UK OFFICIAL

Abstract 22218
Development of an IM Compliant, Minimum Smoke, Double Base Propellant Rocket Motor Containing Refractory Materials

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Who We Are

- Anglo-French company recognised as a European leader in design, development and manufacture of solid rocket motors
  - Provide propulsion systems for land, sea and air defence
  - Also manufacture components for Airbus

- World leader in Insensitive Munitions technology for rocket motors

- Multiple sites across UK and France:

Roxel
Propulsion systems

650 employees

60% of the European market

120 to 150m sales

Roxel

Product Range

- Diverse portfolio of products
- ASRAAM rocket motor
  - Highest IM rated rocket motor in service with UK MoD
- CAMM rocket motor
  - Air defence rocket motor with same IM pedigree as ASRAAM
- IM Brimstone rocket motor
  - First air carried, minimum smoke, IM rocket motor

ASRAAM Fired from F35 © MBDA

IM Brimstone carried on Typhoon © MBDA

CAMM Missile Firing © MBDA

Introduction

- Roxel UK is the manufacturer of an IM rocket motor for a new missile
  - Developed for several helicopter platforms
  - Known in Roxel as Vulcan III

Vulcan III Rocket Motor Static Firing

- Key requirement to provide IM motor (≥ MURAT 1*)
  - Based on highly successful IM Brimstone motor

- Combustion instability issue during development of Vulcan III

- This presentation addresses the challenge to develop a motor:
  - Contain refractory material to dampen instability
  - Whilst maintaining a favourable IM performance

