New Technologies for Safety and Firing Functions in Modern Munitions

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Outline

- Fuze and S&A Devices – Requirements evolution
  - New Requirements – Need Trends

- Technical solutions
  - Electro-mechanical S&A Devices
  - Electronic S&A Devices - EFI and LEEFI-based ESAD
JUNGHANS Defence – The Fuze Company

Complete range of fuzes for all types of munitions

Key competences in Fuzing technologies, Micro-technologies and Ammunition electronics
Main Types of SAD

**Current use**

**Mechanical SAD**
- All type of munitions and missile
- Mainly tube launched munitions

**Electromechanical SAD**
- Missile and aerial bombs, some munitions
- All type of munitions, small missiles

**Electronic SAD**
- High value missile
- Aerial bombs, small missiles, smart munitions

**New trend**
Fuze and S&A Devices
New Requirements - Need Trends
New Requirements directly impacting the Fuze and SAD Evolution

Conventional Safety Requirements

Better Operational Flexibility
Multi-modes / Mode Selection

New Safety Requirements

Terminal Effect Improvement + Collateral Damage Reduction
New Requirements - New Trends

- New Generation of Conventional Munitions
- "Smart" Munitions
- Guided Munitions
- Missiles

New Needs for Safety & Arming & Firing Unit

Munition - Weapon System

Operational Flexibility

Terminal Effect
New Fuze / S&A Device Requirements

New Trends

- IM (Insensitive Munitions)
- STANAG 4187 (2nd Safety Feature)
- STANAG 4368 – Motor ISD
- Self-Destruct Feature
- Self-sterilization / self-neutralization
- Overflight Safety
- Mission Abort
- Back-to-Safe
- Fail-Safe Design

Safety & Arming & Firing Device

- Tailorable / Scalable Effects
- Tunable / Aimable Warhead
- Collateral Damage Reduction
- Hard Target Fuzing

Operational Flexibility
- Multi-mode / Multi-missions
- Mode Selection Before Flight / In-Flight

Modularity

Terminal Effect

- Miniaturization
- Shock hardening
New Requirements - New Functions

**Need for a Safety, Arming and Firing Function**

with

- New Functionalities
- More Flexibility
- More Control

- **Multi-mode / Multi-missions**
- Mode Selection
  - Before Flight / In-Flight
- **Modularity**
- **Miniaturization**
- **Shock hardening**

- IM (Insensitive Munitions)
- STANAG 4187 (2\textsuperscript{nd} Safety Feature)
- STANAG 4368 – Motor ISD
- Self-Destruct Feature
- Self-sterilization / self-neutralization
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New Functionalities

Control of the arming sequence

Activation / de-activation

Arming / de-arming

Programming / Control of arming delay

Control of several initiation points - Timing Sequence

Processing & Management of safety signals delivered by the weapon / munition

Communication with the other modules from the fuze, munition or weapon system

Needs
Electronic Control of the Safety & Arming Function

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New Challenges for the Fuze/ SAD Designer

● **Introduction of electronics in mechanical / electromechanical SAD design**
  - Power supply issues
  - Low power electronics
  - Low energy initiators
  - Design of safety architecture, Fail-safe
    - Hardware
    - Software

● **Resistance to more and more severe environments**
  - Specific integration techniques (electronics)
  - Potting technologies
  - Shock filtering and absorption solutions
  - Mechanical shielding solutions

● **Miniaturization**
Technical solutions
Solution: SAD Electronically Controlled

- Need for control of the safe & arm functions: Electronic command of the SAD
- Two S&A Device technologies are suitable to achieve this function:

**Electromechanical SAD**

*Interrupted Firing Train*

**Electronic SAD**

*In-line S&A Device*
Electromechanical & Electronic SAD - Product Trends

**Electromechanical SAD**

**Now**
Missile and aerial bombs, some munitions

**Trend**
All type of munitions, small missiles

**Electronic SAD**

**Now**
High value missiles, Aerial bomb

**Trend**
Aerial bombs, small missiles, smart munitions
The 2 technologies EMSAD and ESAD evolve and develop together, even in different ways.
Electro-Mechanical S&A Devices
Electro-mechanical SAD
Main Principles & Technologies

● **Principle**
  ■ Firing train interruption by safety barrier (shutter)
  ■ Arming operation: firing train alignment by shutter movement
    ● Operated by actuator
    ● Electronically controlled

● **Technologies**
  ■ Micro-mechanisms
  ■ Actuators
    ● Piston actuators (explosive)
    ● Electromagnetic actuators
  ■ Fail-safe electronics
  ■ Fail-safe software

