MSIAC
Munitions Safety Information Analysis Center

Remote Controlled Fuzing

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Jakob Breiner
TSO Warhead Technology
j.breiner@msiac.nato.int

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Agenda

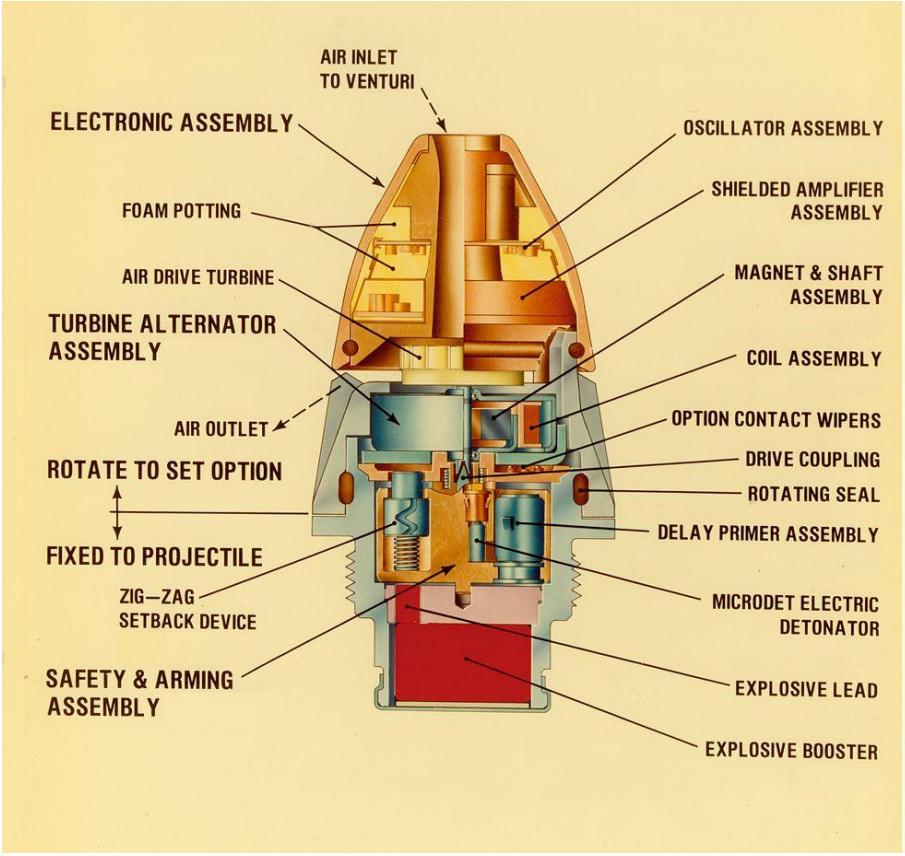
- How SAF systems usually work
- The problem with remote-control in the arming process
- General safety considerations
- RC arming process
- Outlook

