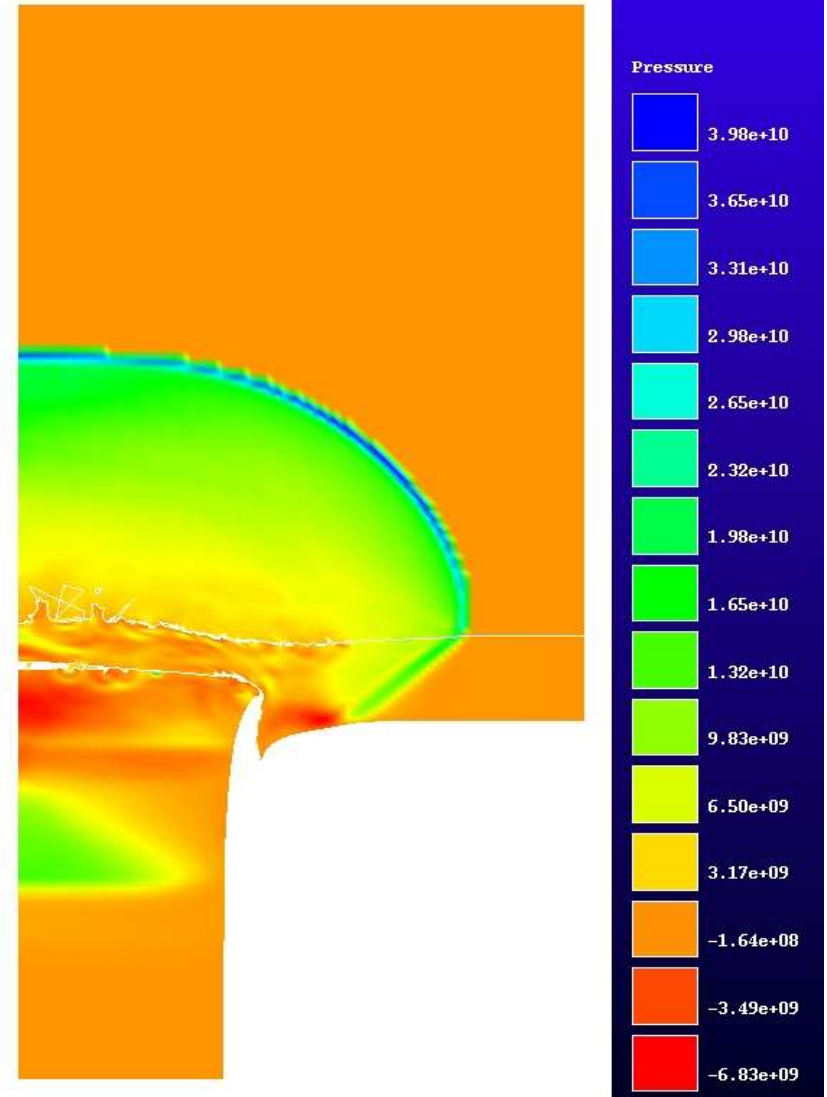


# Fragment Attack of Complete and Sectioned Rocket Motors

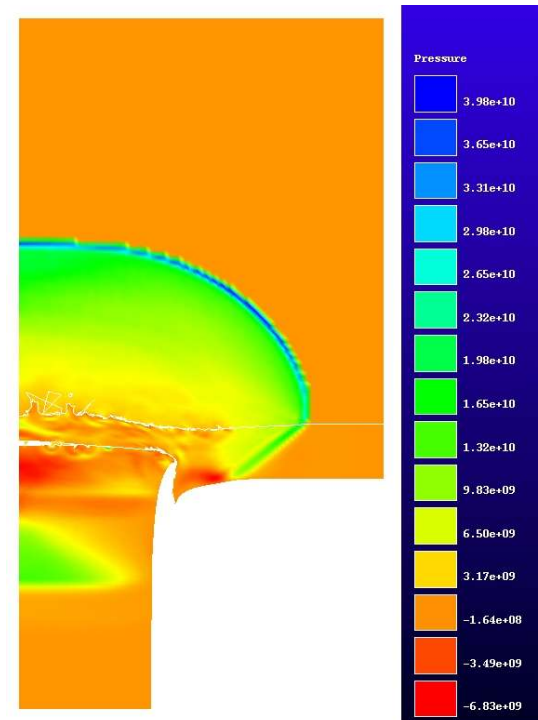
P J Haskins, M D Cook, R I Briggs, P Ottley & M Sharp

A presentation to: NDIA IMEM Technology Symposium

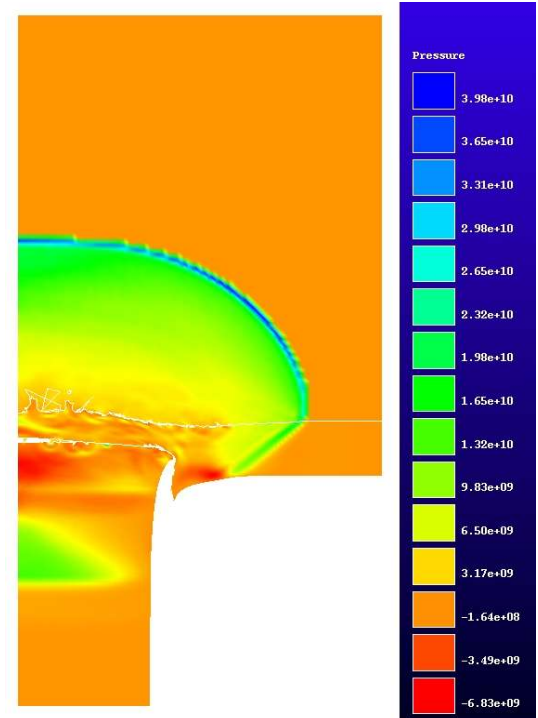


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- 02 Gun Systems
- 03 Rocket Motor and Sections
- 04 Instrumentation
- 05 Experimental Arrangement
- 06 Experiments on Sectioned Rocket Motors
- 07 Experiments on Complete Rocket Motors
- 08 Discussion & Conclusions



