SAFETY SERVICES ORGANISATION

SAFETY AND HAZARD ASSESSMENT MODULE

SAFETY LED DESIGN

SAFETY LED DESIGN - WHAT IS IT? - TERMS

A quick key terms reminder:

Hazard -

- Any item, individual, or situation with the potential to cause harm

Harm -

- Physical or mental damage – Injury, fatality, exposure, etc.

Likelihood -

- The chance or frequency of something happening

Accident -

- The result of a hazard, event, or series of events/hazards leading to a harm

Risk -

- The product of the likelihood of occurrence and the consequence if it does indeed occur
  - A risk does not exist without a hazard.

Definitions source:
HSE Research Report 151. Good practice and pitfalls in risk assessment. Health and Safety Laboratory for the Health and Safety Executive. 2003. https://www.hse.gov.uk/research/rrpdf/rr151.pdf
Acquisition Safety and Environmental Management System. Definitions. https://www.asems.mod.uk

SAFETY LED DESIGN - WHAT IS IT? - TERMS

Control -

- Procedures, products, engineering solutions or methods that reduce the risk

Mitigation -

- Procedures, products, engineering solutions or methods that reduce the consequence of an accident

Risk Assessment -

- A method of identifying and capturing the Risks, Hazards, Controls, and Mitigations
  - Required by The Health and Safety at Work Act and the Management of Health and Safety at Work Regulations

Sentencing -

- The judgement on any required remedial action, e.g. Mitigation Strategy

ALARP -

- As Low As Reasonably Practicable
  - Remember lecture two?

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HSE Research Report 151. Good practice and pitfalls in risk assessment. Health and Safety Laboratory for the Health and Safety Executive. 2003. https://www.hse.gov.uk/research/rrpdf/rr151.pdf
Acquisition Safety and Environmental Management System. Definitions. https://www.asems.mod.uk

SAFETY LED DESIGN - WHAT IS IT? - TERMS

Reasonably -

- The standard of care that a reasonably prudent person would expect under a given set of circumstances. Similarly a reasonable act is one that might fairly and properly be required of an individual.

Practicable -

- Being able to be done/performed/carried out.

Reasonably Practicable -

- As defined by Edwards vs National Coal Board 1949

'Reasonably practicable is a narrower term than 'physically possible' and implies that a computation must be made... In which the quantum of risk is placed in one scale and the sacrifice involved in the measures necessary for averting the risk (whether in time, trouble or money) is placed in the other and that, if it be shown that there is a great disproportion between them – the risk being insignificant in relation to the sacrifice – the person upon whom the obligation is imposed discharges the onus which is upon him.'

SAFETY LED DESIGN - WHAT IS IT? - TERMS

Safety Led Design –

- Safety Led Safety Design uses system knowledge to augment traditional safety analysis techniques allowing the Design Authority to develop a holistic system view, identifying faults as early as possible.
- The system and operational environment are defined.
- A Hazard Analysis is conducted on the as designed system.
- As additional implementation details are defined as the hazard analysis is applied to the subcomponents.
- The hazard analysis feeds the requirements definition, design definition, and verification and validation phases.

When applied correctly, safety led design can be used to efficiently reduce both the risk posed by the system/item, and the total cost of the system/item over its design lifetime

SAFETY LED DESIGN - IM EXAMPLE

Insensitive Munitions –

- To reduce the vulnerability of munitions in order to reduce the risks both during storage and on operation
- IM are not necessarily “insensitive” by textbook definition
  - Simply less sensitive than existing non-IM natures
- Key design driver for new munitions through STANAG 4439

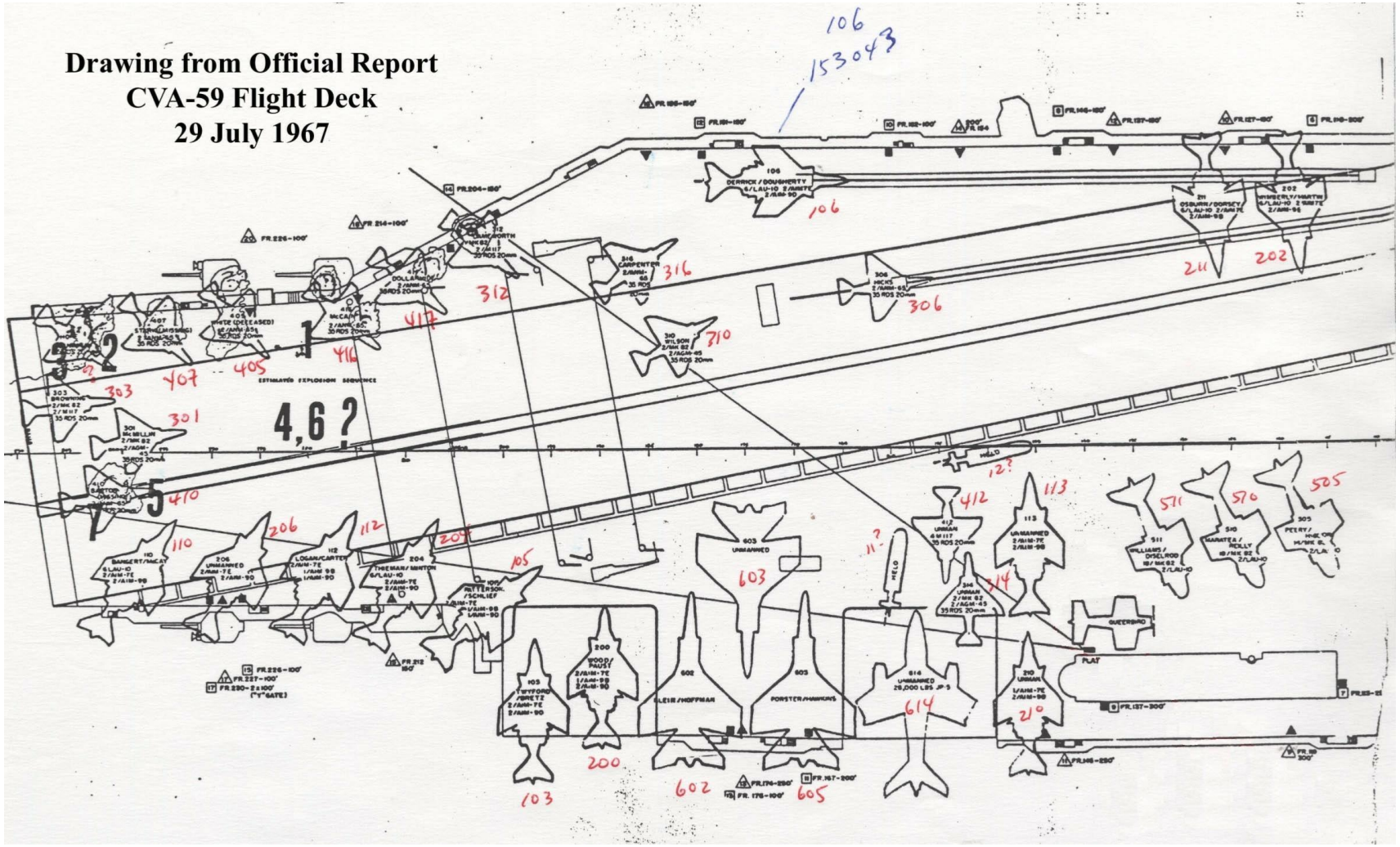
“munitions which reliably fulfil their performance, readiness and operational requirements on demand but which minimize the probability of inadvertent initiation and severity of subsequent collateral damage to weapon platforms, logistic systems and personnel when subjected to unplanned stimuli.”