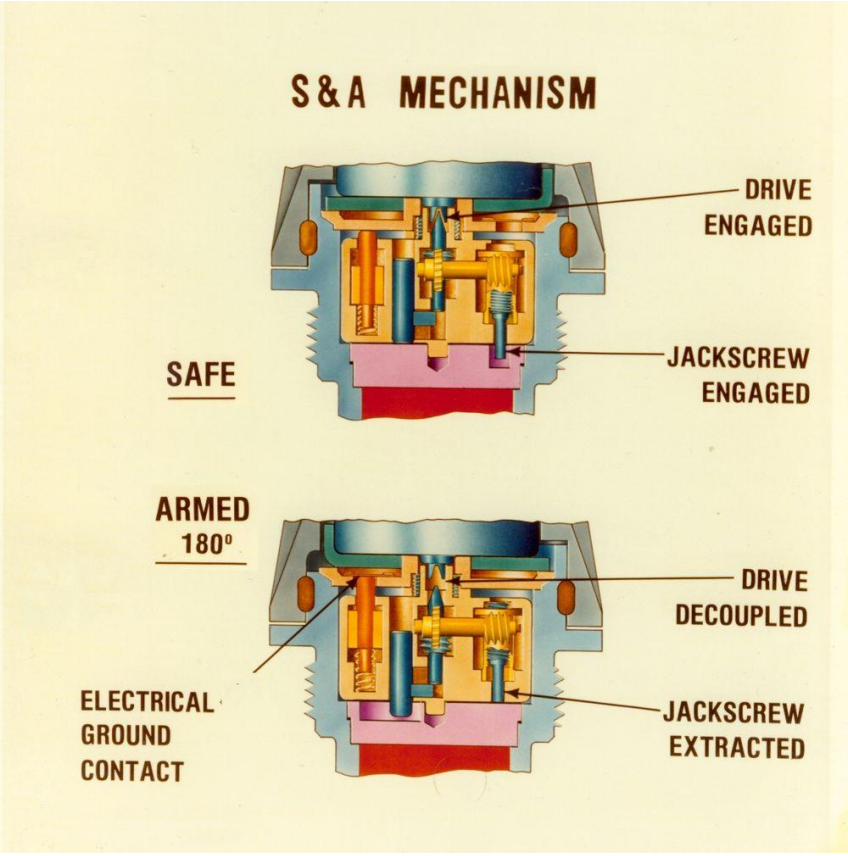
How SAF systems usually work: M734

Out-of-Line System / Electro-Mechanical SAF-Systems

- M734 Light Mortar Fuze [1, 2]



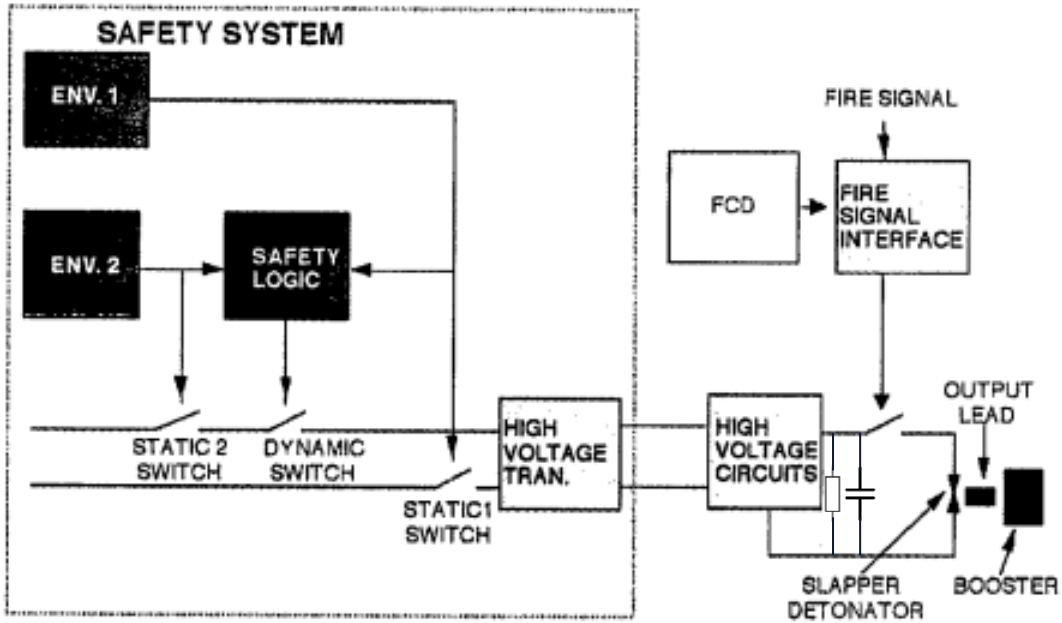




How SAF systems usually work : Basic ESAD Layout

In-Line Systems / Generic ESAF Design

- Features
  - Low side switch (Static 1; Env. 1)
  - High side switch (Static 2; Env. 2)
  - Dynamic switch
    - Coupled to safety logic (e. g. additional time delay)
    - Creates pulse req. for HV
- Additional features are possible if a feedback to the safety circuit can be excluded (e. g. by optocoupling)



Generic ESAF Design (based on [3])

