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# Storm Shadow Warhead System IM Compliance Assessment Through Life

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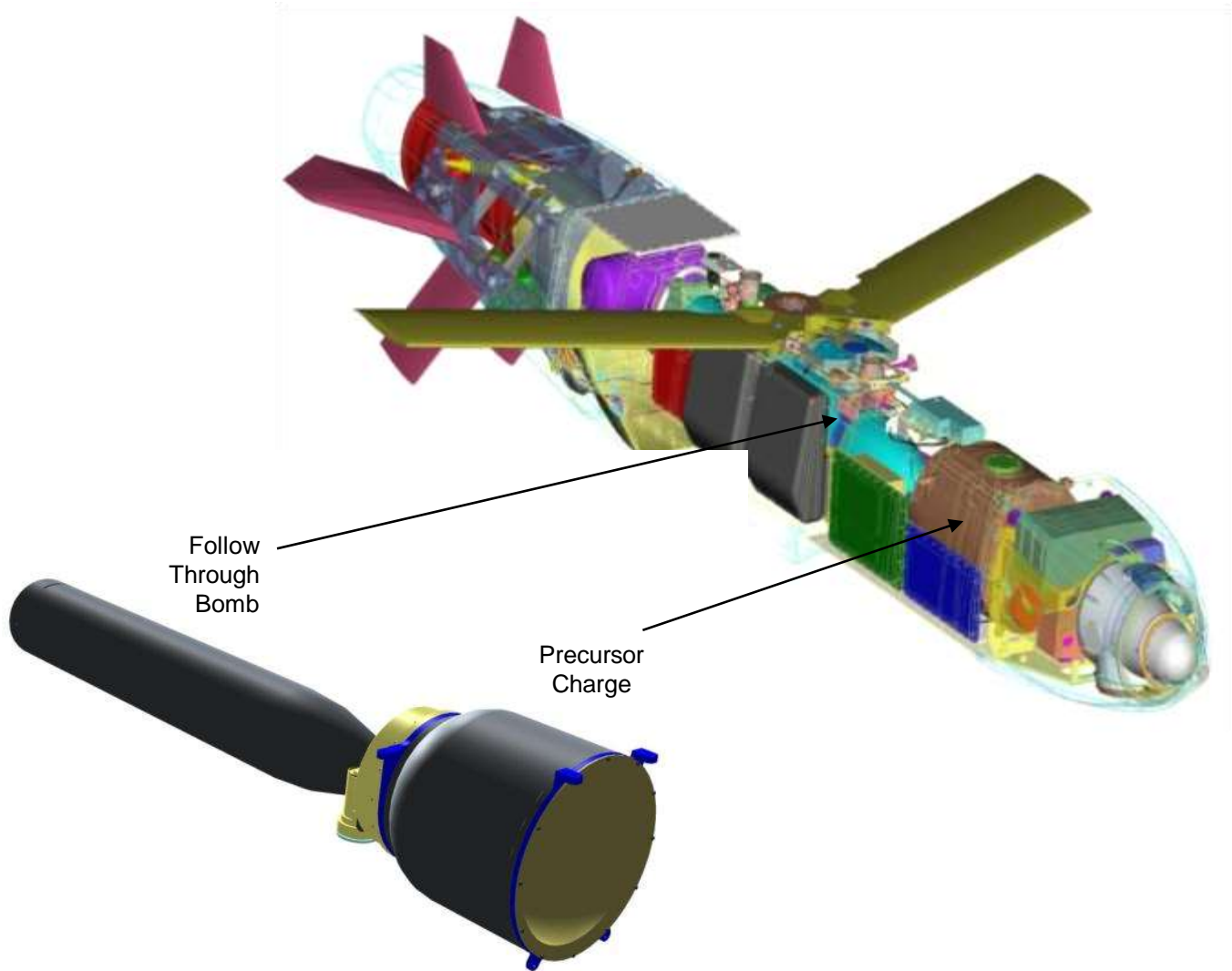
# Presentation Outline

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- Storm Shadow design summary
- UK IM assessment methodology
- Original Qualification and IM assessment
- Re-Qualification and IM assessment
- Surveillance and life extension (SALE)
- Conclusions

# Storm Shadow Missile

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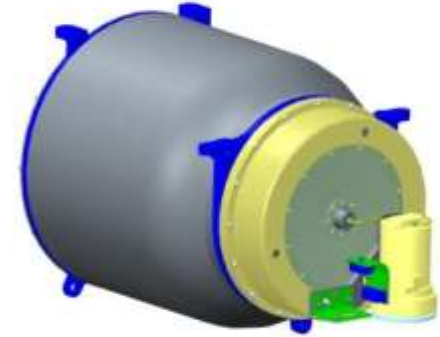


