Performance Tests of Next Generation Solid Missile Propellants

A UK/US/Fr/Ge Programme

Presented by

Dr Adam S Cumming

Dstl, Fort Halstead, UK, Group Chair

Authors

- A S Cumming, J Callaway (Dstl UK),
- C Higgins (QQ, UK)
- S Flynn (Roxel, UK),
- H Sohn, R Huhn (BWB, Ge),
- K Menke (ICT, Ge),
- J Clark (AFRL USA),
- J-M Creti (DGA Fr),
- Y Longevialle (SME, Fr)

Background

- Air Senior National Representatives Long Term Technology Programme on Tactical Missile Propellants
- The active member are US, UK, France, Germany, and include industry and Institutes.
- Work share for this existing programme
  - Fr - Assessment evaluation (ballistic, hazards/vulnerability)
  - Ge - Formulation characterisation and performance calculations
  - UK - Assessment evaluations (mechanical properties, ageing, signature)
  - US - Formulation characterisation and performance calculations

Aims

- Rocket propellant samples for testing were designed to achieve the following requirements

Primary Goals	Secondary Goals	Tertiary Goals
Specific Impulse 240 s	Burn rate ≥ 8mm/sec	Ageing properties
NATO AGARD AA Smoke	Exponent ≤ 0.5	Mechanical properties
UN 1.3 Hazard Classification	Temp Range -54ºC to +71ºC	Density

TACTICAL MISSILE PROPELLANT
Programme Outline

- Formulation of propellants based on AN in combination with other oxidizers (CL-20, HMX, TAGN) and energetic pre-polymers (GAP, PolyGLYN, PolyNIMMO)
- Preliminary assessment of candidate formulations including
    - ballistics
    - card gap sensitivity
    - mechanical properties
    - processability
    - thermal stability
- Selection of candidate formulations for detailed evaluation -done
- Performance and ageing assessment
- Vulnerability assessment – small scale only
- Signature assessment

Collaborative Motor Formulations Tested

ASNR 120cc3
energetic solids
CL-20
AN
binder
GAP/NCO
plasticiser
BTTN
TMETN
stabiliser
2NDPA

ASNR 141 Fe2
energetic solids
Ammonium nitrate
CL20
GZT 24
binder
PolyGLYN
plasticizer 66% v. B.
TMETN
BTTN
stabiliser
MNA / 2 NDPA 1:1
burn rate modifiers

Vulnerability

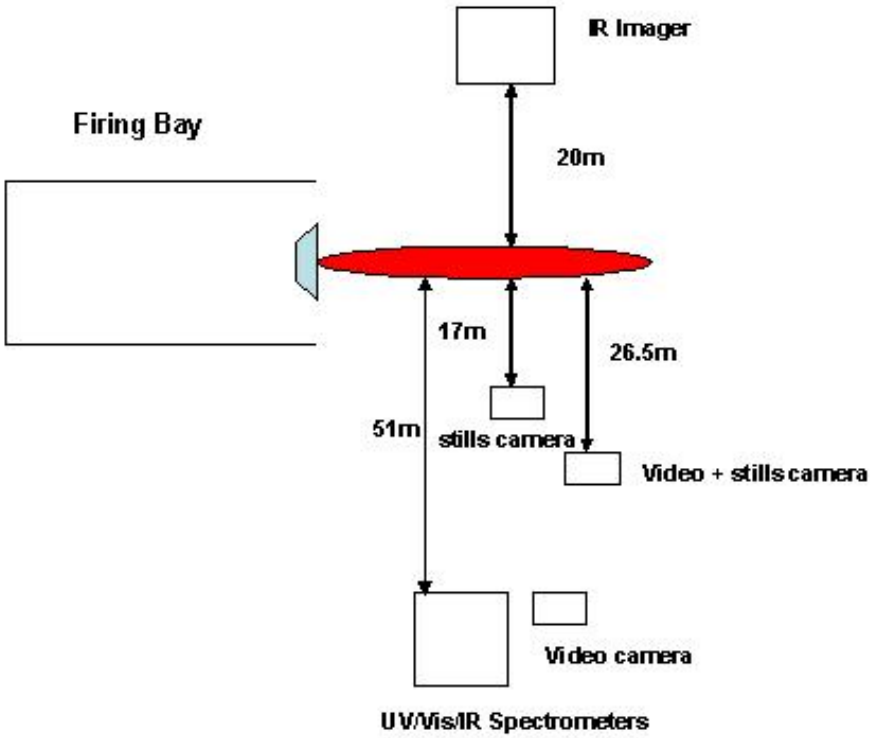
- Small Scale Vulnerability Tests were performed by France
  - All propellants showed reduced vulnerability
  - Details in Paper
- *Hazard Classification for Shipping for both candidates was **UN1.3***

Filled German SERIN Tubes

The Motor Performance Firing Trial

- The main objectives of the trial were to:
  - Record motor performance for comparison against performance predictions.
  - Measure the plume signature for comparison against signature predictions in the infrared (IR) spectrum.
  - Provide an assessment of the smoke-producing properties of the propellant formulations during the motor firings.