SAFETY LED DESIGN - IM EXAMPLE - WHY

Video source:
USS Forrestal - Supercarrier Disaster

SAFETY LED DESIGN - IM EXAMPLE - WHY

Image source:
[The Skyhawk Association - U.S.S. Forrestal Fire 1967]



SAFETY LED DESIGN - IM EXAMPLE - WHY

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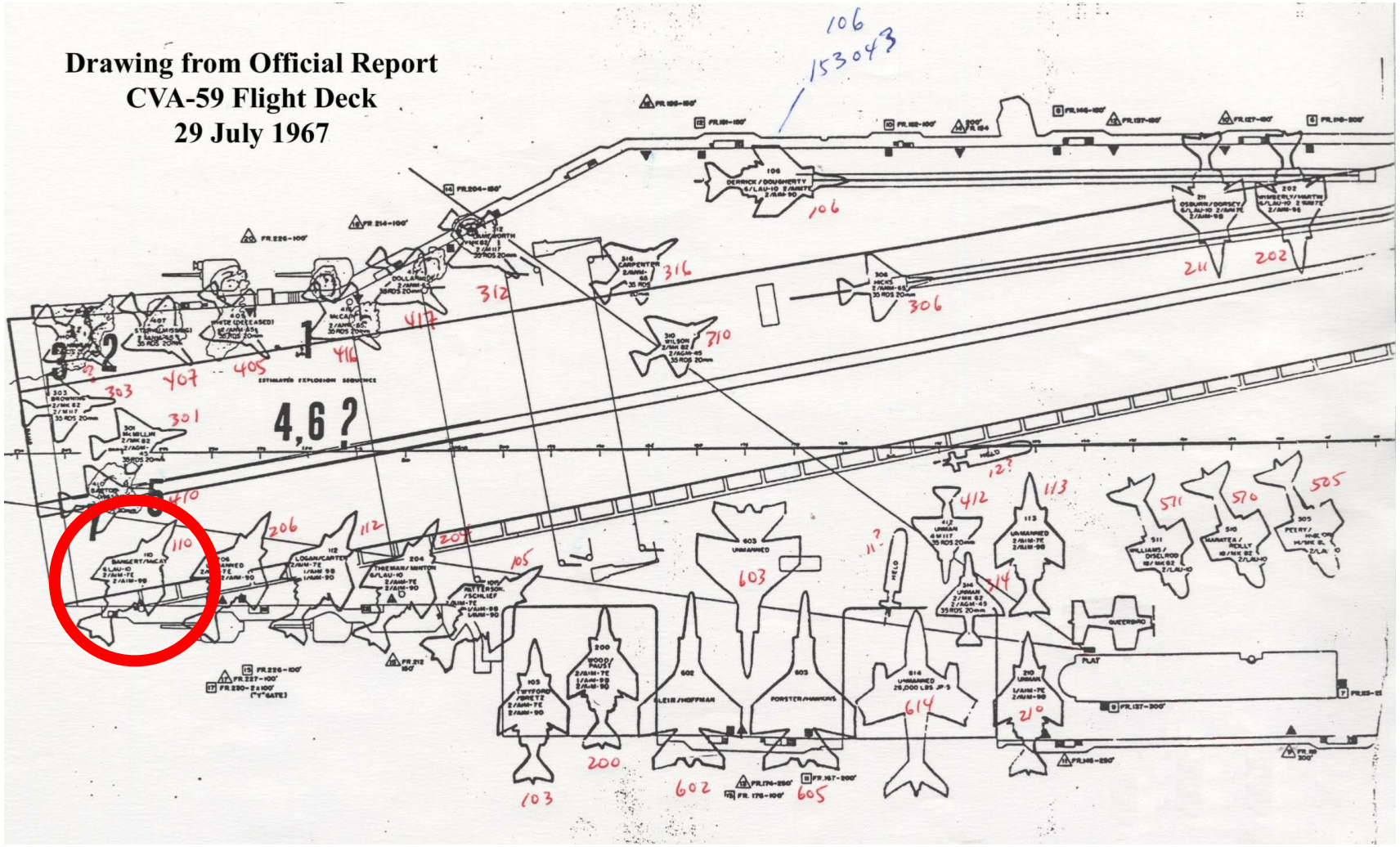
[The Skyhawk Association - U.S.S. Forrestal Fire 1967]



SAFETY LED DESIGN - IM EXAMPLE - WHY

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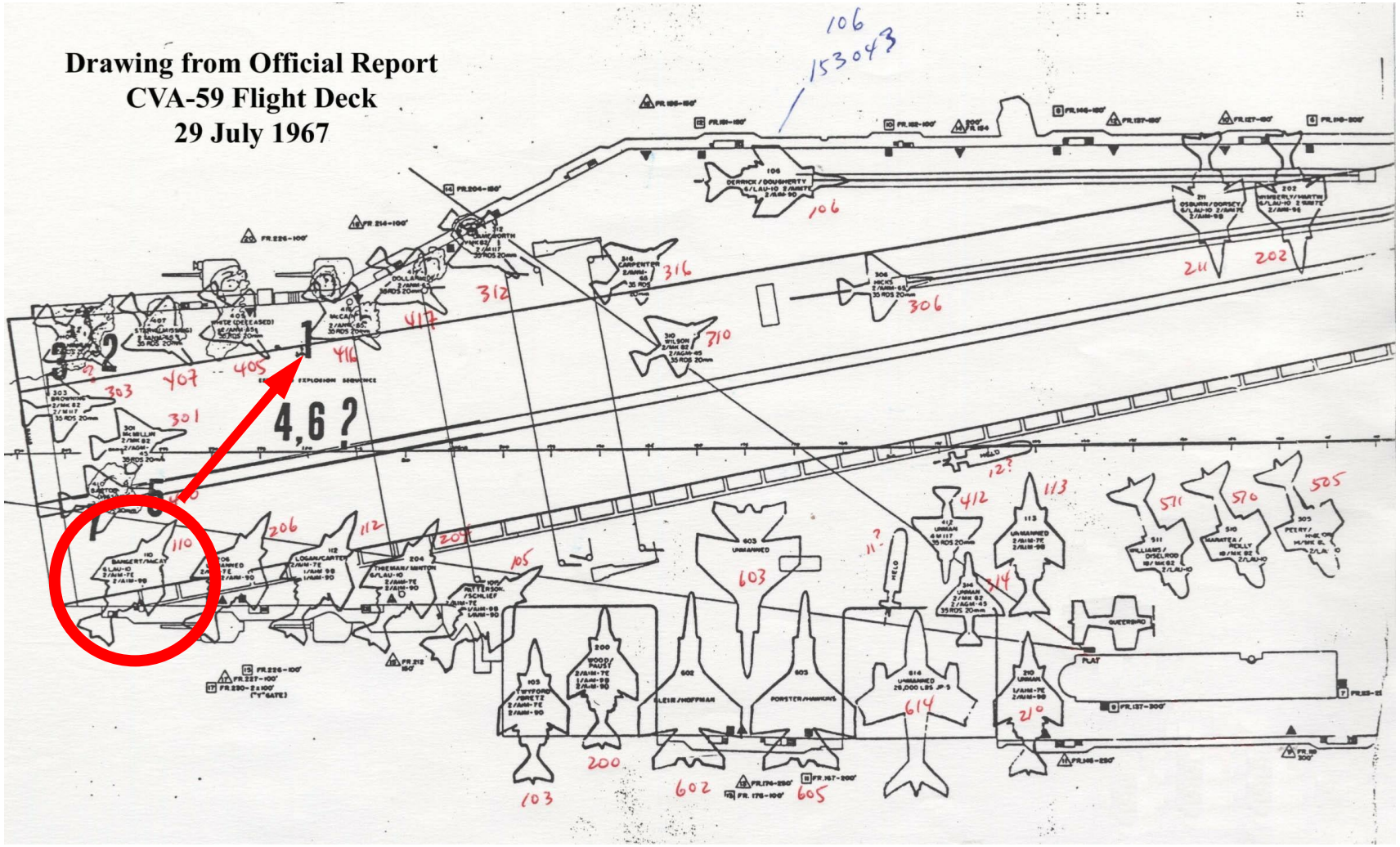

