MSIAC
Munitions Safety Information Analysis Center

Supporting Munitions Safety

Safety considerations for drone-like munitions

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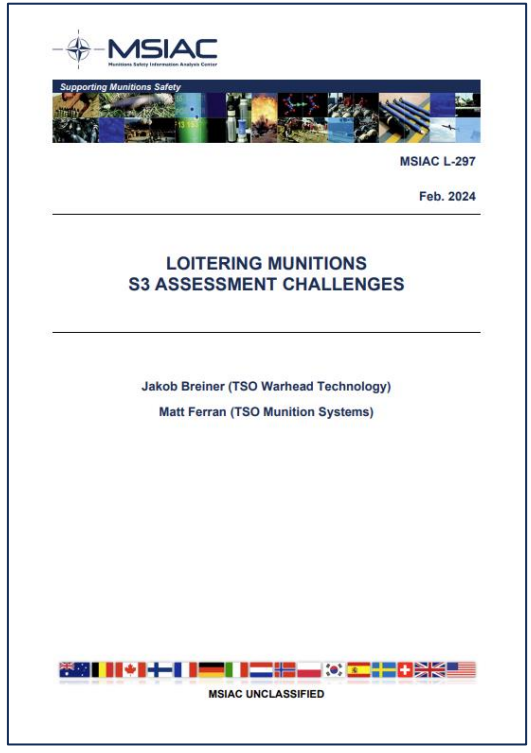
Agenda

- Some background information
- Terminology and categorization
- Safety issues
- Airworthiness discussions
- Conclusion

Background information

- MSIAC Limited Report **L-297 Loitering Munition S3 challenges** was released in February 2024 exclusively to MSIAC nations
  - Approval to NATO and EDA granted
  - Distribution to non-MSIAC nations requires steering committee approval

➢ MSIAC nations gov. or industry can access the report via the MSIAC homepage



Background information

https://www.dailykos.com/stories/2023/4/13/2163703/-Quick-Explainer-Ukraine-s-FPV-drones-may-be-deadlier-than-people-surmised

https://turdef.com/article/ukraine-is-set-to-produce-one-million-fpv-drones-in-2024

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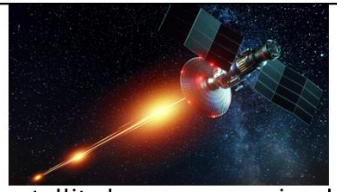
https://interestingengineering.com/military/ukraine-drone-anti-tank-missile

https://www.youtube.com/watch?v=0xfG8CXizho

Terminology and categorization

Loitering Munition (LM) Alignm

	Doctrine Purist - A LM must destroy a target -	**Doctrine Ne** - A LM must incapac
Structure Purist - A LM is single-use -	 A UVision HERO 120 is a LM	 A Honeybee is a loitering munitio
Structure Neutral - A LM delivers an effect -	 A crop duster is a LM	 A Home-Liquor delivery is a LM
Structure Radical - A LM is anything that loiters in an area -	 A satellite laser weapon is a LM	 Parents-in-law are LM

Op. Environments to be considered:
Air
Land
Sea
Subsea
Space

A self-deleting message is a LM
COVID vaccines are LM


Peaky Blinders are LM

Terminology and categorization

https://www.youtube.com/shorts/r7v-8l0gvR0?theme=dark

Is this a Loitering Munition operation by definition?

Terminology and categorization

- Definition of what a Loitering Munition is
  - NATO definition too vague
  - Variety of airborne systems already too large for a precise definition
  - Mix of sea, subsea, land and air vehicles
  - Very close relationship to munition-dropping UAS

- MSIACs definition of airborne LM, adapted by NATO AC/326 and AC/225:

A Loitering munition is a lock-on-after-launch operated guided munition following a non-ballistic and operator influenced trajectory and is capable of non/beyond line-of-sight target verification and precision attack, ***which is destroyed by functioning of its payload****.*

Covers all types of: *Suicide-drones, kamikaze drone, single-way-attack-drones, …*
Does not cover: *Any drone that drops or launches a (modified) munition (i.e. Hand grenade)*