# Storm Shadow Warheads IM Design Aspects

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## Precursor Charge

- High performance requirement and optimised shaped charge
- Cast HMX based PBX main filling – no DDT, low explosiveness
- Proven insensitive booster pellet and pyro cord compositions
- Closures designed to fail as temperature increases beyond environmental limits
- Steel & aluminium case construction
- Body lined for thermal insulation and shock mitigation



## Follow Through Bomb

- High strength and mass conflict with need for venting
- Small cross section means large aspect ratio
- Cast RDX based PBX main filling – no DDT, low explosiveness
- Proven insensitive booster pellet composition
- Vent holes incorporated in rear closure for main fill and boosters
- Body lined for thermal insulation and shock mitigation
- Controlled thermal ignition site position – supported by modelling



UK IM assessment carried out by IM Assessment Panel (IMAP)

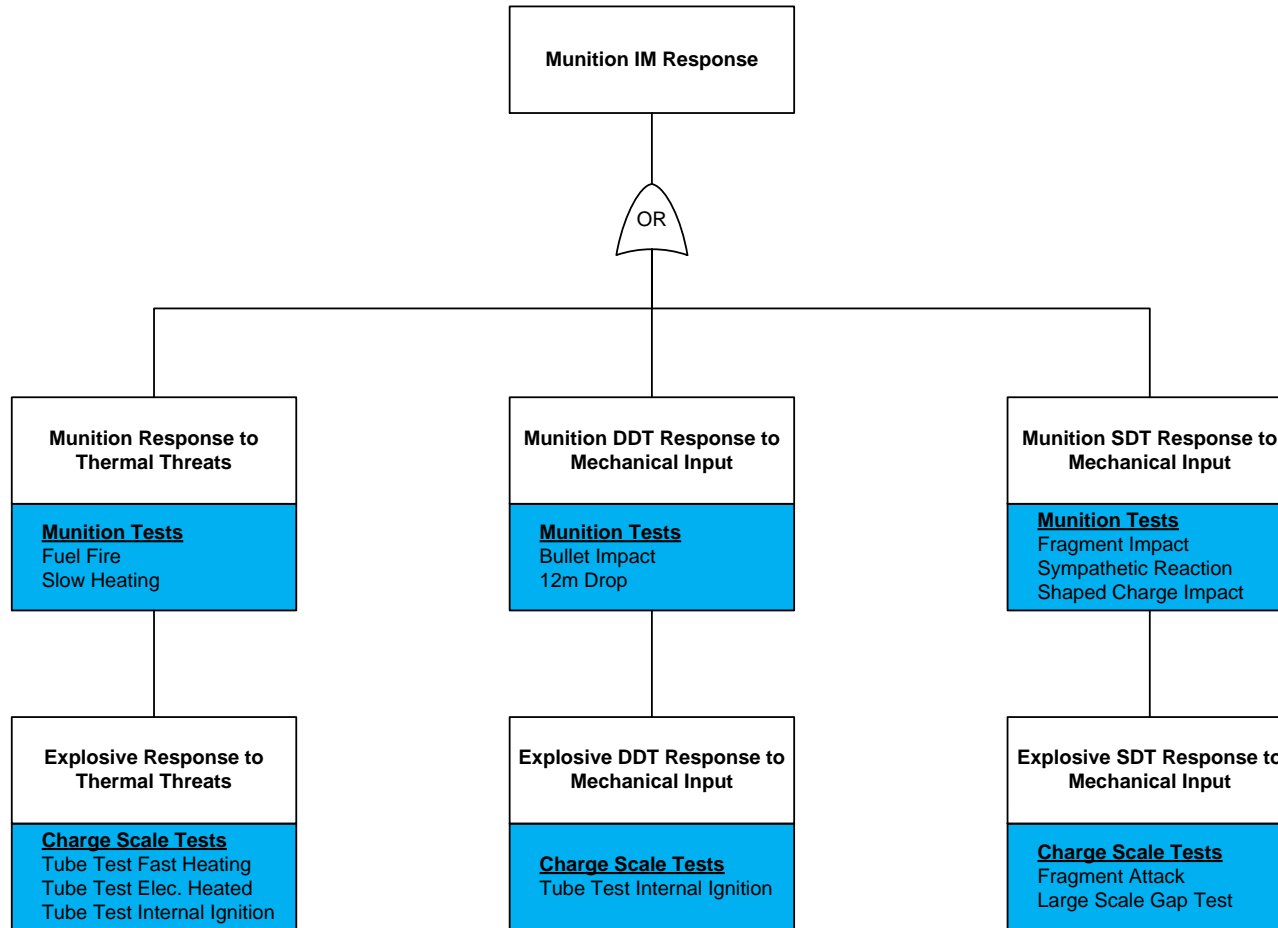
Basing IM Assessment solely on the results of full scale IM tests is not practical because:

