IM TACTICAL SOLID ROCKET MOTOR FAILURE MODE ANALYSIS PROTOCOL

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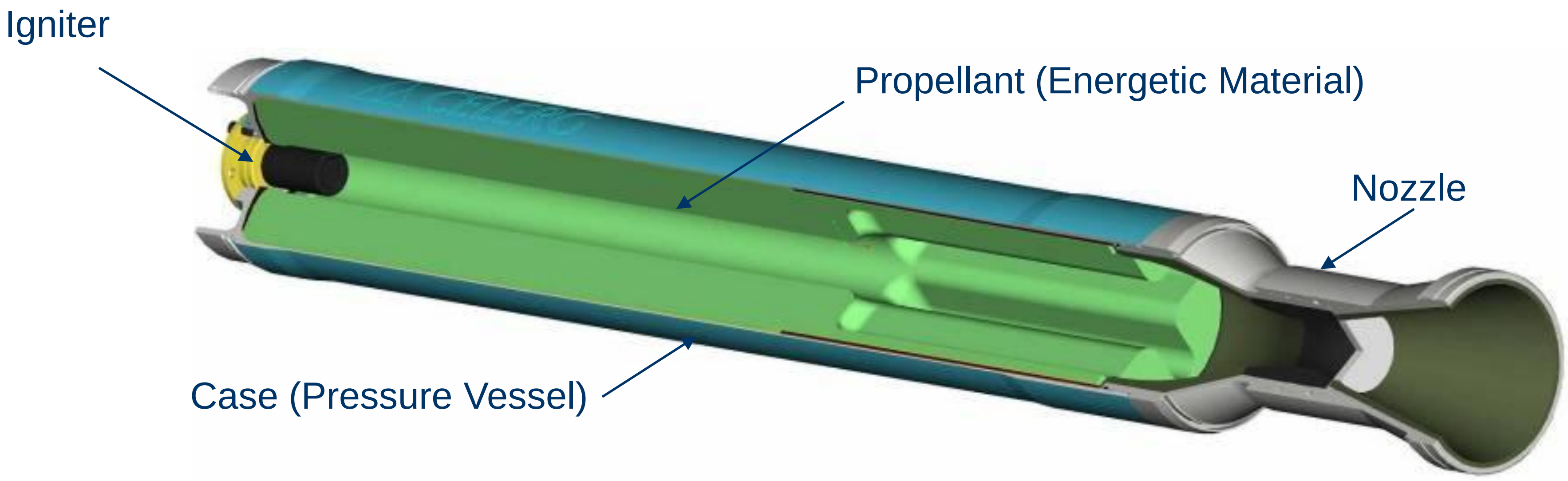
Summary

- INTRODUCTION - IM Solid Rocket Motor Overview
- FRENCH IM ARP “APTE’’ LOGIC
- FRENCH IM SRM DATABASE
- IM NEW PROTOCOL FOR TACTICAL SRM FAILURE MODE ANALYSIS
- SRM ARCHITECTURE BEHAVIOR IMPACT ON IM RESPONSE
- ANALYSIS EXAMPLES
- CONCLUSION

IM Solid Rocket Motor Overview



IM response of a Solid Rocket Motor (SRM) is an increasingly critical requirement.