Terminology and categorization

- No Loitering Munition categorization scheme exists; UAS schemes comparably coarse
  - ➢ Merged NATO/US DoD/EASA system suggested
- Matching with UAS airworthiness requirements
  - No NATO standard for rotary wing < 150 kg ident.
  - STANAG 4703 / AEP-83 (fixed wing < 150 kg) utilizes elements from manned aircraft regulations
  - EASA Specific or Certified (= manned aircraft) category operation
    - – Specific op. based on predefined missions or specific operations risk assessment (SORA) and the specific assurance integrity level (SAIL) of the UAS
    - – Specific category is questionable if a warhead is involved
    - – GBR and AUS Mil. UAS regulations reflect the EASA framework to large parts

MTOM	NATO	US DoD	EASA
< 0.25 kg	Class I Micro (max. 66J, 200 ft AGL)	Group 1 (max. 100 kn / 1200 ft AGL)	Open / C0/1 (max. 120 m AGL; Alt. Specific)
< 0.90 kg	Class I Micro (max. 66J, 200 ft AGL)		
< 4 kg	Class I Micro/Mini		Open / C2 (max. 120 m AGL; Alt. Specific)
< 9 kg	Class I Mini (max. 2000 ft AGL)		
< 15 kg		Group 2 (max. 250 kn / 3500 ft AGL)	Open / C3 or C4 (max. 120 m AGL; Alt. Specific)
< 25 kg	Class I Small (max. 5000 ft AGL)		
< 150 kg		Group 3 (max. 250 kn / 18.000 ft MSL)	Specific Category (Authorization by STS, PDRA, SORA, or LUC)
< 600 kg	Class II (max. 18.000 ft AGL)		
> 600 kg	Class III	Group 4 / 5	Certified Category

Terminology and categorization

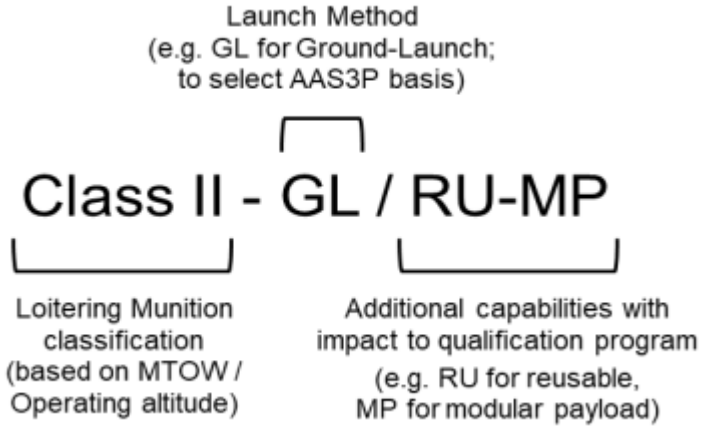
- Classification system based on merged UAS classes
  - Based on NATO, US DoD and EASA
  - Nano/Micro/Mini/small not to be mixed up with NATO classes → different MTOW
  - No rotary wing LM > 15 kg identified !

➢ Recommended for NATO standardization by AC/225

LM class	MTOM	Rec. max. op. alt.	Subcategory	Ref. UAS standard (adapted to LM)	Exemplary system
Class I Nano	< 4 kg	300 m AGL	Fixed-Wing	DoD UAS/Group 1 [21] STANAG 4670/I Micro [20] STANAG 4703/AEP-83 [35] EASA specific/cert. [22]	Aerovironment Switchblade 300 [11]
			Rotary-Wing		Raphael Spike Firefly [14]
Class I Micro	4 – 9 kg	300 m AGL	Fixed-Wing	DoD UAS/Group 1 [21] STANAG 4670/I Mini [20] STANAG 4703/AEP-83 [35] EASA specific/cert. [22]	WB Warmate [4]
			Rotary-Wing		IAI Rotem [24]
Class I Mini	9 – 15 kg	1100 m AGL	Fixed-Wing	DoD UAS/Group 2 [21] STANAG 4670/I Mini [20] STANAG 4703/AEP-83 [35] EASA specific/cert. [22]	IAI Green Dragon [12]
			Rotary-Wing		Diehl Libelle [5]
Class I Small	15 – 25 kg	1100 m AGL	Fixed-Wing	DoD UAS/Group 2 [21] STANAG 4670/I Small [20] STANAG 4703/AEP-83 [35] EASA specific/cert. [22]	UVision Hero 120 [3]
			Rotary-Wing		-
Class II	25 – 150 kg	5500 m MSL	Fixed-Wing	DoD UAS/Group 2 [21] STANAG 4670/I Mini [20] STANAG 4703/AEP-83 [35] EASA specific/cert. [22]	Elbit Skystriker [7]
			Rotary-Wing		-
Class III	150 – 600 kg	5500 m MSL	Fixed-Wing	DoD UAS/Group 3 [21] STANAG 4670/II [20] STANAG 4671 [34] EASA certified [22]	MBDA Fireshadow [6]
			Rotary-Wing	DoD UAS/Group 3 [21] STANAG 4670/II [20] STANAG 4702/AEP-80 [36] EASA certified [22]	-

