Pyro-MEMS
Technological breakthrough in fuze domain

Fuze Conference 2009

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Lake Buena Vista, FL

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Approved for public release
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2. Design & Demonstration of MEMS SAU
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1. **NEXTER Munitions Fuze activities**
NMu: Fuzing System manufacturer

**Products:** Fuzing system & SAU for missile, tank ammunition (120, 100, 90 mm caliber), naval artillery (100mm caliber) and medium caliber (40, 30 and 25 mm caliber).

**Strengths:**

- Pyrotechnical components manufacturer (primary & secondary)
- Own proving ground
- The complete munition designer
NMu: Fuzing System designer

Applications:
- Airbursting ammunition
- Opto-Pyro
- LEEFI
- ...

Strengths:
- Modelisation
- Data recorder
- Own proving ground (static, pyrotechnics, dynamic)
- Same group than weapon system designer (NEXTER Systems)
1) **Design & Demonstration of MEMS SAU**

Contract 03.04.078 – Demonstration of miniaturized SAU
1) MEMS SAU

Technology MEMS

Pyrotechnical interruption

Miniaturized Electronic driver

STANAG 4187 compliance
Micropyrotechnics, Synergy of mechanics, electronics & pyrotechnics

The Step Forward

03/2007 – delivery of 10 µ-SAUs

Requirement

- Pyrotechnical safety managed by electronically controlled MEMS
- Volume less than 2 cm³
- In accordance with STANAG 4187 (last edition)
- Ignition of EIDS
- Low cost
- Generic SAU
Arming ability and reversibility
MEMS design according to STANAG 4187 requirements

ARMED

SAFE

1st Safety lock

2nd Safety lock

Arming displacement
Environnemental conditions :

► 120mm ammunition Polynege (Laser guided tank ammunition) firing (~10 000 g)

View of the actuators after firing
1) **MEMS SAU**

Technology MEMS

**Pyrotechnical interruption**

Miniaturized Electronic driver

STANAG 4187 compliance
Reliability and safety performances obtained by hardened tests (GTPS)

- **Reliability**: 0.999 with 75% confidence level
- **Safety**: 0.9999995 with 90% confidence level

* Interruption test on PETN booster
Pyrotechnical tests

Transmission

Interruption

Detonator
SAU body
MEMS

TIME

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1) **MEMS SAU**

- Technology MEMS
- Pyrotechnical interruption
- **Miniaturized Electronic driver**
- STANAG 4187 compliance
High density PCB

- 8 layers
- High density of parts
- « In Pad » vias
- In board vias
- « Flex » PCB
Integration
Integration
1) MEMS SAU

Technology MEMS

Pyrotechnical interruption

Miniaturized Electronic driver

**STANAG 4187 compliance**
Compliance with STANAG 4187

- Two independant orders to authorize arming sequence [Exg 6.a).1] : OK
- Physical shutter between detonator and booster [Exg 8.a).1] : OK
- Explosive assessment and approval : COTS pyrotechnical devices OK [Exg 7.a]) : OK
- Non-armed guaranty during assembly and installation : [Exg 12.a]) : electrical information about shutter status is available
1. **Design & Demonstration of 25mm Airburst ammunition-Mk I**

   Contract n°05.50.208 – Improvements of medium calibre ammunition

   *Demonstrator for a programmable air bursting 25 mm round*
Aims of the study

► Airburst has to be initiated above the target with an accuracy of 1 m at 1000 m

► Airburst mode shall be compliant with the maximal range of the 25, 30 and 40 mm weapons

► Impact mode available

► Compliance with STANAG 4187

► Airburst Fuze Programming Unit shall be able to equip existing weapons systems (retrofit)
► Programming Unit
- Inductive coil (Mode + Chronometry)
- Impact mode remains available without programming unit

► Operational modes
- Airburst +PD +Self-destruct

► Airburst performances
- Chronometry: +/- 50 cm at 1000 m

► Environment conditions:
- Medium calibre 25x137: 100 000 g 1000rd/s
Electronics and SAU designs are deeply fit into each other during engineering process.
Recorded flight tests

- Accumulated energy is generated by setback acceleration
- Chronometric accuracy assessment
- Detonator firing sequence
## EMC immunity assessment

**Measures from 2 GHz to 18 GHz**

<table>
<thead>
<tr>
<th>Spectral analyser</th>
<th>ampli</th>
</tr>
</thead>
<tbody>
<tr>
<td>receptor</td>
<td>emitter</td>
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</table>

Induced voltage within the round coil is deduced by analysis from measures achieved thanks to vectorized spectral analyser.
EMR hazards immunity

Measures from 60 MHz to 18 GHz

<table>
<thead>
<tr>
<th>Networks analyser</th>
<th>ampli</th>
<th>emission</th>
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<tbody>
<tr>
<td>reception</td>
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STEP 1: measure of max. level without ammunition

<table>
<thead>
<tr>
<th>shell</th>
<th>ampli</th>
<th>emission</th>
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STEP 2: measure of max. level within ammunition

- Measures permits to assess the shell faradisation
- Analysis permits to evaluate the existing safety margins against EMR aggressions
Demonstration NEXTER Munitions
French MOD – September 08
Conclusion

- The maturity levels have grown quickly till today
- This growth is partially due to the new experimental techniques like in-flight data recorder at high level of acceleration
- 2009 – 2010 will be the time for the demonstrations tests!
1. Design & Demonstration of 25mm Airburst ammunition-Mk II

Self-funded study
Synthesis

• Merge both programs (airburst and μSAU)

• μSAU advantages
  ▶ MEMS technology particularly adapted to Medium caliber ammunition: size & number of ammunition to produce
  ▶ Cheaper: electronics industry
  ▶ More reliable
  ▶ Robust
  ▶ Settable for the complete range of medium caliber
Self funded-study

- μSAU design based on NMu pyro-MEMS experience
- Study of safety locks reacting straightly to the arming environments
- MEMS SAU designed for electrical or mechanical detonators
- Workflow
  - Simulation, static and dynamic tests on each device (setback & rotation safety lock, motion of the shutter)

  Down selection

  - Simulation, static and dynamic tests for the complete MEMS SAU
### Time schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<tbody>
<tr>
<td>SAU MEMS DESIGN</td>
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<tr>
<td>Safety locks study</td>
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<td>MEMS production and evaluation iterations</td>
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**TRL6**

*SAU MEMS DESIGN* Complete SAU study

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Work in progress

- MEMS SAU design done (patented)
- First batch of MEMS produced
- First batch of MEMS tested
  - Structure able to withstand 100,000g
  - Safety locks operate
Thanks to your attention