- Test conditions may not be reproducible
- Energetic materials response may be variable
- Statistically insignificant due to cost limitations

For these reasons a 'whole body of evidence' approach is taken which includes the following:

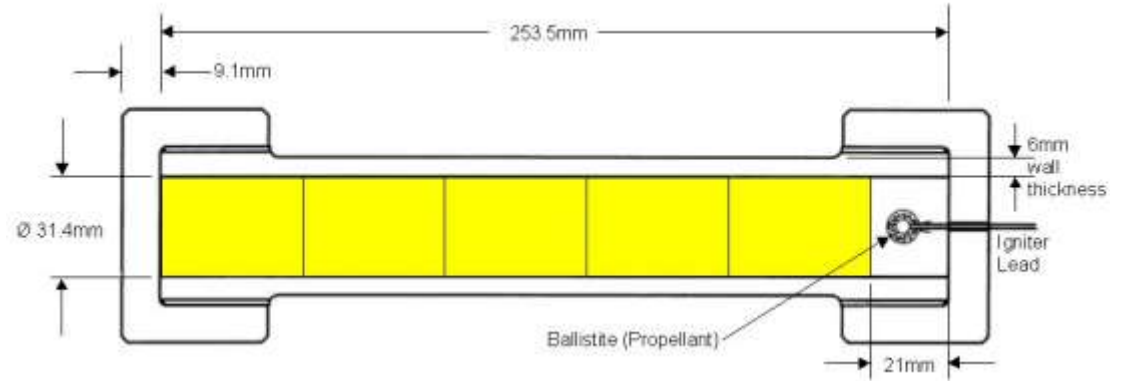
- Assessment of the energetic materials
- Analysis of the weapon system design
- Full scale IM testing

# Munition/ Explosives Test Correlation

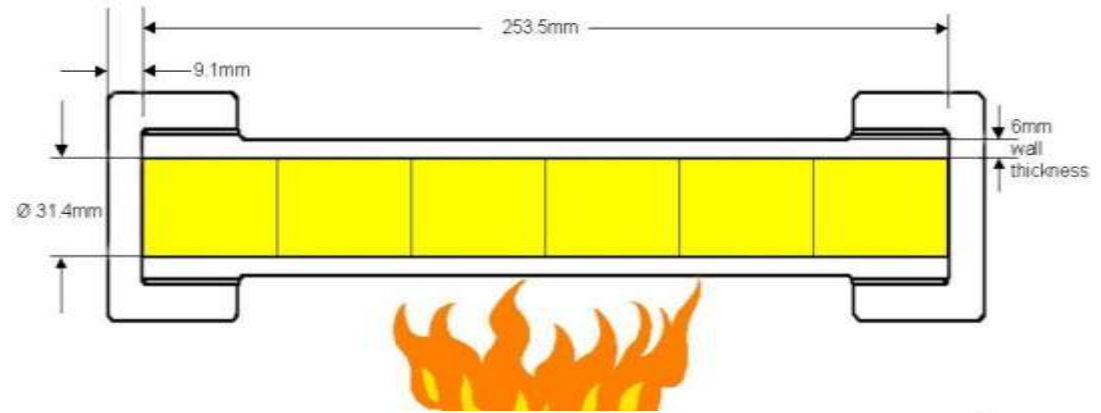


# Tube Tests

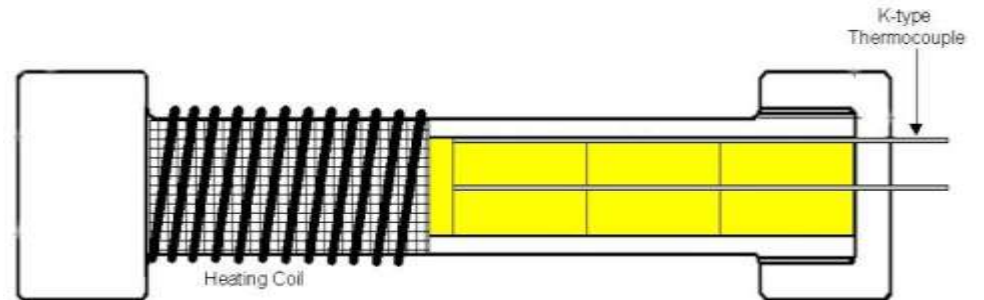
Internal Ignition Tube Test



Fast Heating Tube Test



Electrically Heated Tube Test





# Tube Test Results Assessment

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Tube fragmentation used to categorise relative explosiveness of test composition. Multiple tests conducted to assess reproducibility and give confidence in results.