● **Possible use of new technologies for micro-actuators**
  ■ Piezo-motors
  ■ Silicon MEMS micro-actuators

**Electro-mechanical SAD**
**Main Principles & Technologies**

**Technologies**
- Micro-mechanisms
- Actuators
  - Piston actuators (explosive)
  - Electromagnetic actuators
- Fail-safe electronics
- Fail-safe software

**Possible use of new technologies for micro-actuators**
- Piezo-motors
- Silicon MEMS micro-actuators
Exemple of current, in-service product

- **Tank Ammunition Fuze DM173** for DM11 round (120mm)

- **Programmable fuze**
  - Impact - Impact Delay
  - Airburst (from 64ms to 12s)
  - Self-destruct

- **SAD operation**
  - Safety criteria: acceleration detection and gas pressure switch
  - Electronic control of the SAD arming with piston actuator

- **In production, in service with the German Army and the US Marine Corps**
Survivability to impact/penetration shock
Cylinder diam. 20mm x 22mm includes:

- Safety electronics
- 1st safety event
- Firing train interruption device
- Explosive train
- Piston actuator
- Explosive output

Integration in a mortar multi-function fuze
Miniaturized Electro-Mechanical SAD

- Qualified in tube launched environment (mortar and artillery)
  - 1st safety event: setback acceleration, mechanical switch integrated in the SAD
  - 2nd safety event: provided by the fuze control electronic module (flight detection, electronic)

- Adaptable to other type of munitions, with suitable external safety event
  - "Smart" fuze and Guided munitions fuze, artillery, mortar, etc
  - Shoulder-launched weapon
  - Any other warhead S&A devices

VULCANO Guided Munition With MEMSAD
New Generation Electro-Mechanical SAD and ISD (Motor Ignition)

- New foreseen uses - Main Challenges:

- SAD for warhead in smart/guided munition (tube-launched munitions, rockets, small missiles)
  - Various environmental conditions: with or without spin, acceleration/shock conditions, etc...
  - Safety event sensing

- ISD for rocket motor
  - Low cost/small missiles
  - Air-launched or surface-launched munitions/missiles
  - STANAG 4368 compliance
  - Firing train alignment reversibility

- SAD for warhead for "soft" environment munition
  - Safety event sensing
Electronic S&A Devices
Electronic S&A Device – Main components

Key components of the fireset
- EFI
- HV capacitor
- HV switch
- Voltage converter

EFI (Exploding Foil Initiator)
Slapper Detonator

Interface Electronics
Control Electronics (Safety Management)
High Voltage and Firing Electronics

Mechanical Structure
Environment/ Safety Event Sensors

ESAD

Fireset
High level of insensitivity (IM) with secondary explosives

Resistance to electromagnetic and electrostatic disturbances

Able to withstand very high mechanical stresses (hard target penetration)

Flexible: electronic safety management and safety event processing

Makes testing operation easier during the whole life-cycle

Come back to initial safe status in case of system failure (collateral damages and UXO risk reduction)

Enables "smart warhead" design (multipoint initiation, precise ignition timing)

STANAG 4187 ed.4 safety design compliant
Company background in ESAD / EFI area

30 years experience in ESAD and slapper detonators


VT1 ESAD
ASTER ESAD
AS30LS ESAD
ASTER (2) ESAD
FBM21 Bomb Fuze
Heavyweight Torpedo Fuze
FBM21 Upgrade (LEEFI)

1990
2000
2010
2015

Strip line EFI
Plug-in EFI
LEEFI study start (PV)

SCB LEEFI research (MCM ITP FR-UK)

French MoD contract awards for LEEFI development

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Exemples of current, in-service product

- **FBM21 Aerial Bomb Fuze**
  - Multirole Fuze: General Purpose and Penetration / Hard target capability. Proximity mode (with external sensor)
  - For use with 3" fuze pocket bombs, dumb or guided bombs, Paveway II & III, Enhanced Pw II & III, AASM (Hammer), JDAM
  - In mass-production since 2009, combat proven
LEEFI-based SAD

- Interface Electronics
- Control Electronics (Safety Management)
- Environment/Safety Event Sensors
- High Voltage and Firing Electronics
- EFI
- Fireset (1000 to 1500V)
- ESAD

Replacement of Triggered spark gap switch by new HV switch solution

1500V capacitor instead of 3000V capacitor
Main benefits provided by LEEFI technology (Low Energy Exploding Foil Initiator)