Schematic of Trial Setup



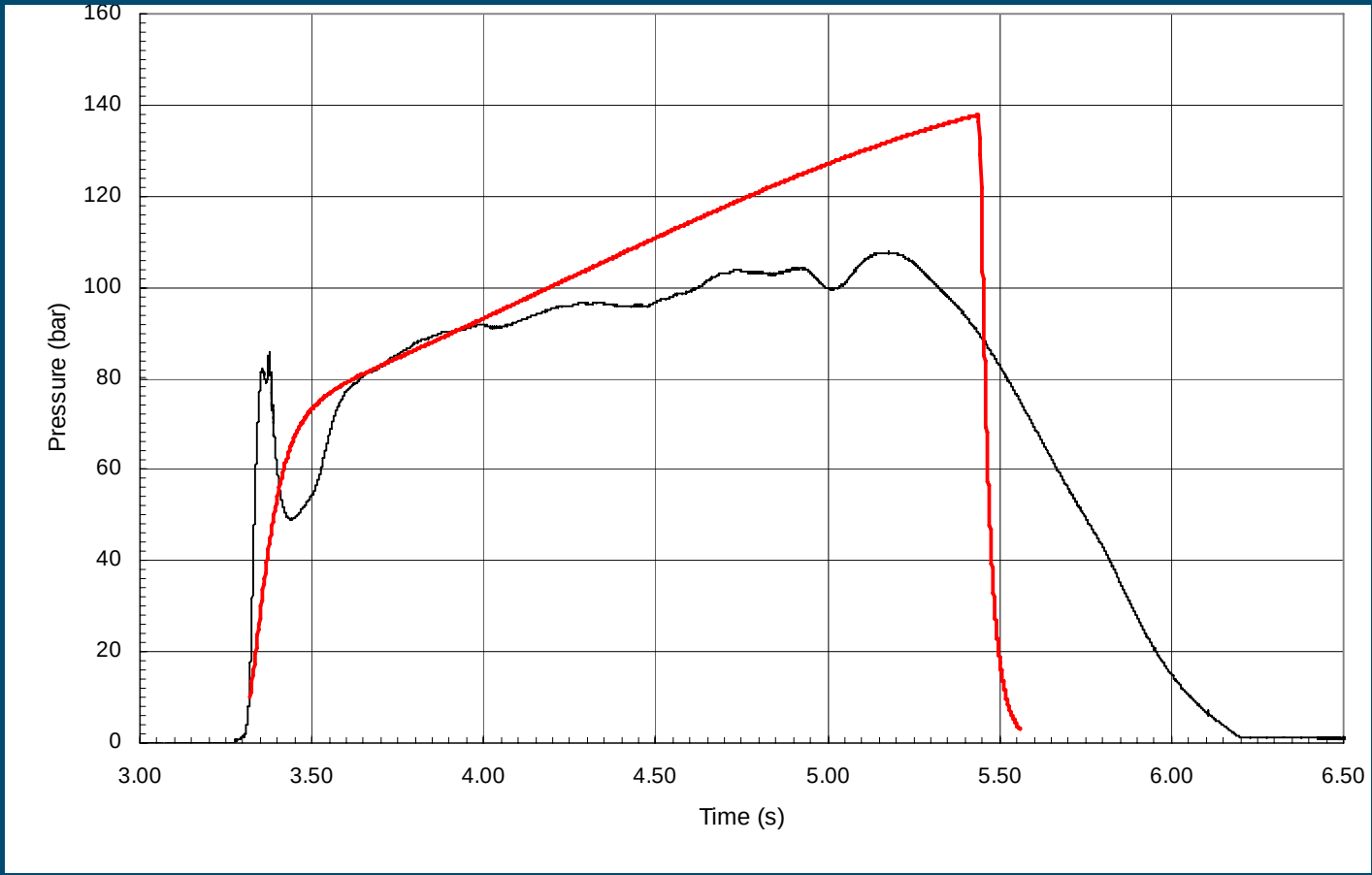
Trial Instrumentation

- IR
  - FTIR spectrometer
    - 2 – 12
  - Dual band calibrated thermal imagers
    - Mid IR ~2 - 5 and Far IR ~8 -12
- UV
  - UV spectrometer
    - 0.2 - 0.4
- Visual
  - Visible spectrometer
    - 0.4 - 0.9
  - 3 Digital video camera
    - At both measurement points and firing point
- Temperature and humidity meter

