“SLIM”
A 180 mm diameter IM compliant Min Smoke rocket motor

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Agenda

- Introduction and Design Overview
- IM Response
- Propellant Testing and Hazard Classification
- Trial Results
  - Hellfire IM Motor FCT Work
  - SLIM TDP
- Conclusions

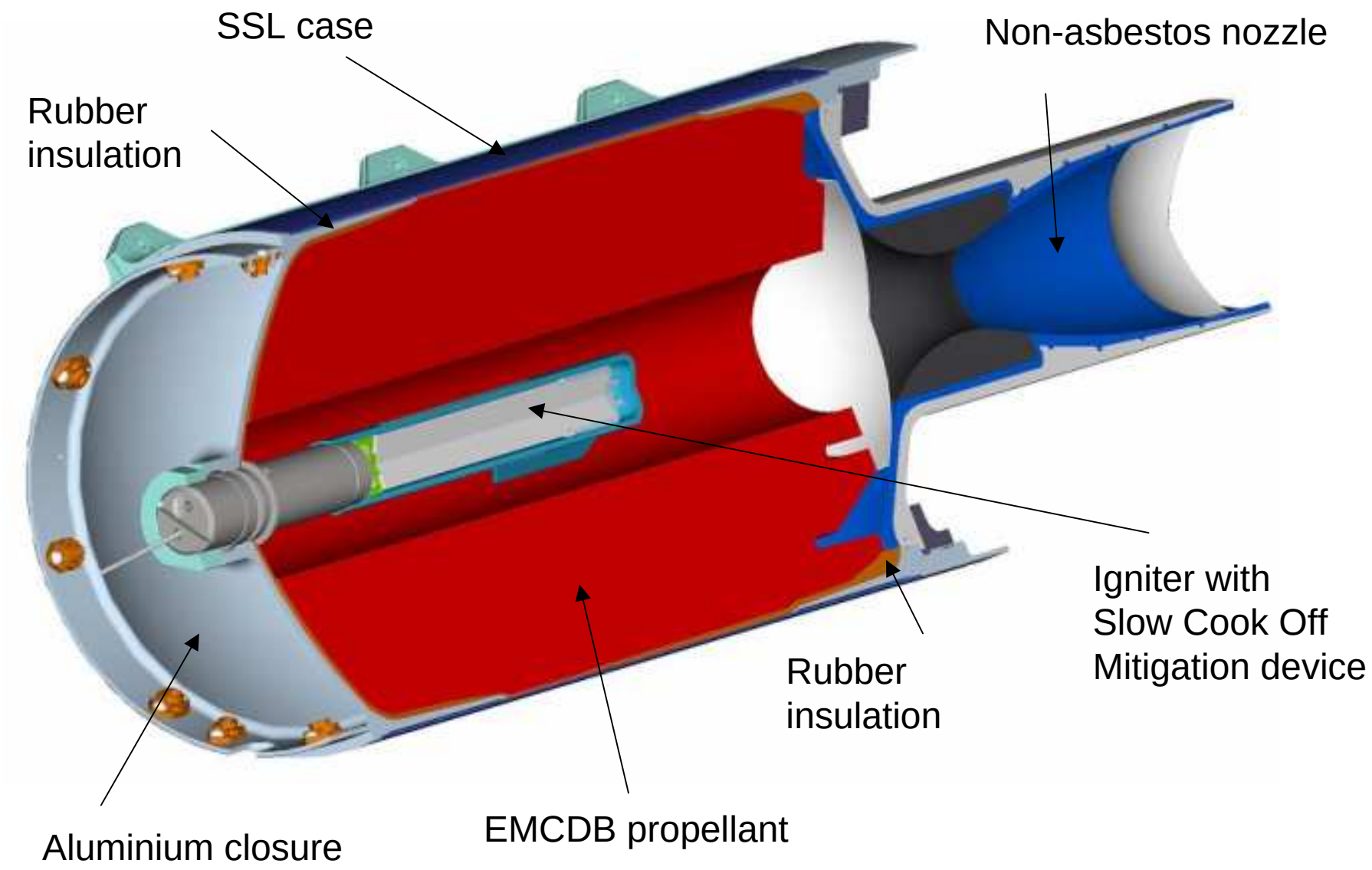
Introduction

- **S**mokeless **L**arge **I**nsensitive **M**unitions (SLIM) Technical Demonstrator Programme (TDP) was completed in late 2005
  - UK MoD (DEC) funded
  - DOSG Project Managed
- EMCDB Propellant with 178 mm (7”) diameter SSL case
  - Hellfire and Brimstone type applications
- Followed on from self funded and Hellfire IM motor FCT demonstration work
- Assessment studies
- > 20 motor trials