- Lower design constraints
  - Circuit layout is made easier due to reduced voltage
  - Increased margin

- Smaller size
  - Smaller circuit design and smaller high-voltage components
  - Adaptability to various applications sizes and form factors
  - Higher resistance to high shock

- Lower cost
  - Lower voltage enables the use of standard components instead of application specific HV components

Enable the use of ESAD solutions in a broad range of applications, for both munitions and missiles
Main/ New Applications for LEEFI Based ESAD

- **Rocket Motor Ignition**
  - STANAG 4368 compliance
  - Possibility of multi-pulse ignition (dual stage motor)
  - Possible use of TBI (through bulkhead initiation device) or direct ignition of propellant
  - Adaptation to various form factors

- **Smart warhead initiation**
  - Multi-point initiation for selectable and tailorable effects
    - Smaller size firesets
    - Precise control of timing
  - Possible combination of both Warhead and Rocket Motor safety/firing control device

- **Guided munitions and small missiles warhead SAD**
  - Fuzing/SAD functions distributed
  - Multi-point initiation
J UNGHANS Defence's LEEFI Based Fireset Development Main Objectives

- Rely on company background, proven through several EFI and ESAD products design and manufacturing
- Select key materials and components of the LEEFI and fireset from secured supply chains
- Optimize the LEEFI-based fireset design and manufacturing, as a whole (not only as single LEEFI component)
- Design LEEFI/Fireset capable of all expected applications from hard-target weapon to aerial-target weapon, for warheads and rocket motors
- Consider industrial constraints, either in the manufacturing process or from the supply chain
  - Keep required performances even with possible deviations from materials and components

Versatile LEEFI based fireset with robust design
LEEFI-based Fireset and ESAD

- Development programme supported by French MoD (DGA) through two R&D contracts, now completed
  - Development of LEEFI-based ESAD, suitable for several applications, including hard-target fuze
  - Design/validation of LEEFI-based ESAD able of multipoint initiation (ignition) warhead (up to 6 initiation points)

- Objective: obtain mature technology enabling new ESAD/Fuze development
  - LEEFI characterized according to STANAG 4560
  - Fireset and ESAD performances validated in relevant environment conditions (shock / acceleration, extreme temperatures)

Significant support from French MoD (DGA) has enabled to achieve mature design of a LEEFI and LEEFI based Fireset
**Main Achievements**

**LEEFI & Fireset critical components**

- **LEEFI design: Validation of the main parameters**
  - Operating voltage and fusing bridge/flyer characteristics
  - Explosive material compound
  - Plug-in LEEFI component
  - High shock resistance validation: tested on concrete slab firing shock > 10,000g
  - STANAG 4560 characterization

- **High-Voltage Switch: Assessment of various options**
  - COTS solid-state components
  - Design of a new silicon switch (MOS technology) from European founder
  - Design of an alternative "hybrid" HV switch solution: Selected option

**LEEFI and Fireset key components are validated with the whole spectrum of specifications**
Main Achievements

Fireset module and ESAD Modules

- Fireset module: designed in view of distributed multi-point initiation
  - Tested under high-shock condition (hard target penetration)

- Other fireset designs achievable, with different form factors, distributed or integrated within ESAD / ISD

- Design and validation of a LEEFI version specifically adapted for rocket motor ignition, directly igniting propellant
  - Small size and cost-effective solution compared to the use of TBI component

LEEFI-based ESAD, compliant with STANAG 4187 and 4368, tested in operational munition environment
Hard Target - Shock Test

Video
The ultimate wish

- Re-use of proven technical solutions/modules: "off-the-shelf" (or nearly OTS) "pin-to-pin" compatible device!

Main issue: Munition or Missile Applications often require:

- Specific interfaces, size, safety events/signals, power supply
- Specific environment and stress resistance (hard target or not)

The realistic view

- Getting a real generic S&A solution is a problem
- A more realistic option is to share and re-use basic design and common technology
  - Common architecture and design
  - for Electromechanical SAD: re-use the interruption train system and electronics
  - for ESAD: re-use the fireset and electronic architecture
Conclusion

- Modern S&A and Firing devices have to deal with new requirements for munitions and missiles, in terms of performances and safety features.
- New microtechnology solutions as well as electronic integration techniques lead to significant improvements in both Electromechnical S&A device and ESAD domains.
  - Providing additional functions to S&A Devices, suitable for modern use of munitions.
  - Enabling the use of these technologies in a broader range of application.
Thank you for your attention.

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