IM SRM subject to unplanned stimuli must minimise

Probability of inadvertent initiation

Severity of subsequent collateral damage to weapon platform and personnel

but

IM SRM problematic

Compliance to Thrust & Pressure vs. time required

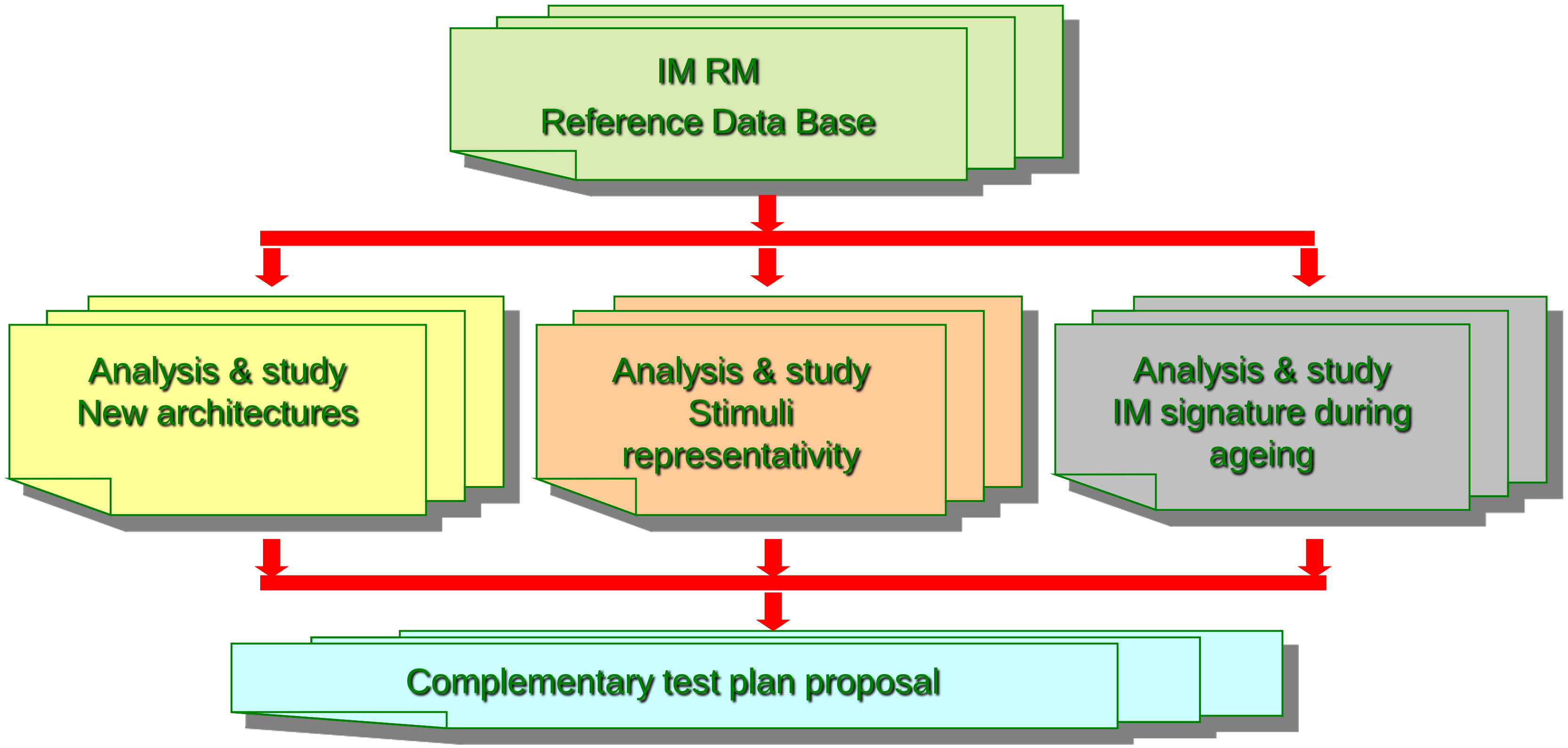
Propellant Sensitivity & reactivity under thermal and mechanical aggressions

RM confinement enhancing reaction effects.

French IM ARP “APTE” Logic

End 2008, French MOD funded ARP APTE (Tactical Propulsion Improvement).
ARP conducted by French RM manufacturers Roxel and SAFRAN/SPS
The IM part of this ARP is devoted to:

- **Search the best IM compromise for solid rocket motor hardware,**
- **Analysis of the stimuli representativeness and results interpretation,**
