"EDA Joint project on Insensitive Munitions & Ageing (IMA): overview"

2012 IM&EMTS - Las Vegas - Nevada

May 14 - 17, 2012

Caroline NGUYEN

SAFRAN Herakles

Background

➔ Great advances in ammunition development, for the last 20 years

- Safety and Vulnerability are of major concern for ammunition
- IM concept has been developed
- Today IM are “In-Service” Munitions

➔ And now…

- IM signature is assessed on pristine ammunition in ambient conditions
- Life duration extension context
- Multiple use, in different operations theatres

What about IM label, during ammunition life cycle ?

Background

Ageing aspects versus IM assessment

- **New concern emerging with IM introduction in forces**

- **Adapted for a European cooperation, within the framework of EDA**
  - Common European research topic
  - Complementary approaches :
    - ✓ A great scope of applications, ammunitions
    - ✓ Wider range of methodologies : trials, modelling …
    - ✓ Large database available

- **IMA (Insensitive munitions and Ageing) : one of the first EDA project, under French leadership.**

Content

I. **IMA project overview**

II. **Ageing programs and first results**

/01/

IMA project overview

Overall objectives

➔ Need

- To quantify and predict if ageing can influence ammunition vulnerability
  - ✓ To take into account ageing aspects and their consequences on safety and vulnerability aspects, from the early development steps
  - ✓ To have a dedicated and reliable methodology for vulnerability assessment, that would take into account ammunition real life cycle

➔ Final goal

- To be able to predict ammunition IM signature, for any ammunition all along its life cycle

IMA project objectives

➔ IMA project : a study focused on Energetic Material

- **To investigate ageing effects on EM vulnerability characteristics**, considering factors such as:
  - vulnerability behaviour (insensitiveness properties changes …),
  - mechanical properties,
  - chemical properties…

- To study and develop **surveillance methods** to characterize materials properties with ageing

- And then to offer **a first step of an overall methodology** able to predict if an IM signature assessed on pristine ammunition can be kept all along its life cycle

SAFRAN Herakles

Project organization

➔ 7 participating nations (MoD & Industries)

- Czech Republic : Explosia
- Germany : ICT / ISL
- Finland : PvTT
- France : Herakles (former SNPE)
- the Netherlands : TNO
- United Kingdom : DSTL
- Sweden : FMV

➔ 4 technical "Work Packages" (WP), described in a Technical Arrangement

- State-of-Art (WP1)
- **Predictive methodologies** : identification of major safety / vulnerability parameters and characterization through ageing (WP2)
- Selection of pertinent parameters for **surveillance,** with dedicated methodologies (WP3)
- Synthesis (WP4)

➔ Project total duration : 5 years, started in January 2009

SAFRAN Herakles

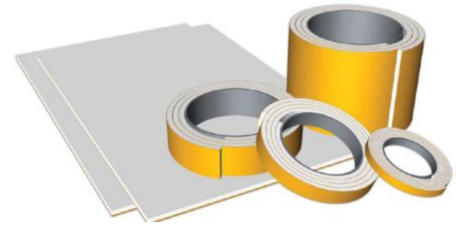
/02/

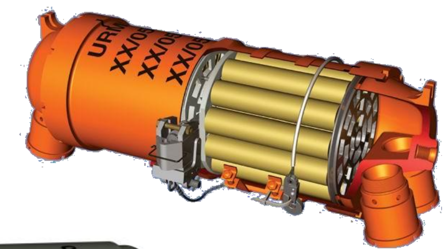
Ageing programs and first results

Czech technical program

➔ Compositions

Type	Product name	Composition
High Explosive	Semtex® Pl SE	M1RDX/polymere (88/12)
	Semtex® Pl SE	HMX/polymere (88/12)
Rocket propellant	ROP	NC/NG/CI/DNT
(double base propellant)	ROP1	NC/NG/CI/substitution of DNT
Gun propellant *(triple base propellant)*	D380	NC/NG/NQ/CI