SAFETY LED DESIGN - IM EXAMPLE - WHY

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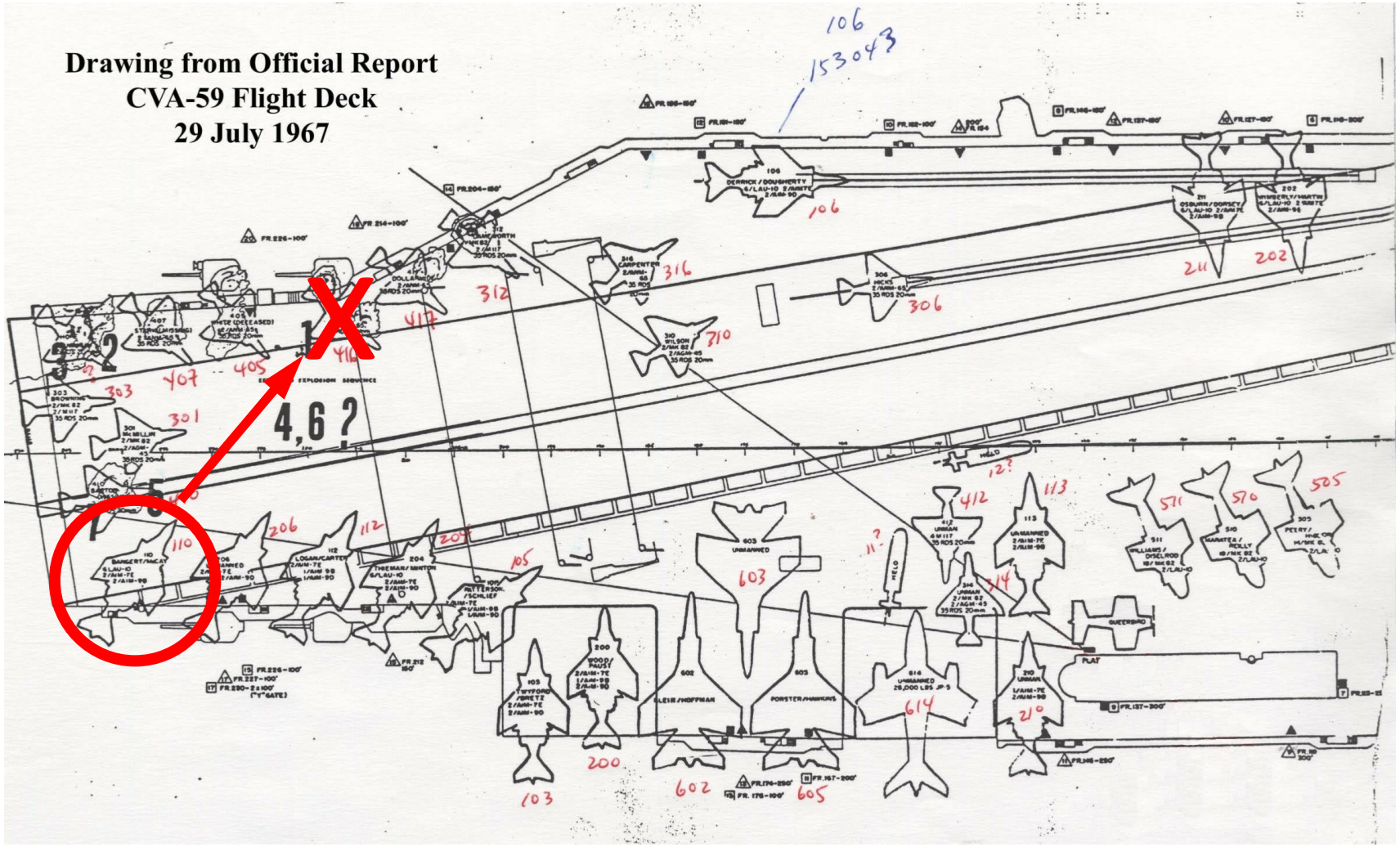
The Skyhawk Association - U.S.S. Forrestal Fire 1967



SAFETY LED DESIGN - IM EXAMPLE - WHY

Image source:
Aviation News - The Forrestal Fire

SAFETY LED DESIGN - IM EXAMPLE - WHY

Image source:
NPR - Ex-Navy Carrier USS Forrestal

SAFETY LED DESIGN - IM EXAMPLE - WHY

Image source:
History Net - Carrier Fires

SAFETY LED DESIGN - IM EXAMPLE

Insensitive Munitions assessments are undertaken as part of a whole system approach taking into account all areas of the munition design. Aspects to be assessed and considered update for IM, included but are not limited to:

- Operating environment (threats)
- Energetic Materials
- Design & Construction
- Packaging
- Other measures, barriers etc

SAFETY LED DESIGN - IM EXAMPLE

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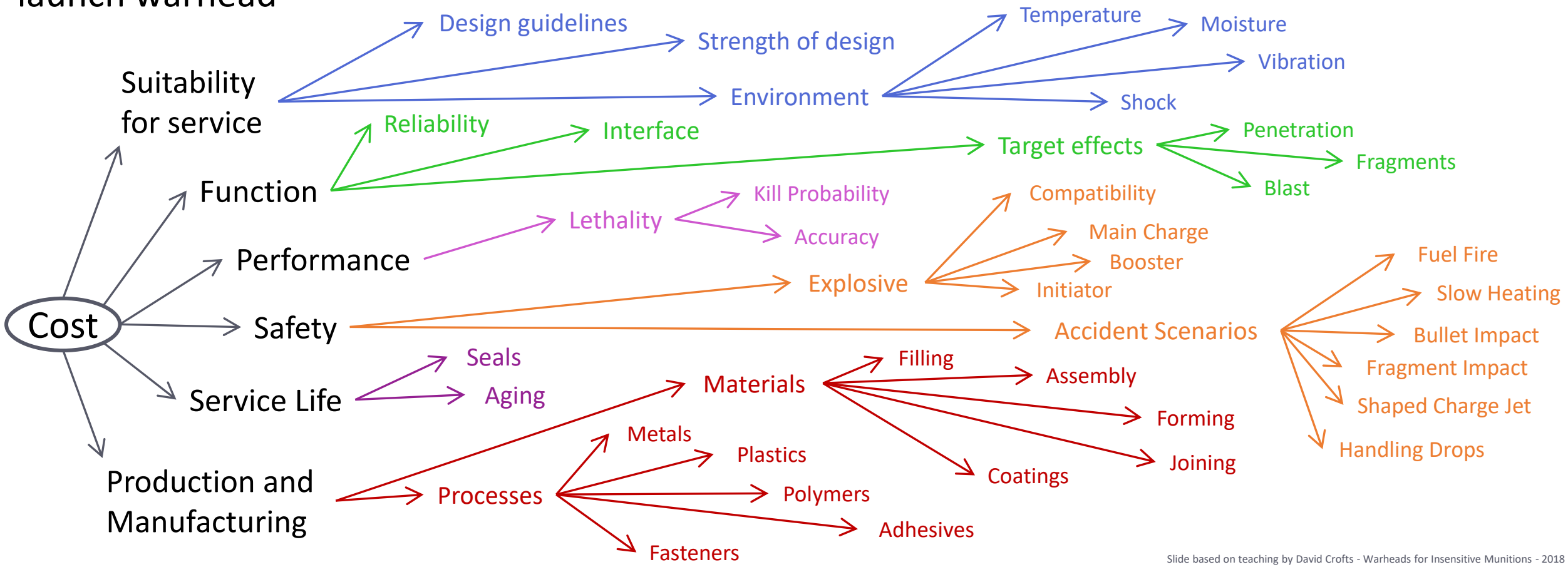
SAFETY LED DESIGN - IM EXAMPLE

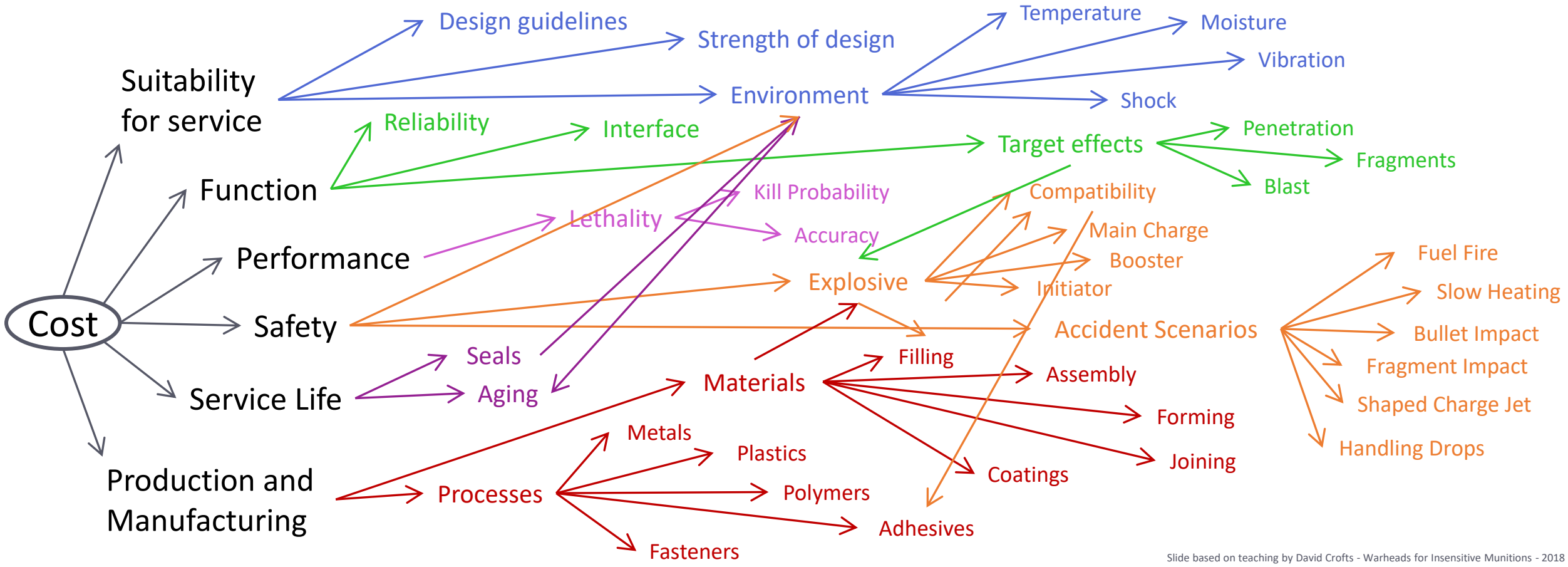
Safety plays a large role in design trade offs that must be considered, take the example of a air launch warhead