- **Knowledge of MURAT signature evolution during lifetime**



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French IM Tactical SRM Database

A database has been populated in 2011 with more than 220 different test results conducted on SRM and mock-ups in France since the 80’s, and will be continuously populated with new results.

- Characteristics of the tested objects
  - 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
- Results for all the aggressions, with measurement results and hazard classification (reaction level) achieved
  - 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

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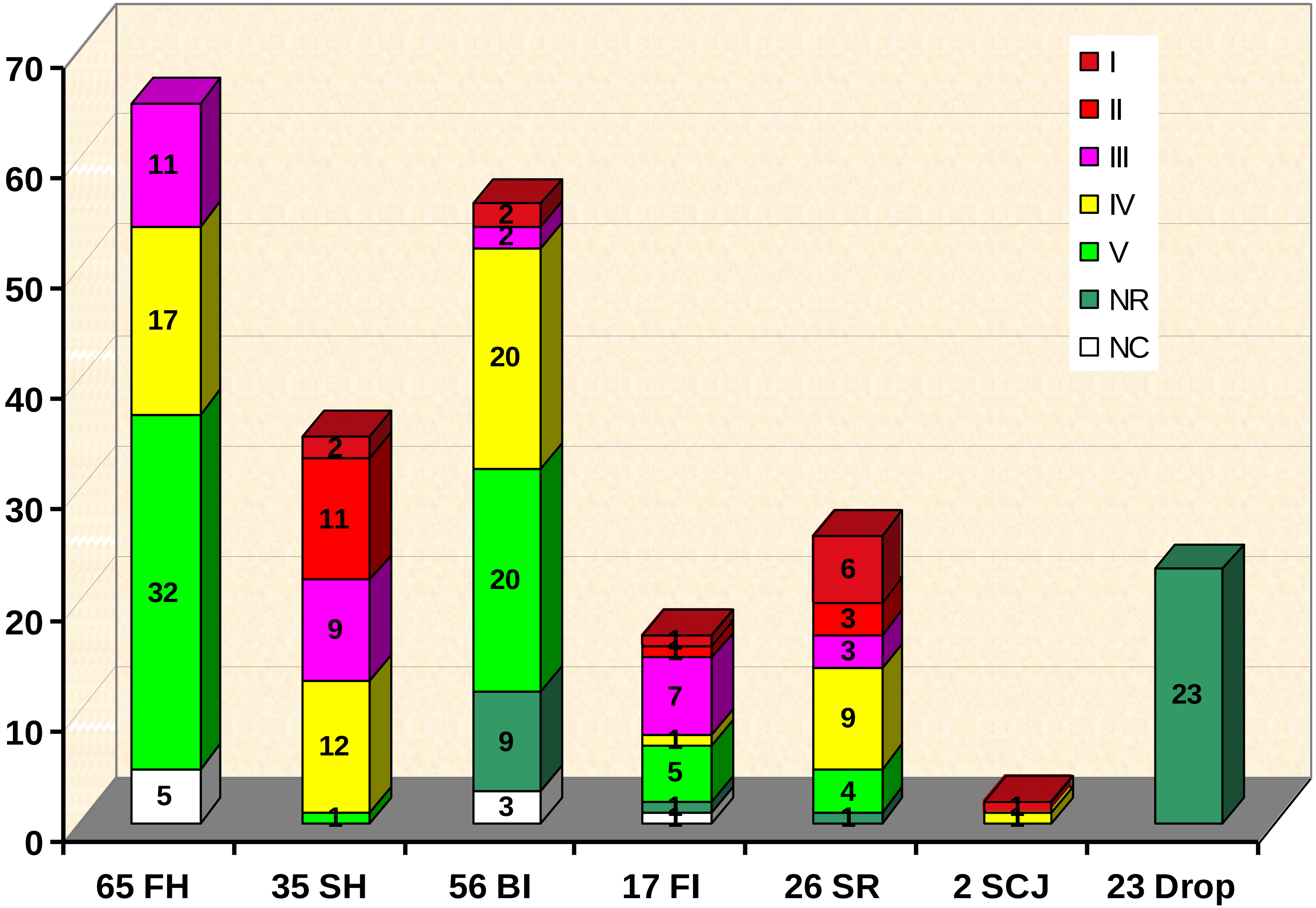
French IM Tactical SRM Database