Centrifuge firing

Vibration

SLIM Design Overview



IM Response

Insensitive Propellant with Case Venting

- The IM response of the SLIM motor is a result of the propellant and case design

- Propellant
  - Elastomer Modifed Cast Double Base (EMCDB)
    - High range of burn rates and low Pi-K (on plateau) result in good Total Impulse and Thrust
  - Powder Granule manufacturing process
  - No RDX or Refractories included

- Motor Case
  - Steel Strip Laminate (SSL) construction : bonded
  - SCO Mitigation Device

SSL Cases

- SSL rocket motor technology commenced in 1954
  - 40,000 + SSL motors produced

- Principle : Bonded structure, high strength steel
  - Case unwinds during Fast Heating
  - Case is weakend in Slow Heating
  - Steel type results in large vent areas during Bullet/Fragment Impact

- SSL technology well established and in-service
  - Rapier (ground based : SSL and EMCDB)
  - ASRAAM (fixed wing : SSL and HTPB)
  - Seawolf boost motor (naval: SSL and CDB)

IM Response

- **Legacy motor**
  - XLDB (high Nitramine)
    - HD 1.1
  - Rotary Wing limited to + 63 ℃
  - Fixed Wing capability

	FH	SH	BI	SR	FI
NR					
V	☺				
IV					
III					
II					
I		☹	☹	☹	☹

- **SLIM* (IM Brimstone/Hellfire)**
  - EMCDB/SSL
    - HD 1.3
  - Rotary Wing + 71℃ capability
  - Fixed Wing capability

	FH	SH	BI	SR	FI
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* Based upon FCT and SLIM TDP results

Roxel Motor Design: Greatly Improved IM

Non IM Motor

Bullet Attack
(Aluminium Case)

SLIM Motor

Bullet Attack

Propellant Testing and Hazard Classification

SLIM Propellant : Card Gap & Tube Testing

- Large Scale Gap Test (EMTAP test No. 22)
  - Median Gap result of 11.8 mm, equivalent to a **Card Gap of 47**
    - UK Card Gap results are considered = US NOL value

- Tube Test – Fast Heating (Fuel Fire, EMTAP test No. 41)
  - All 10 results ranked as reaction class 1
    - Scale is 0 to 4, with class 4 = detonation

- Tube Test – Electrically Heated (EMTAP test No. 42)
  - 3 results ranked as reaction class 1 and 2 with reaction class 2

- It was concluded* that **“the propellant is comparatively insensitive to shock initiation and ..demonstrates low explosiveness when heated”**

* Mullinger, D.C. “Charge Scale Gap Testing of EMCDB Propellant”, QinetiQ/05/00917, June 2005

Roxel

SLIM Propellant : Sensitiveness Testing

- Results for the SLIM propellant are summarised below (2 samples)
  - Rotter Impact
    - Median Height : 22.1 and 16.5 cm
    - F of I : 16 and 17 (RDX = 80)
  - Mallet Friction
    - Steel/Steel : 50 % ignitions and 50 % ignitions
    - Maple/ Yorkstone
      / Hardwood : All 0 % ignitions and 0 % ignitions
      / Softwood
  - Rotary Friction, F of F : 3.9 and 4.1
  - Temperature of Ignition : 160.5 and 158.7 ^{o}C
  - Electric Spark : No ignitions at 4.5 J (for either sample)

Motor 1.3 Hazard Classification

- The SLIM motor was classified by the UK MoD's ESTC Competent Authority in October 2004
  - ESTC Item Number T3312 applies
    - Hazard Classification Code : 1.3C
    - UN Serial Number 0186

- Roxel's earlier IM Hellfire motor, that uses the same type of propellant and Steel Strip Laminate case as the SLIM motor, was also classified by the United States Department of Transport's Competent Authority in November 1998
  - Reference Number EX-9811079 applies
    - Hazard Classification Code : 1.3C
    - UN Serial Number 0186