The problem with remote-control

RC in the arming process

- AOP-4187 [4]:
  - Arming process based on sensing two independent, functionally isolated environmental criteria
    - One criteria required to ensure safe separation distance
    - One criteria featured on sensing first motion or post-launch environment
    - No sensing prior to launch cycle
  - **No Operator influence to arming**
  - Arming shall not rely solely upon defined operating drills or procedures to provide safety (*soldier-proof*)
  - Safety shall be maintained under all environmental conditions and credible accident scenarios
  - Elements of fuzing system that prevent arming should be located in a single safety and arming device

- Remote control is only compliant with AOP-4187 as following *on-top* safety method
- As AOP-4187 is the overarching standard, this is the (only) way



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The problem with remote-control

RC in the arming process

- AOP-4497 [5]:
  - Following munitions are excluded […] (5) Networked Munitions
  - Design shall ensure that
    - Independent safety feature controls […] are physically separated
  - Prior to commencement of the arming sequence. The probability of arming, or functioning irrespective of arming, between manufacture and the intended commencement […] shall not exceed one in a million

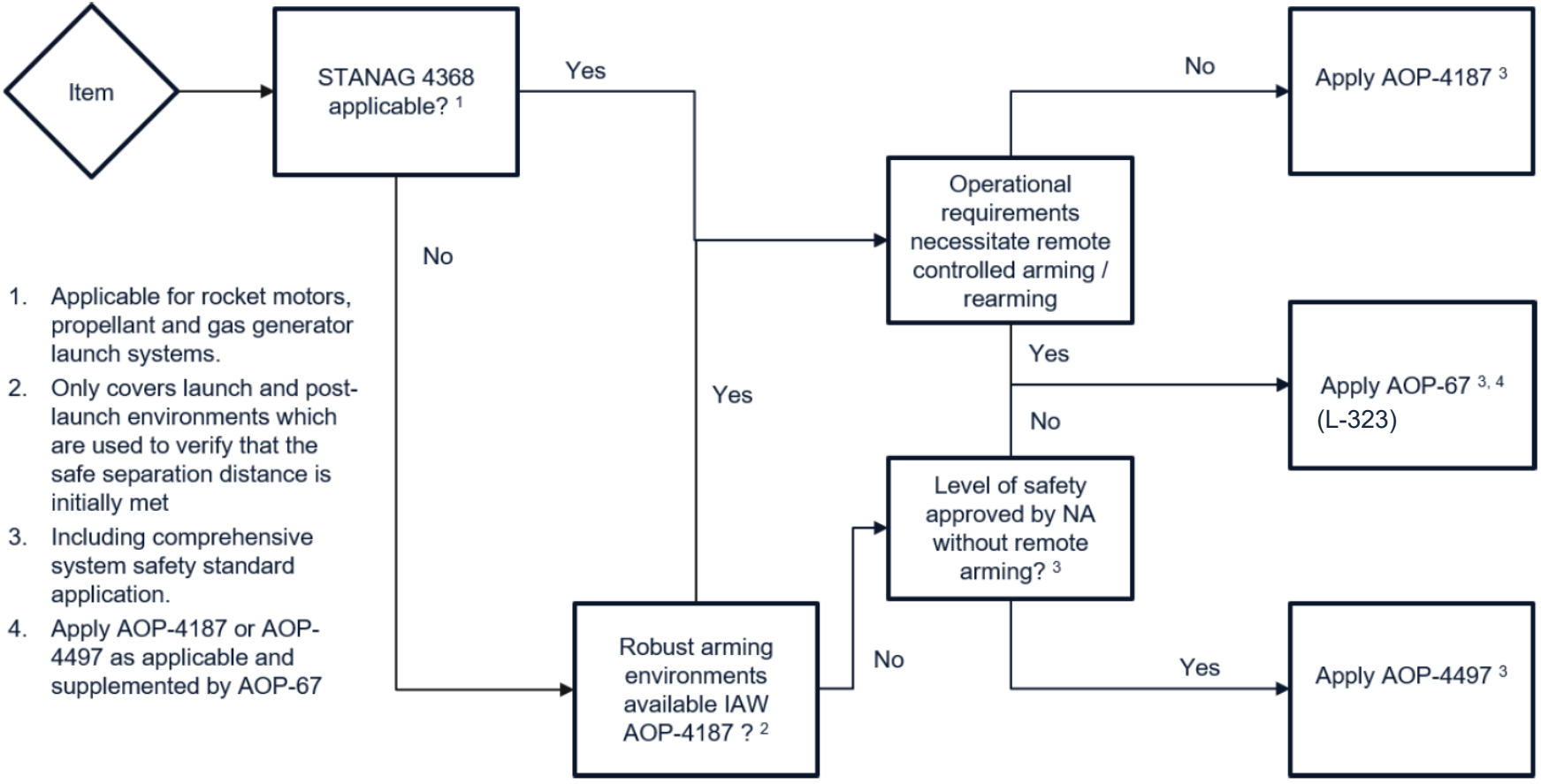
- Remote control is only compliant with AOP-4497 as
  - Replacement of one arming event (**only by exception**)
  - Following *on-top* safety method **(preferred)**

