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Influence of Ageing on an IM Signature

Anti-Aircraft Missile Propulsion Unit

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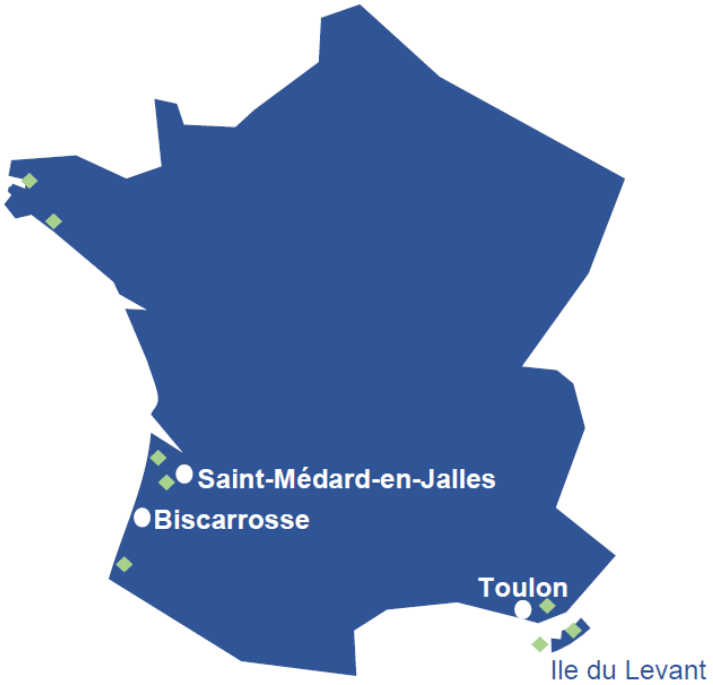

50 YEARS OF EXPERIENCE AND EXPERTISE

3 main sites

- Gironde
- Landes

test and measurement ship « Le Monge »

- Méditerranée

950 staff DGA Missiles testing

Key figures (/year)

- **120 M€** Sales
- **80 M€** Invests
- **~400** Missiles and weapon systems tested
- **~250** Targets used
- **~100** Ground tests

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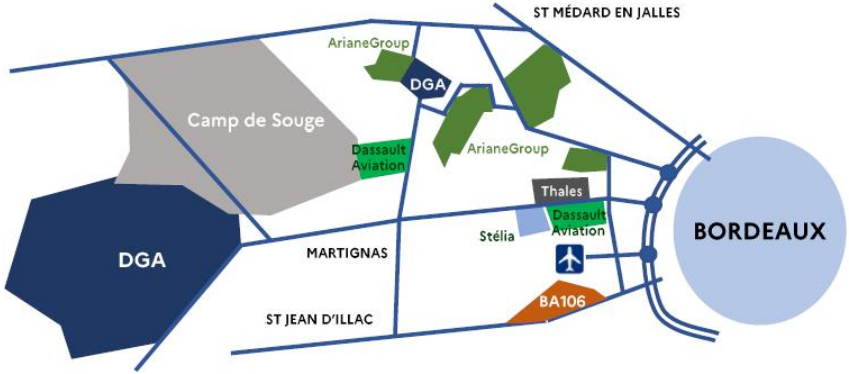
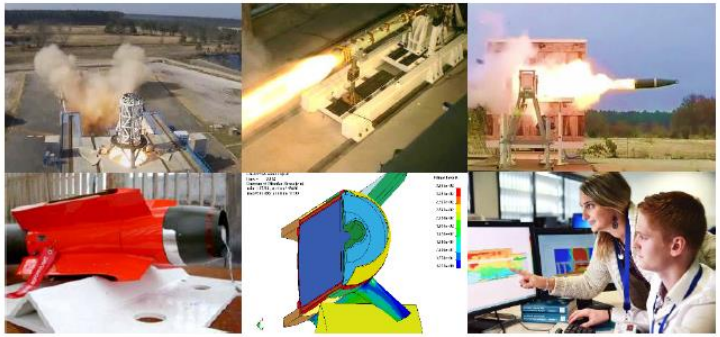
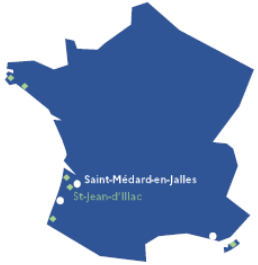




GIRONDE SITE



2 locations
St Médard-en-Jalles
& St Jean d'Illac

10 Test Benches

- In **different configurations**
- **Safety** test areas
- A unique **altitude flight** assessment facility in Europe

ACTIVITIES

TACTICAL PROPULSION
Ageing programs
Upstream studies and technologies
Amont and technologies

EXPERTISE
Assistance for project management
Support for testing
Referent experts

HEAVY PROPULSION
MSBS (M45 ; M51.x)
Spatial (ARIANE, VEGA, ARTA,...)