# 01 Introduction



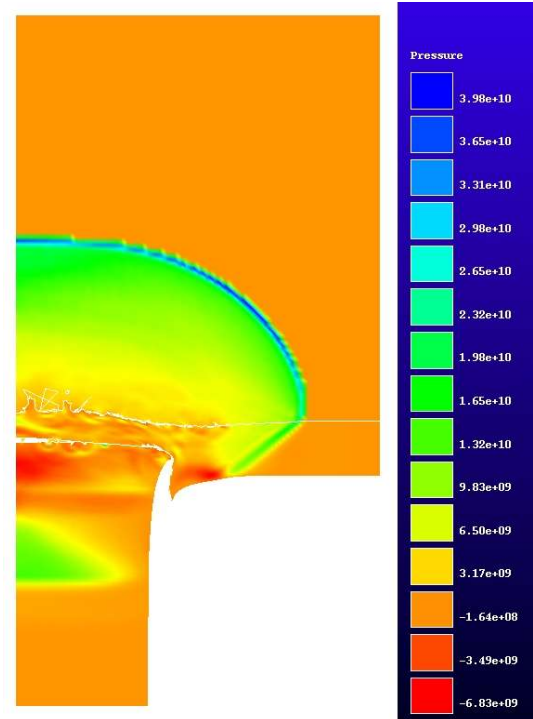
# 01 Introduction

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High velocity fragments can pose a significant threat to weapon safety.

- As a consequence STANAG 4496 stipulates a testing regime which requires a standard Fragment Simulating Projectile (FSP) to be fired at the weapon under test.
- In the work presented here we have studied the response of a large rocket motor to three different FSPs. These were:
  - The STANAG FSP (a 14.3mm diameter steel rod with a 160° conical nose).
  - A 20mm diameter flat-ended steel cylindrical projectile, mass 27g.
  - A 30mm diameter flat-ended hollow-backed steel cylinder, mass 100g.
- Most tests were carried out on sections of rocket motor although two confirmatory tests were conducted on All-Up motors with the STANAG FSP.

# 02 Gun Systems



## 02 Gun Systems

Our approach to fragment impact testing is to use our 30mm gun for the lower STANAG velocity requirement (1830m/s) and our new 40mm gun for the higher velocity test (2530m/s).

- Whilst the 40mm gun could be used for all velocities this approach has benefits due to reduced operating costs and faster turn around times for the 30mm gun.
- For both gun systems the STANAG and 20mm diameter projectiles are housed in discarding plastic sabots and fired through a stripper plate to ensure that the target is not struck by sabot fragments. The 30mm FSP has a nylon driving band and was launched from the 30mm gun only.
- The 30mm ammunition is of two-piece construction, whereas the 40mm ammunition is one-piece, with the sabot and fragment pressed into the cartridge case before loading.
- The 40mm gun barrel is evacuated prior to firing when high velocities are required. It should be noted in this context that to achieve 2530m/s at impact with the target it is necessary to have a muzzle exit velocity of ca. 2700m/s when working at a typical muzzle to target separation of 10m.

## 02 30mm Gun System





## 02 QinetiQ 40mm High Velocity Gun



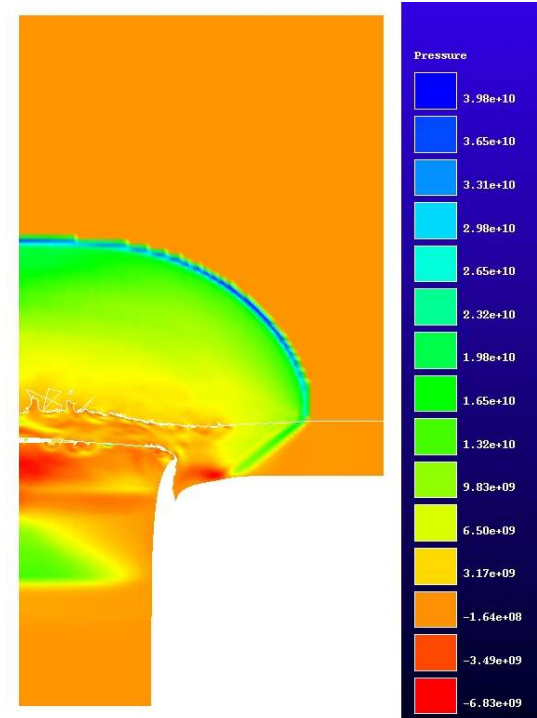


## 02 30mm Ammunition (left) and 40mm Ammunition (right)



# 03

## Rocket Motor and Sections

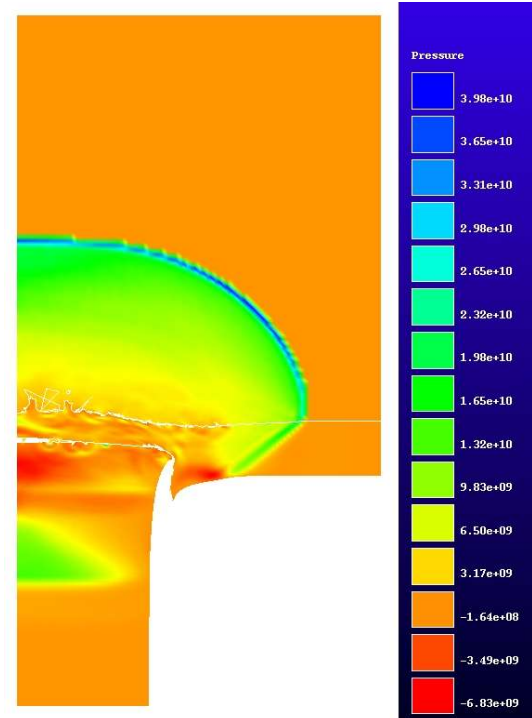


## 03 Rocket Motor and Sections

The rocket motor studied was ca. 2m long by 23cm diameter.

