Active Passive Mitigation Devices

S3 Assessment

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BACKGROUND

- Introduction of active mitigation systems has developed a need to better understand the safety and suitability for service assessment (S3)
  - Design guidance needed to advise manufacturers on what is likely to be acceptable
  - Guidance on test and evaluation; S3 assessment methodology also required

Guidance should ideally be available to mitigation device developers from concept

INTRODUCTION

The purpose of this presentation is to discuss the safety and suitability for service assessment of active and passive mitigation devices.

- Definitions of active and passive mitigation
- Examples of techniques
- Potential methodology for Safety and Suitability for Service (S3) assessment
- This presentation is not a national or international position.
- Paper was produced to help assist discussion in this area.

Mitigation Definitions

- Two subsets have been loosely defined: passive and active mitigation.
  - Passive Mitigation
    - devices which act in a manner which does not provoke a response from the energetic material; they do not contain energetic substance and do not do not themselves generate or provoke any explosive effects.
  - Active Mitigation
    - Active mitigation features include those which either develop thermal or explosive effects on action and/or can cause an energetic response from the munition system.

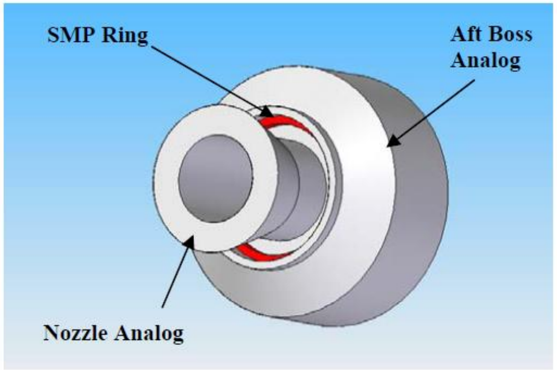
Passive Mitigation Examples

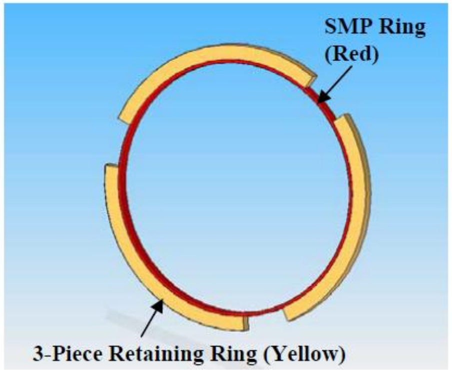
- Many techniques have been developed and are in service.
- Typical examples include:
  - Enclosure release using meting or softening of components
  - Use of Shear bolts
  - Preferentially weakened case (stress raisers)
  - Intumescent pain
  - Venting paths
  - Shielding for mechanical and thermal threats
  - ……

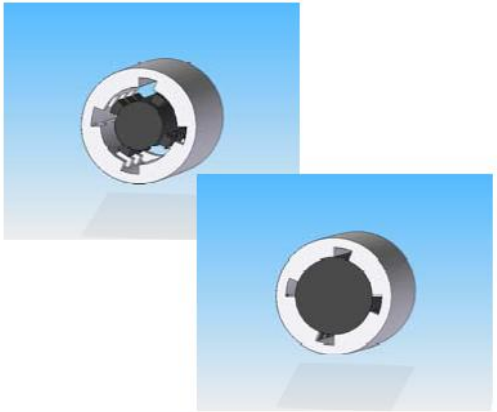
Passive Mitigation Examples

Composite Case technology

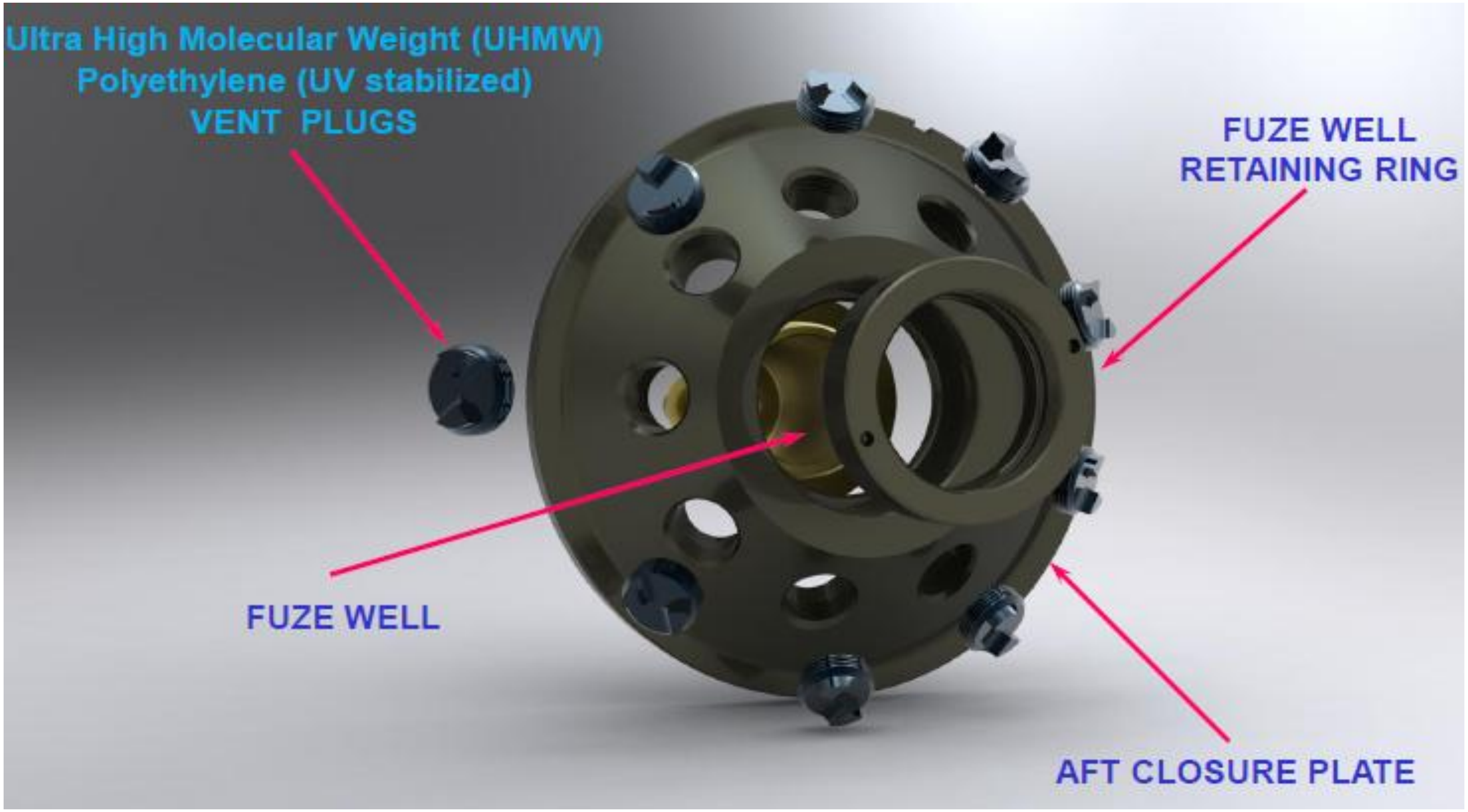
Venting technology using Shaped Memory Polymers -
Michael Fisher
Cornerstone Research Group, Inc.
IMEMTS 2010