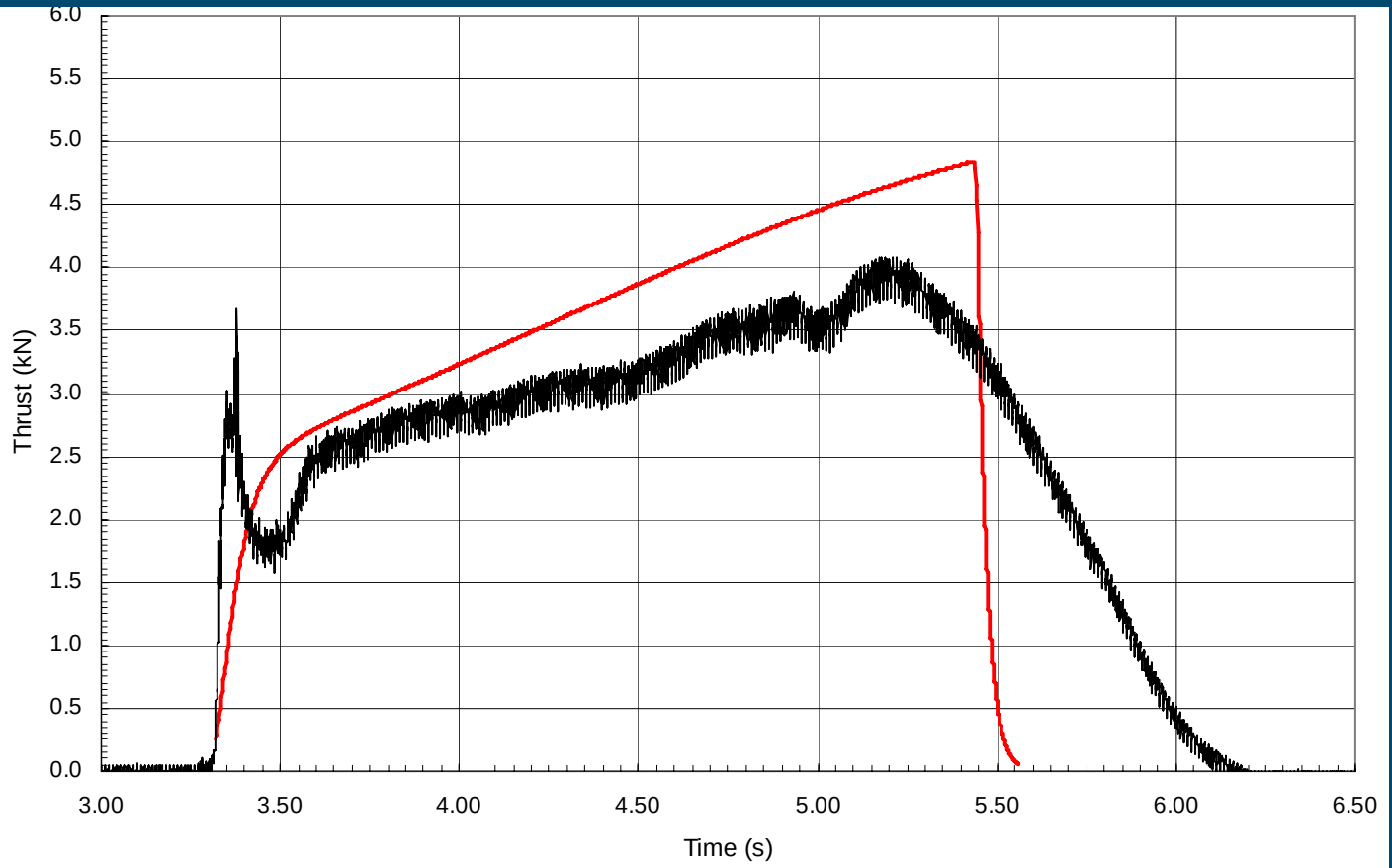
SERIN 141Fe2 Mounted on Firing Rig

Two Images showing the burning ASNR 141Fe2 motors

Chamber pressure measurement and modelling prediction (141Fe2)