Vulcan III Rocket Motor

Fragment Impact Responses

2 fragment impact IM trials of the same motor design

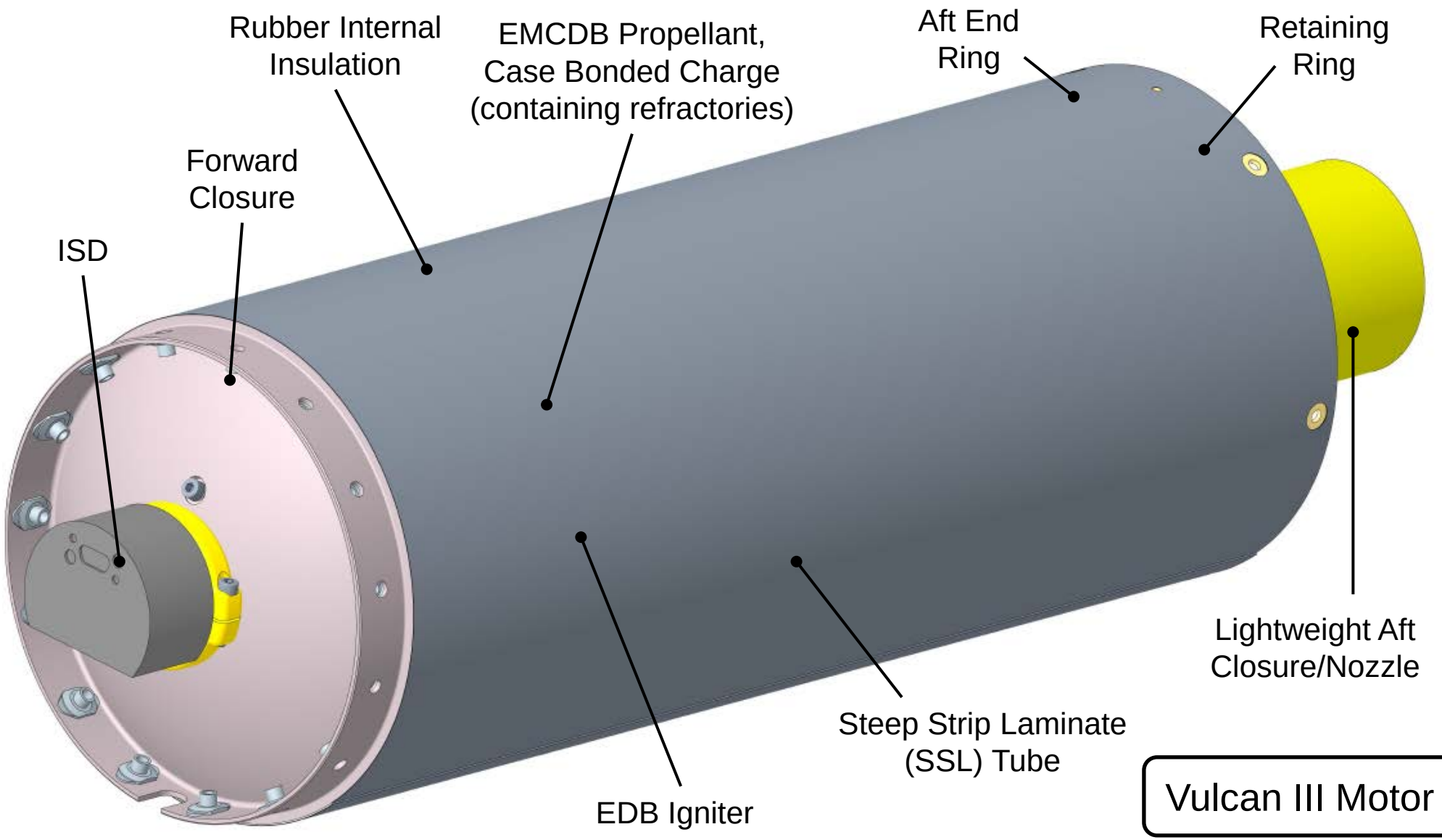
2 levels of refractory in propellant

2 different IM responses!

Type I Response

Type IV/V Response

Vulcan III Rocket Motor Design



Combustion Instability

- Acoustic driven combustion instability is a function of…
  - Propellant grain geometry
  - Any cavities within the combustion chamber
  - Propellant composition
  - Combustion pressure
  - Internal flame field

- Presents as large oscillations in pressure traces

- Can lead to problems during a firing including
  - Damage to the charge
  - Reduced burn time
  - Undesirable thrust profile

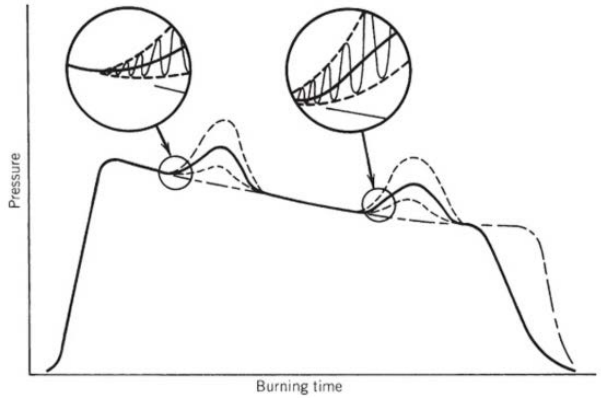
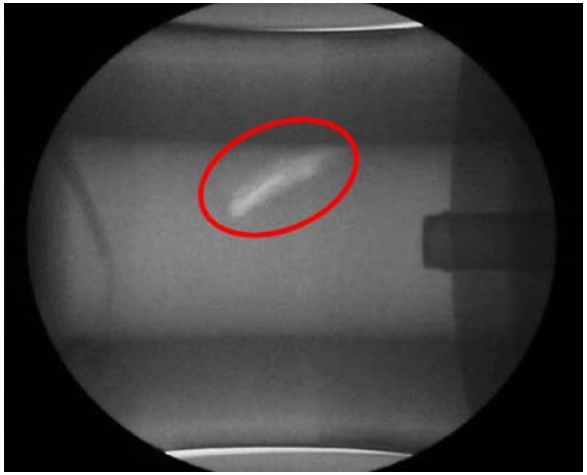