Passive Mitigation Examples



Venting Techniques for Penetrator Warheads –
Stephen Kelley Air Armament Center USAF
IMEMTS 2010

Active Mitigation Examples

- Although not as widely used there has been a renewed interest in such devices primarily to reduce violence to thermal IM threats.
- Latest examples include:
  - ‘Poison Pill’ type devices – energetic material selected and placed to ignite vulnerable energetic fills below their ignition temperature
  - External sensor detects temperature and when critical conditions are reached initiates a firing train. The result can be:
    - Case weakening or disruption
    - Early ignition of energetic payload
    - Controlled location of ignition
- One example widely reported:
  - TIVS (thermal initiated venting system) used on US aircraft carrier destined AIM 120 AMRAAM missiles

Design Requirements

- A key requirement is that the introduction of IM mitigation technology improves the level of safety throughout the environment lifecycle profile. It must be assessed for:
  - IM Mitigation Technology Benefit for specific weapon application
    - Impact over whole environmental lifecycle profile
    - Identify consequences of activation of device
  - Effectiveness of the technology
    - Designed not just to pass a test but to address threat range over lifecycle
  - Initiation Boundary Conditions
    - Comprehensive Failure Modes and Effects Analysis with Acceptable Risk
    - Accident response issues (possible early ignition in heating scenario)
    - Indication of change of status (i.e. functioning or partial)
  - Maintain service life
    - Device survive and remain effective for service life
    - Must be chemically compatible with no changes on ageing

Suitability of the Device

- The device must be suitability for the extended role.
  - Operational Capability. The device must not adversely affect the operational capability through e.g unacceptable parasitic mass or reduced reliability of functioning.

  - Mitigation Capabilities. The device must be capable of delivering significant benefits in reducing the violence of reaction which translate to reduced risk.

Suitability of the Device, Example

- The device must designed to provide protection for the appropriate threat range identified in STANAG 4439
  - The device should not be designed just to pass a particular full scale test condition. For example,
    - A device designed to mitigate slow cook-off response should not be designed to function in a narrow envelope around 3.3°C/hr as per STANAG
    - Such a device could allow the munition to pass the full scale test but this would be misleading as the device would provide little value in a real accident scenario were the heating rate is highly variable.
    - A threat assessment for the environment lifecycle profile can prove valuable in determining typical threats

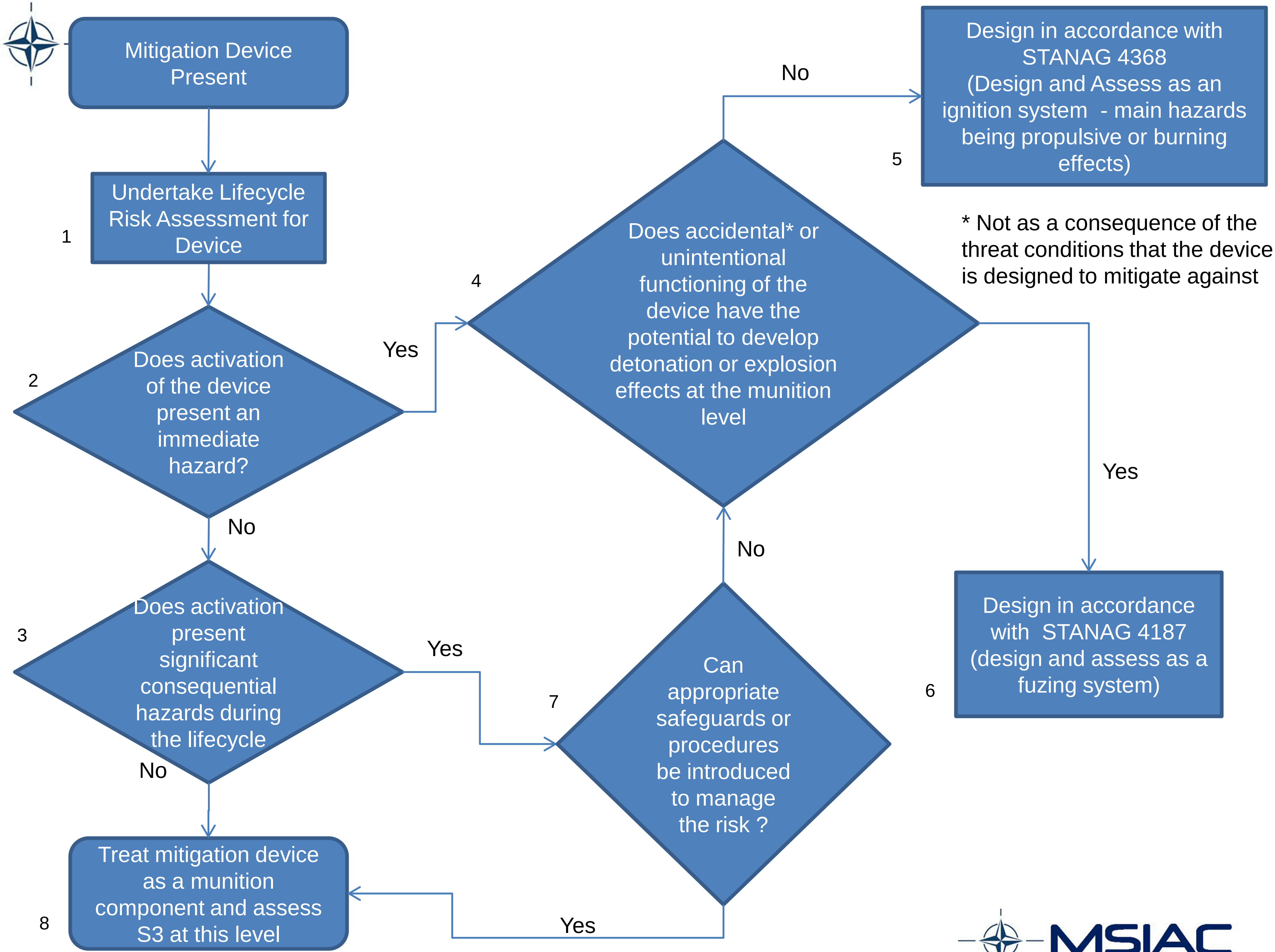
S3 Assessment Proposals

- To achieve the goal of maintaining intrinsic safety NATO design standards and S3 assessment procedures should be applied to mitigation devices whenever relevant