- The propellant was an AP/Al/HTPB/iron oxide composition and the grain was centre perforated with four axial slots (broad at the nozzle end tapering to narrow at the nose).
- The critical diameter of the propellant was considerably in excess of the motor diameter and consequently the motor was incapable of sustaining a detonation.
- The motors were cased in steel, ca. 3mm thick.
- Four rocket motors were sectioned into samples with a length to diameter ratio of ca. 2, giving four sections per motor, and a total of sixteen sections for testing.
- Two other rocket motors were used complete for All-Up Motor fragment impact tests.
- The motors were X-rayed before sectioning and the results indicated that the propellant grain was in excellent condition.

# 04 Instrumentation



## 04 Instrumentation - High-Speed Video Photography

All tests were filmed using high speed video (Phantom 7 cameras).

- One camera, typically running at 100,000 frames per second (fps), was used to determine projectile velocity, projectile stability and target reaction details.
- The events were back-lit with flash bulbs behind a diffusing screen.
- A white board (marked with black lines to indicate one foot squares) of dimension 8 by 4 feet was placed behind the diffusing screen.
  - This board was illuminated using two further banks of seven flash bulbs.
  - The timing of these flash bulbs was arranged to occur later than the first set to capture break-up of the rocket motor casing and expansion of the products.
  - A second Phantom camera running at 47,000fps was used to capture a broader view of the target.

## 04 Additional Instrumentation

Blast gauges were used to assist with determining the response from fragment impact of the rocket motor charges.

- The blast gauges were angled at approximately  $45^\circ$  to the shot line and spaced at 5, 10 and 15m from the store.
- Two banks of gauges were used, one set dedicated to the 30mm gun and the other to the 40mm gun.

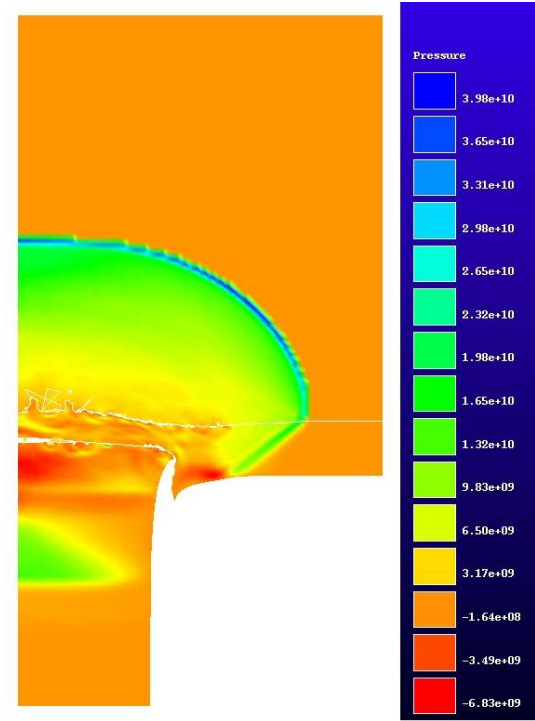
Time-of-arrival gauges were used to measure the early phase of case expansion following fragment impact.

- Comprised of PMMA bar 350mm long, 50mm wide and 12 mm thick with 8 micro-coaxial cables (3mm in diameter), spaced 20mm apart.
- The micro-coaxial cables were mounted such that they stood 1mm proud of the PMMA bar. Sections of aluminium foil were attached to the outer wall of the rocket motor or section casing using double sided tape.