IM Tactical SRM Database Analysis Method

All SRM tests recorded in the database are analysed by 2 methods:

- Examination and comments of all results, in particular oldest tests conducted before STANAG 4439, AOP39 and associated test procedures.

- Analysis of all results through an updated IM SRM Failure Mode Analysis Protocol valid for all aggressions of STANAG 4439 and new French IM policy 211893 2011 July.

This updated Protocol, presented hereafter, takes into account:

- RM materials design and confinement
- Propellant sensitivity an reactivity
- Stimuli

New IM Protocol For Tactical SRM Failure Mode Analysis

Why a new PROTOCOL:

- First approach : Analyses following AOP39 protocols

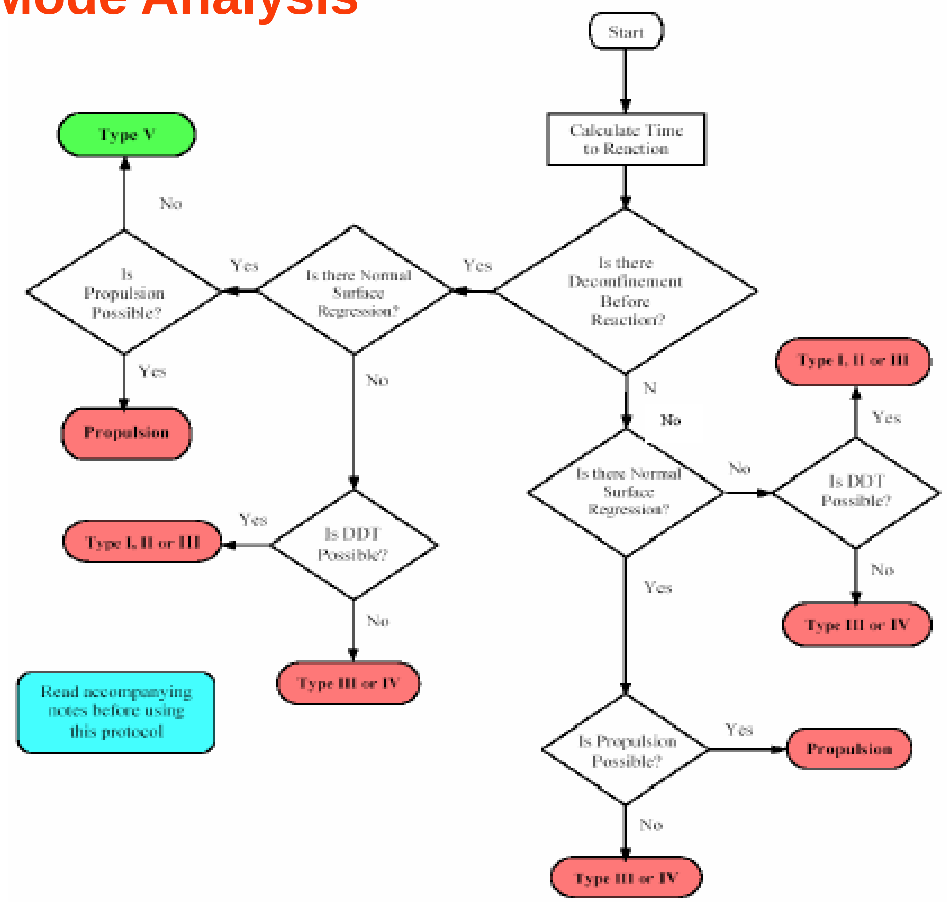


Figure C-1 Simplified Hazard Protocol – Fast/Slow Heating

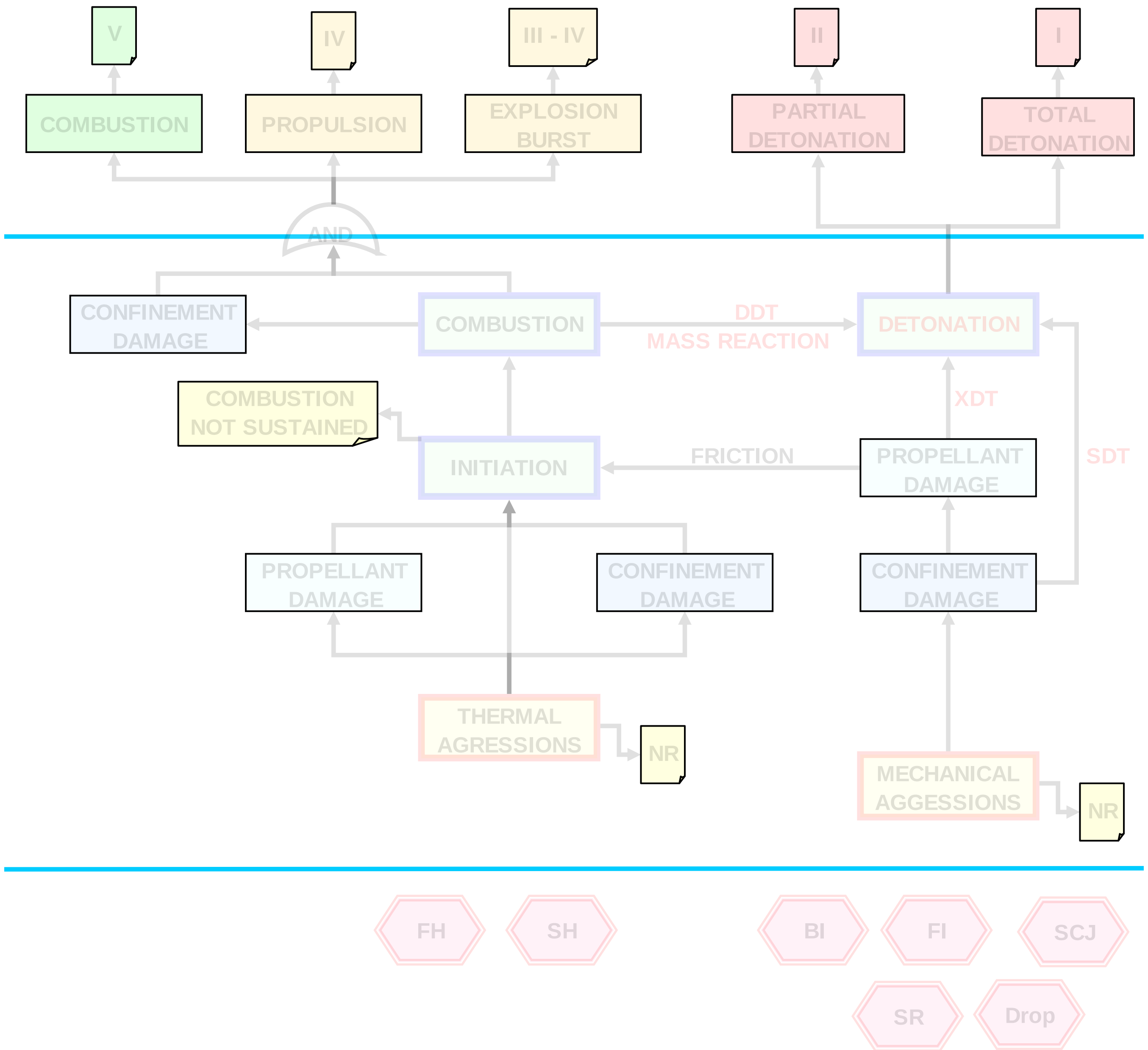
- But :
  - There is one different protocol for each stimuli
  - AOP39 protocols are too much oriented for an overall munition
  - Analyses with AOP39 protocols are too complex for our ARP APTE objective

New IM Protocol For Tactical SRM Failure Mode Analysis

New IM Protocol objectives :