➔ Test matrix definition

- **Quantitative analysis** - HPLC/UV, GC/MS
- **Chemical stability tests** - Test @ 100°C (HT100), Bergman Junk test at 120°C, Methyl - *violet test*
- **Sensitivity & stability tests** – TAM, HFC, VST - Vacuum stability test, DSC, DTA
- **Mechanical tests** - Friction sensitivity test, *BAM fall-hammer* Impact sensitivity test
- **Impact & shock sensitivity tests** - BI test, SCJI test

SAFRAN Herakles

Czech technical program

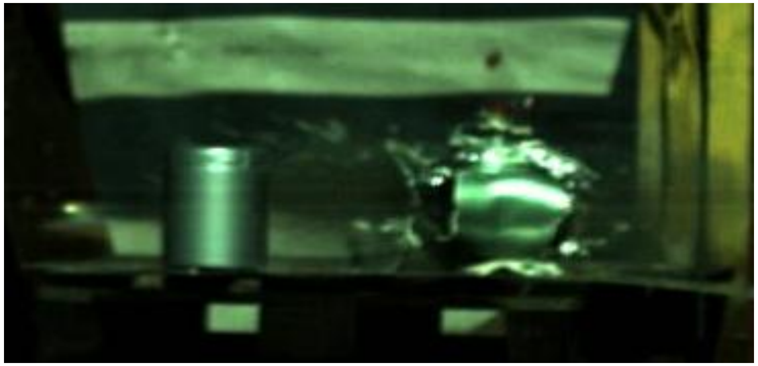
EXPLOSIA

➔ Ageing conditions

	⇔ 10 years, 25°C For EM without NC		⇔ 10 years, 25°C For NC based EM	
Temperature of ageing (°C)	**[days of ageing]**		**[days of ageing]**	
80	24		10.6	
89	10.5		3.83	
For NC based propellant	⇔ 5 years	⇔ 10 years	⇔ 15 years	⇔ 20 years
65	32,4	64,9	97,3	129,7

➔ First results / comments

- No evolution after ageing (80 / 89°C) is observed through BI tests



Modular charge

Bullet impact test @ 12.7mm **B-32 API & BZT API-T**

Rescue rocket motor

Finnish technical program

PVTT

Compositions

- Two PBX formulations are included in Finnish IMA work, FOXIT and FPX 7
    - Both sample explosives include the same ingredients but having different sensitivity properties
    - The basic composition of the samples are HTPB / RDX / AP / Al and both are cured with IPDI

Test matrix definition

- Several tests were conducted to find out the effect of ageing
- Testing program included testing of sensitivity, thermal, mechanical properties as well as chemical analysis

Sensitivity / GAP tests	Thermal properties	Mechanical properties	Chemical analysis
EIDS GAP (FOXIT)	Deflagration point	Tensile test (+23 °C & -40 °C)	FTIR (double bonds)
LSGT (FPX 7)	Heat Flow Calorimetry	Dynamical Mechanical Analysis	HPLC (antioxidant)
/	Differential Scanning Calorimetry	/	/

SAFRAN Herakles

Finnish technical program

PVTT

➔ Ageing conditions

- Artificial Ageing program is based on Finnish long term storage conditions
  - Ageing is conducted at different temperatures
  - Ageing times at each temperature were selected so that they represent storage for 5, 10 and 15 years
  - Ageing times were calculated according to van't Hoff rule

Corresponding storage time (years)	Ageing Temperature and ageing times in days				
	40 °C	50 °C (f = 2,0)	50 °C (f = 2,5)	60 °C	70 °C
5	154	140	62	25	10
10	308	281	123	49	20
15	400	365	160	64	25

➔ First results / comments

- Test program almost finished, results to be further analyzed

SAFRAN Herakles

French technical program

Compositions

- 2 PBX : PBXN109 (HTPB / Al / I-RDX) and B2214B (HTPB / NTO / HMX) – EURENCO's PBX
- 1 classic HTPB / AP/ Al propellant (reduced smoke)

Test matrix definition

- Focus on SH / BI / SR threats
- Parameters to be evaluated through ageing:

EM \ Threat	Mechanical	Slow Heating (SH)	Bullet Impact (BI)	Sympathetic Reaction (SR)
Rocket propellant	Uniaxial tensile test, DMA	DTA	Friction sensitivity	/
		SCO test	Friability (Shot gun), High pressure Combustion	/
PBXN109	Uniaxial tensile test, DMA	DTA	Friction sensitivity	/
		SCO test	/	/
B2214B	Uniaxial tensile test, DMA	DTA	Friction sensitivity	Micro GAP test
		/	Friability (Shot gun), High pressure Combustion	/

Sensitivity (grey rows)

Violence of Reaction (orange rows)

- Validation tests on mock up (BI / FI / SCO), on both non aged and aged (equiv. 20 years) EM

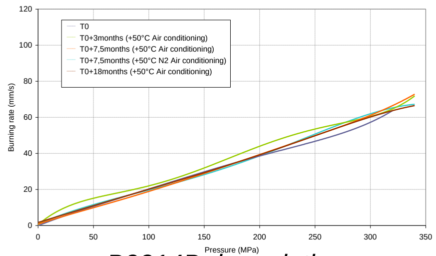
French technical program

Ageing conditions

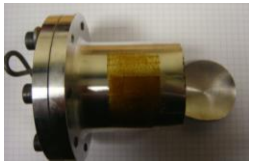
Position	Ageing T° RH dry	Ageing time (Years)	Ageing time (Months)	Corresponding storage time (years)
REFERENCE T0		**0**	**0**	**0**
Surface Air	**+20°C**	2	24	2
		5	60	5
		10	120	10
	+50°C	0,25	3	2
		0,625	7,5	5
		1,5	18	12
		2,5	**30**	**20**
		3,125	**37,5**	**25**
In depth Nitrogen	**+20°C**	5	60	5
		10	120	10
	+50°C	0,625	7,5	5
		1,5	18	12
		2,5	**30**	**20**
		3,125	**37,5**	**25**

First results / comments

- Hardening of EM is observed, especially on rocket propellant
- No significant evolution on safety / vulnerability tests, after 20 years equiv. ageing
- 2 years @ +20°C ⇔ 3,5 months @ +50°C

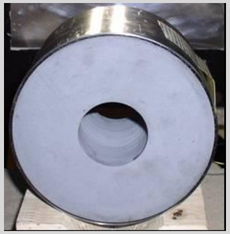


B2214B rb evolution



SCO test on PBXN109

Rocket propellant mock up



~30% of unburned propellant is recovered

Fragment Impact @ 1888 m/s → Type III-IV reaction

(Reference test)

German technical program

➔ Compositions

- 4 compositions of high explosive charges (HEC) are made and investigated by Germany

Used components I-RDX: insensitive RDX from EURENCO S-RDX: standard RDX from Dyno	GAP diol, I-RDX / S-RDX, class 1 and 5 HTPB R45M, I-RDX / S-RDX, class 1 and 5
Composition **(high explosive charge, HEC)** Two formulations with I-RDX (class 1 and 5) Two formulations with S-RDX (class 1 and 5) - for comparison to I-RDX formulations	**GAP-N100 bonded I-RDX / S-RDX** 75% RDX (I or S), 15% binder GAP-N100, 10% plasticizer BDNPA_F **HTPB-IPDI bonded I-RDX / S-RDX** 80% RDX (I or S), 12% binder HTPB-IPDI (+AO), 8% plasticizer DOA