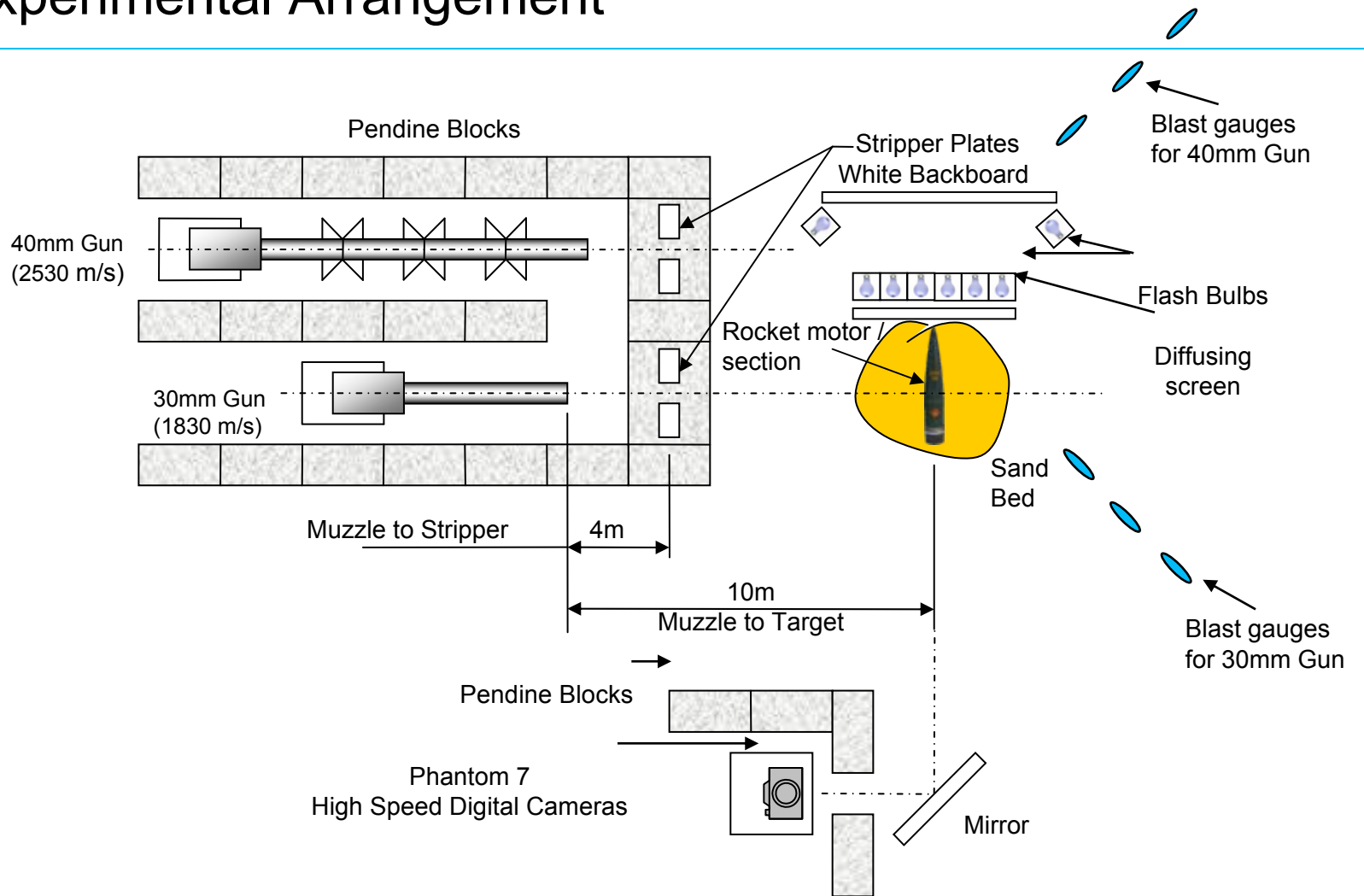


05

# Experimental Arrangement



# 05 Experimental Arrangement



## 05 Experimental Set-up (1)



View of setup showing:

- Rocket motor section,
- Diffusing background,
- Flash banks,
- White backboard.