VULNERABILITY/SECURITY
Essential step before operational use by the forces
Unique French test center labeled NATO

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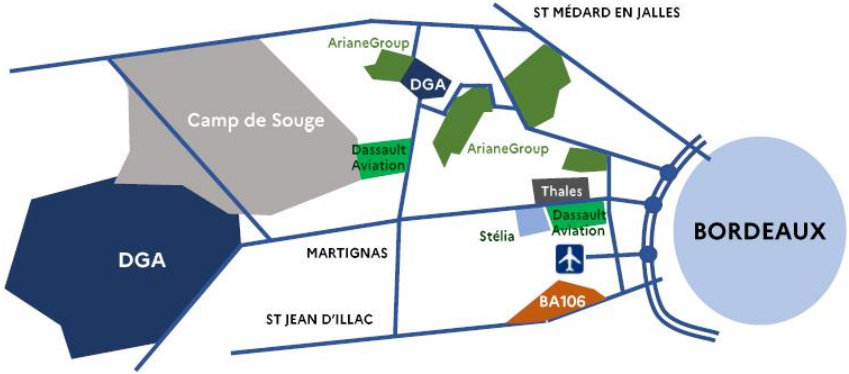

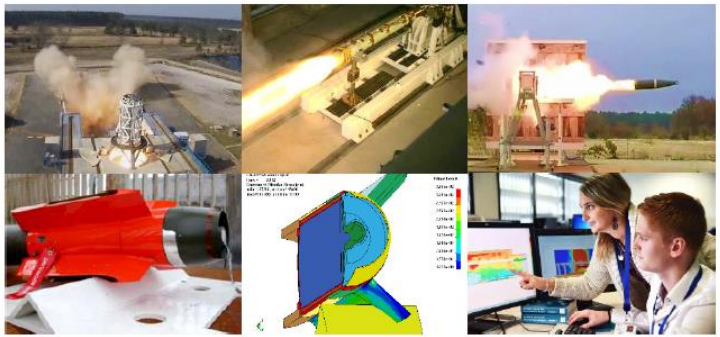

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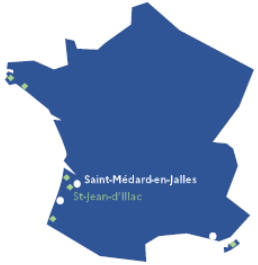

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Munitions Performances and Ageing Assessment

DGA MT Scope:

- Prime contractor for entire or partial ageing programmes (definition, thermal cycle, test, analysis, etc)
- Assessment of the service life duration of pyrotechnical devices
- Expertise and support for Armament Programs

Tested Items:

- Solid Rocket Motors
- Warheads
- Pyrotechnical devices (SAU, batteries, etc)
- Complete missiles

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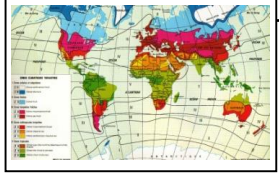
Reference Documents

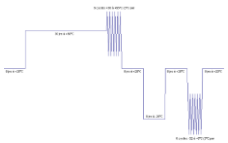
STANAG 4370, AETCP-230, …

Threat Health Analysis



Ageing Program Definition

Thermal Cycles



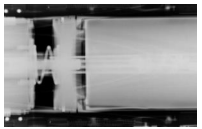
Mechanical Environment Test

Ageing Program Realization

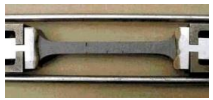
Natural or Accelerated Ageing

Non-Destructive Inspection

(X-ray, Fluoroscopy, Endoscopy, …)



Dissection



Evaluation of the Aged Specimens

Bench Firing (-50 à +80°C)