- As AOP-4187 is the overarching standard, this is the (only) way (exclusively for HEMs without robust arming environments)



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General safety considerations



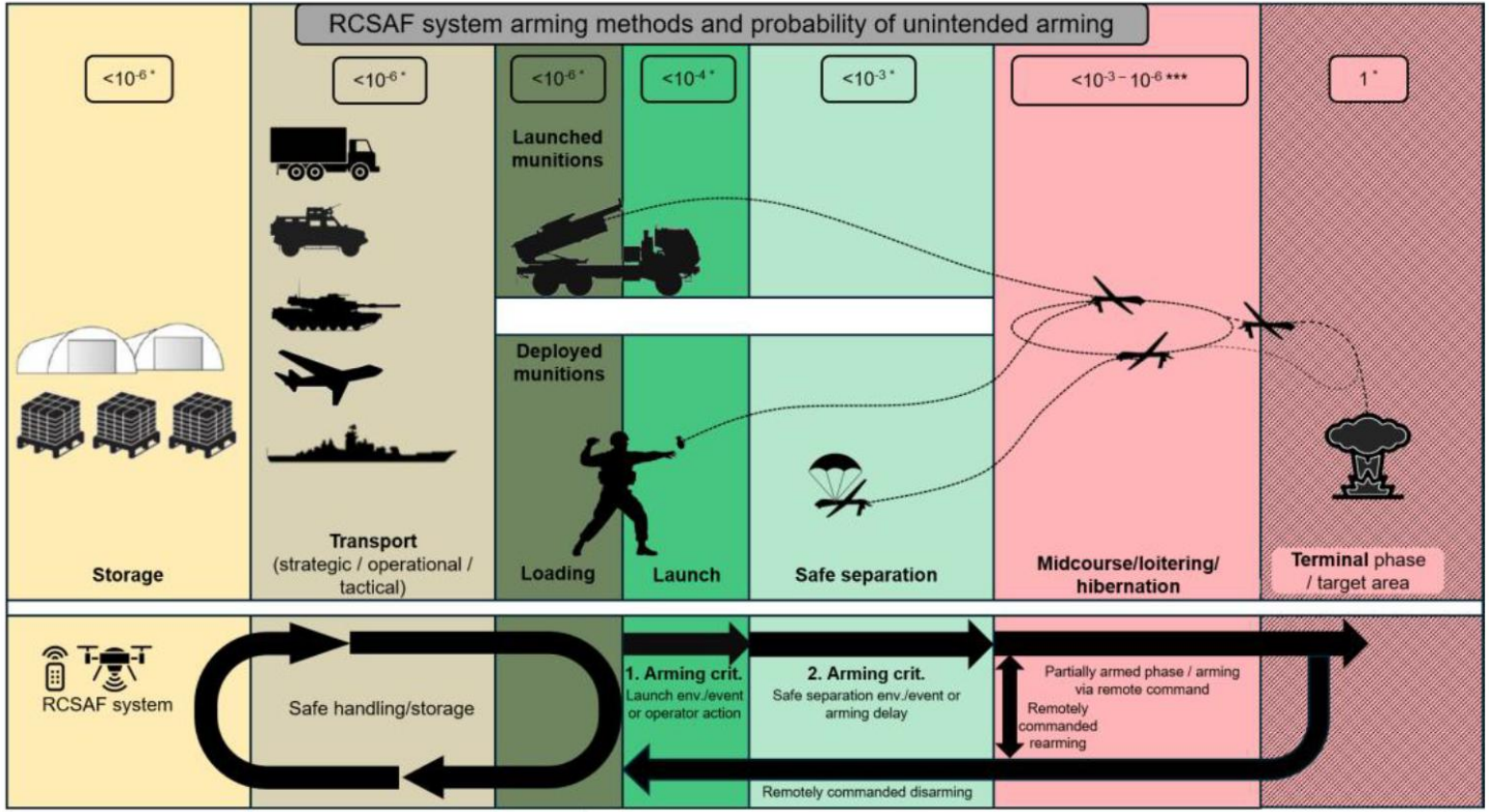
General safety considerations

RC Arming:

- All AOP-4187 states apply
- Additional states might be implemented
  - Should refer to AOP-4187 states e.g. *Ready-to-Arm* = *Partially Armed*
  - Allows for requirements alignment e.g. *Ready-to-Arm* = 10^{-4} probability of unintended arming

Ser	Term	Description	
		Interrupted Explosive Train SAD	Non-Interrupted Explosive Train SAD
(a)	(b)	(c)	(d)
1	Unarmed	Interrupter locked, by all safety features, in the original position designed to prevent initiation of the main charge by the detonator.	Firing Capacitor Energy (FCE) shall not be present. All safety features in their original unpowered condition shall prevent accumulation of FCE (power supply to the SAD is off).
2	Partially Armed	The interrupter is in any position where the probability of initiation of the main charge by the detonator is less than 0.005 at the 95% single sided lower level of confidence, but with the safety features not fully applied as in the unarmed state.	FCE is greater than in the unarmed state and/or the Safety Features are not all fully applied. The FCE is less than the Armed Stimulus of the Electro Explosive Device.
3	Armed	The interrupter position is such that the probability of propagation of the explosive train is ≥ 0.005 at the 95% single sided lower level of confidence.	The FCE is greater than or equal to the Armed Stimulus of the Electro Explosive Device.