## 05 Experimental Set-up (2)

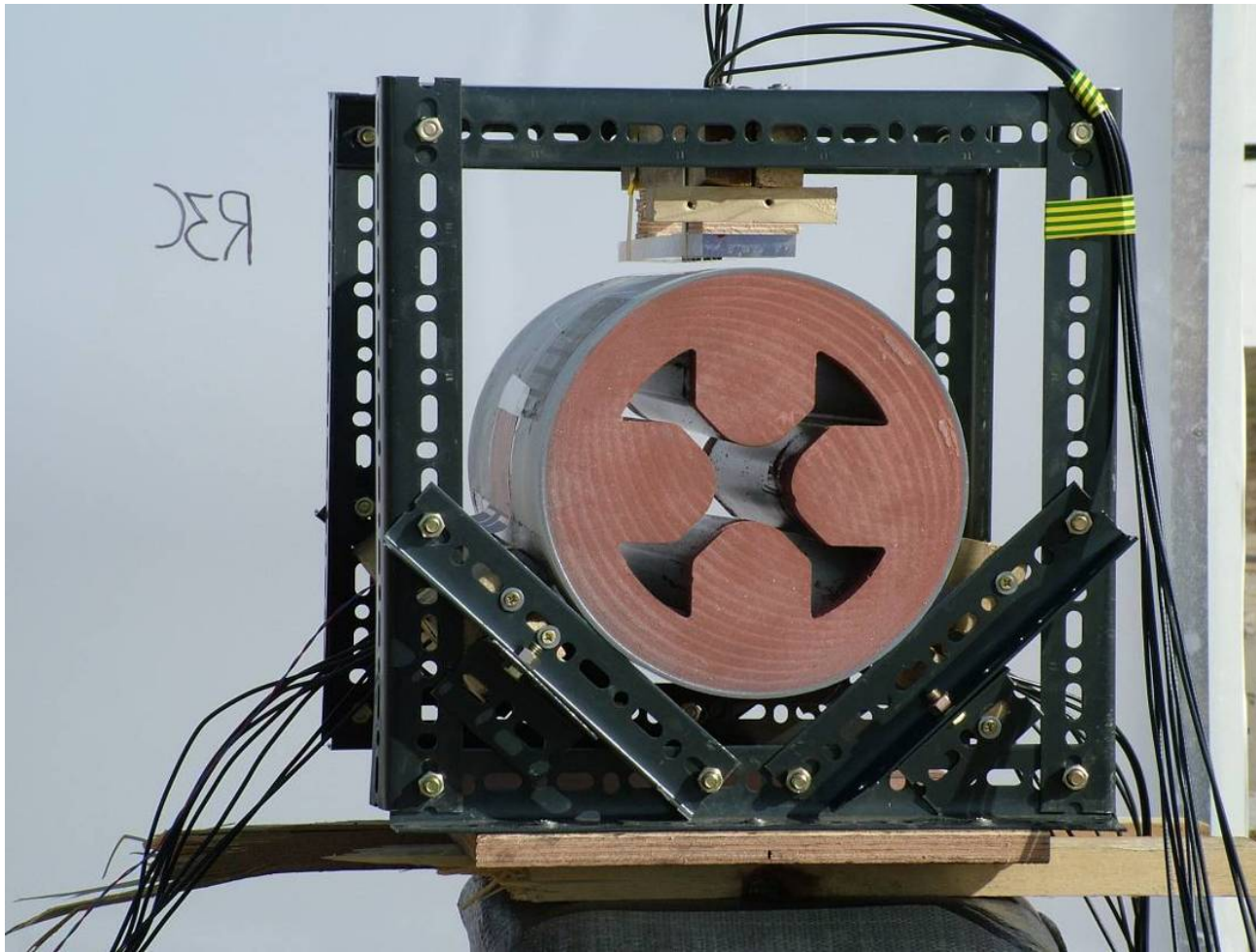


View from camera direction showing:

- Rocket motor section,
- Diffusing background,
- White backboard,
- Sabot traps
- Blast gauge positions.



## 05 Close-up of Rocket Motor Section Prior to Firing



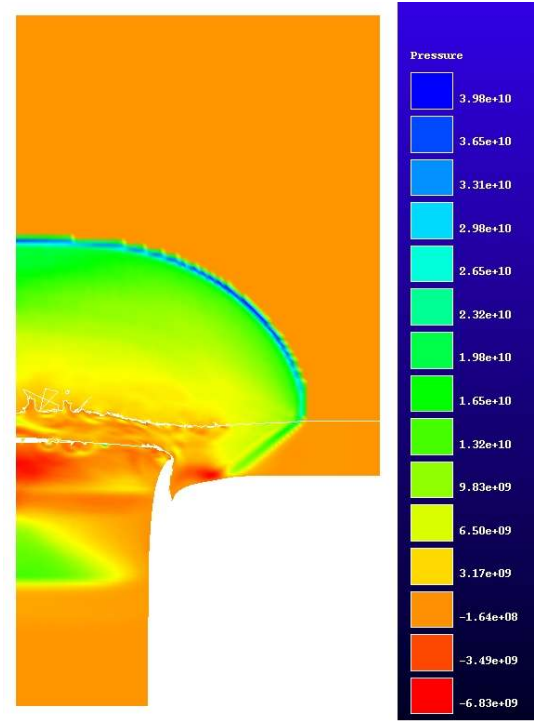
The motor section is shown in a cage which allowed the time-of-arrival probes to be spaced off from the motor casing.

A make foil can be seen attached to the left surface of the motor section.

The round number can be seen marked on the diffusing screen behind the cage.

06

# Experiments on Rocket Motor Sections



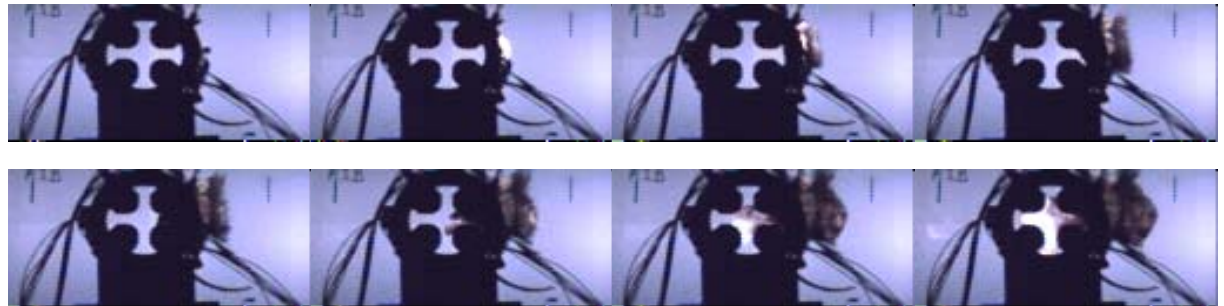


## 06 STANAG FSP at 1890m/s on Rocket Motor Section

Impact occurs in the second frame of the Phantom high-speed video record.

The FSP caused an ignition on impact and a larger burning reaction in the bore after ca.  $80\mu\text{s}$ .

The propellant burnt out and the casing remained intact.

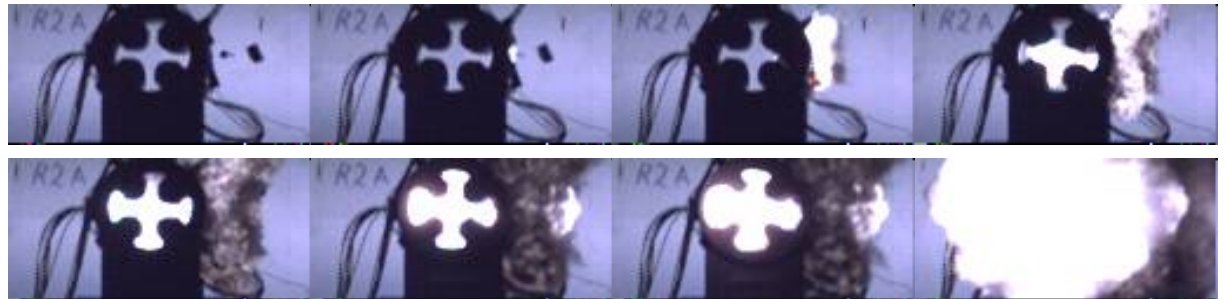


## 06 STANAG FSP at 2584m/s on Rocket Motor Section

The Phantom high-speed video record shows the projectile impacting in the second frame.