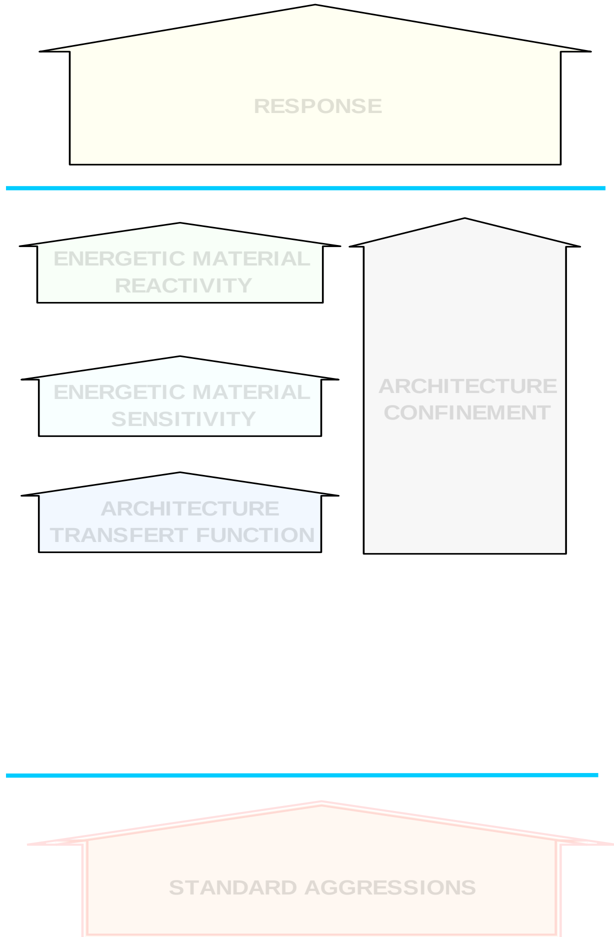
- Simple protocol available for all the stimuli
- Dedicated for Tactical Solid Rocket Motors
- Using the same logic of the AOP39 “simplified hazard protocols”
- Adding a better SRM architecture behavior identification (confinement release)

IM Tactical SRM Failure Mode Analysis Update Protocol



Update Protocol general description

- **Decomposition in 3 steps :**
  - Stimuli
  - Reaction way
  - SRM Response

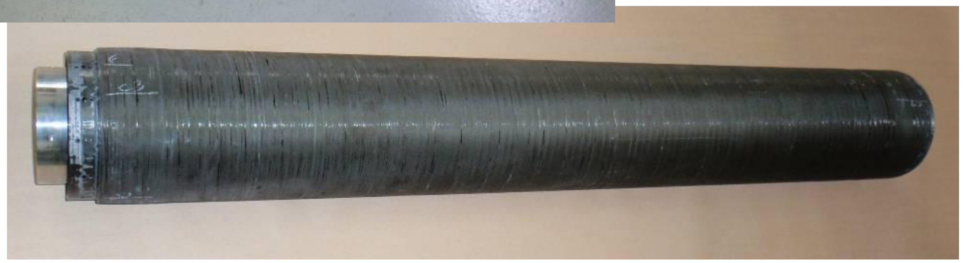


- **Interaction between components :**
  - Transfer Function induce by architecture
  - Energetic material behavior

- **Stimuli :**
  - STANAG 4439's aggressions
  - Other aggression

SRM Architecture Behavior Impact (Confinement Release)

- **Architecture behavior– example 1 : FCO on SRM with Kevlar or Carbon epoxy case (HTPB propellant – BKNO3 Igniter)**



The two cases are designed for the same pressure level

- **FCO on Kevlar case (thickness 2mm) : reaction at 6' 25'' → type IV**
  (Case perforation on one generatrice and propellant ignition)
- **FCO on Carbon case (thickness 1mm) : reaction at 1' 47'' → type V**
  (overall case degradation and propellant combustion at atmospheric pressure)

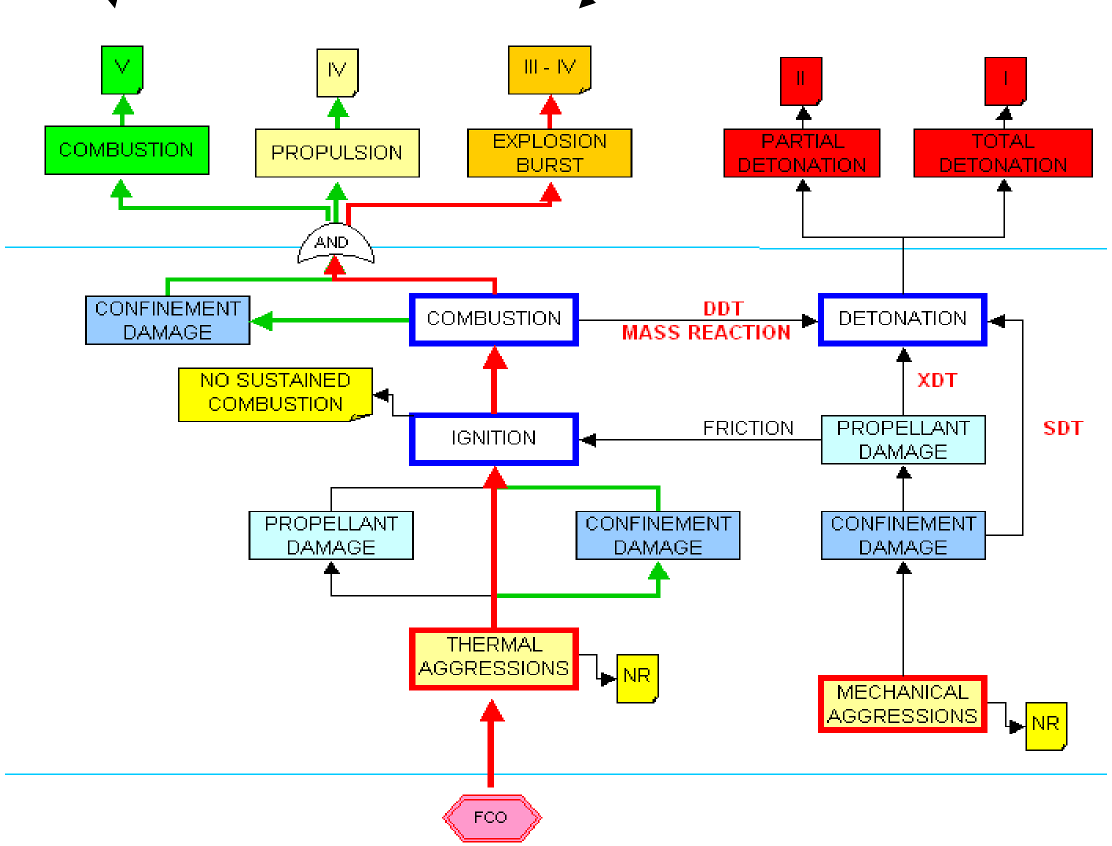
IM Tactical SRM Failure Mode Analysis Update Protocol