4	Partially Disarmed	A state in which the SAD, having been armed, is in any configuration where the probability of initiation of the main charge by the detonator is less than 0.005 at the 95% single sided lower level of confidence, but with the safety features not fully applied as in the disarmed state.	After having been armed, the FCE is greater than in the unarmed state and/or not all the Safety Features are fully applied. The FCE is less than the Armed Stimulus of the Electro Explosive Device.
5	Disarmed	A state in which the SAD, having been armed meets all of the following: a. Is rendered incapable of functioning the main charge. b. Meets the safety requirements of Paragraph 3.3.1. c. Can be rearmed.	A state in which the SAD, having been armed meets all of the following: a. Firing capacitor energy shall not be present. b. Meets the safety requirement of Paragraph 3.3.2. c. Can be rearmed.
6	Sterilized	A state in which the SAD is rendered permanently incapable of functioning the main charge. This shall be accomplished by either removal of the detonator or permanent interruption of the explosive train, or similar means.	A state in which the SAD is rendered permanently incapable of functioning the main charge.
7	Self-functioned	The SAD is armed and functioned deliberately, without necessarily sensing a target, with the purpose of functioning the main charge.	The SAD is armed and functioned deliberately, without necessarily sensing a target, with the purpose of functioning the main charge.
8	Self-disrupted	The SAD (or Secondary SAD) is functioned deliberately, without necessarily sensing a target, to operate a specific mechanism with the purpose of breaking up the munition without functioning the main charge.	The SAD (or Secondary SAD) is functioned deliberately, without necessarily sensing a target, to operate a specific mechanism with the purpose of breaking up the munition without functioning the main charge.