- Active mitigation devices which present an explosive hazard should meet minimum or preferably exceed current safety standards and guidance
    - NATO Safety precepts should be applied when relevant
    - Of particular importance for active mitigation is whether STANAGs 4368 or 4187 on ignition systems and fuzing systems respectively are relevant

System Safety Concerns

- Safety concerns - possibility of increased risk posed to personnel and defence material by inadvertent or accidental functioning of these devices.
  - More of an issue for active mitigation devices which can directly generate explosive effects or elicit an energetic material response in the weapon component
  - Passive devices can impact safety in a more subtle manner but may still have significant safety related consequences.
    - structural changes to the munition such as developing vent paths or reducing structural integrity could result in catastrophic failure of the munition if subsequently used.



Mitigation Device Present

1 Undertake Lifecycle Risk Assessment for Device

2 Does activation of the device present an immediate hazard?

Yes

No

3 Does activation present significant consequential hazards during the lifecycle

Yes

No

4 Does accidental* or unintentional functioning of the device have the potential to develop detonation or explosion effects at the munition level

No

Yes

5 Design in accordance with STANAG 4368 (Design and Assess as an ignition system - main hazards being propulsive or burning effects)

* Not as a consequence of the threat conditions that the device is designed to mitigate against

6 Design in accordance with STANAG 4187 (design and assess as a fuzing system)

7 Can appropriate safeguards or procedures be introduced to manage the risk ?

No

Yes

8 Treat mitigation device as a munition component and assess S3 at this level

S3 Assessment Proposals

- The application of either STANAG 4368 or 4187 would require input from the national authority to determine specifically which requirements were relevant or waived.

    - These documents were not written with active mitigation systems in mind

- Chemical compatibility testing must be undertaken, as per STANAGs 4147 and 4170.

- Activation must be obvious
    - Activation of the passive or active mitigation component must be obvious when the safety state of the munition is adversely affected
    - In some cases a specific indicator of activation may have to be included

S3 Assessment Proposals

- All mitigation devices must be present during any munition S3 testing or other munition level tests when there is a possibly that their interaction could affect the outcome.
    - Device should not inadvertently function and should retain functionality after completing testing.
    - Exposed to the environmental lifecycle profile for the munition system to ensure that the risk is sufficiently characterised.
    - Wherever practicable, supplemental small scale testing and analysis at the device level should be undertaken to develop additional confidence that the intrinsic safety of the munitions system is not impacted.

Examples

	Device Type	Assessment Process	Reasoning/Comments
Passive	Thermal insulation	Follow normal munition qualification process	Characterise munition behaviour for thermal threat extremes; it has been noted that addition of insulating materials can delay but result in more violent response as the munitions is exposed to a slower heating threat.
	Case weakened (e.g. Introduction of stress raiser)	Follow normal munition qualification process	Design review must determine that structural integrity requirements have not been compromised (particularly for rocket motors).
	Confinement disrupted by physical processes or mechanical means (melting or softening of plugs or components; case disruption caused by mechanical threat)	Follow normal munition qualification process	Design review must determine that structural integrity requirements have not been compromised over lifecycle environment profile.

Examples

	Device Type	Assessment Process	Reasoning/Comments
Active	Active case weakening (e.g. linear shaped charge)	Design and assess as a fuzing system (STANAG 4187)	Accidental or unintended functioning causes immediate explosive effects with potentially significant consequences through detonation of the cutting charge and potential burning of the munition. Required device to meet levels of safety applicable to fuzing systems.
	Pre-ignition device (causes early ignition of a munition component mitigating violence of response particularly for slow cook-off)	Design and assess as an ignition system for rocket motors (STANAG 4368)	Clear relevance for STANAG 4368 for pre-ignition devices used in rocket motors where the inherent hazard from inadvertent or unintended functioning presents an identical hazard to the user when compared to unintended ignition by the ignition system . If applied to a warhead then the resulting deflagration or burning response may present a similar level of hazard and hence the device should meet the same levels of safety as for more conventional ignition systems. Safety implications from early mitigation device induced ignition in an accident scenario could reduce the effectiveness of fire fighting measures which have the potential to prevent any reaction from the munition. Hence, there may be occasions where an earlier less violent response may be less desirable than a much later more violent response.