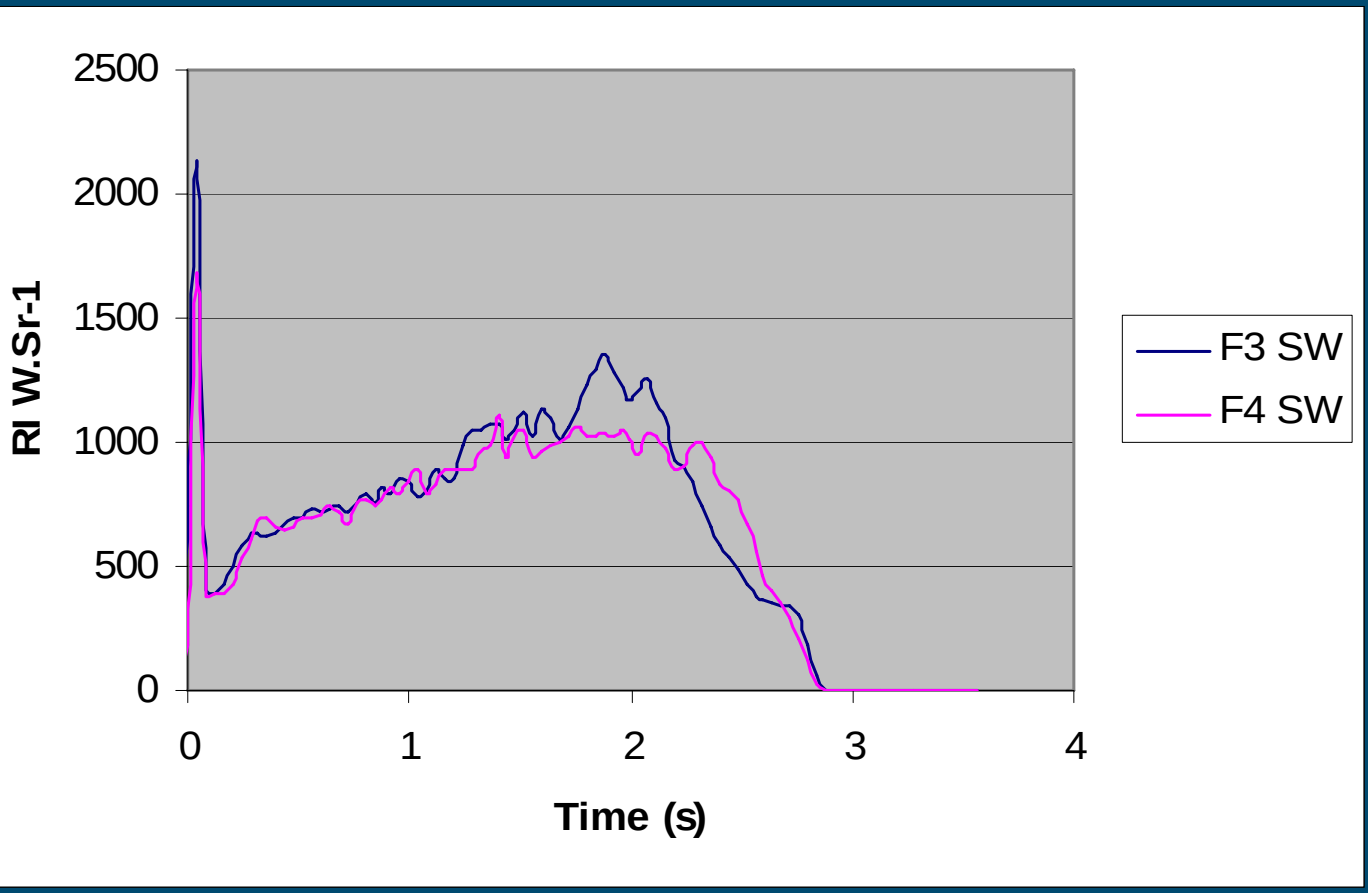


Thrust measurement and modelling prediction (141Fe2)