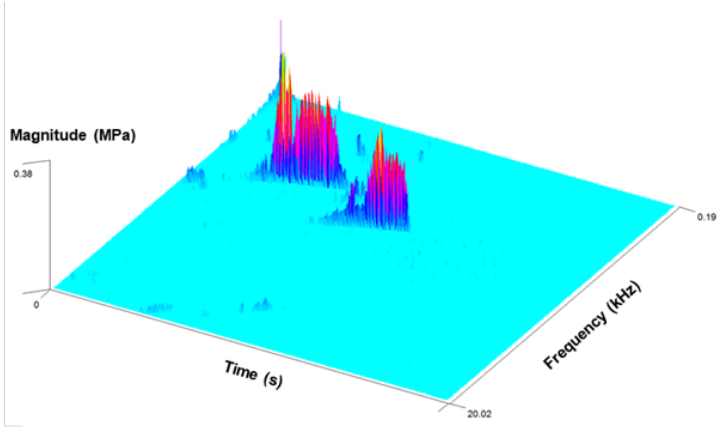
Illustration of effect of combustion instability on pressure trace. Rocket Propulsion Elements; G Sutton © Wiley & Sons



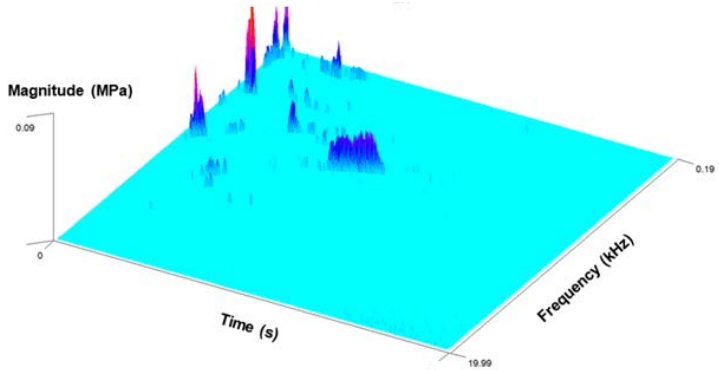
Charge damage observed during firing

Combustion Instability Suppression

- Combustion instability suppression
  - Traditional and novel techniques trialled for instability suppression
  - Suppression techniques assessed for motor performance and IM
  - Introduction of refractory materials gave the best, balanced performance



FFT analysis of motor without refractories

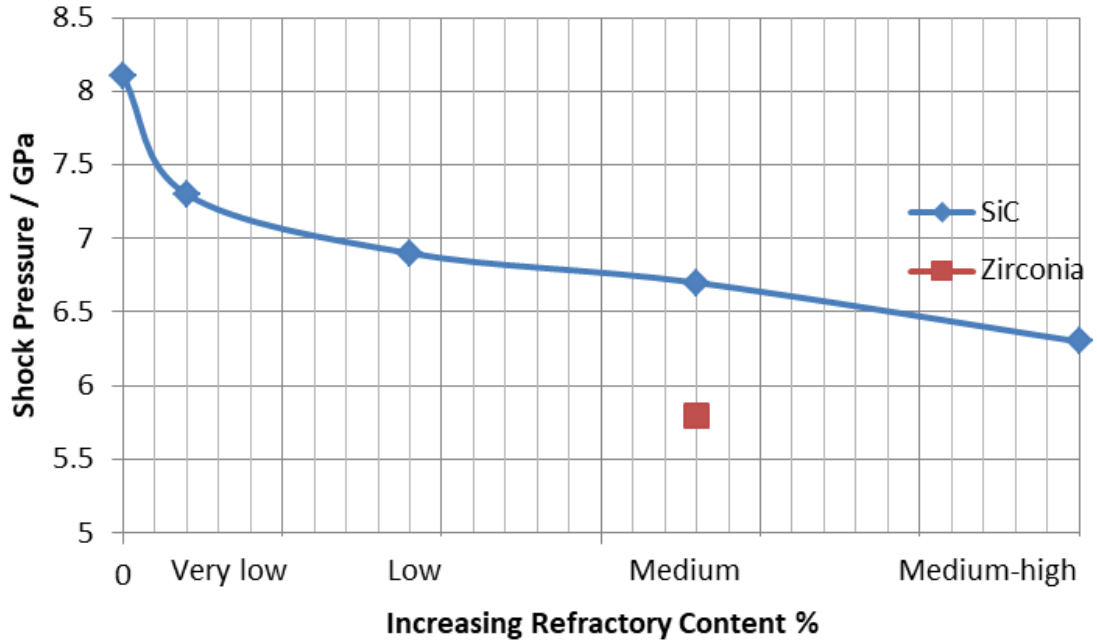


FFT analysis of motor with refractories

- Test plan to assess impact on propellant sensitivity with refractory content
  - Conducted at small scale and motor scale trials
  - Supports assessment of IM performance