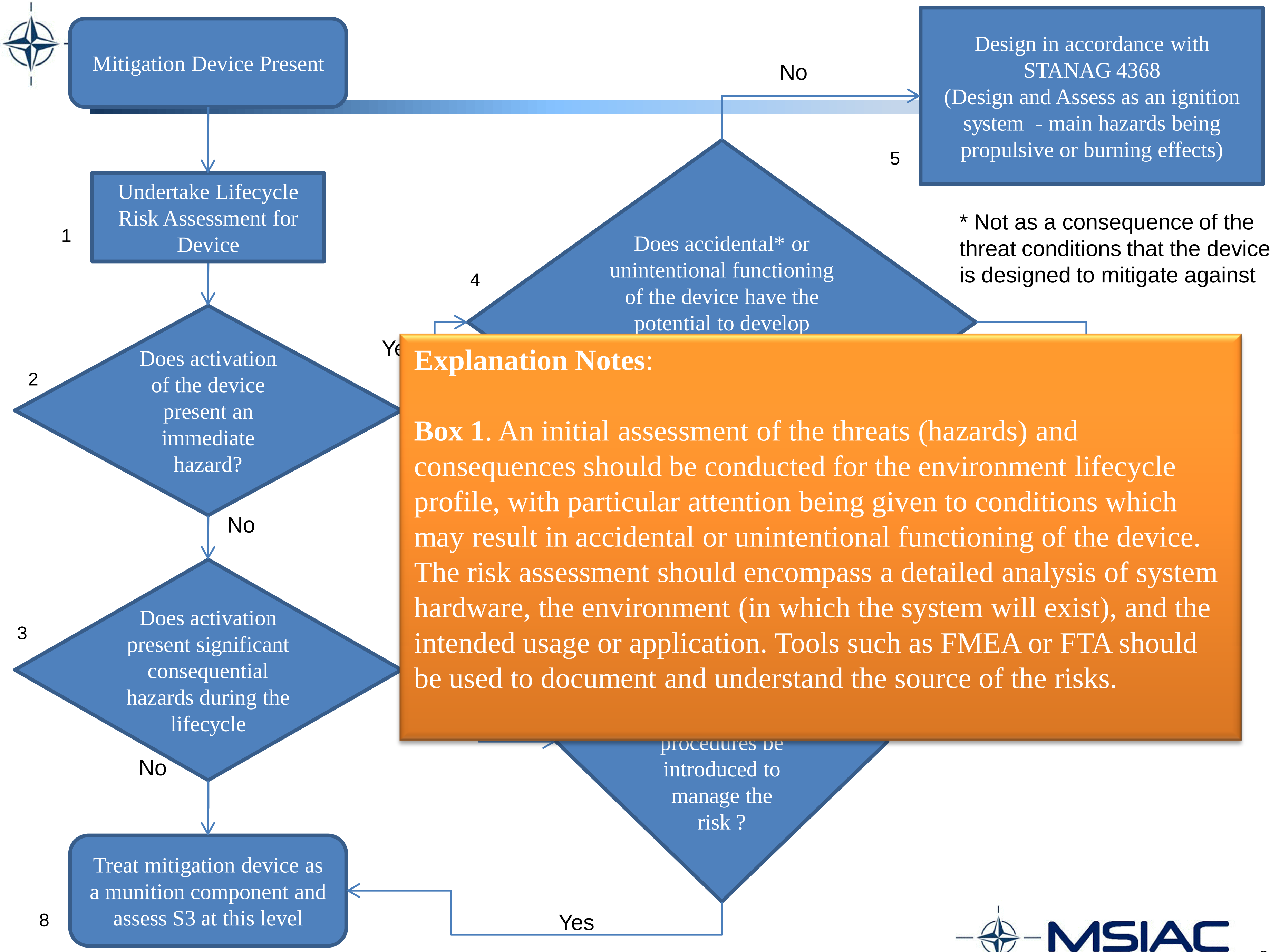
Conclusions

- The main conclusions of this paper are that:
  - Intrinsic safety of a munition should not be adversely affected by the addition of a mitigation device.
  - Current safety design requirements and assessment methodology should be adopted and specifically applied to the mitigation device when there is potential for similar consequences for inadvertent or accidental activation of the device when compared to igniters or fuze.

Way Ahead

- UK MOD DOSG Guidance document produced
- US Navy Paper produced
- Presented paper to AC-326 SG3 with comments being requested through National Points of Contact
- Presented to the US FESWG (Fuze Engineering Standardization Working Group) and will be in a future focused meeting

QUESTIONS ?



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procedures be introduced to manage the risk ?

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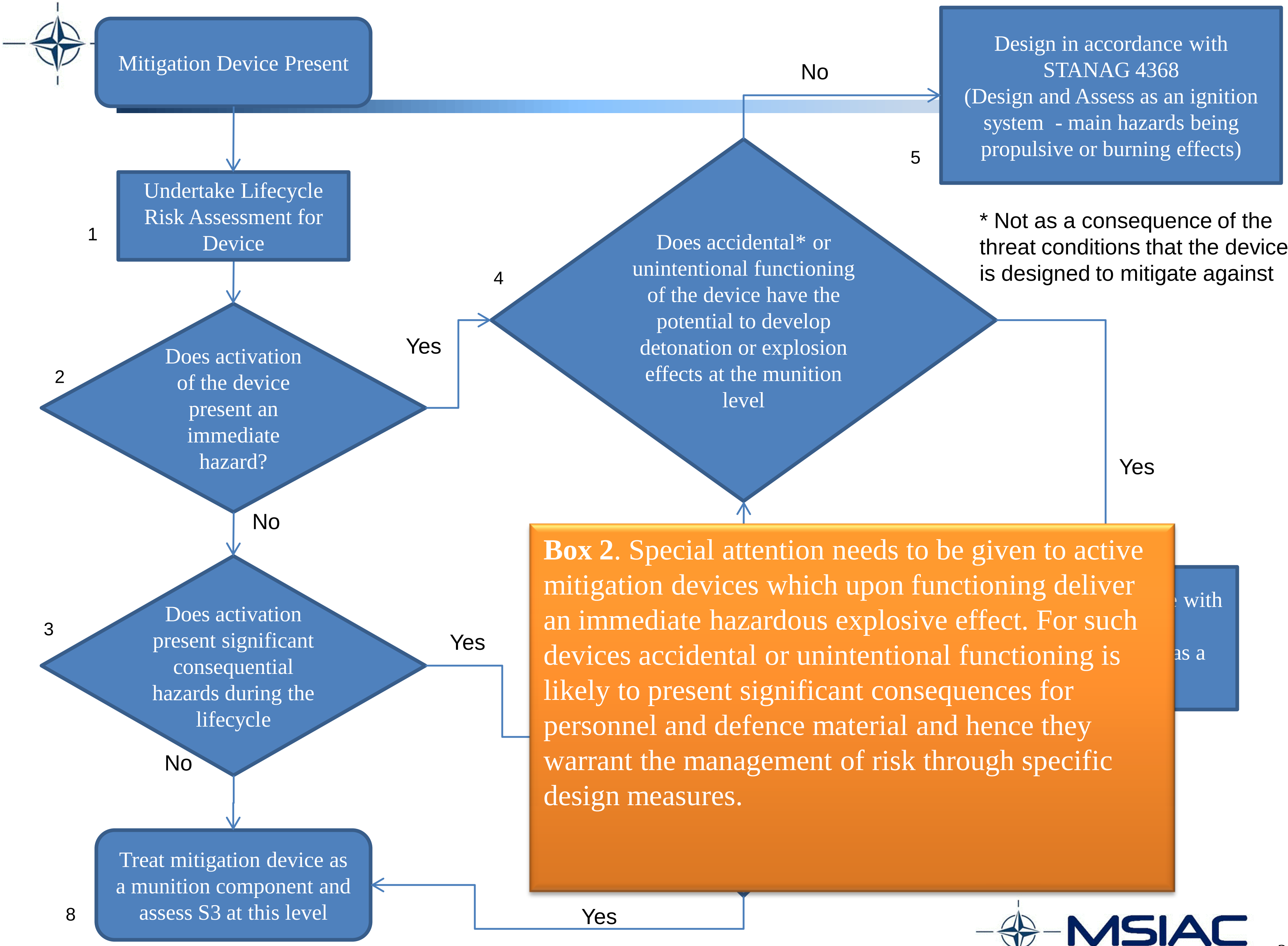
Explanation Notes:

Box 1. An initial assessment of the threats (hazards) and consequences should be conducted for the environment lifecycle profile, with particular attention being given to conditions which may result in accidental or unintentional functioning of the device. The risk assessment should encompass a detailed analysis of system hardware, the environment (in which the system will exist), and the intended usage or application. Tools such as FMEA or FTA should be used to document and understand the source of the risks.