As in the previous test the FSP caused an ignition on impact and a larger burning reaction in the bore after ca. 40-70 $\mu$ s.

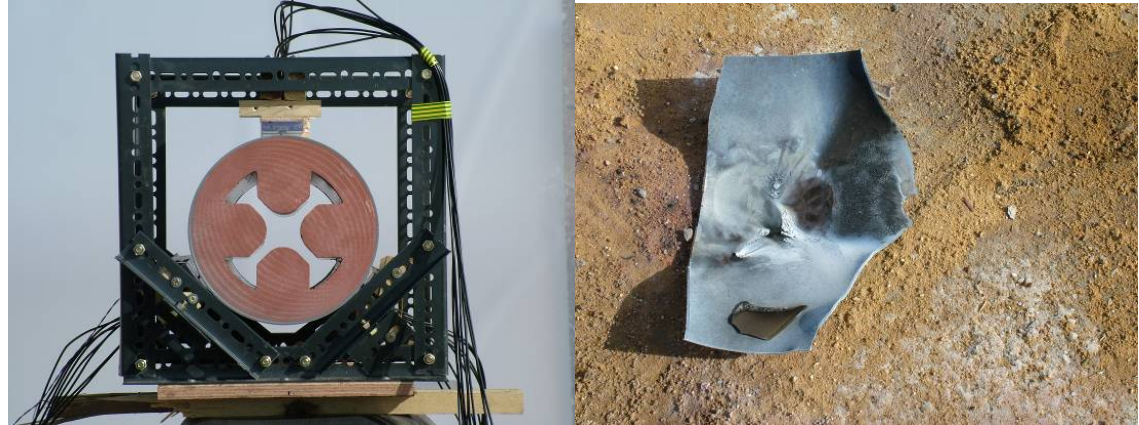
The result was a pressure burst with the casing split into two pieces. A small amount of propellant was recovered.



## 06 30mm FSP at 1743m/s on Rocket Motor Section

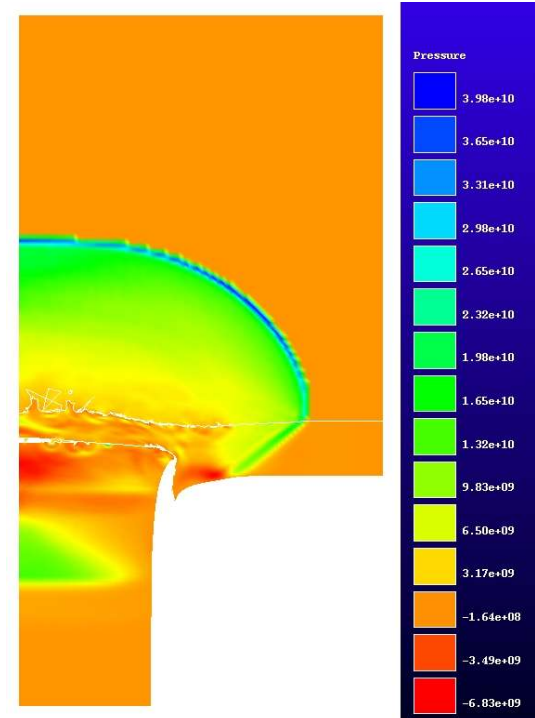
The impact occurs in the second frame and is through the thick portion of the propellant grain.

The result was a violent pressure burst generating the highest blast pressure of any of the tests on motor sections (25.3 kPa @ 5m).



07

# Experiments on Complete Rocket Motors

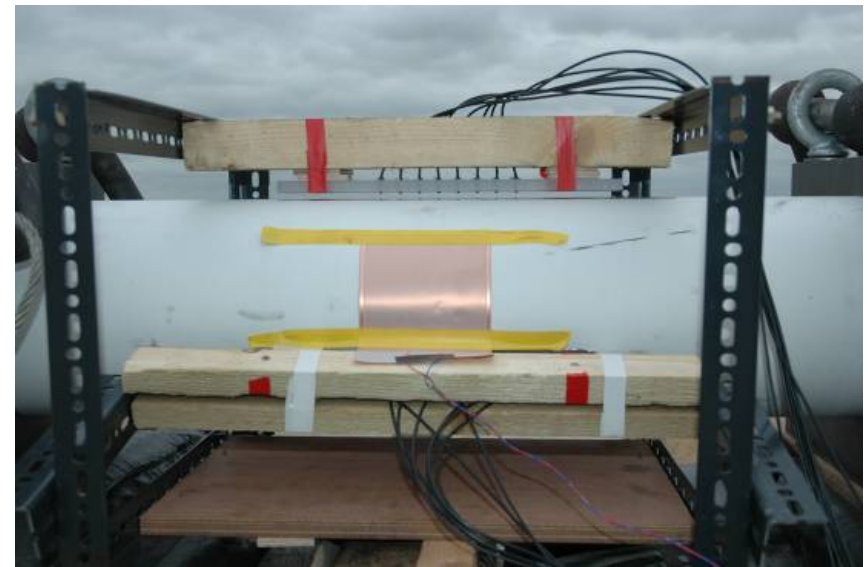




## 07 Experiments on Complete Rocket Motors

We have carried out two tests on complete motors, both with the STANAG projectile. The intention being to test at the higher (2530m/s) & the lower (1830m/s) stipulated velocities.

The set-up for the 1<sup>st</sup> test at the higher velocity is shown below. The motor is clamped and tied to several 1.5 ton reinforced concrete blocks.