Trials Results

Hellfire IM Motor FCT Work

Hellfire IM Motor FCT : Background

- 1995 motors sent to US DoD for test against a competitive request for demonstrators
  - Roxel (then RORM) won competition
  - IM capability demonstrated
  - FCT contract awarded for qualification (1998 - 2000)

- Build Standard submitted
  - SSL case
  - Unfilled ‘generation 1’ EMCDB
  - No Nitramines or other fillers
  - matched existing motor’s performance requirements

Hellfire IM Motor FCT Trials (1998 – 2000)

- 29 live motors tested at Roxel, 3 structural motor cases
  - Tested at +63 ℃ and +71 ℃
    - Transit drop shock and transport vibration at +71 ℃
    - Captive flight vibration, firings at +63 ℃
- 12 motors supplied to AMCOM for their system tests
- Success in all aspects
  - Initial problem with + 71 ℃ un-packaged vibration trial in longitudinal axis has been overcome in SLIM self funded work

Trials Results

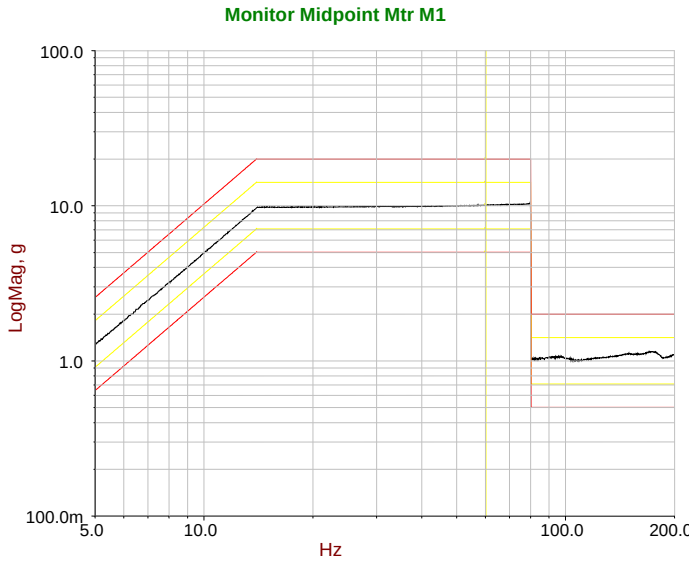
SLIM Technical Demonstator Programme (TDP)

Self Funded Work

- Design to broadly meet Hellfire/Brimstone thrust gates
- Hardware Manufacture
- Propellant Development
- Internal Insulation Development
- Motor Trials
  - 3 Ballistic
  - 2 Vibration
  - 2 Aeroheat
- SCO Mitigation technology

Unpackaged 71 ℃ transport Vibration passed

- Represents “un-sprung bogie” rail transport
  - 25 mm displacement at low frequency, 10 g
  - unpackaged and at 71 ℃
- Very difficult trial to pass
  - Success with SLIM motor in 2005



Summary of Self Funded Ballistics Design Work

- Objective
  - Meet both the Hellfire and Brimstone thrust gates concurrently
- Proposed blend of two casting powders
  - Provide burn rate control flexibility by means of blending
- Deliberate non-inclusion of refractory additives
  - In order to maintain 1.3 hazard classification
- Conclusion
  - All ballistic performance objectives realisable

SLIM TDP Funded Programme

TDP Programme Summary

- Ballistic Firings
  - 2 x + 20 ℃, 2 x + 71 ℃, 2 x - 46 ℃
- Centrifuge
  - 1 x + 71 ℃, 1 x - 46 ℃
- Aeroheating
- Packaged vibration at – 43 ℃ and + 63 ℃
- Prelim Ageing trial (to 10.6 years)
- IM
  - 1 x Slow Heating
  - 2 x Bullet Attack
  - 2 x Fast Heating