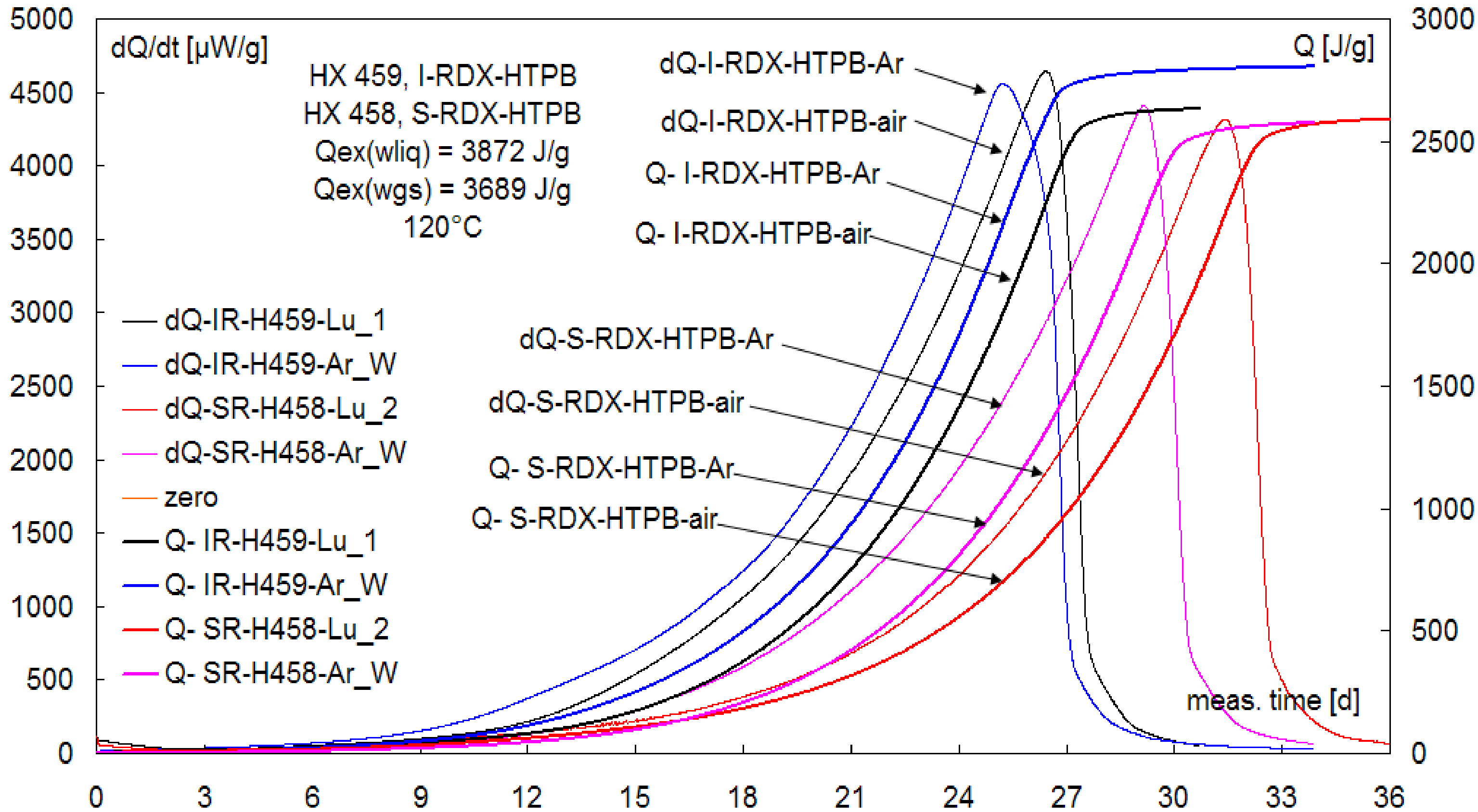
➔ Test matrix definition

- Basic characterization of energetic components (I-RDX) and HEC :
  Impact and friction sensitivity / Vacuum stability / Auto ignition temperature / Density
- Tests :
  - ARC (Accelerating Rate Calorimetry)
  - DSC (Differential Scanning Calorimetry)
  - HFMC (Heat Flow Micro-Calorimetry)
  - DMA (Dynamic Mechanical Analysis)
  - 21 mm GAP detonation sensitivity
  - 30 mm bullet (12.7mm) impact test