IM Tests

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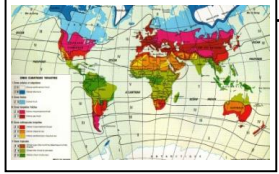
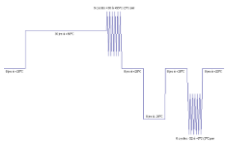
Reference Documents
STANAG 4370, AETCP-230, …

Threat Health Analysis



Ageing Program Definition

Thermal Cycles



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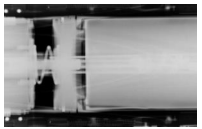
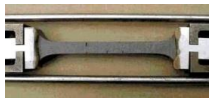


Dissection



Evaluation of the Aged Specimens

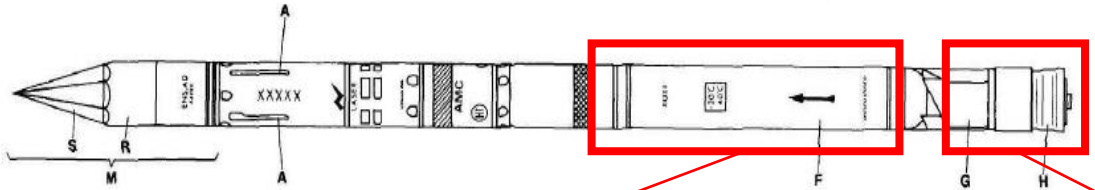
Bench Firing (-50 à +80°C)

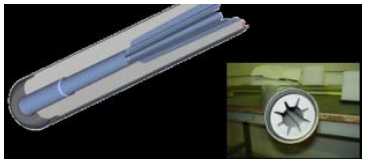
IM Tests

⇒ **First Results on a Anti-Aircraft Missile Propulsion Unit…**

Presentation of the Munition

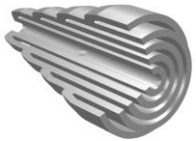
Anti-Aircraft Missile Propulsion Unit





Rocket Motor

- Butalane 68/20 Propellant
- Composite structure (kevlar/epoxy) with humidity barrier



Launch Motor

- Solventless Propellant (EDBP)
- Printed block enclosed in a metallic structure

⇒ **Different types of ageing phenomenology**

Main Ageing Phenomenologies

Launch Motor

Solventless Propellant (EDBP)

- Thermolysis
  - ⇒ **Decomposition of Nitrate Esters**
  - ⇒ **Consumption of stabilizer**
- Migration of Plasticizer
  - ⇒ **Weakened material**
- Migration of Nitroglycerin
  - ⇒ **Exudation**
  - ⇒ **Waste of potential**

Consequences

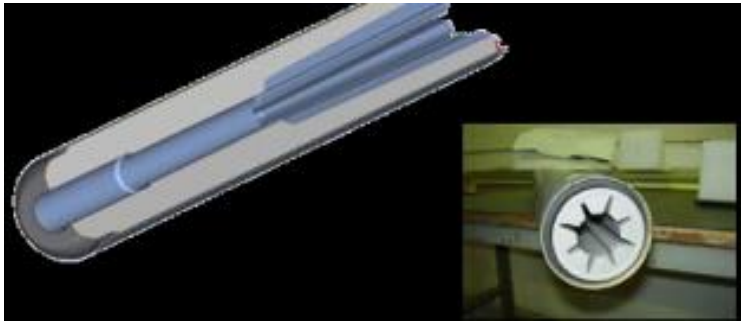
- Impact on the Mechanical Behavior and Safety
- Potential loss in ballistic performances

Main Ageing Phenomenologies

Rocket Motor

Composite Propellant (Butalane with PBHT binder)

- Thermo-oxidation
  - ⇒ **Binder Hardening**
  - ⇒ **Weakened material**
  - ⇒ **Higher cracking risk**
- Hydrolysis
  - ⇒ **Propellant Softening**



Consequences

- Impact on the mechanical behavior
- Safety risk in case of cracking or loss of mechanical property
- If softening, small impact on ballistic performances