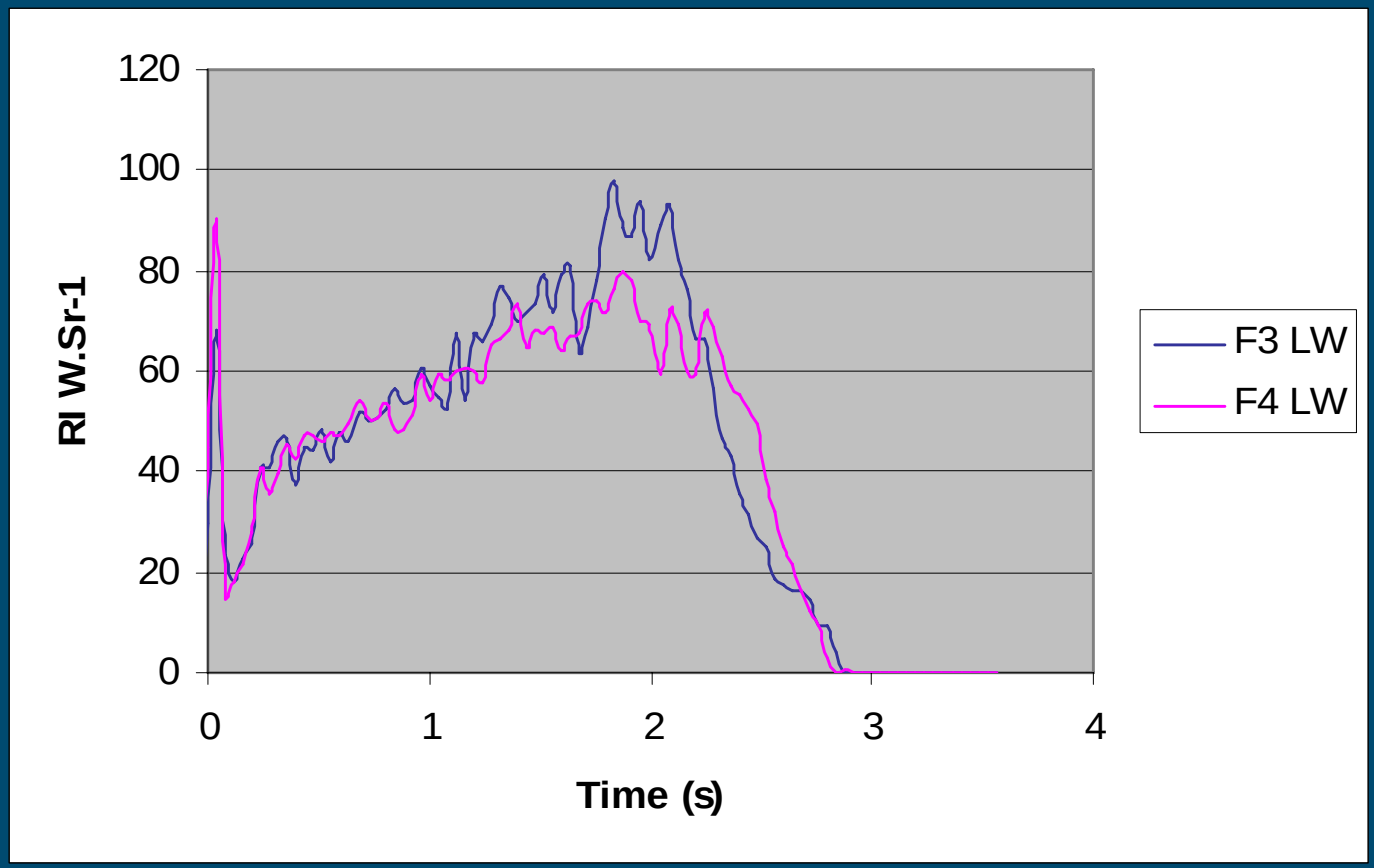
oscillations due to combustion instability

Radiant Intensity/Time profile from imager for ~2 - 5 waveband (141Fe2)



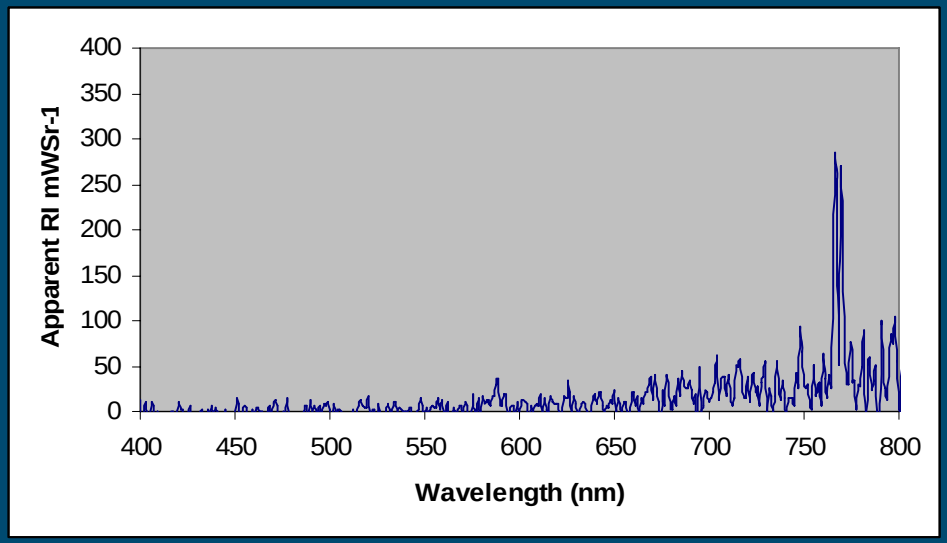
2 overlaid plots

Radiant intensity/time profile from imager for ~8 - 12 waveband (141Fe2)