German technical program

➔ First results / comments

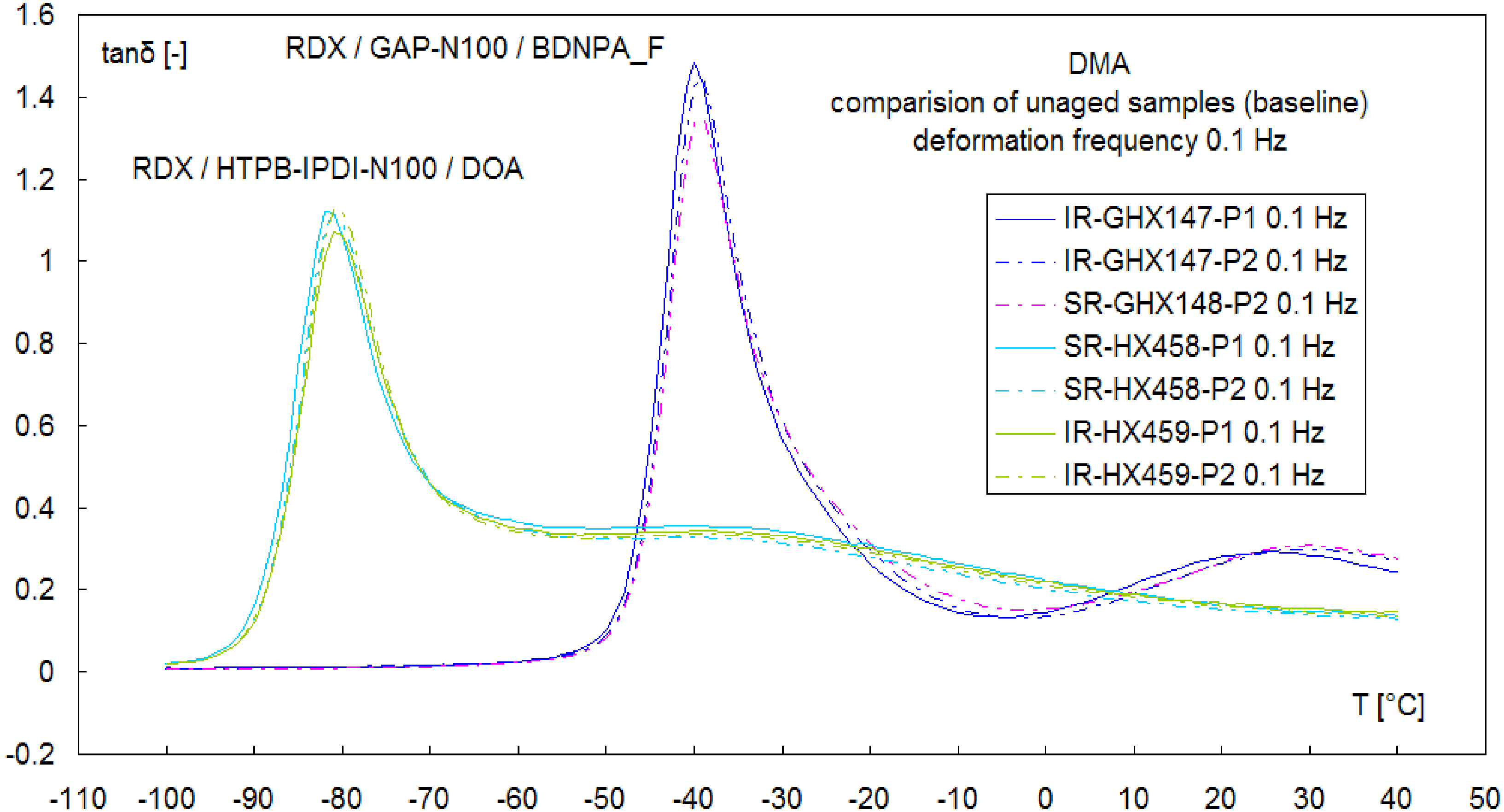
- Microcalorimetry: Heat Generation Rate dQ/dt and Heat Generation Q at 120°C, in air and in argon; comparison of I-RDX-HI and S-RDX-HI formulations



German technical program

➔ First results / comments

- Comparison of loss factor of I-RDX and S-RDX HI and GN formulations (≠ bonded)



Netherlands technical program

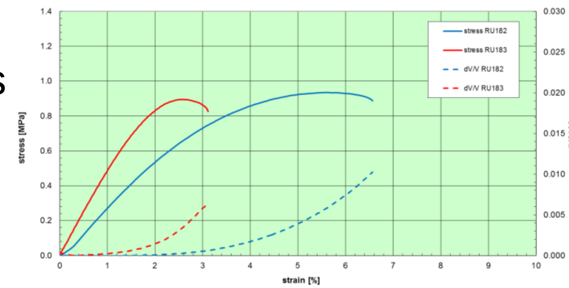
TNO innovation for life

Compositions

- 2 Bimodal RDX-HTPB-based explosive (85 wt% solid loading) with NCO-OH ratio of 1.2 and 1.4 (last one is “chemically aged”), first one artificially (high T) aged

Test matrix definition

- IM testing : Fragment impact and Cook-off (0.06°C/s and 0.006°C/s
- Friability testing
- Gas DilatoMetry (GDM tensile strength test with ΔV/V)
- SEM...