Slide based on teaching by David Crofts - Warheads for Insensitive Munitions - 2018

SAFETY LED DESIGN - IM EXAMPLE

… along with the interconnected nature of those design decisions.



Slide based on teaching by David Crofts - Warheads for Insensitive Munitions - 2018

SAFETY LED DESIGN - IM EXAMPLE

By understanding the operating environment, the potential threats are assessed and can be tested against already agreed tests:

Simulated Threat	Test	IM Response Requirement
Magazine, store, aircraft or vehicle fuel fire	Fast Heating	No response more severe than Type V (Burning)
Fire in adjacent magazine, store, aircraft or vehicle	Slow Heating	No response more severe than Type V (Burning)
Small arms attack	Bullet Impact	No response more severe than Type V (Burning)
Fragment munition attack	Fragment Impact	No response more severe than Type V (Burning)
Most severe reaction of the same munition or store	Sympathetic Reaction	No response more severe than Type III (Explosion)
Shaped charge weapon attack	Shaped Charge Jet Impact	No response more severe than Type III (Explosion)

SAFETY LED DESIGN - IM EXAMPLE

Assess current Insensitive Munitions Signature

Response \ Stimulus		Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Reaction	Shaped Charge Jet Impact
None	-	✓	✓	✓	✓	✓	✓
Burning	V	✓	✓	✓	✓	✓	✓
Deflagration	IV	X	X	X	X	✓	✓
Explosion	III	X	X	X	X	✓	✓
Partial Detonation	II	X	X	X	X	X	X
Detonation	I	X	X	X	X	X	X

SAFETY LED DESIGN - IM EXAMPLE

Assess current Insensitive Munitions Signature

Response \ Stimulus		Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Reaction	Shaped Charge Jet Impact
None	-	✓	✓	✓	✓	✓	✓
Burning	V	✓	✓	✓	✓	✓	✓
Deflagration	IV	X	X	X	X	✓	✓
Explosion	III	X	X	X	X	✓	✓
Partial Detonation	II	X	X	X	X	X	X
Detonation	I	X	X	X	X	X	X

BREAK TIME

15 MINUTES FOR COFFEE

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SAFETY LED DESIGN - IM EXAMPLE

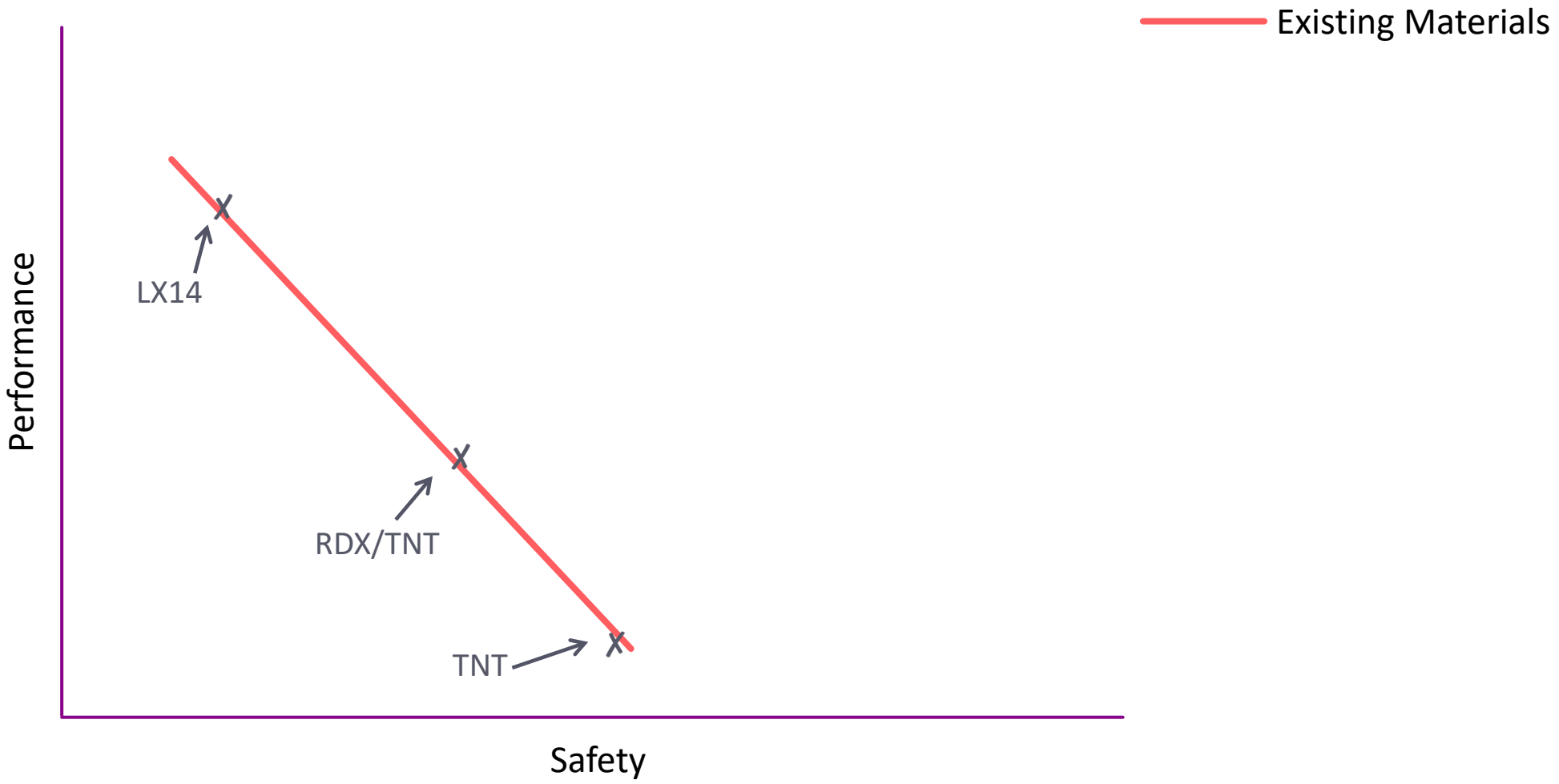
The problem is that explosives are generally poor materials from a mechanical standpoint.