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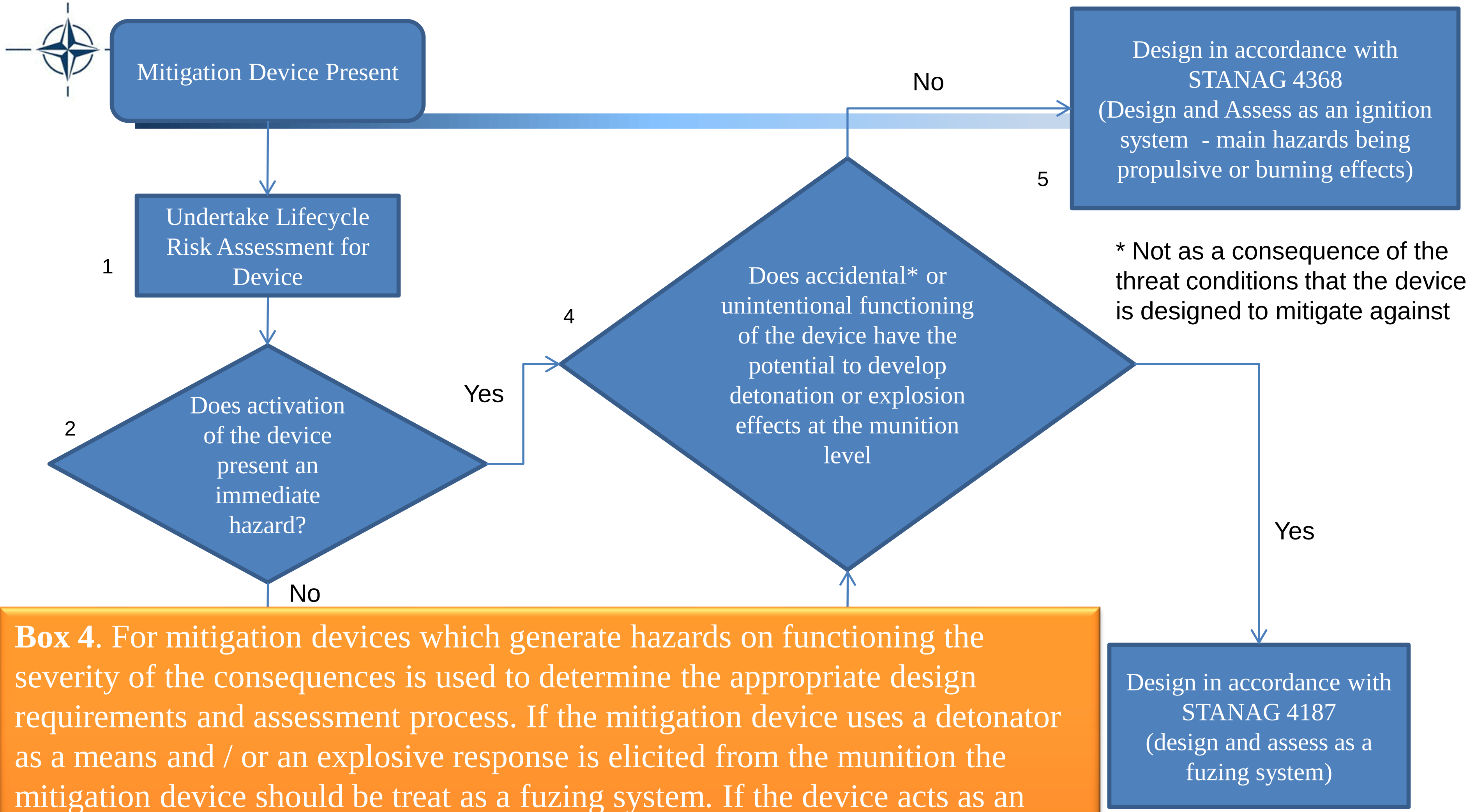
Box 2. Special attention needs to be given to active mitigation devices which upon functioning deliver an immediate hazardous explosive effect. For such devices accidental or unintentional functioning is likely to present significant consequences for personnel and defence material and hence they warrant the management of risk through specific design measures.



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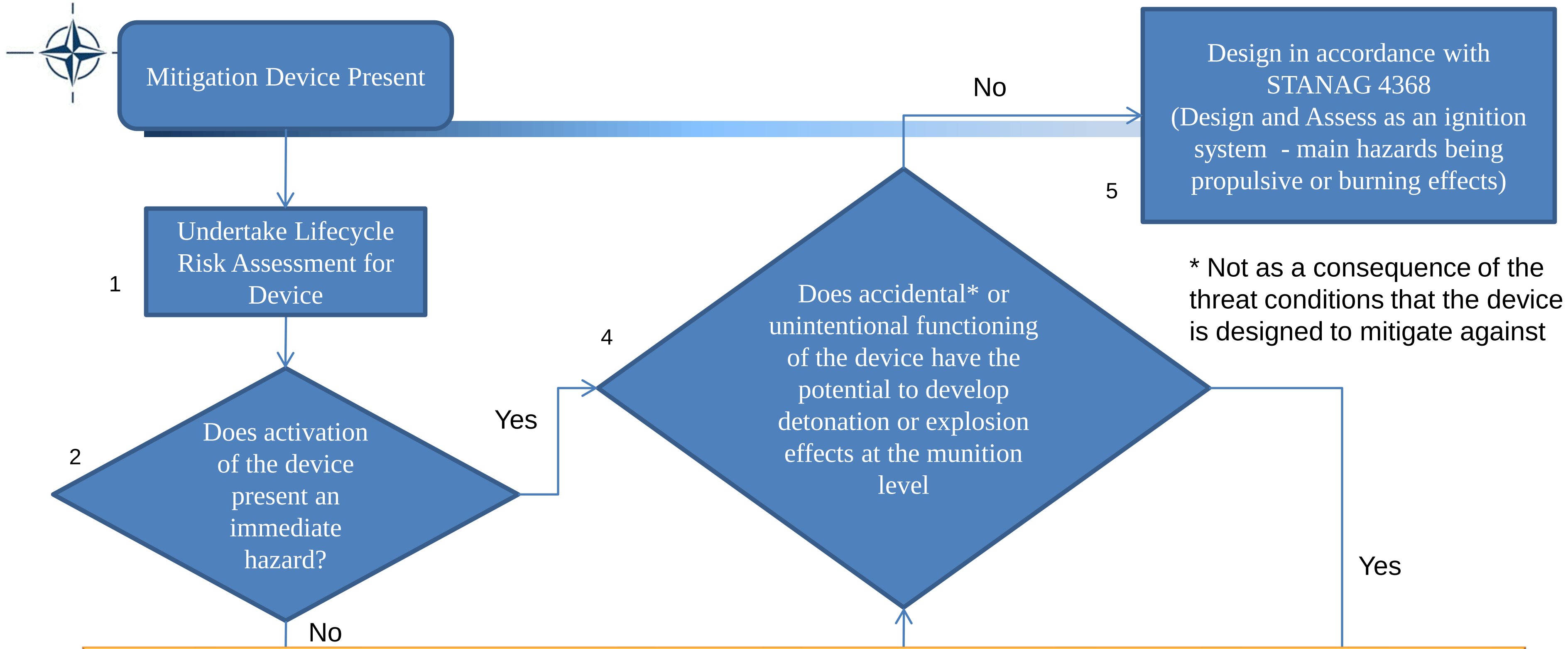
Box 4. For mitigation devices which generate hazards on functioning the severity of the consequences is used to determine the appropriate design requirements and assessment process. If the mitigation device uses a detonator as a means and / or an explosive response is elicited from the munition the mitigation device should be treat as a fuzing system. If the device acts as an igniter which also elicits a burn, propulsion or deflagration response in the munition then the device may be considered as an ignition device used in rocket motors. The munition response levels are those defined in AOP-39. The decision to impose design requirements is justified by the fact that inadvertent or accidental initiation of the mitigation system meets these explosive effects criteria and delivers similar consequences to those for fuzes or ignition devices.