Small Scale Testing

- EMTAP Test No. 22 demonstrated…
  - Inclusion of refractories results in a step change to the shock sensitivity
  - Effect of different refractory materials
  - Further increases in shock sensitivity are not linear
  - Saturation point was achieved with relatively low levels of refractory content

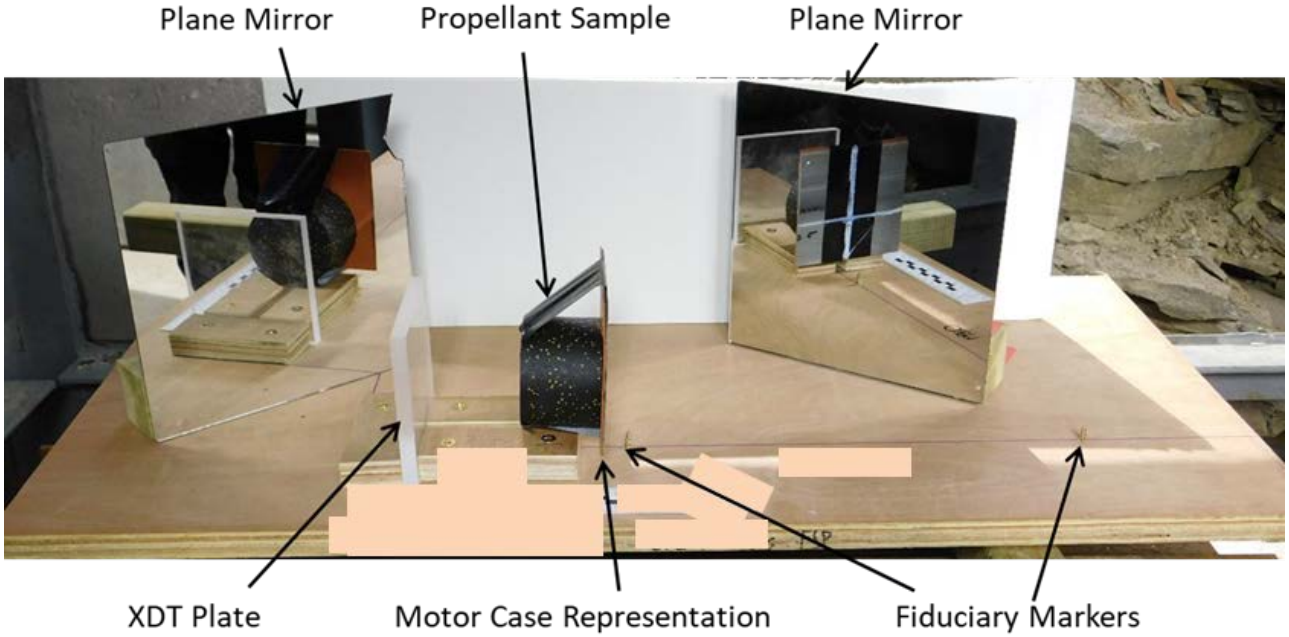


EMTAP Test No. 22 results

Small Scale Testing

- EMTAP Test No. 36A used to understand motor level response to Fragment Impact
  - Impacted samples with STANAG fragments at varying speeds
  - Provides estimate of SDT velocity