- Low strength
- Low elongation
- Generally brittle
- Prone to cracking
- Large thermal expansion coeffecients
- Significant changes of state / properties close to military operation temperatures

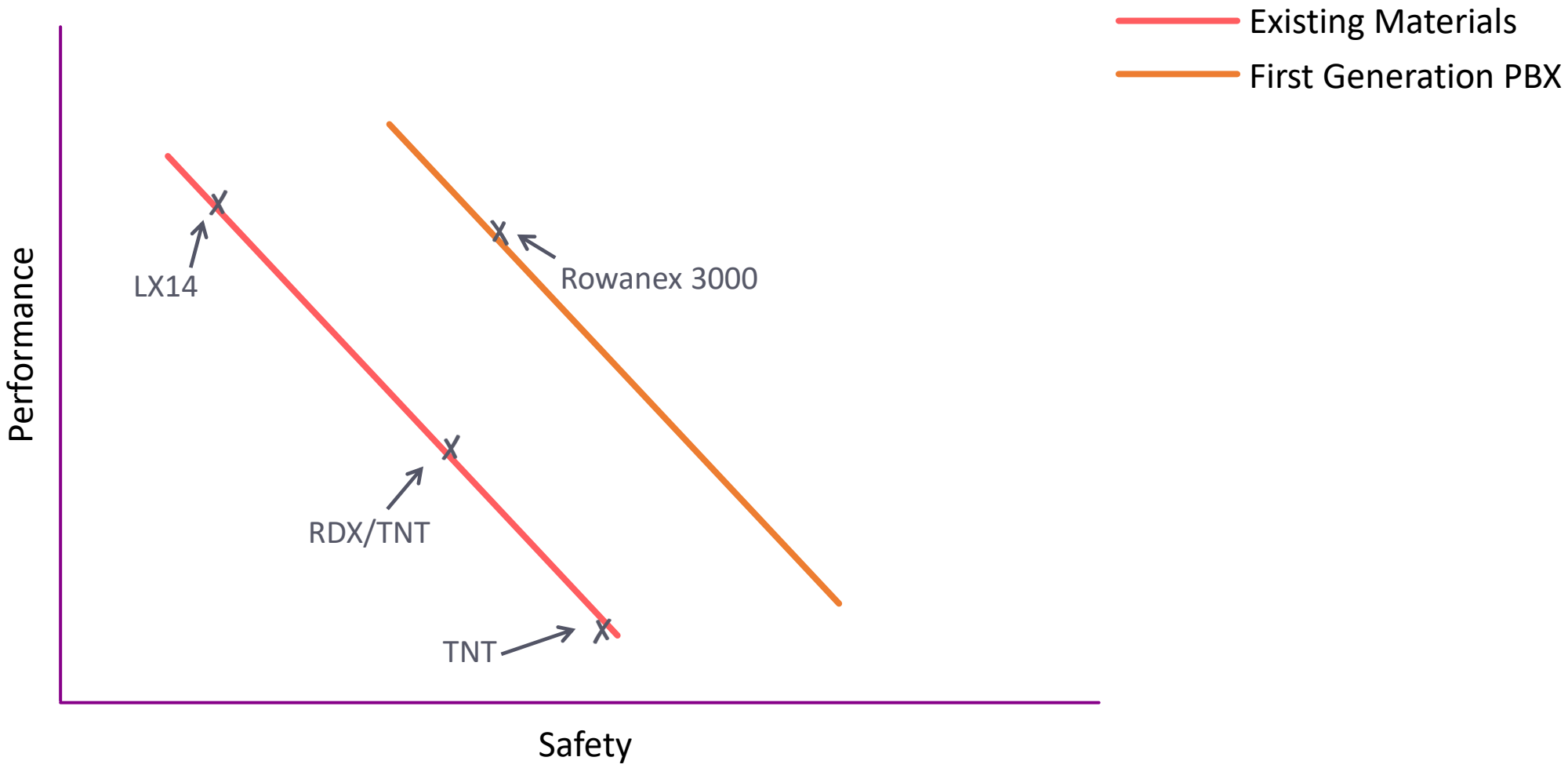
They are by definition relatively sensitive to thermal, mechanical and chemical stimulus

- Sensitivity is tested by the Energetic Materials Testing Assessment Policy (EMTAP) Tests, whole different lecture!