## 07 Results of STANAG Test at 2434m/s

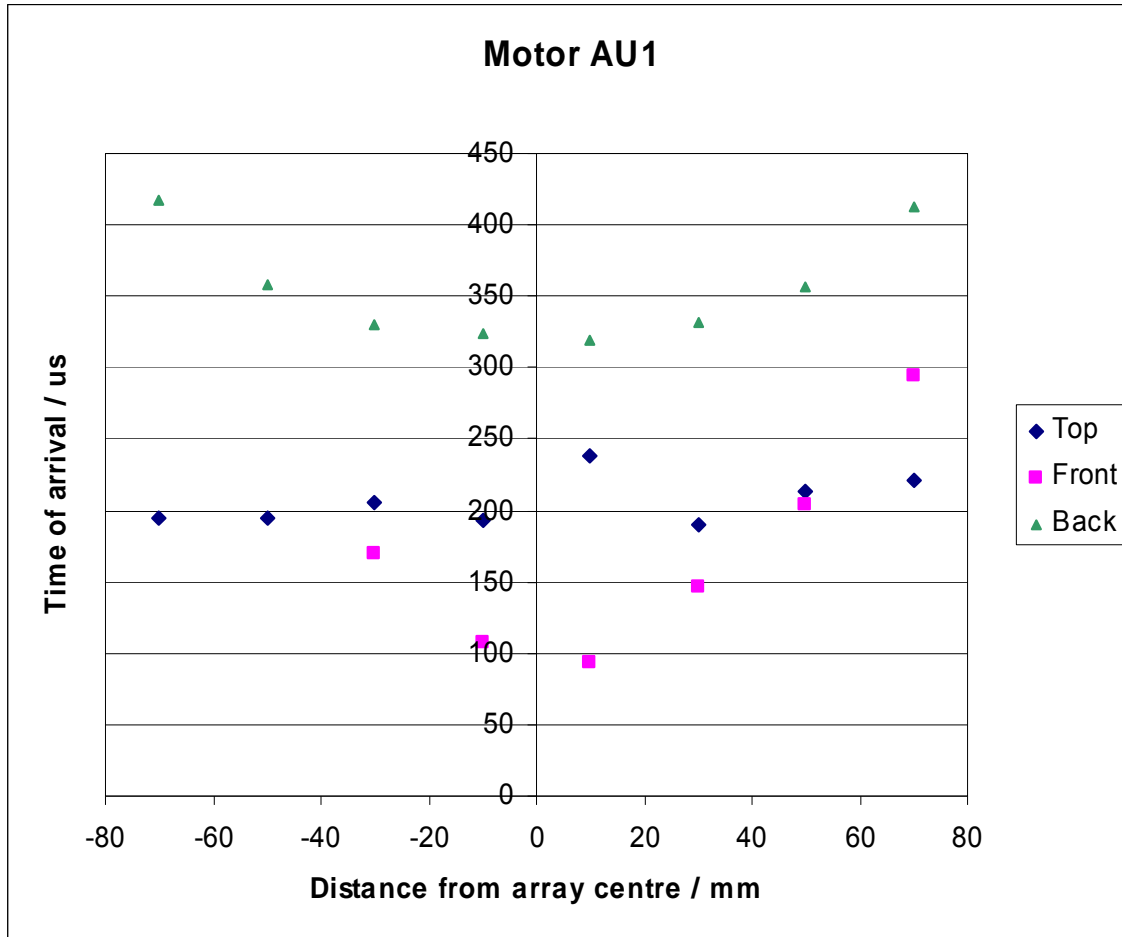
The rocket motor was arranged such that the thin wall of the propellant grain was in the shot line.

The motor burst, splitting into three parts, and then burnt out.





# 07 High Speed Video & Time of Arrival Gauges for Motor STANAG Test at 2434m/s



Impact

20 $\mu$ s

40 $\mu$ s

60 $\mu$ s

80 $\mu$ s

100 $\mu$ s



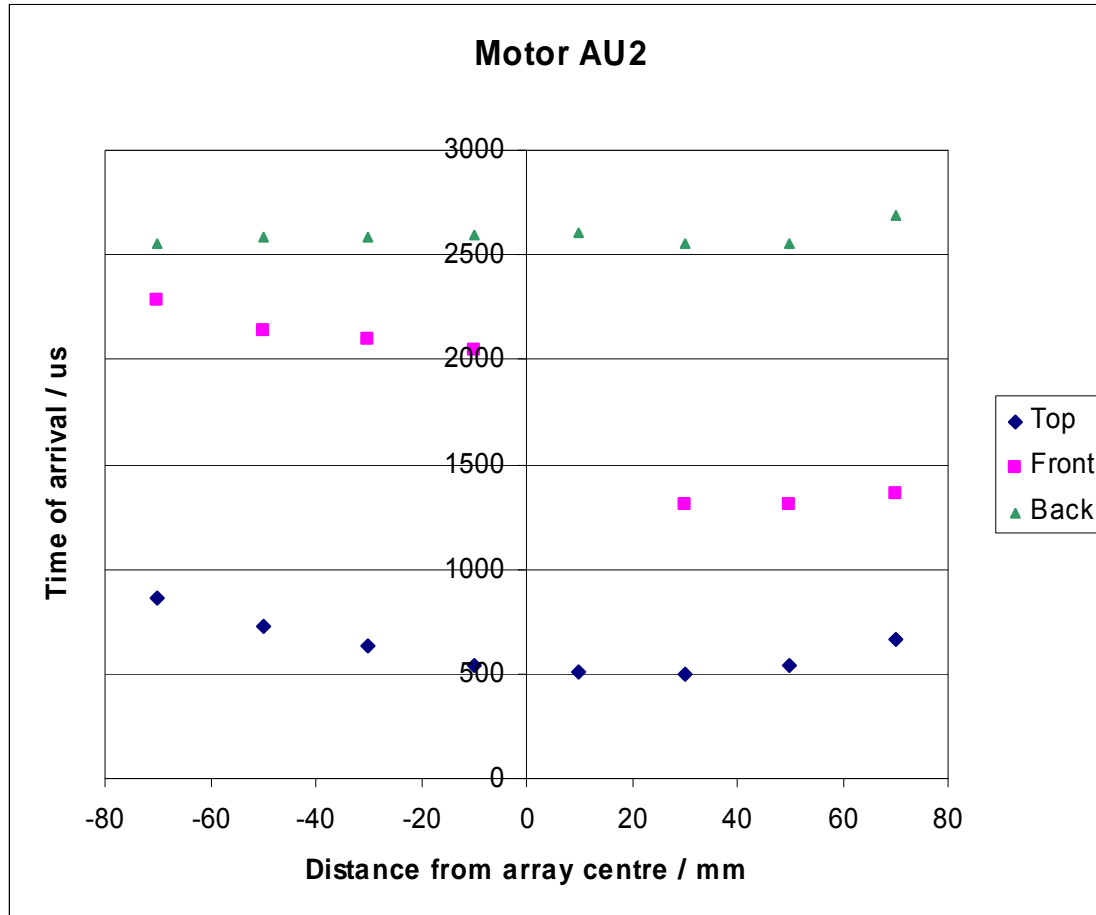
## 07 Results of Motor STANAG Test at 1828m/s