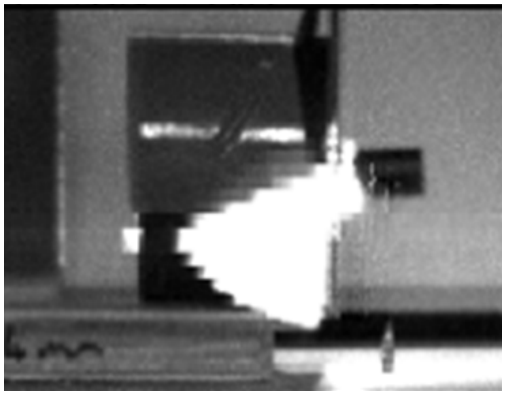
- Propellant samples 70mm diameter, 50mm thick mounted on test stand
  - Representative motor case materials included
  - Some samples included missile pack representations



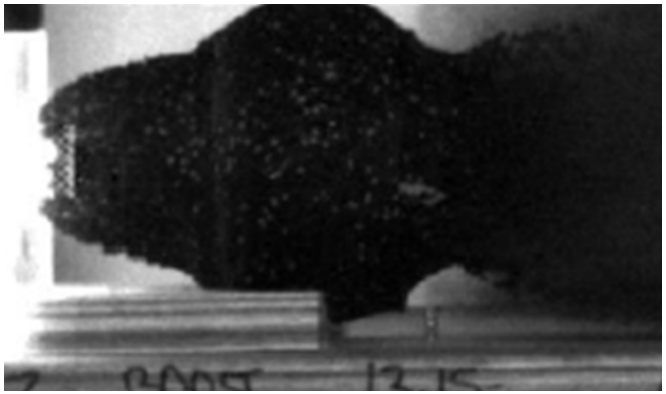
EMTAP Test No. 36A Setup – Bare motor configuration

EMTAP Test No. 36A Testing

- High Speed Video used to determine velocity and response
  - 120,000 FPS used to ensure event captured
  - Looking for prompt initiation of impact surface (SDT)



Sample showing SDT response



Sample showing lower order response

- Plate of PMMA included to assess XDT responses

Sample Type	SDT Velocity	XDT
Propellant + Case	1790 m/s	None
Motor in missile pack	1900 m/s	None

Average results of testing

Fragment Impact Testing

- Motor level trials undertaken to understand if any “scale up” effects occur
  - UK SME’s unofficially rated the results as…

% SiC	Response
Very Low	Type IV/V
Low	Type IV/V
Medium	Type I

- Demonstrated IM compliance with satisfactory refractory content

Decreasing instability suppression — Balanced — Decreasing IM Performance

Very low SiC% response

Low SiC% response

Medium SiC% response

Fragment Impact Testing

Low SiC% response

Medium SiC% response

Sympathetic Reaction Testing

- Motor level trials undertaken to understand effect of refractories to SR threat

- Trial consisted of two motors side by side
  - Held at forward end representing assembled missile
  - Structure between motors representing missile pack
  - Motor separation representing missile storage

Low SiC% response

- Low SiC content gave Type III response
  - Multiple firebrands
  - Acceptor fully engulfed by donor detonation
  - No secondary peak on blast gauges

Medium SiC% response

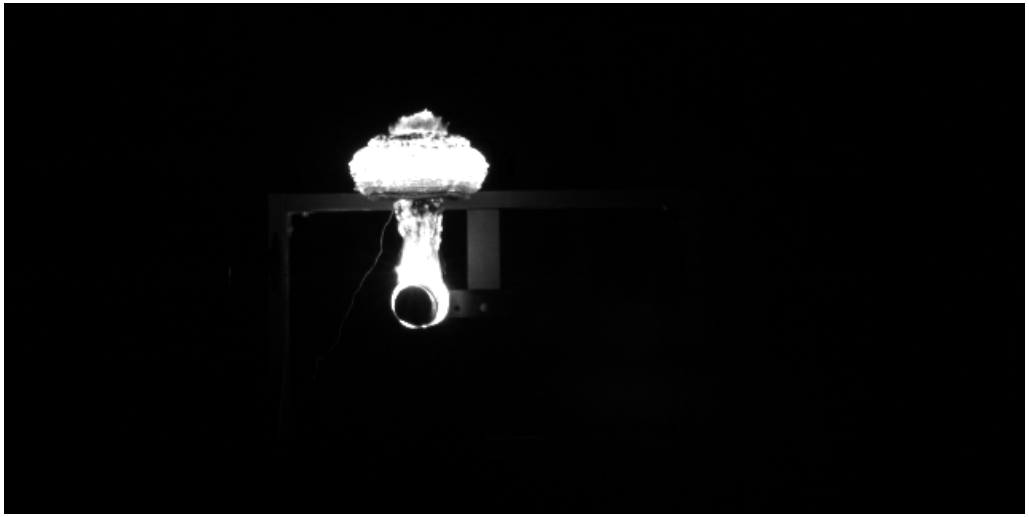
- Medium SiC content gave Type I response
  - Secondary peak on blast gauges
  - Asymmetric growth of blast front