LM Report summary

- Introduction of a tag system
  - to identify S3 relevant capabilities
  - Catalogue to be enhanced in the future



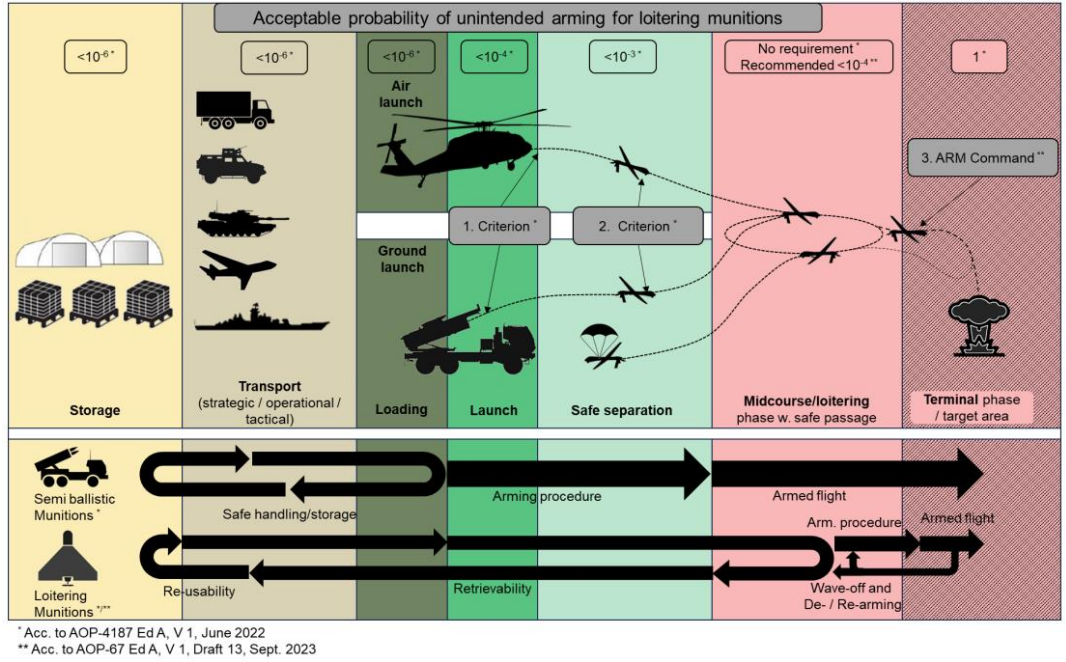
Tag	Category	Description
ML	Launch	Man or hand launched system Apply AAS3P-10 (for soldier-mounted launch systems) or AAS3P-26 (for soldier-thrown/started systems; aft. promulgation)
GL	Launch	Ground, sea or underwater launched system (e.g., man-portable tube, or catapult launch); Apply AAS3P-11
VL	Launch	Vehicle launched system (ground/sea/underwater; e.g., vehicle tube launcher); Apply AAS3P-11
AL	Launch	Aircraft launched system (e.g., drop launch); Apply AAS3P-12
LC	Launch	Large-Caliber gun launched (>40 mm); Apply AAS3P-20
MC	Launch	Medium-Caliber gun launched (20…40 mm); Apply AAS3P-21 (after promulgated)
SC	Launch	Small-Caliber gun launched (<20 mm); Apply AAS3P-22
RT	Capability	Retrievable; Fuzing safety for transport required
RU	Capability	Directly or indirectly reusable; Implies RT cap.; Hazard and reliability measures required
MP	Capability	Modular interchangeable payloads with non-destructive characteristics (e.g., Warhead replacement by additional battery); High probability of UAS-certification necessity
SP	Capability	Safe Passage capability; Fuzing safety for overflying own forces required
WO	Capability	Wave-off capability; Disarming and Rearming required
AT	Capability	Participation in Air-Traffic; High probability of UAS-certification necessity
…	…	…