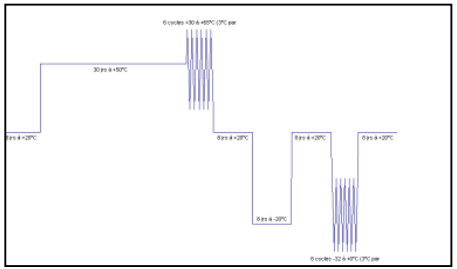
Accelerated Ageing Program

Objectives:

- Predict the lifespan of amunition regarding its operational life
- Control of the operational safety and performances

Principles:

- Replicate the life of the munition
- Definition of climatic and mechanical cycles



Application to the Anti-Aircraft Missile Propulsion Unit:

- Accelerated Ageing of 23 or 24 years
- Representative ageing for the Ejector more important than for the Rocket Motor

γ_{10} **EDBP propellant** > γ_{10} **butalanes**

Control After Ageing

Non-Destructive Controls:

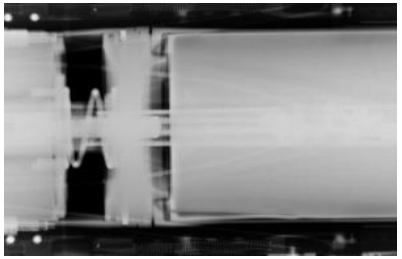
- Integrity of the specimen before firing
- State of the filling contour

Dissection:

- Material evolution
- Reliability of the architecture

Bench Firing:

- Validation of the ballistic performances
- Control of the security of firing and the aptitude to complete mission



And for IM tests ?

NATO References and Reaction Types

Policy for Introduction and Assessment of Insensitive Munitions (IM)	**STANAG 4439 Ed. 4** AOP-39 Ed. D V. 1
Fast Heating (FH)	**STANAG 4240 Ed. 3** AOP-4240 Ed. A V. 1
Slow Heating (SH)	**STANAG 4382 Ed. 3** AOP-4382 Ed. A V. 1
Bullet Impact (BI)	**STANAG 4241 Ed. 3** AOP-4241 Ed. A V. 1
Fragment Impact (FI)	**STANAG 4496 Ed. 2** AOP-4496 Ed. A V. 1
Shaped Charge Jet Impact (SCJI)	**STANAG 4526 Ed. 3** AOP-4526 Ed. A V. 1
Sympathetic Reaction (SR)	**STANAG 4396 Ed. 3** AOP-4396 Ed. A V. 1
Safety Drop	**STANAG 4375 Ed. 3**

Type I – Detonation

Type II – Partial Detonation

Type III – Explosion

Type IV – Deflagration

Type V – Burn

Type VI – No Reaction

Initial IM Signature

Factory Fresh

	Ejector	Rocket Motor
Fast Heating	V	V
Slow Heating	III	(I/II)
Bullet Impact	III	IV
Fragment Impact	(I/II)	(I/II)
Shaped Charge Jet Impact	(I/II)	(I/II)
Sympathetic Reaction	(I/II)	(I/II)

(X): No test performed (type I/II expected)

Drop Test	NR	NR

Initial IM Signature

Factory Fresh

	Ejector	Rocket Motor
Fast Heating	V	V
Slow Heating	III	(I/II)
Bullet Impact	III	IV
Fragment Impact	(I/II)	(I/II)
Shaped Charge Jet Impact	(I/II)	(I/II)
Sympathetic Reaction	(I/II)	(I/II)

(X): No test performed (type I/II expected)

Drop Test	NR	NR

⇒ **Great Interest to observe the evolution of FH, SH, BI and DT results with Ageing…**

Influence of Ageing on the IM Signature

Fast Heating on the complete propulsion unit

Factory Fresh	After Ageing
Complete propulsion system in its tactical configuration Combustion of the propulsion unit after 6 min 35 s Short distance projections No propulsion effect measured ⇒ **Type V**	**Natural Ageing > 20 years** Similar results compared with the Factory Fresh item ⇒ **Type V**

No influence on the FH Test Results for the Ejector and the Rocket Motor

Influence of Ageing on the IM Signature

Slow Heating on the Ejector

Factory Fresh	After Ageing
SH Test done on the entire Propulsion Unit Reaction of the Ejector led to the projection of the Rocket Motor far from the Hoven Extensive fracture on the case of the Ejector Low Pressure wave throughout the test area Outside combustion ⇒ **Type III**	**Natural Ageing > 15 years** SH Test carried out on the Ejector with an inert Rocket Motor Similar results compared with the Factory Fresh item ⇒ **Type III**