Sympathetic Reaction Testing

Low SiC% response – Arena View

Low SiC% response – Motor View

Medium SiC% response – Arena View



Medium SiC% response – Motor View

Discussion

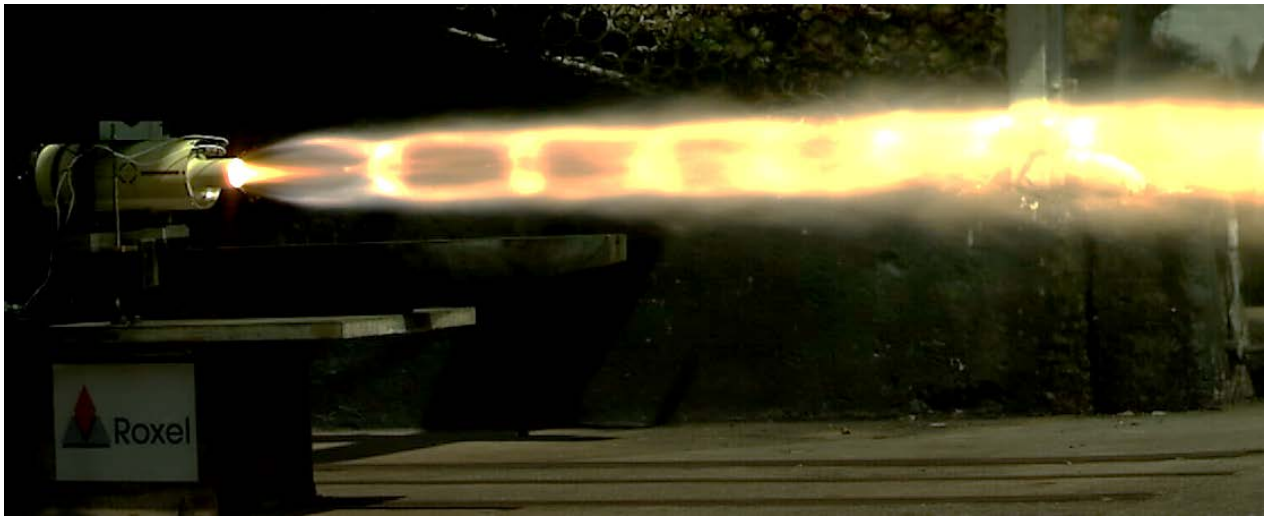
- Small scale trials demonstrated traditional view of refractory filled propellants
  - Step increase in sensitivity
  - Non-linear increase in sensitivity for increasing levels of refractory
  - Different refractory materials have different levels of sensitivity increase

- EMTAP Test No. 36A can be useful for predicting motor level response
  - Result is pessimistic due to sample configuration compared to motor

- Subtle changes in refractory content can have significant motor level changes

Conclusions

- Roxel UK completed development of a rocket motor with sufficient refractory materials to dampen combustion instabilities but maintain IM compliance
- Demonstrated inclusion of inert refractories does not increase XDT propensity
- Further work to characterise alternative refractories could be considered
  - New or “soft” materials
  - Coated materials to reduce sensitivity increase



Vulcan III rocket motor in operation

Acknowledgements

Roxel
Propulsion systems

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