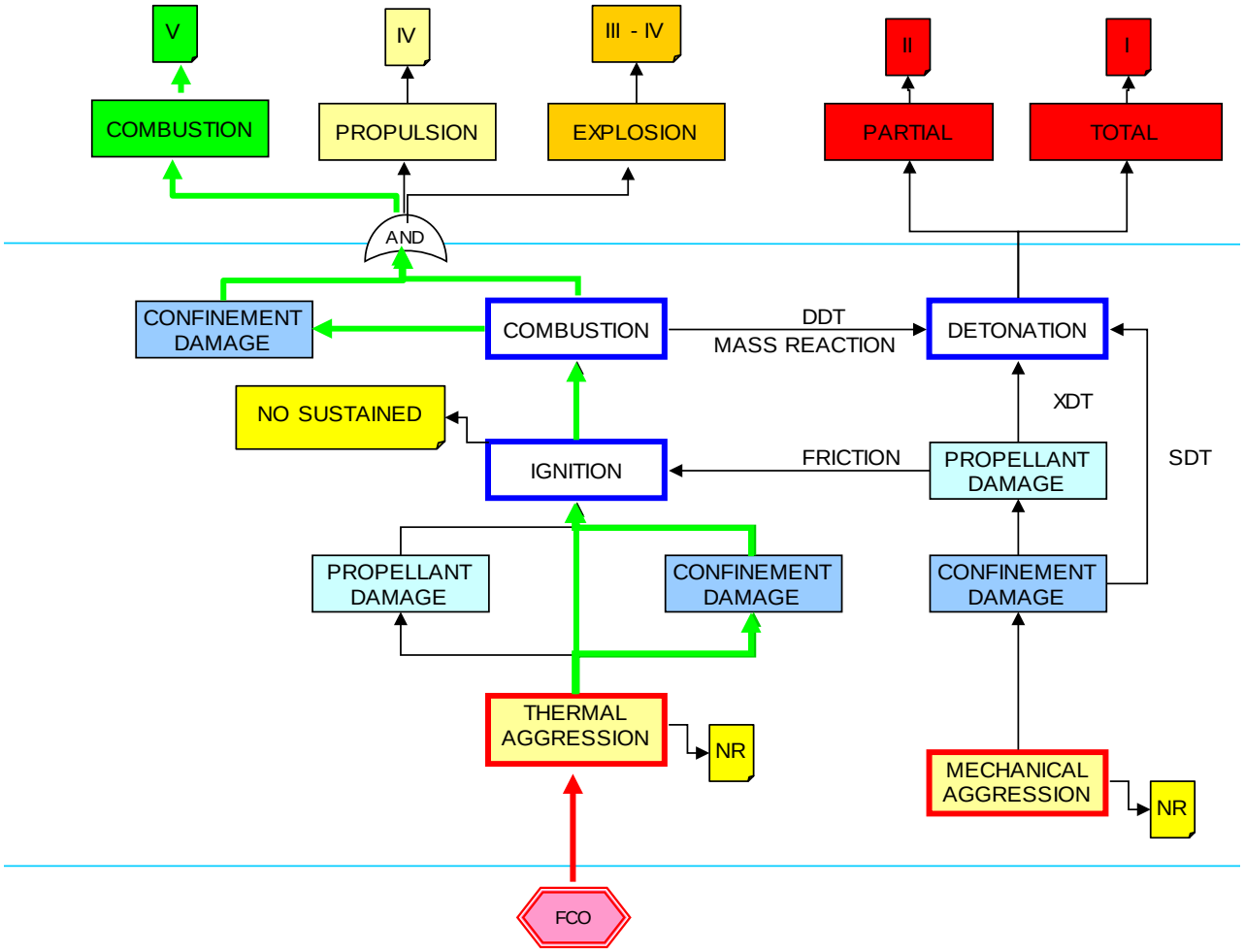
TEST PLAN OUTCOME OVERVIEW : New Architecture (FH)

- **FH Test results :**
  - Average temperature : 950°C
  - Results :
    - Reaction at 74s
    - Overall deconfinment of the structure at low pressure (composite case and rear end passive venting)
    - No thrust
    - Fragments :
      - Passive venting rear end recovered in the pool
      - Inert fragment < 15m
      - Unburned propellant < 30m

→ Classification : Type V

TEST PLAN OUTCOME OVERVIEW : New Architecture (FH)

➢ Application of the global IM protocol for SRM :