Example 1 : FCO Analyses

Carbon epoxy motor case
SSL motor case
Low burning rate HTPB propellant

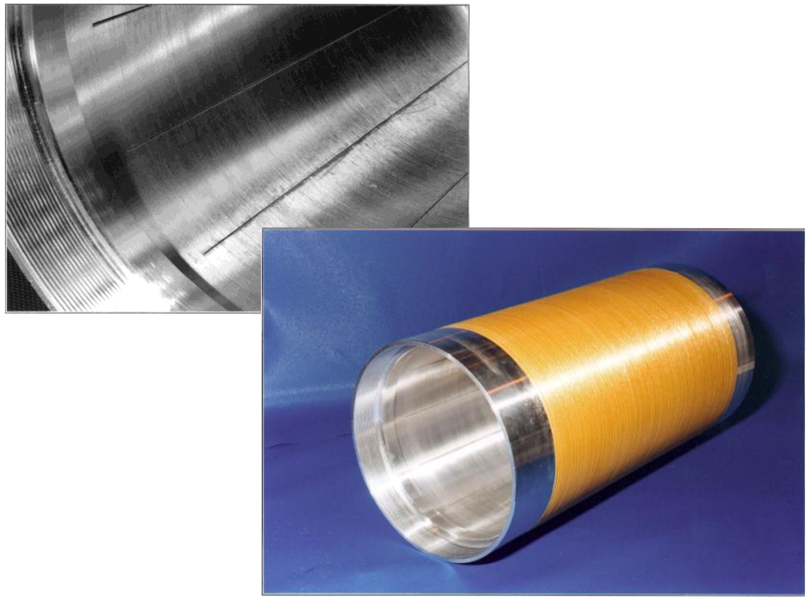
Kevlar epoxy motor case
Low burning rate HTPB propellant

Metallic case
medium burning rate propellant



SRM Architecture Behavior Impact (Confinement Release)

Architecture behavior, example 2 : FCO and SCO on metal and Hybrid metal / composite cases



FCO

SCO

- **FCO on aluminum alloy case : Propulsive reaction at 3’ 04’’ → type IV**
- **FCO on aluminum alloy / overwarp Kevlar case : combustion at 9’ 55’’ → type V**
- **FCO on aluminum alloy / overwarp polyethylene case : combustion at 4’ 25’’ → type V**
- **SCO 3,3°C/h on aluminum alloy / overwarp polyethylene case with SD Igniter : Igniter reaction → type IV**
  (reaction at 142°C, ignition induce propellant combustion and aft closure venting)