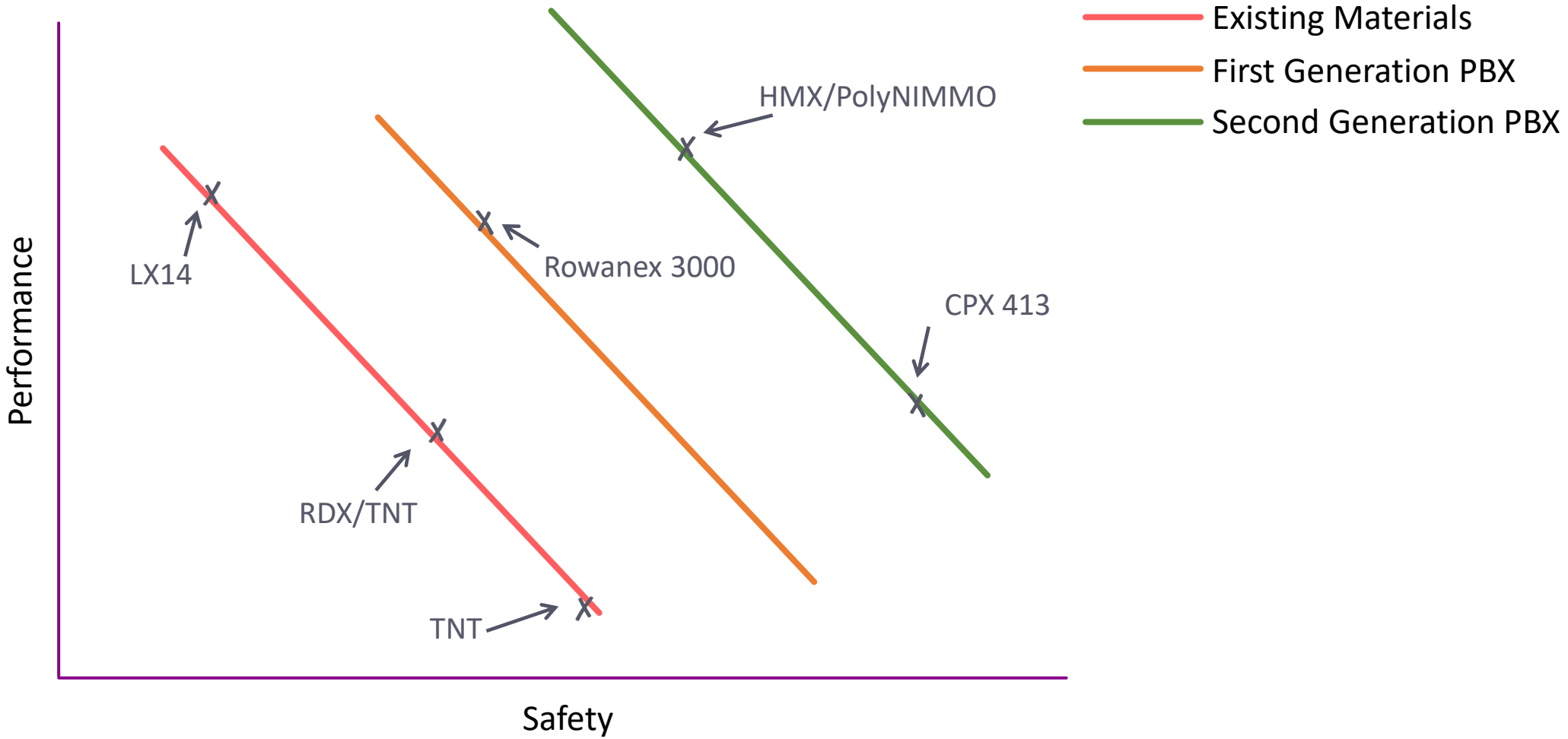
SAFETY LED DESIGN - IM - MATERIALS



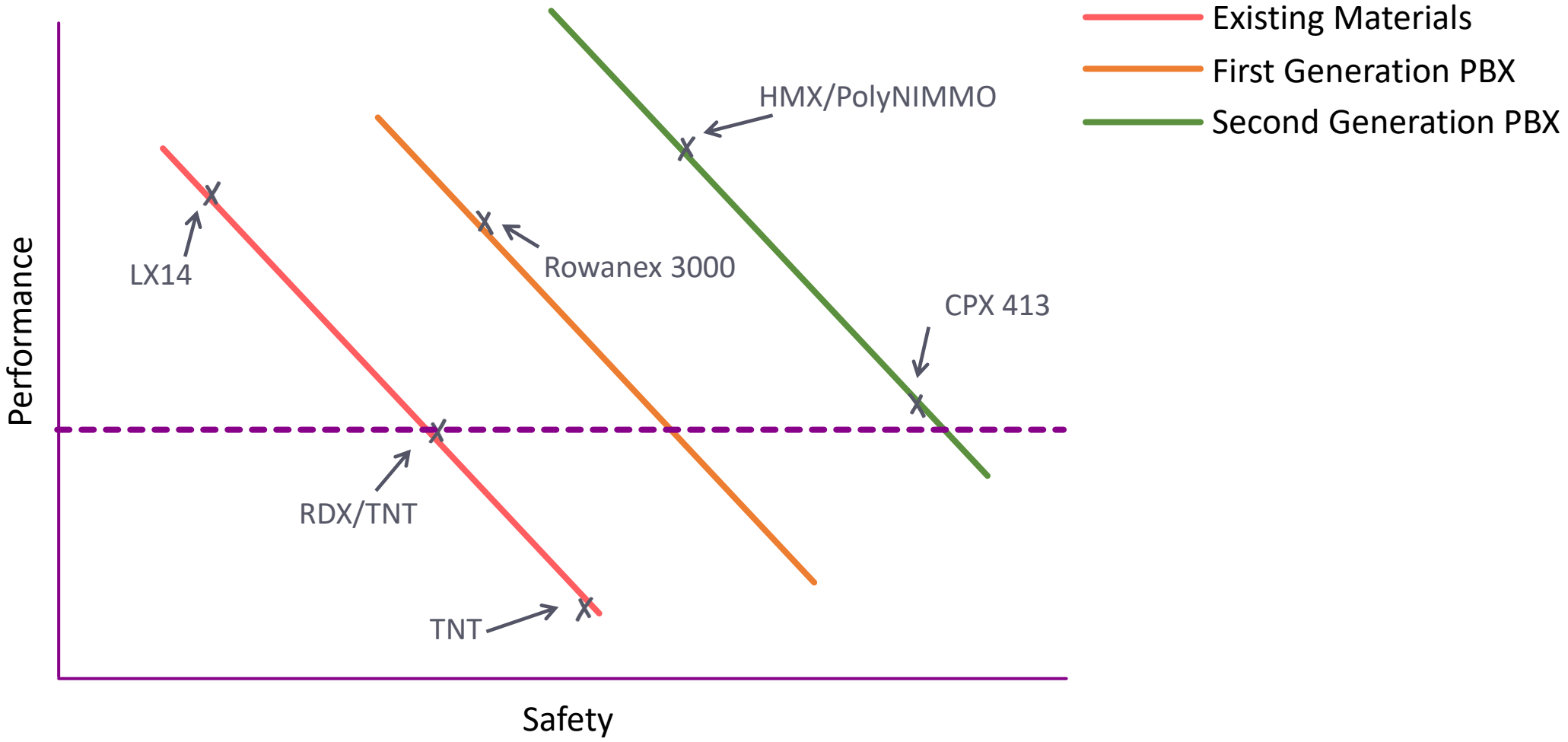
SAFETY LED DESIGN - IM - MATERIALS



SAFETY LED DESIGN - IM - MATERIALS



SAFETY LED DESIGN - IM - MATERIALS



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SAFETY LED DESIGN - IM - MECHANICMS

In order to improve the response to threat stimuli, it helps to understand the detonation mechanisms behind the response types.

There are three main routes for a munition to reach a detonation state.

- Deflagration to Detonation Transition (DDT)
  - A fast burning event leading to detonation
  - Primarily seen in ignition, fires and slow heating
- Shock to Detonation Transition (SDT)
  - Shock input directly leading to a detonation
  - A result of kinetic energy insults
- Unknown/Unexplained to Detonation Transition (XDT)
  - Less common result of insults where the test item has a gap, conduit or cone, resulting in detonation
  - Possible in both thermal and kinetic insults, but primarily kinetic.

SAFETY LED DESIGN - IM - DESIGN

With knowledge of the system weaknesses combined with an understanding of detonation mechanisms we can interrupt the explosive chain (or control any event should it initiate) in an attempt to make sure that the Explosive or Munition only functions in 'Design Mode'.

- Heating and impacts tend to lead to burning reactions
  - Burning should not be allowed to DDT - examples of mitigation strategies to help prevent this
    - Thermal barriers
    - Venting (active or passive)
    - Low explosiveness fillings (low burn rate)
- High speed impacts tend to lead to ignition and/or burning reactions
  - Examples of mitigation strategies to help prevent SDT
    - Barrier materials
    - Internal and external linings
    - Low shock sensitivity explosive fillings

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SAFETY LED DESIGN - IM - PACKAGING

Image sources:
army.mil/article/238532
australiandefence.com.au/news

Much akin to internal munition design, packaging design can be used to help improve Insensitive Munitions signature. One example of this can be seen in research by the Defence Academy Shrivenham:

The shell in question is known to be weak to both fragment attack and sympathetic reaction, including whilst packaged. This can lead to an extremely detrimental cascade of store detonations in depot storage.

A design exercise was carried out in attempt to mitigate against this threat – It was not possible to change the design of the shell so modifications to packaging were investigated instead

Slide based on teaching by Chris Stennett - Packaging, Mitigation, Through-Life Assessment - 2018

SAFETY LED DESIGN - IM - PACKAGING

Image sources:
fas.org

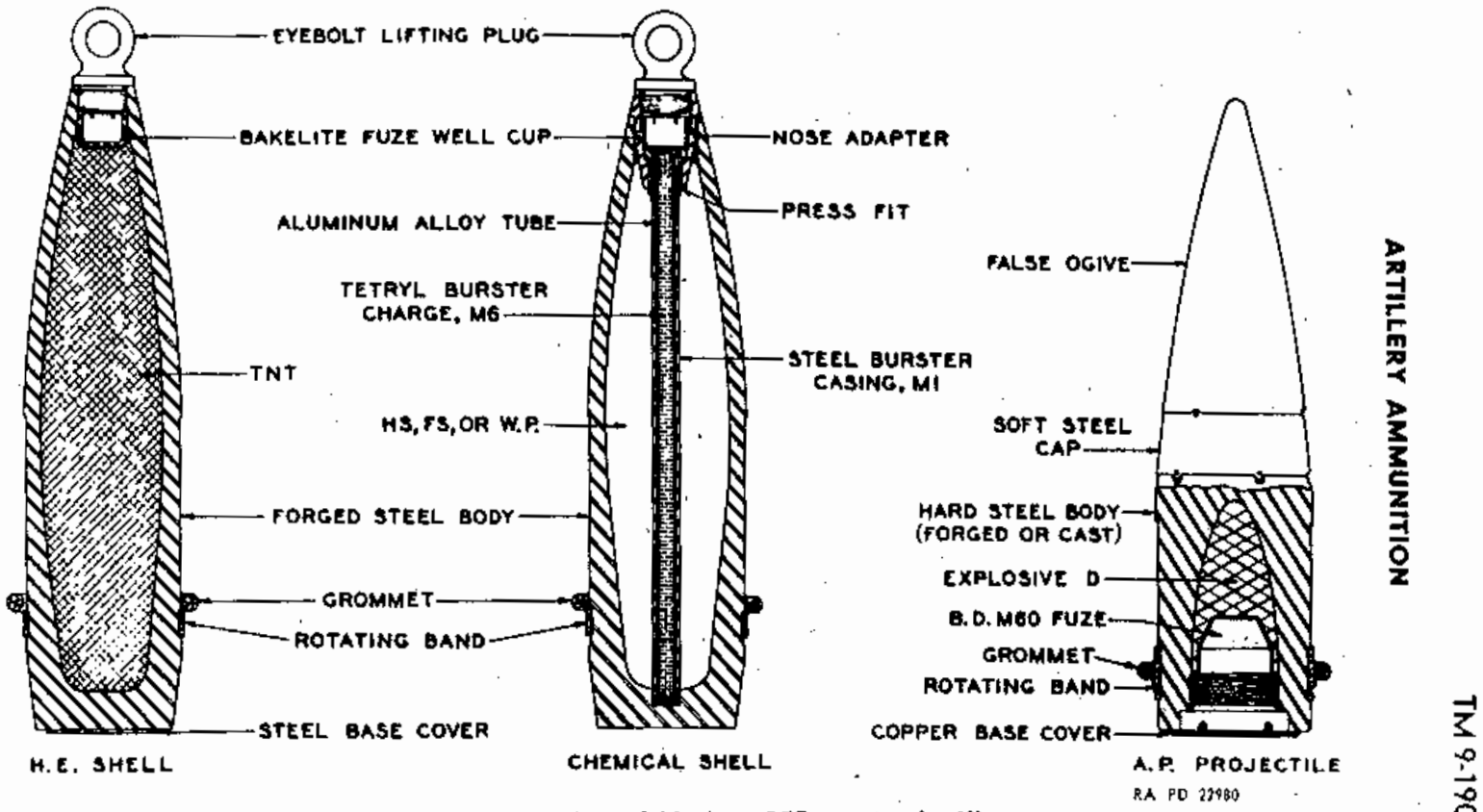


Figure 199 — Section of Modern 155-mm Projectiles

Slide based on teaching by Chris Stennett - Packaging, Mitigation, Through-Life Assessment - 2018