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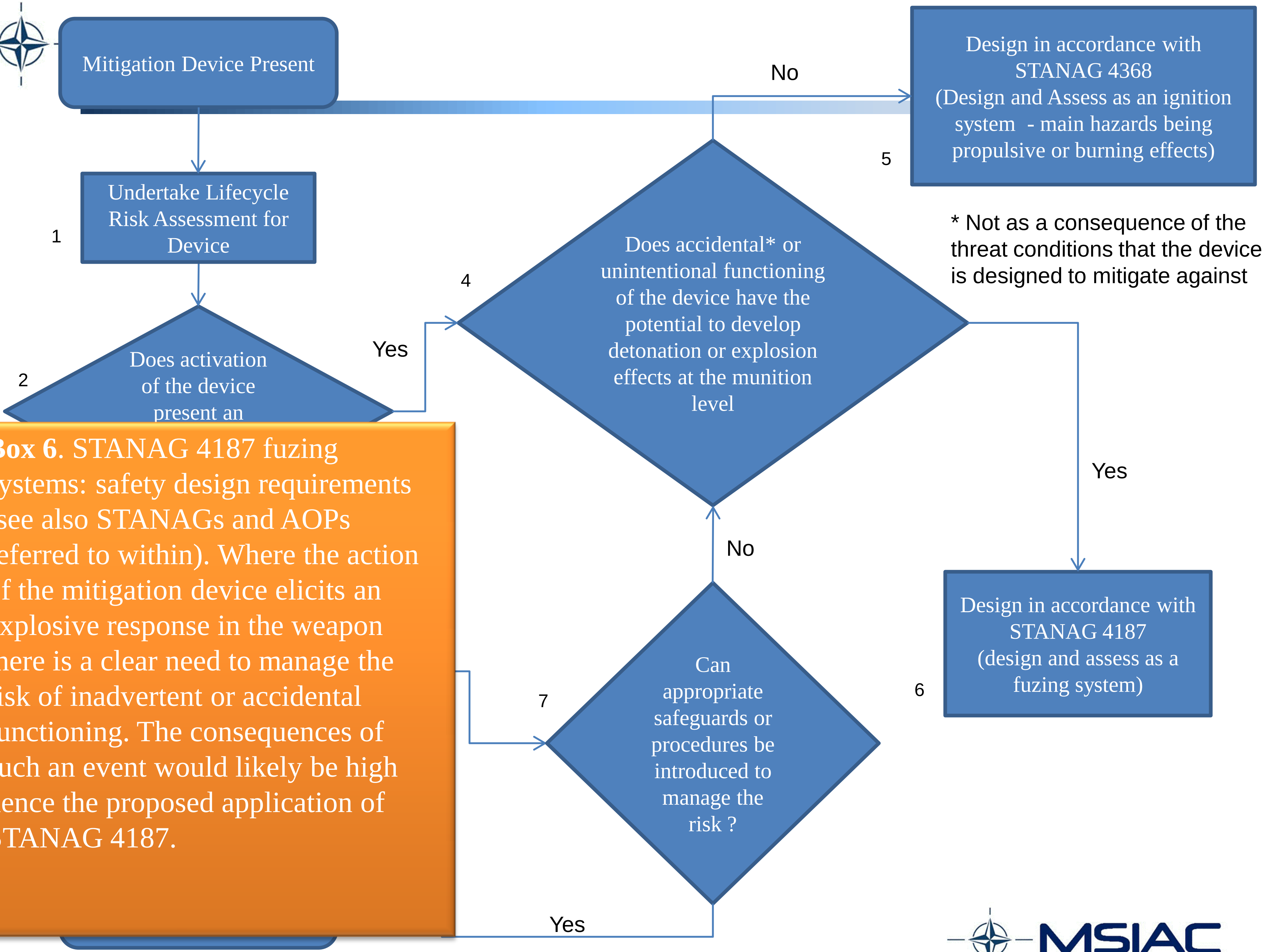
Box 5.STANAG 4368 for ignition systems for rocket motors and guided missile motors (see also STANAGs and AOPs referred to within). The relevance of application will be clearer for mitigation devices acting on rocket motors where there is a potential for an unintentional launch event. However, many of the safety principals could also be relevant in controlling risk and characterising the probability of inadvertent ignition and burning of, for example, a warhead component. There is a clear need for the national safety authority to make a judgment on the suitability of STANAG 4368 or 4187 (fuzing systems) based on the mitigation device design and munitions response when it functions. One should note that exclusion from the application of the STANAG 4368 is possible if the consequence of the inadvertent functioning of the device is assessed as not presenting significant hazard.



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7 Can appropriate safeguards or procedures be introduced to manage the risk ?