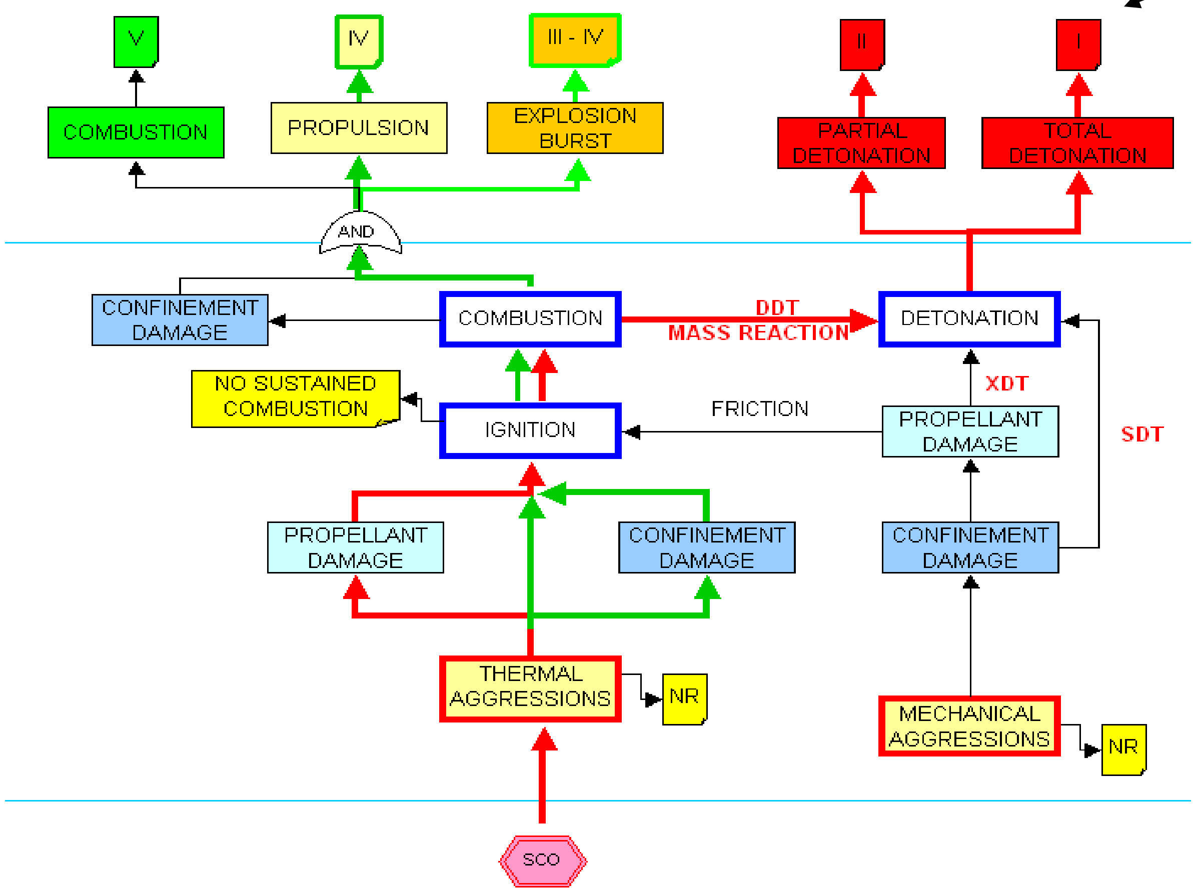
Example 2 : SCO Analyses

Hybrid case
LTI
Low burning rate propellant

Aluminum alloy case
EDB propellant

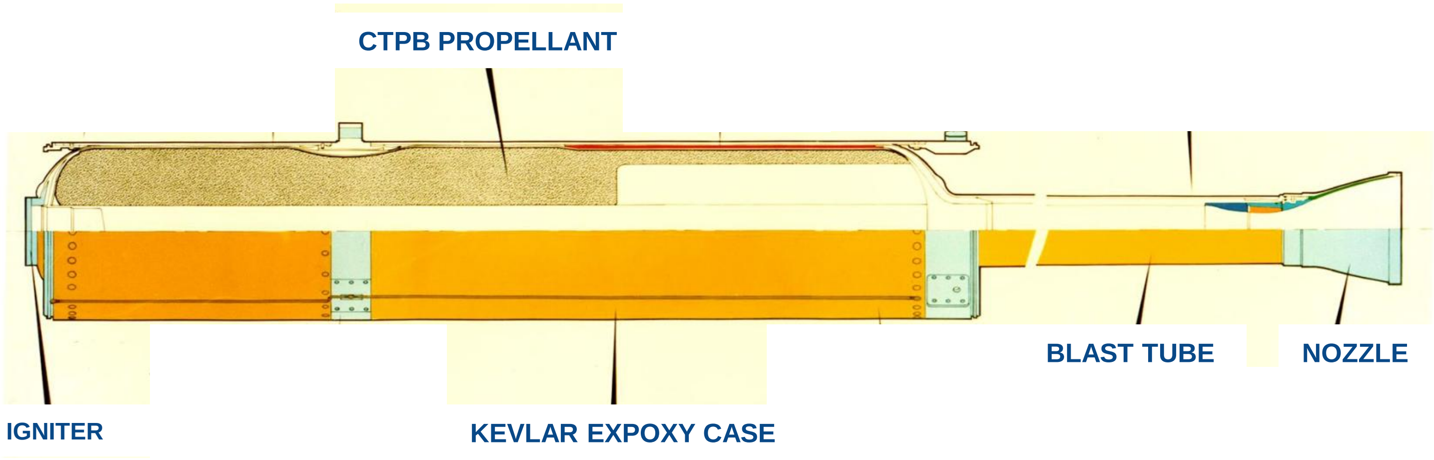
Metallic case
High burning rate

Metallic case
medium burning rate propellant



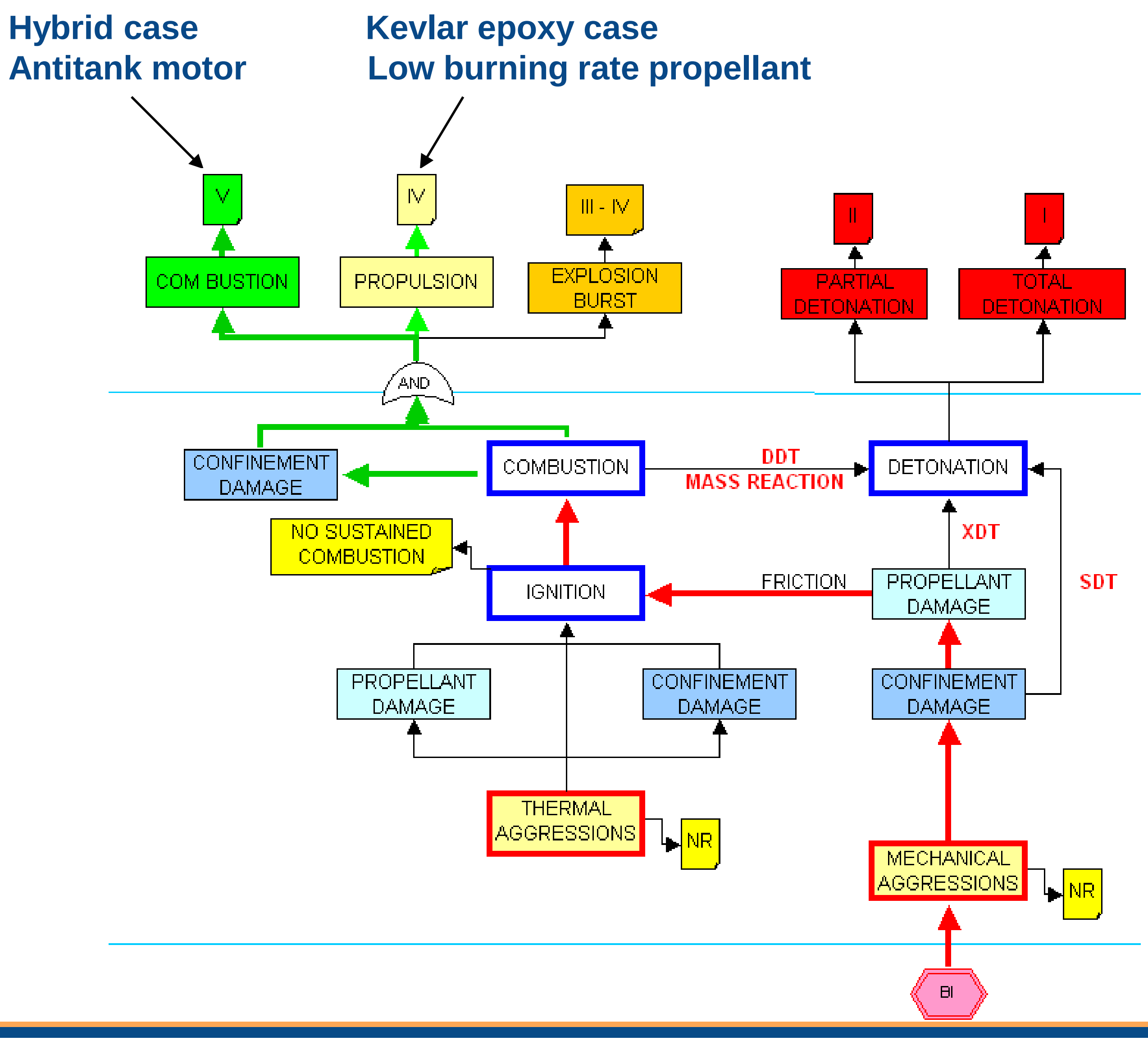
SRM Architecture Behavior Impact (Confinement Release)

Architecture behavior, example 3 : BI 5,56 caliber



- **Shoot on fore section (Kevlar 7 mm + cylindrical bore) : reaction at 1' 49'' → type IV**
- **Shoot on aft section (Kevlar 10 mm + finocyl) : No Reaction**

Example 3 : BI Analyses



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The protocol has been used successfully to identify the deficiencies and the technological gaps and to build the IM test plan which is still on going.

Deficiencies and Gaps summary

AGEING:	Ageing influence on IM SRM response
SRM TEMPERATURE:	Influence of SRM temperature on SRM response to impact threats
HBR PROPELLANT:	SRM IM response with HBR propellant in composite case for calibre > 150 mm
STIMULI VARIATION:	Stimuli variation analysis
NEW TECHNOLOGIES:	Confinement analysis & IM behaviour evaluation of new case concepts
	Mitigation Device efficiency & reliability.
ADVANCED PROPELLANT:	IM behaviour of large RM with advanced propellant
SCJ:	Improvement of SCJ threat phenomena knowledge

Conclusion

- **Proposition of a Simple and Unique SRM Protocol for all IM aggressions considering confinement release**

- **Ease Arborescence to identify :**
  - mitigation way to propose to reduce the reaction level
  - behavior difference induce by ageing

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Acknowledgements & Questions

Members of

Any Questions ?

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