No influence on the SH Test Results for the Ejector

Influence of Ageing on the IM Signature

Slow Heating on the Rocket Motor

Factory Fresh	After Ageing
SH Test done on the entire Propulsion Unit in its tactical configuration Reaction of the Ejector led to an interuption of the heating cycle No reaction observed for the Rocket Motor **=> Type I/II expected**	**Natural Ageing > 15 years** SH Test carried out on the Rocket Motor with an inert Ejector in its tactical configuration Violent Reaction of the Rocket Motor Important fracture of the case Shock wave with an important magnitude (partial detonation) ⇒ **Type II**

Consistent with the expected reaction for the Rocket Motor

No improvment of the reaction with Ageing

Influence of Ageing on the IM Signature

Bullet Impact on the Ejector

Factory Fresh	After Ageing
Complete propulsion system in its tactical configuration Impact Velocity: 847 m/s Extensive fracture on the case of the Ejector Low Pressure wave throughout the test area Outside combustion from a part of the propellant Undamaged rocket motor ⇒ **Type III**	**Equivalent Age > 20 years** Complete propulsion system in its tactical configuration Impact Velocity: 844 m/s Similar results compared with the Factory Fresh item ⇒ **Type III**

No influence on the BI Test Results for the ejector:

- Valid only for direct shock ignition phenomenology

Different conclusion in case of lodged fragment?

- To explore in the future

Influence of Ageing on the IM Signature

Bullet Impact on the Rocket Motor

Factory Fresh	After Ageing
Complete propulsion system in tactical configuration Impact Velocity: 851 m/s Separation of the case in 2 large pieces Low Pressure wave throughout the test area Long distance projection of the Ejector No measurement of propulsion ⇒ **Type IV**	**Equivalent Age > 20 years** Complete propulsion system in tactical configuration Impact Velocity: 840 m/s Similar results compared with the Factory Fresh item Phenomenology of propulsion measured ⇒ **Type IVp**

No influence on the BI Test Results for the Rocket Motor:

- Valid only for direct shock ignition phenomenology

Different conclusion in case of lodged fragment?

- To explore in the future

Influence of Ageing on the Drop Test Results

Complete Missile

Factory Fresh	After Ageing
Complete missile in logistical container ⇒ **No Reaction** Complete missile in Tactical Tube (worst configuration) ⇒ **No Reaction**	**Equivalent Age > 20 years** Complete propulsion unit with inert warhead Damages similar to the Factory Fresh test ⇒ **No Reaction**

No influence on the Drop Test Results for the Rocket Motor and the Ejector

Conclusion

First Results about the influence of Ageing on an IM Signature

- Old program with out-of-date IM objectives
- Entire IM Spectrum not covered

Good results on FH, SH and BI Tests for Composite and Double-Base Propellant

- BI Results valid only for direct shock ignition phenomenology

Perspective to do a complete analysis on a more recent program

- Specimen collection at the end of its operational life

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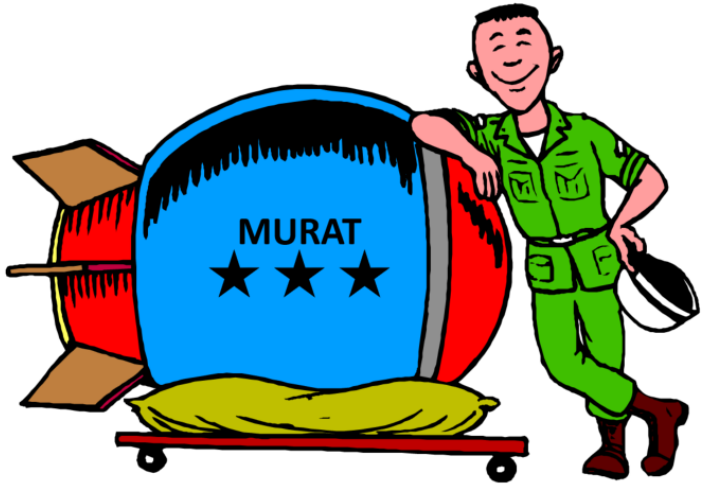
Questions ?



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