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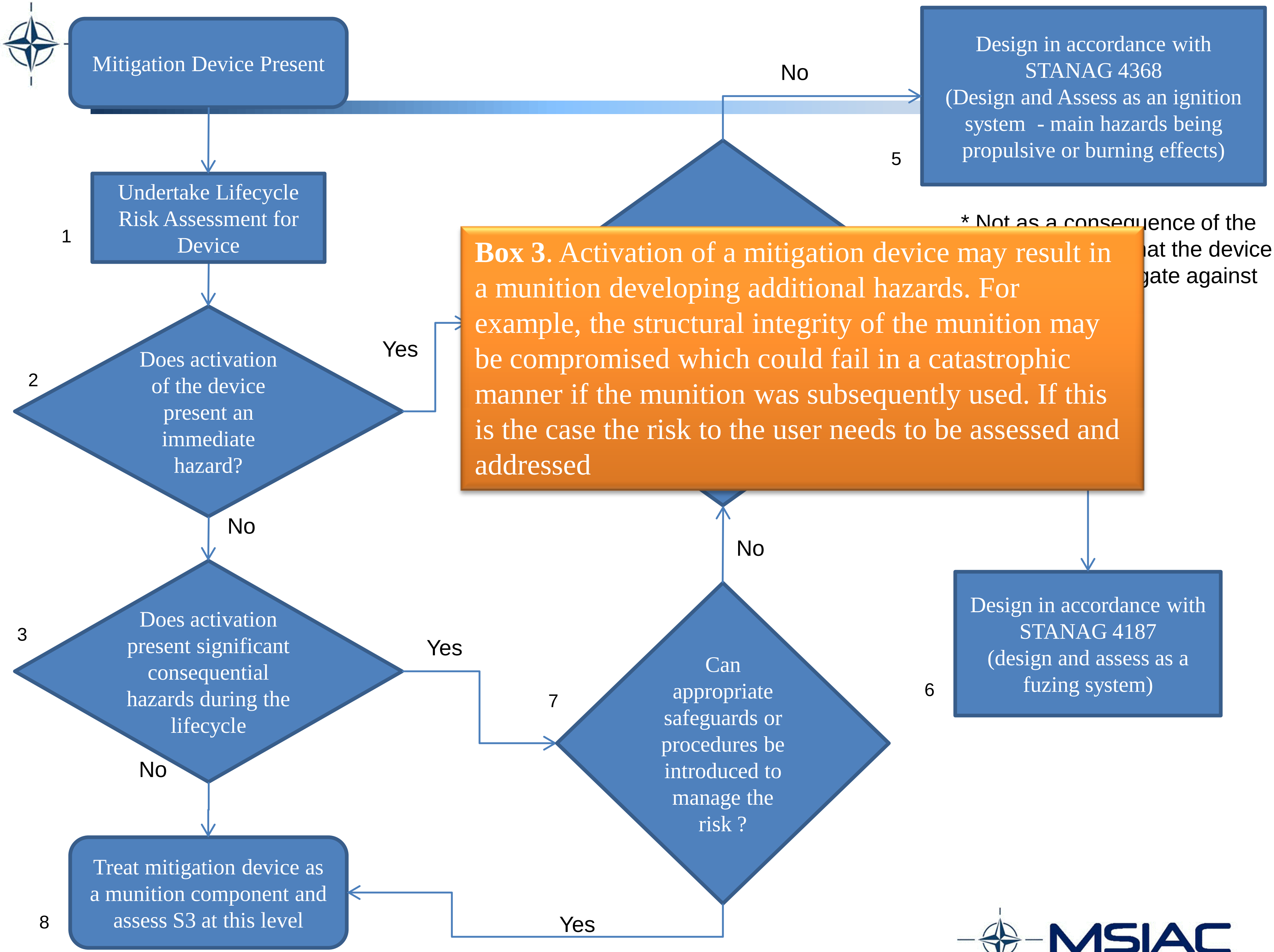
Box 6. STANAG 4187 fuzing systems: safety design requirements (see also STANAGs and AOPs referred to within). Where the action of the mitigation device elicits an explosive response in the weapon there is a clear need to manage the risk of inadvertent or accidental functioning. The consequences of such an event would likely be high hence the proposed application of STANAG 4187.



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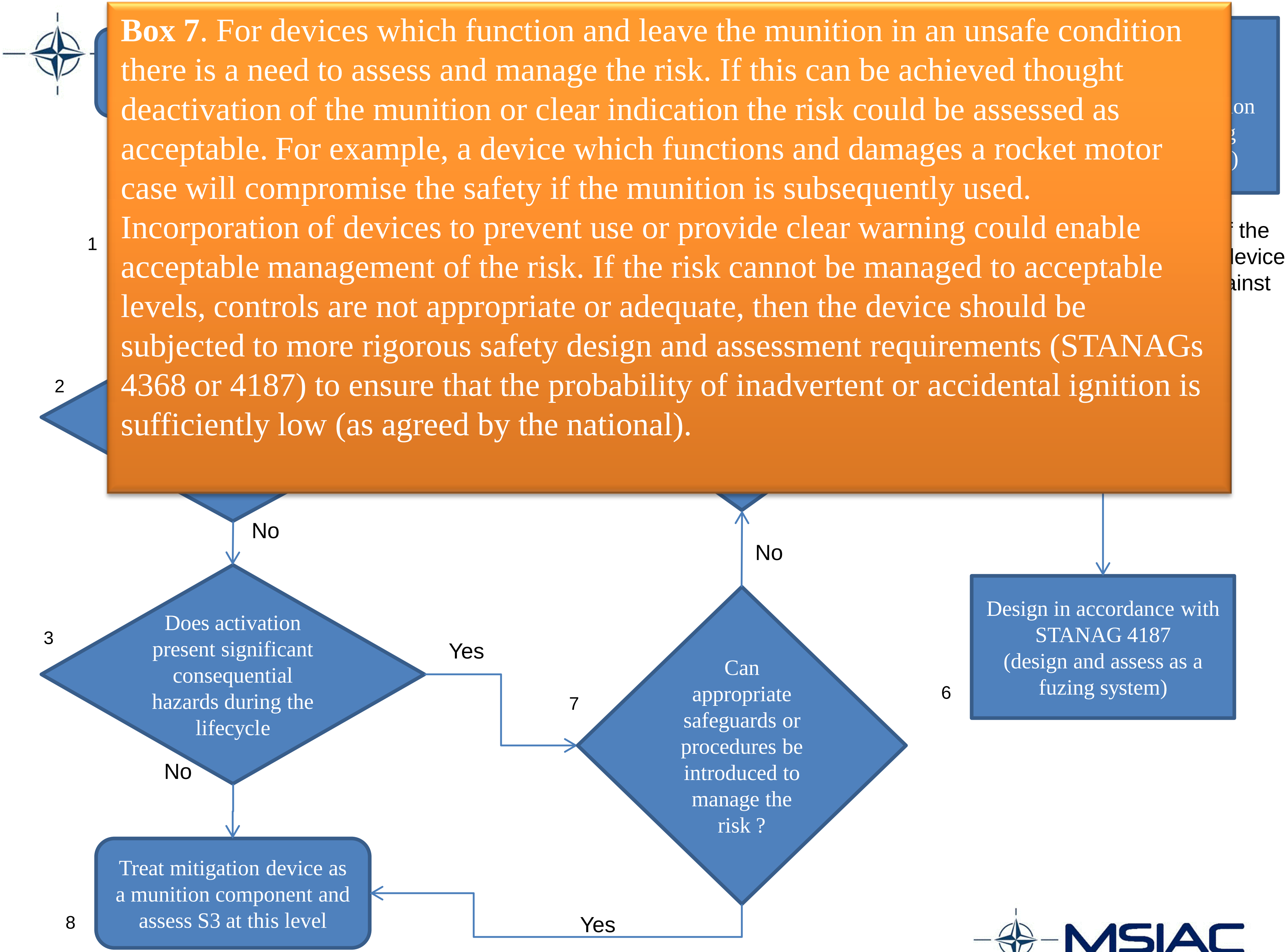
Box 3. Activation of a mitigation device may result in a munition developing additional hazards. For example, the structural integrity of the munition may be compromised which could fail in a catastrophic manner if the munition was subsequently used. If this is the case the risk to the user needs to be assessed and addressed