Safety issues

- Loitering Munitions areas of safety concerns
  - Fuzing
  - Software, datalink and electronic warfare
  - Weapon system autonomy

Safety issues

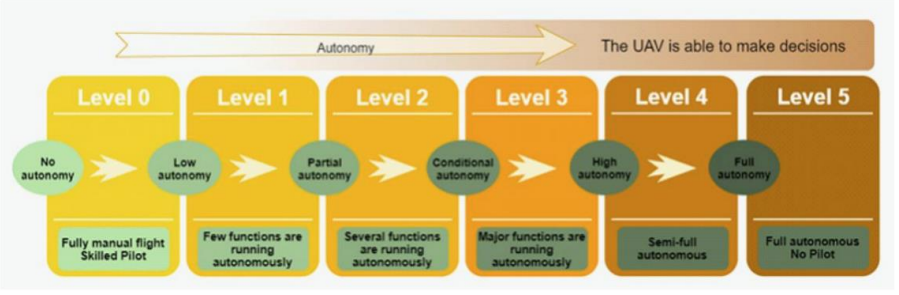
- Fuzing safety merges with system safety and safe-separation plus safe-passage challenges are very hard to meet with AOP-4187 conformal SAF units
  - AOP-67 not to be promulgated soon
  - Challenges can be met either by SAF sys. or safety crit. weapon computer which meets the requirements
  - ➢ **Very few COTS systems provide sufficient fuzing / system safety**



Safety issues

- Software, datalinks and electronic warfare
  - LM are digital & networked and extremely prone to SW/HW robustness and EW
  - General robustness to be ensured by DO-178C+DO-254 or IEC 61508 or AOP-52+MIL-STD-882 system level qualification (or comparable) → **Underestimated!**
  - Active electronic warfare hardening is **crucial**!
    - GPS jamming/spoofing is real (Example: JDAM in UKR > 30 m CEP)
    - Jamming of RC datalink is ludicrously easy
      - A civ. 10 km RC DL emits < 2 W of power, a R-330Zh jammer est. several kW
      - Back-up autonomy (i.e. sterilization or safe-zone termination) required
  - Cyberattacks will for sure happen and sufficient countermeasures are necessary
    - Hardening of the RC (at least AES-256 encryption, GCS pairing, etc. mandatory)
    - RC Arming (AOP-67) enables cyberattacks to target the warhead! Suitable AOP-4187 environmental criteria required to prevent premature arming/detonation.

Safety issues



- UAS / Weapon system autonomy
  - Full autonomy (lvl. 5, no human in the loop) is inacceptable
  - High level of autonomy by Human in or over the loop widely acceptable (semi-autonomous weapon system)
  - Subsystem autonomy levels up to 5 even necessary (!) as i.e. user input to arming is prohibited by AOP-4187
  - Examples of qualified highly autonomous weapon systems:

Airworthiness discussions

- Determination of a *red line* between airworthiness and non-airworthiness certified systems
  - ***Basic*** LM without airworthiness certification should have *missile like* conops
  - ***Complex*** LM with have capabilities that make airworthiness cert. mandatory to ensure safe operation
  - The *grey zone* between
    - Retrievable and indirectly reusable systems (refurbished by manufacturer)
    - Interchangeable lethal payloads (warhead variants)
    - Training and exercise units (depending on national policy)
    - Safe-passage capable systems with non-hazardous airframes
    - Air-launched *basic* LM systems
    - …

Conclusion

- The variety of munitions make a clear terminology picture necessary for meaningful discussions
- No agreed categorization system for loitering munitions exists, which prevents a standardized approach to safety and suitability for service (S3) assessments
- Promulgated NATO standards (based on the AAS3P-Series) can serve as framework for basic LM S3 programs
  - Special safety issues (i.e. fuzing and software safety) need to be addressed properly by the application of appropriate standards (most crucial: System Safety)
  - AAS3P-1.1 SRD (in drafting) will cover those specific topics
- Larger, more complex systems require larger, more complex S3 programs…
  - AAS3P-XX, AOP-4187 (or -67 in the future) and IEC 61508 (or DO…) still apply – Basic framework applicable but too limited for complex LM
  - Additional assessments regarding LM specific capabilities (reusability, modular payloads, air traffic deconflicting, …) necessary. The variety and uncertainty of LCEPs will drive the test efforts.

Thank you for your attention