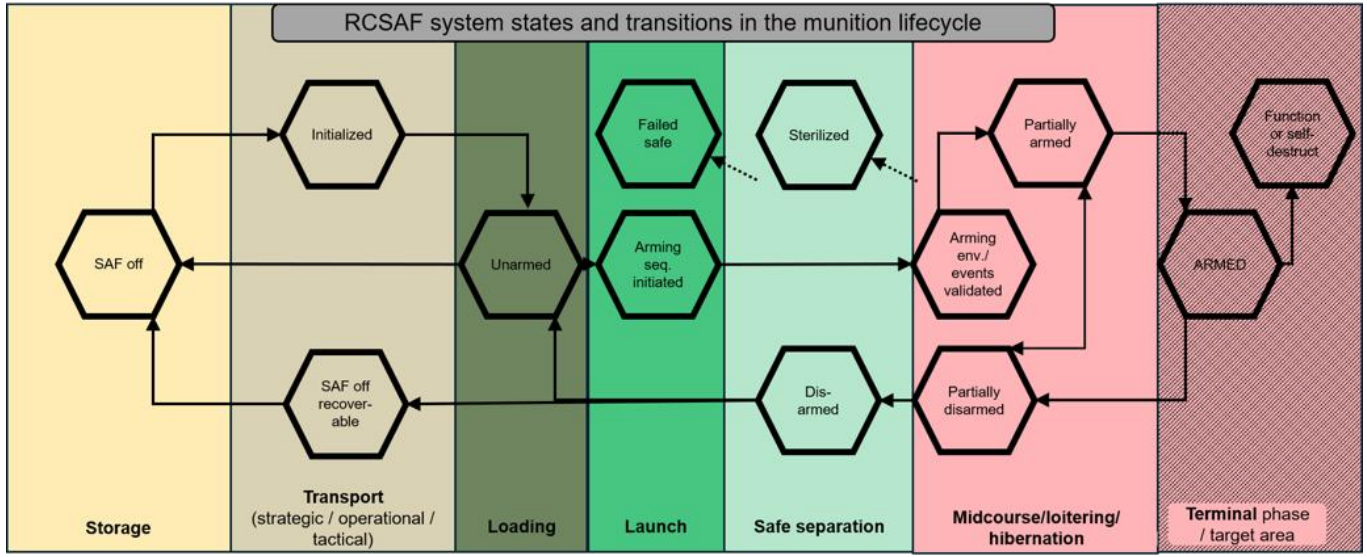
RC arming process



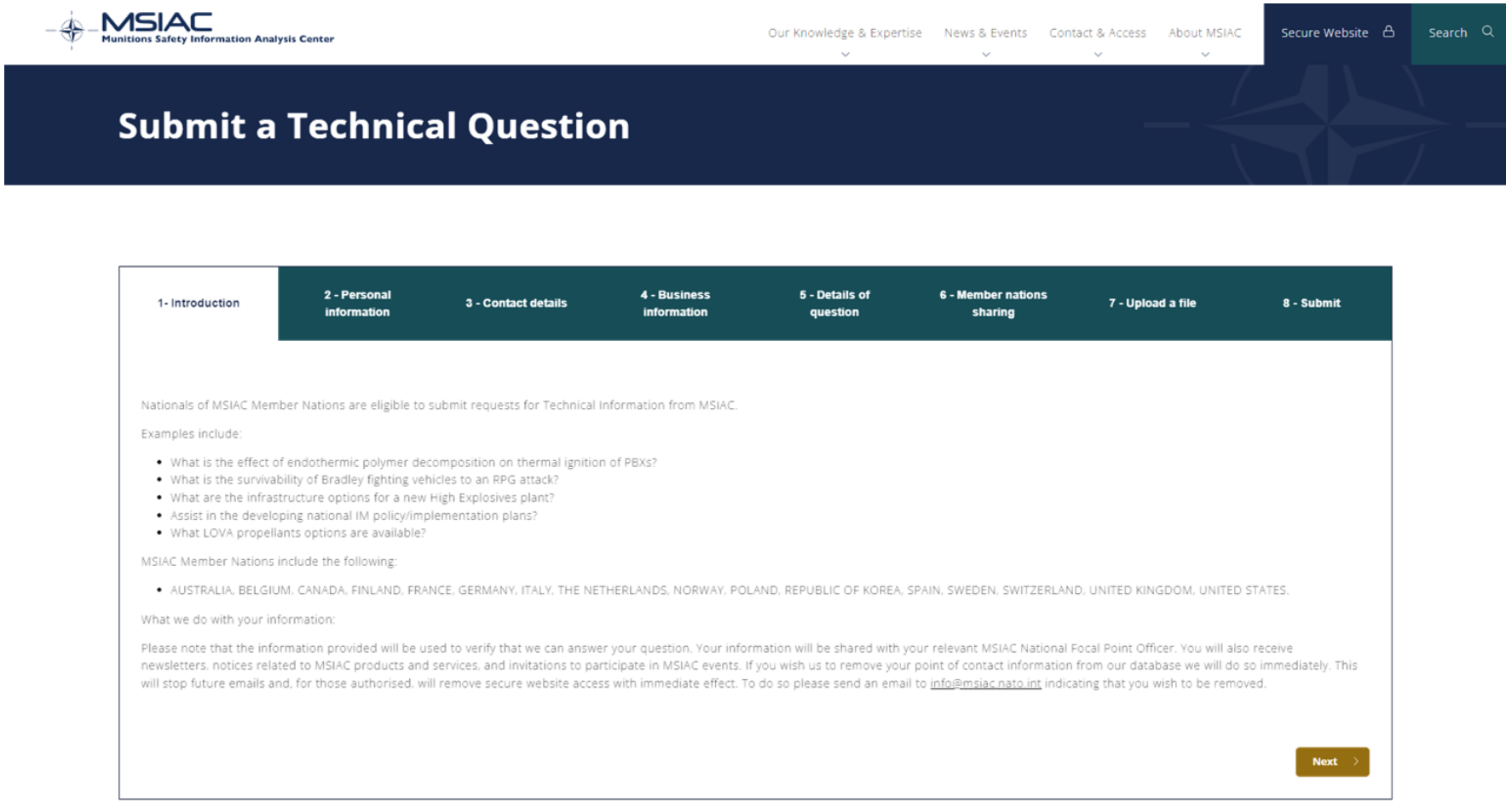
* Acc. to AOP-4187 Ed A, V 1, June 2022
** Acc. to AOP-4497 Ed A, V 1, Sept. 2020
*** Depending on the system requirements, 10^{-4} recommended

Outlook: Future SAF system challenges

- Some applications require many remote controlled states (e.g. Aerial Loitering Munitions, smart Area Denial Systems, etc.)
- L-323 provides comprehensive guidance on the internationally acceptable procedures, SAF system arming states and safety requirements (reviewed by UK and US safety board SMEs)
- Other important documents
  - USA: JOTP-57
  - GBR: WTS/0730
  - NATO: AOP-67 (draft) publication expected early 2028



Online Technical Questions Form



Questions



References

[1] L3Harris, *M734A1 Multi-Option Fuze for Mortars*, https://www.l3harris.com/sites/default/files/2021-08/as-pes-resource-fos-m734a1-mofm.pdf, accessed 13.09.2023, published 08/2021

[2] Military-History, *M734 Fuze*, https://military-history.fandom.com/wiki/M734_fuze, accessed 20.10.2026

[3] Fowler S. E., *Safety and Arming Device Design Principles*, Naval Air Warfare Center Weapons Division, https://apps.dtic.mil/sti/pdfs/ADA363924.pdf, Published by DTIC, accessed 20.10.2026, China Lake, CA, May 1999

[4] NATO, AOP-4187, *Fuzing Systems – Safety Design Requirements*, Edition A, Version 1, NATO Standardization Office (NSO), June 2022

[5] NATO, AOP-4497, *Hand-Emplaced Munitions (HEM), Principles for Safe Design*, Edition A, Version 1, NATO Standardization Office (NSO), Sept. 2020