Box 7. For devices which function and leave the munition in an unsafe condition there is a need to assess and manage the risk. If this can be achieved thought deactivation of the munition or clear indication the risk could be assessed as acceptable. For example, a device which functions and damages a rocket motor case will compromise the safety if the munition is subsequently used. Incorporation of devices to prevent use or provide clear warning could enable acceptable management of the risk. If the risk cannot be managed to acceptable levels, controls are not appropriate or adequate, then the device should be subjected to more rigorous safety design and assessment requirements (STANAGs 4368 or 4187) to ensure that the probability of inadvertent or accidental ignition is sufficiently low (as agreed by the national).



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Can appropriate safeguards or procedures be introduced to manage the risk ?

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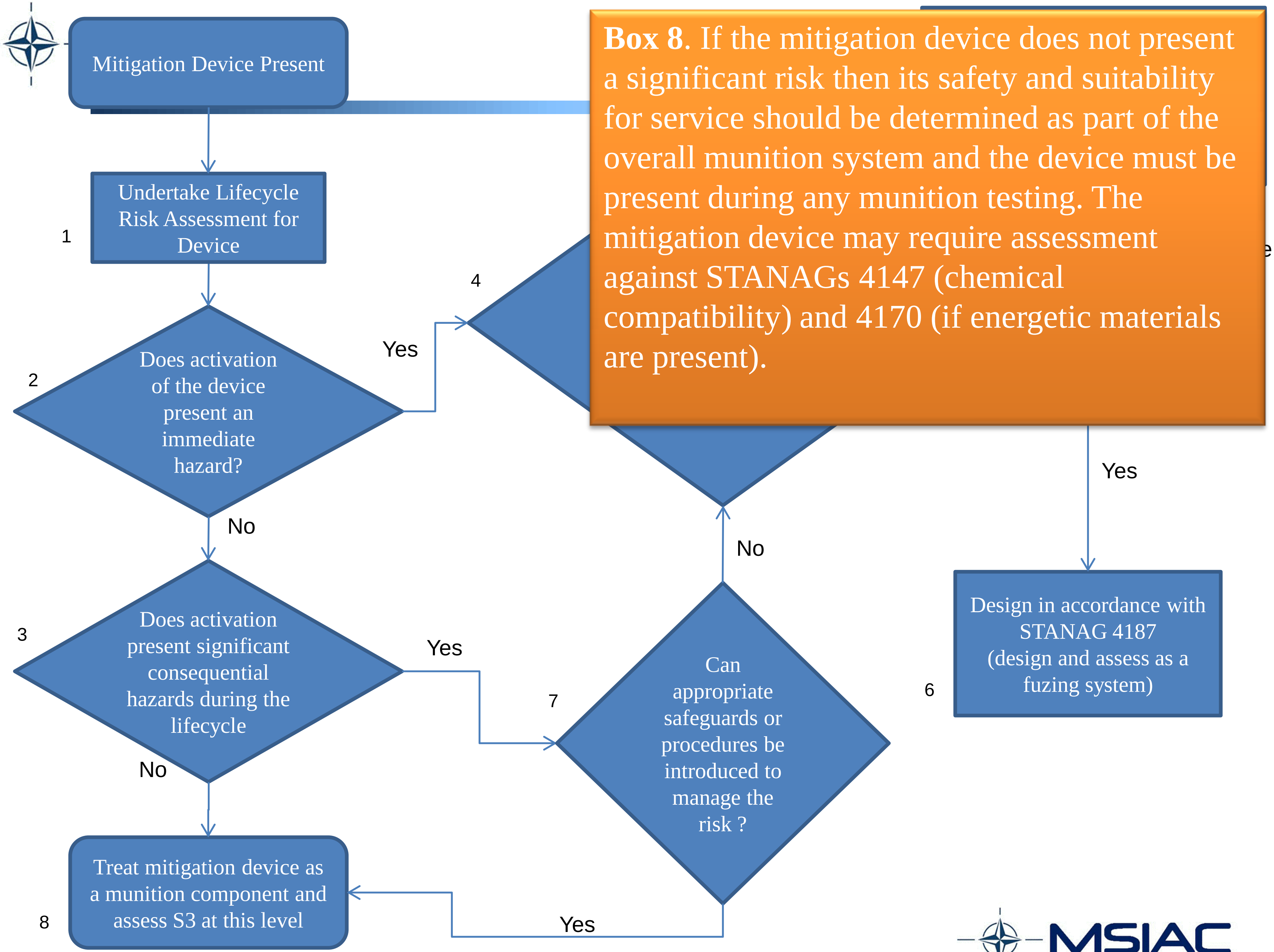

Box 8. If the mitigation device does not present a significant risk then its safety and suitability for service should be determined as part of the overall munition system and the device must be present during any munition testing. The mitigation device may require assessment against STANAGs 4147 (chemical compatibility) and 4170 (if energetic materials are present).