Ageing conditions

- Ageing at 70°C in contact with air inside the oven

First results / comments

- Detonation in reference testing of SCB at 0.06°C/s
  → more investigation of the cause of this unexpected event
- In middle of test series and analyses

SAFRAN Herakles

Swedish technical program

➔ Compositions

- 2 LOVA-propellants NL007 and NL008 have been tested.
- 1 propellant lot of NL008 without graphitization has also been analyzed

Component	NL007	NL008
RDX	76.5 %	73 %
CAB (cellulose acetate butyrate)	9 %	12.7 %
NC (nitrocellulose)	7.2 %	5.3 %
TBC (Tributyl citrate, plasticizer)	7 %	8.6 %
Centralite I (NC-stabilizer)	0.4 %	0.4 %

➔ Test matrix definition

Analysis method	Property studied
Uniaxial Compressive Testing	Mechanical properties
Density	
Vented bomb	Grain capacity to withstand high pressure. Burning properties in general.
Slow cook-off	Thermal properties
DSC	
HPLC	NC-stabilizer content

SAFRAN Herakles

Swedish technical program

➔ Ageing conditions

- Ageing temperatures: 50°C, 65°C and 80°C.
- Storage temperature: 25°C
- Sample collection at 0, 1, 5 , 10 and 20 years of forced ageing.
- Thermal cycling

K_T = Thermal acceleration factor
T_1 = Storage temperature
T_2 = Ageing temperature
E_a = Activation energy

Simulated age = K_T x storage time at elevated temperature →

$$K_T = e^{\frac{E_a}{R}\cdot\left(\frac{1}{T_1}-\frac{1}{T_2}\right)}$$

➔ First results / comments

- No severe negative impact of ageing / thermal cycling on properties for graphitized propellants.
- Probable splitting of grains at combustion of aged non-graphitized propellants.
- NL007 : ≠ trends in results between ageing @ 50°C and ageing @ 65°C & 80°C.
- Uniaxial compressive testing does not seem to be a suitable test method for studying the ageing behaviour of these propellants due to either propellant composition or geometry.
- Vented bomb analysis seems to be a promising method for propellant surveillance.

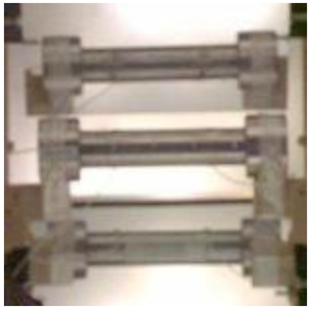
UK technical program

➔ Compositions

- Torpedo warhead PBX (AP/ RDX / Al / HTPB)

➔ Test matrix definition

- Tube tests :
  - Fragment impact
  - Fast Heating



➔ Ageing conditions

- 6 months at 80°C (<10% relative humidity)

➔ First results / comments

- Test program to begin FY 2012-13 for contractual reasons

Conclusions

- **IMA project status, after 3 years of work :**
  - 7 European nations are participating to the project
  - Ageing programs are going on, involving different EM, experimental protocols…
  - Numerous data are now been gathered, and need to be further analyzed

- **IMA project :**
  - a first step of an methodology → predicting if an IM label is still valid after ageing

- **IMA project : a successful EDA cooperation**

- **To be followed…**

Acknowledgment

European Defence Agency

PVTT

EXPLOSIA

SAFRAN Herakles

ISL FRENCH-GERMAN RESEARCH INSTITUTE OF SAINT-LOUIS

TNO innovation for life

dstl

Fraunhofer ICT

FOI

And all participating nations MoDs.

KEY MISSIONS, KEY TECHNOLOGIES, KEY TALENTS