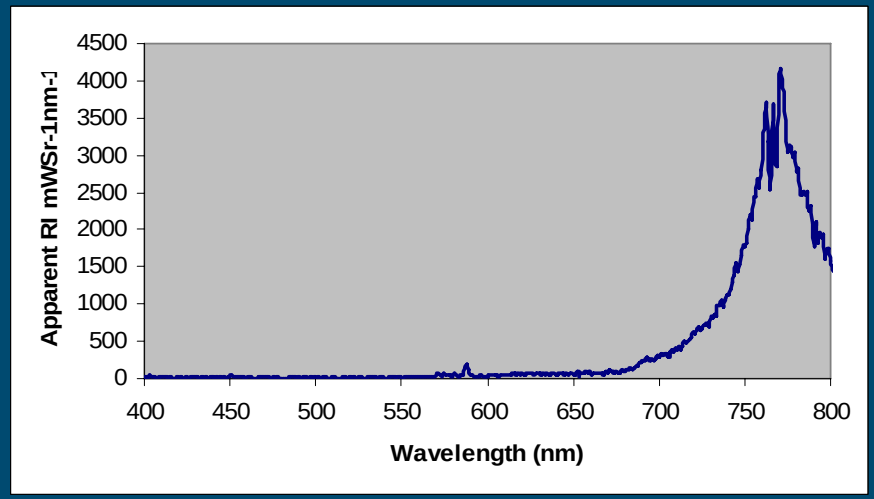


2 overlaid plots

Visible apparent radiant intensity for motor burn phase (141Fe2)

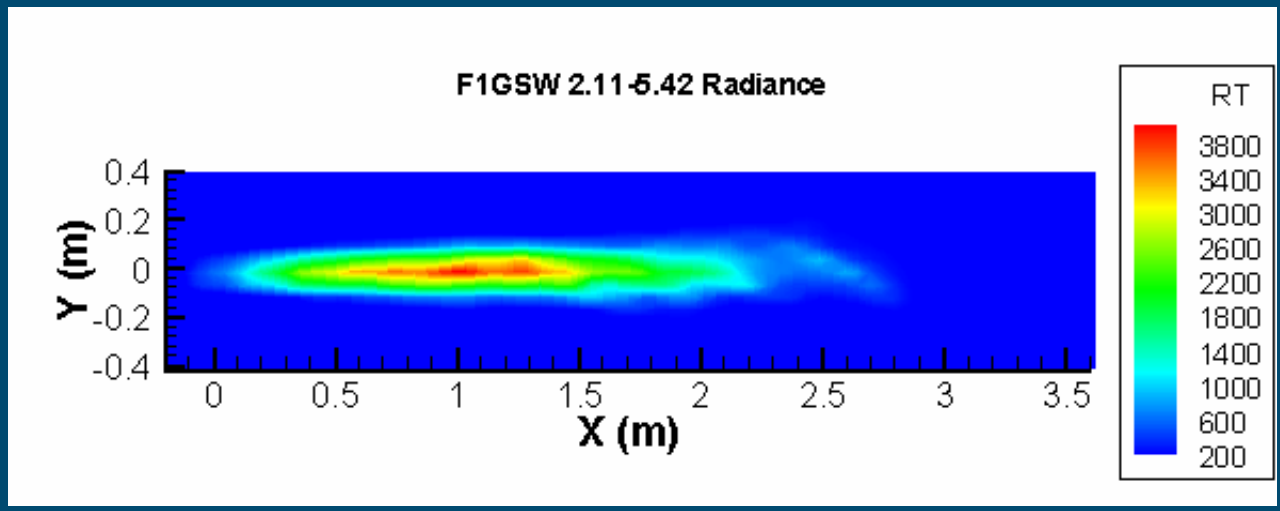


Main burn phase

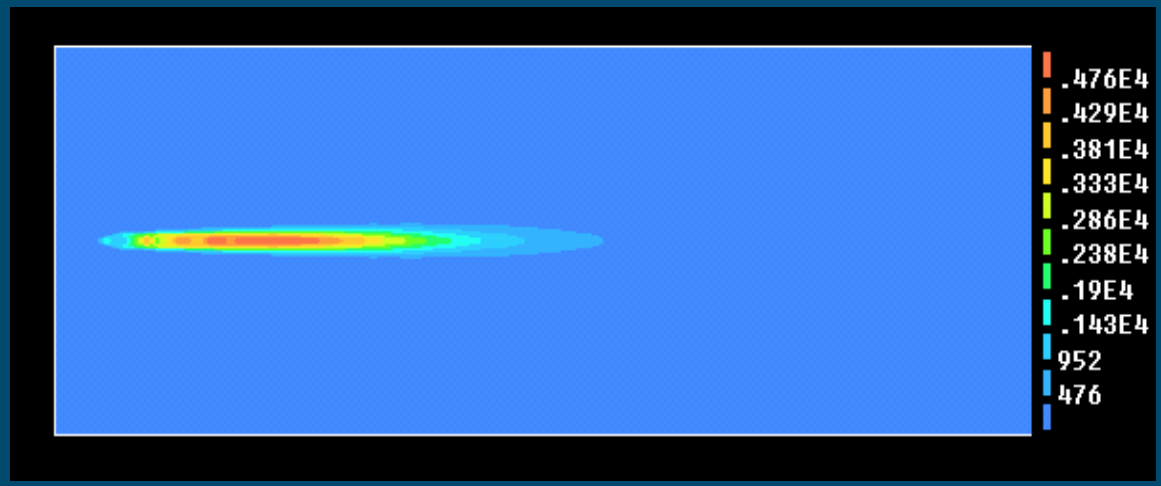


Ignition phase

Mid IR Image and Prediction (141Fe2)