Category 1 – Pressure Burst



Category 2 - Deflagration



Category 3 - Explosion




Category 4 - Detonation





# Tube Test Results Comparison

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Tube Tests		Explosiveness	STANAG 4439 Full Scale IM Tests	
Category	Description		Description	Category
0	No reaction	Low  High	No reaction	Type VI
0/1	Burning/ decomposition		Burning	Type V
1	Pressure burst		Deflagration	Type IV
2	Deflagration		Explosion	Type III
3	Explosion		Partial Detonation	Type II
4	Detonation		Detonation	Type I

# Explosives Qualification Charge Scale Test Results

- Low explosiveness in Tube Tests:

Composition	Internal Ignition Tube Test Category (No. off)	Fast Heating Tube Test Category (No. off)	Electrically Heated Tube Test Category (No. off)
FTB Main Charge	0(10)	1(10)	1(6)
PC Main Charge	0(8), 1(2)	1(10)	1(6)

- Low shock sensitiveness in LSGT:

Composition	50% Detonation Gap	50% Detonation Pressure
FTB Main Charge	31.0mm	4.72 GPa
PC Main Charge	38.5mm	3.49GPa

- Low shock sensitiveness in Fragment Attack test:

Composition	SDT Threshold Velocity
FTB Main Charge	~1800 m/s
PC Main Charge	~1800 m/s

- Good mechanical properties, and the ability to withstand all mechanical environments without cracking or other physical degradation which could detrimentally affect IM performance.
- Maintain chemical, mechanical and sensitiveness properties after accelerated ageing to represent a 25 year Service life.

# Storm Shadow Missile IM Compliance

- FCO, SCO, BI and SR demonstrated by full scale test
- Assessment conducted on Fragment Impact threat
- Full compliance with IM requirements achieved
- Missile IM signature based on testing and assessment as follows;

Threat	Acceptable Reaction	Result
Fast Cook-off	Type V	Type V
Slow Cook-off	Type V	Type V
Bullet Impact	Type V	Type V
Fragment Impact	Type V	Type V
Sympathetic Reaction	Type III	Type V



- First weapon of its size to be fully IM compliant

# Re-Qualification Requirements

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- Re-manufacture of the Storm Shadow Warhead System after a break in manufacture of ~ 5 years.
- Change of industrial structure and closure of facilities resulted in:
  - Change in manufacturing locations
  - Change of supplier for RDX and HMX
- The following re-qualification activities were required:
  - Explosives qualification
  - Warhead environmental qualification
  - IM assessment

# Re-Qualification Charge Scale Results Comparison

- Tube Tests Results Comparison:

Composition	Internal Ignition Tube Test Category (No. off)	Fast Heating Tube Test Category (No. off)	Electrically Heated Tube Test Category (No. off)
FTB Main Charge	0(10)	1(10)	1(6)
FTB Main Charge Requal	0(10)	1(10)	1(3), 2(2)
PC Main Charge	0(8), 1(2)	1(10)	1(6)
PC Main Charge Requal	0(10)	1(9), 2(1)	1(3), 2(2)

- LSGT Test Results Comparison:

Composition	50% Detonation Gap	50% Detonation Pressure
FTB Main Charge	31.0mm	4.72GPa
FTB Main Charge Requal	29.1mm	4.81GPa
PC Main Charge	38.5mm	3.49GPa
PC Main Charge Requal	39.5mm	3.52GPa

- Direct comparison of Fragment Attack results not possible due to test variations, but showed both compositions not sensitive to impact by high velocity fragments and better low explosiveness response than equivalent insensitive PBX compositions.

# Re-Qualification Test Summary

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- Tube tests gave low explosiveness (Category 0, 1 and 2) responses for both compositions, and the level 2 responses were relatively benign within the category.
- Large Scale Gap Test and Fragment Attack test results showed that both compositions have low shock sensitiveness.
- Mechanical testing showed comparable tensile properties and modulus
- Environmental testing demonstrated ability to withstand worst case environments
- Accelerated ageing tests demonstrated retention of explosives properties through life
- All results showed that significant explosives characteristics were unchanged from the previously qualified compositions and enabled read across of IM signature.





# Conclusions

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- Storm Shadow design enabled full IM compliance with no compromise of performance.
- Charge scale testing carried out as part of explosives qualification provided data in support of IM assessment.
- This provided a valuable baseline against which to assess the effects of changes in materials, suppliers and manufacturing locations during re-qualification.
- Re-qualification test results enabled read across of IM signature
- SALE testing carried out to confirm retention of explosives properties through life and give confidence in continued IM compliance.