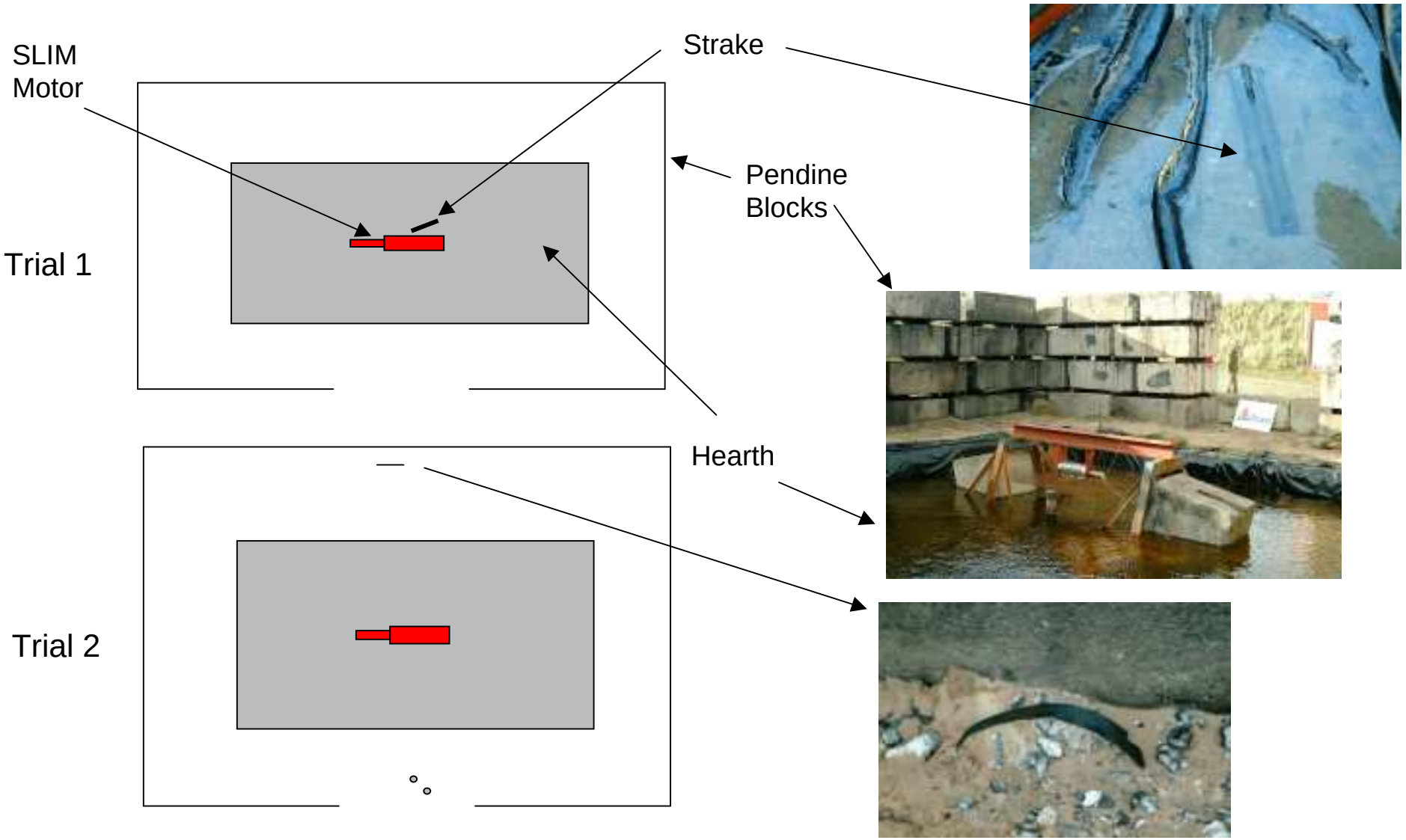
Pendine IM Trials

- Site : UK MoD Range, Pendine, Sept & Nov 2004

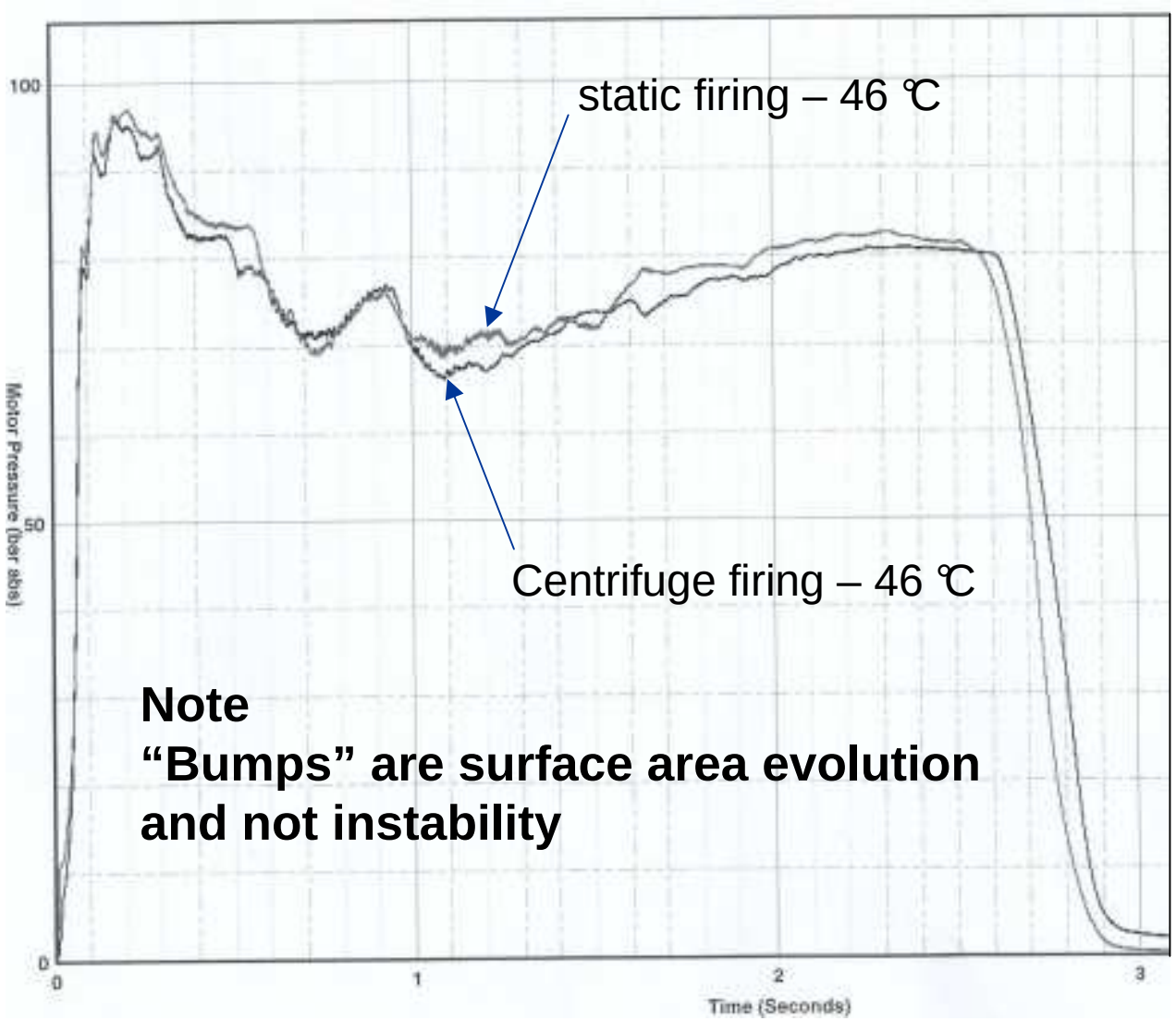
- Set up
  - Igniter installed, Strakes fitted for Fast Heating
  - 2 motors tested for response to Fast Heating
    - STANAG 4240 Edition 2
  - 2 motors tested for response to Bullet Attack
    - STANAG 4241 Edition 2

- Results
  - No hazardous fragments beyond 15 m
  - No discernible blast recorded
  - All four tests gave Type V reaction

Fast Heating : Fragment Maps (2 Trials)



Example : Centrifuge Firing



- TDP Test
  - + 71 & -46 ℃
  - 40 g Vertical
  - 34 g Long
  - ➢ 52.5 g resolved

TDP Stretch potential study

Eight configurations assessed

- Boost/Sustain Cartridge Loaded (similar to JCM)
- Pulse motor
- Pintle
- Dual Thrust, radial burning
- Increased Energy Propellant
- Aeroheat protection
- Stealthy Propellant
- Longer (by 178 mm) motor

Conclusions

- Ballistic performance of SLIM motor successfully demonstrated
  - Combined Brimstone/Hellfire thrust gates met
    - Static firings 71 ℃ to – 46 ℃
    - > 50g axial acceleration loads
      - Centrifuge trials at both 71 ℃ and – 46 ℃
- IM performance demonstrated
- Ability to survive the US MIL STD 810C vibration
- Ageing to equivalent to 10.6 years successfully demonstrated
- The SLIM motor offers a low risk IM compliant solution for Brimstone and Hellfire type applications