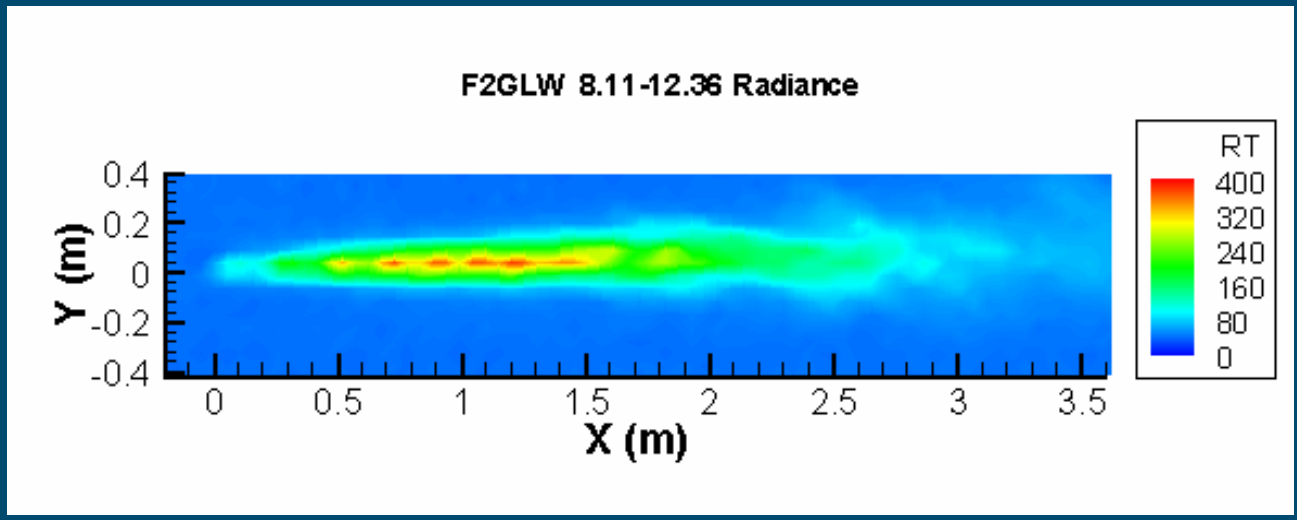


Shortwave plume radiance image

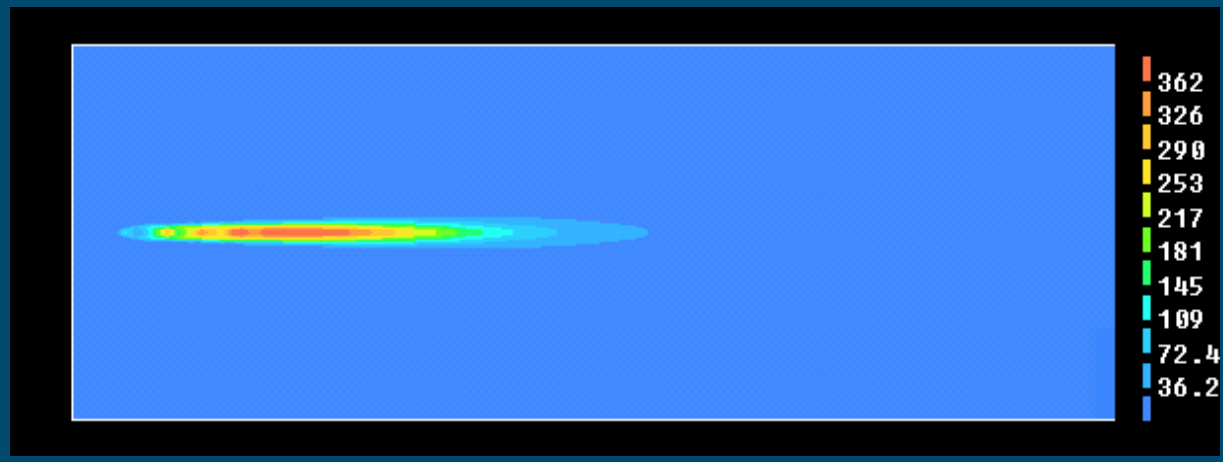


Predicted shortwave plume radiance

Far IR Image and Prediction (141Fe2)