SAFETY LED DESIGN – IM – GENERAL ASIDE

Threats

- Understand the known threats
- Prioritise remedial action around any weak points or high priority threats

Responses

- Model the threat and system response to it
- Evaluate through expert analysis and assessment
- Confirm model and theory through small scale testing

Solutions

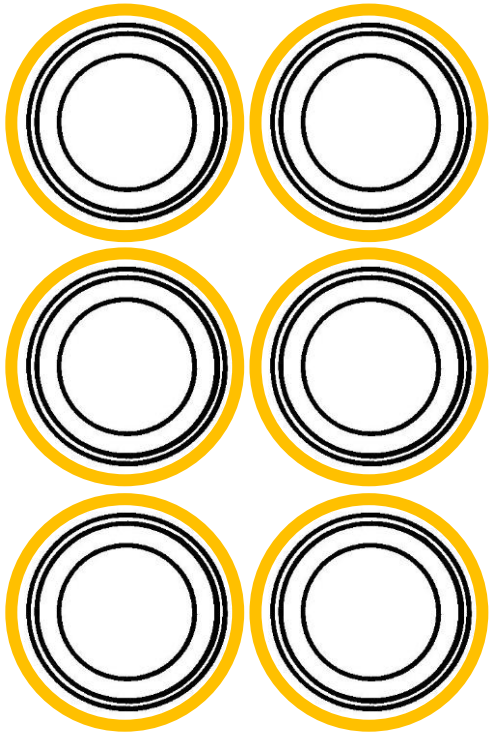
- Determine the effect of any proposed solution
- Decide any trade off needed
- Validate through large scale testing AUR testing

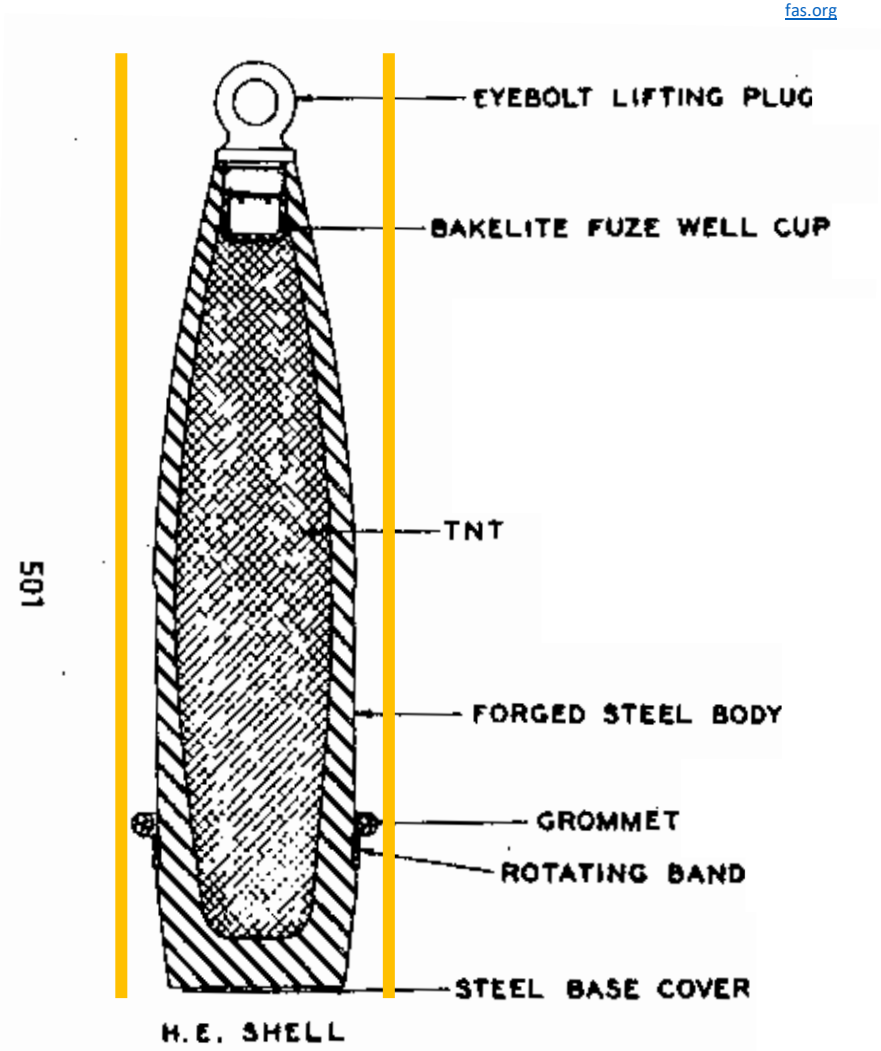
SAFETY LED DESIGN - IM - PACKAGING

Image sources:
fas.org

The design was required to fit within the existing ammunition box footprint without reducing the overall carrying capacity. This leaves minimal area in which to work, around 30 mm around each shell.

A sleeve was designed to house each shell and afford additional protection from both the initial enemy fragment impact and any subsequent fragments from sympathetic reaction by absorbing impact energy into the sleeve.





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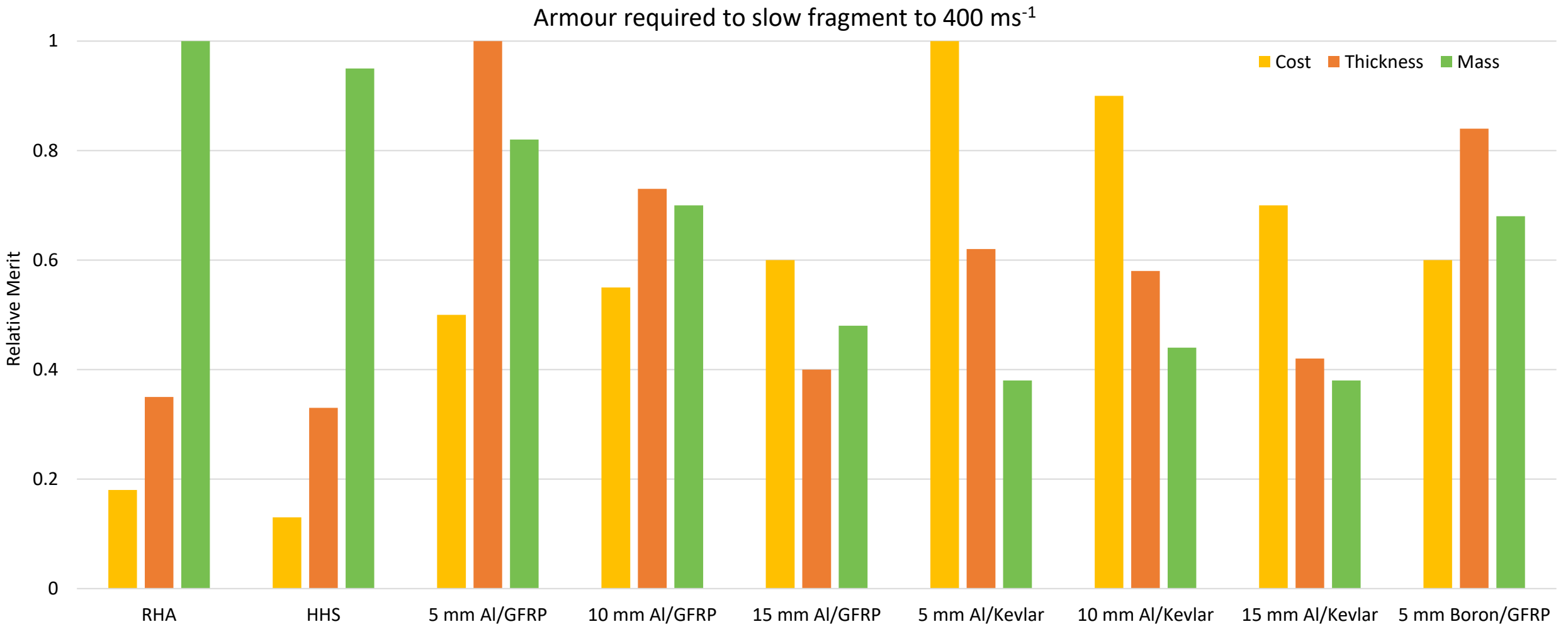
SAFETY LED DESIGN - IM - PACKAGING