The projectile caused the motor to ignite and then rapidly overpressure blowing out the upper central section of the motor.

The remaining parts of the motor burnt out completely and with significant thrust.



# 07 High Speed Video & Time of Arrival Gauges for Motor STANAG Test at 1828m/s



Impact

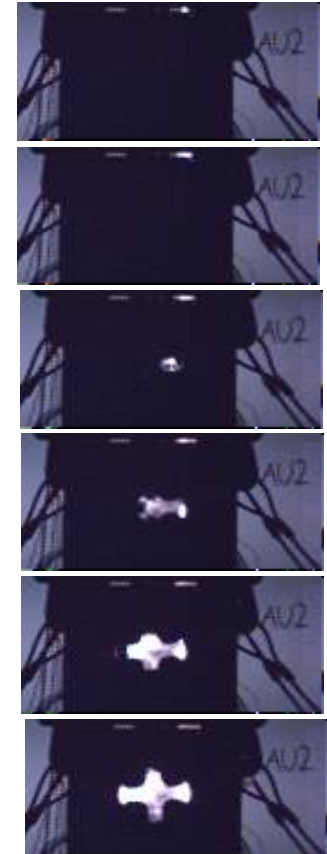
20 $\mu$ s

40 $\mu$ s

60 $\mu$ s

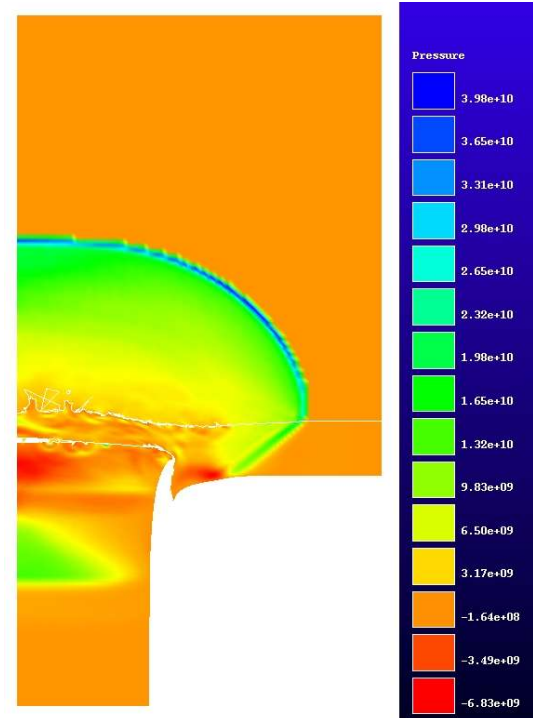
80 $\mu$ s

100 $\mu$ s



08

## Discussion & Conclusions



## 08 Discussion & Conclusions (1)

Tests were carried out on a total of 14 motor sections and 2 All-Up motors.

- Responses ranged from Type 1 to Type 2/3 depending on the fragment type and velocity employed.
- As might be expected there was a general trend towards increased violence as both the velocity and mass of the fragment were increased.
- Vigorous burning reactions were usually observed in the damaged bore section of the motors, and in a detonable propellant it is likely that many of these reactions would have progressed to detonation through an XDT mechanism.
- The increased confinement offered by a complete motor, compared with a section, gave rise to a more violent event under the lower velocity STANAG test condition.
- The blast gauges and time-of arrival probes have yielded valuable data which it is hoped to use for testing and validation of future modelling studies.

## 08 Discussion & Conclusions (2)

Orientation of the propellant grain with respect to the shot line appeared to influence the violence of the response.

- For the STANAG projectile the most violent reactions were observed when the thin part of the propellant grain was along the shot line.
- In the case of the 20mm projectile similar events were observed in both orientations.
- Only two firings were carried out using the 30mm FSP but they suggested that more violent events may be expected when firing through the thicker portion of the propellant grain. This projectile gave the most violent reactions from any of the sections, presumably as the result of increased damage to the propellant grain by the heavier fragment.

The use of motor sections enables a larger, more statistically significant, number of tests to be carried out and aids the use of diagnostics in determining response mechanisms. However, the additional confinement offered by complete motors can lead to differences in response violence and this needs to be considered when carrying out a hazard assessment.



***QinetiQ***