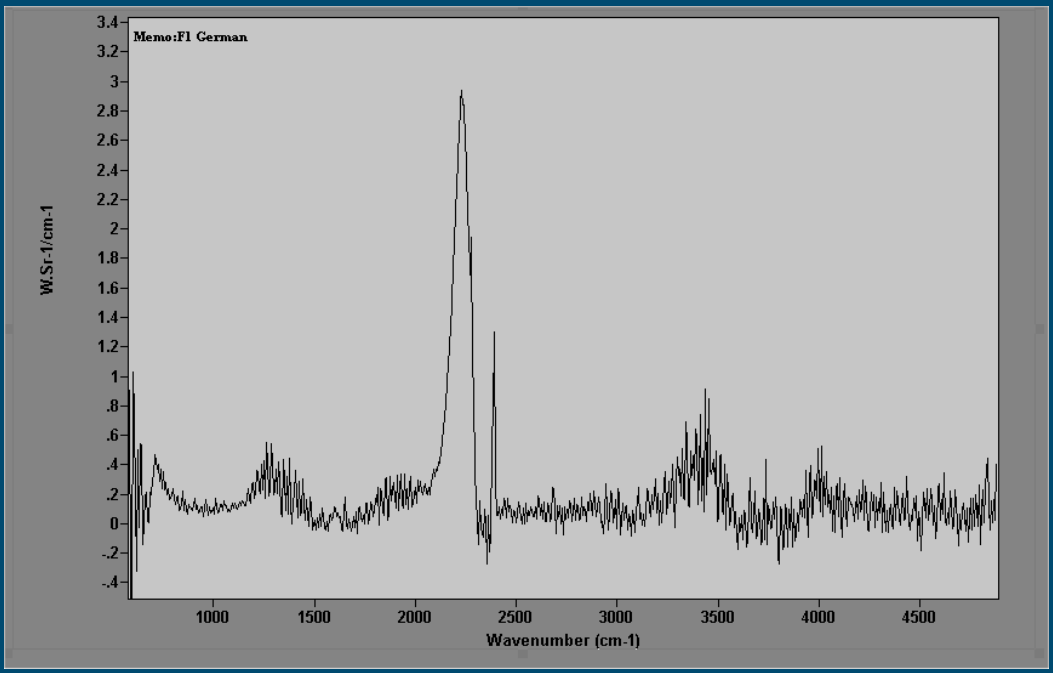


Longwave plume radiance image



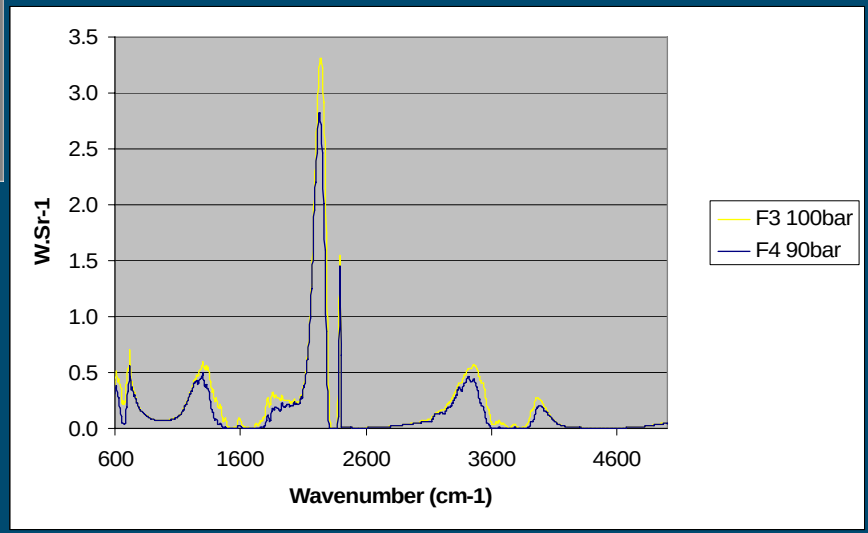
Predicted longwave plume radiance

IR Spectra and Prediction (141Fe2)



Apparent IR spectral radiant intensity (InSb detector)

Predicted apparent IR spectral radiant intensity
2 overlaid plots



Dstl is part of the Ministry of Defence

Visual Comparison of Sustain Phase of ASNR 141Fe2 Motor and a Typical Composite Motor

ASNR 141Fe2

Typical Air-to-Air Composite Motor

Image shows the fired US Filled ASNR 120cc3 Motor

Conclusions

This has been a complex but successful programme

- *We have succeed in demonstrating a next generation composite rocket propellant that is*
  - *Green*
  - *Insensitive*
  - *Low multispectral signature with no smoke*
- *Initial predications show the propellant thrust performance similar to service motors, with lower signature*
- *The US motor results show that this is by no means a trivial task*
- *All four participants have gained a significant amount of information about the application of new ingredients in propellant compositions*
- *The UK PolyGLYN has been shown to be capable of successful application.*

Acknowledgements

- *This programme of work could not have been carried out without the support of many people in all four nations. It is essential to mention Frank Roberto, Eric Marshall, Ted O'Day, Tony Cunliffe, Stefan Wilker as particular contributors. The support of the national MOD sponsors is also gratefully acknowledged*