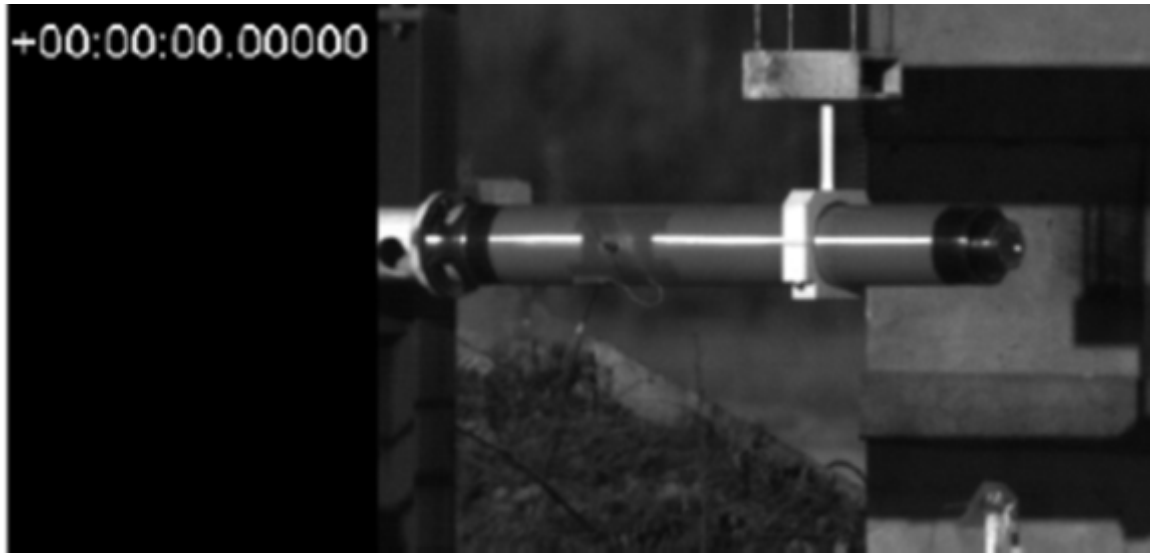


TEST PLAN OUTCOME OVERVIEW : Lesson learned – Test set-up influence (BI)

➢ Specimen overview :

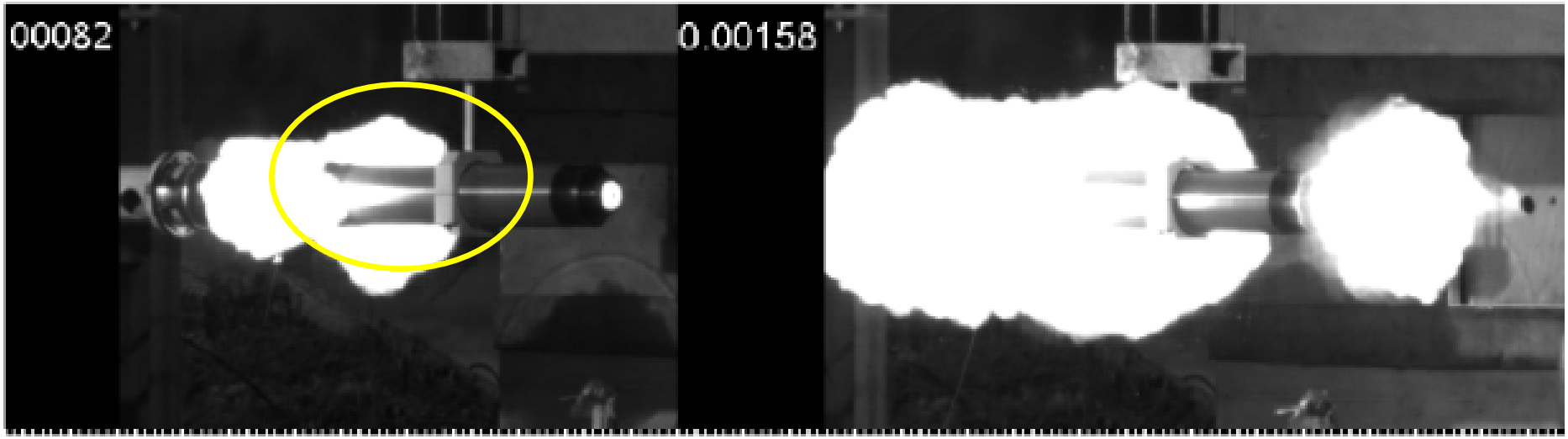
- Kevlar over-wrapped grooved steel case **(**external diameter : 165 mm / Length: 1340 mm)
- High Burning Rate Propellant (Finocyl shape / about 30 Kg)

➢ BI Test Set-up :



TEST PLAN OUTCOME OVERVIEW : Lesson learned – Test set-up influence (BI)

- **BI Test results :**
  - Test bench rear belt support prevented full venting of the case at low pressure :



→ **Classification : Type IV instead of Type V expected** due to test bench attachment mean

CONCLUSION

- Identification of deficiencies and gaps in the technology and knowledge to be evaluated in IM ARP APTE.
  - Simple and unique SRM protocol for all IM aggressions has been established
  - About 40 full scale tests performed by DGA French test centre
  - Knowledge gap filled

- Interest of new architecture to upgrade the reaction level classification
  - Some architectures have been identified to be used for future applications

- Alternative stimuli and test conditions impact evaluated

- Lesson learned : Take care about test set-up influence

Acknowledgements & Questions

Members of

Any Questions ?