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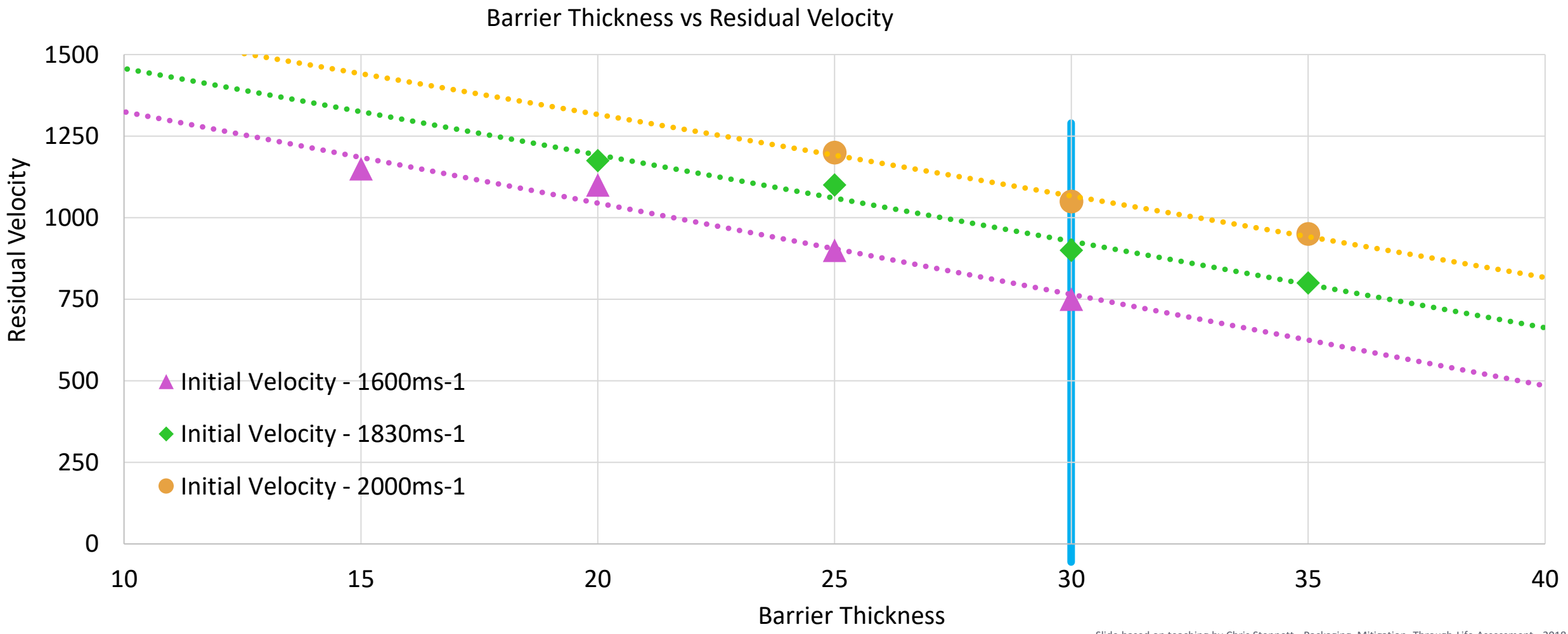
SAFETY LED DESIGN - IM - PACKAGING



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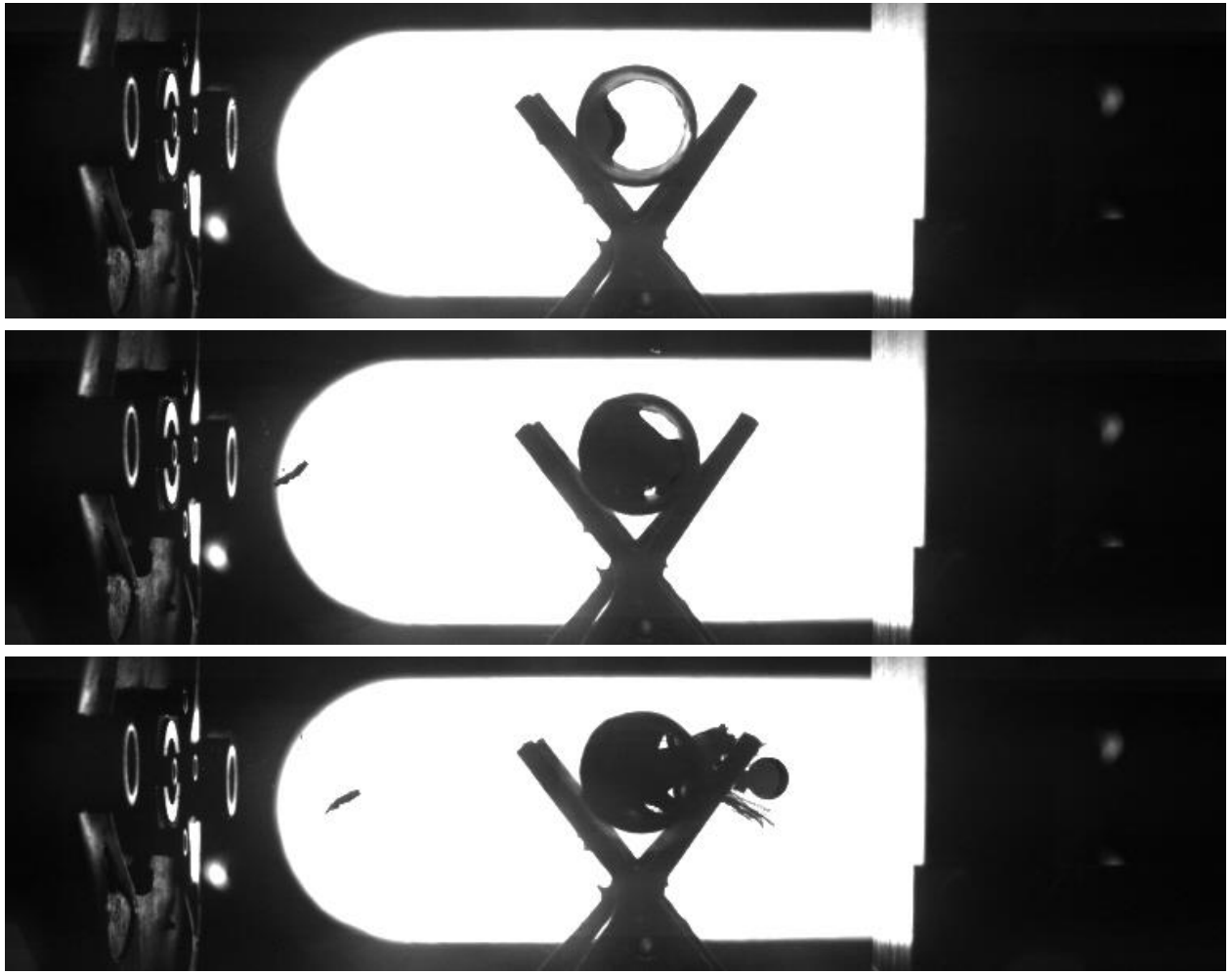
SAFETY LED DESIGN - IM - PACKAGING

The barrier material giving the greatest reduction in fragment velocity was chosen. This was a function of areal density and overall thickness.

At a thickness of 30 mm, the barrier material was able to produce a reasonable reduction in impact energy, reducing the impact energy on the store and the chance of detonation.



Slide based on teaching by Chris Stennett - Packaging, Mitigation, Through-Life Assessment - 2018

SAFETY LED DESIGN - CONCLUSION

By taking time to understand the system and its operating environment Safety Led Safety Design can be used to effectively mitigate issues in a safe and cost effecting manner.

Using knowledge applied to existing systems, design strategies can be employed to mitigate existing issues to improve the overall safety argument of the existing design, or suggest improvements for any further revisions at a holistic system or subsystem level.

Improvements made to any part of the system can be used to help the overall argument, as long as the interplay between systems is understood.

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SAFETY LED DESIGN – EXERCISE

GROUP DISCUSSION - WE HAVE DISCUSSED A FEW METHODS OF IMPROVING THE SAFETY OF MUNITIONS – WHAT ELSE CAN WE DO?

THANK YOU FOR LISTENING

ANY QUESTIONS?

SAFETY SERVICES ORGANISATION