Sub-Scale Fast Cookoff Test Results

NAVAIR

Weapons Division

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Purpose

- Repeatability of test method
- Thermal Stimulus Effects
- Scaling
  - Sub-scale to full scale comparison
- Effect of Ullage
    - Time to Reaction
    - Violence of Reaction

Introduction

- Progress on effort to develop a subscale alternate test protocol for external fire test used in final hazards classification
- Supports efforts to develop a controlled fast cookoff test
  - DDESB
  - Air Force
  - Army
  - Navy

Background

- **Hazard Classification - Assignment of HD 1.1 through 1.4**
  - **Liquid fuel/external fire test**
- **Insensitive Munitions (IM)**
  - **Fast cookoff**
- **Move to harmonize the testing**

System Level Tests

- Expensive
- Late in development phase
  - Difficult to make changes
- Few tests
  - Results may be misleading

Why Bother?

- External fire test must be performed on full scale item in its shipping configuration
  - Problem with large solid rocket motors
    - Cost of the asset + test (>$30 million US)
    - Hazard associated with test performance
      - Difficult to secure propulsive item in its shipping container
      - Large amounts of liquid fuel required
    - Real estate required for test site
    - Environmental Concerns
    - Single test on a probabilistic event
      - Results may be misleading

Thermal Stimulus

Fuel Fire

Thermal Stimulus

- **Fuel fires are difficult to describe and impossible to control**
  - **Alternate test should be controllable**
- **Flux in fuel fire varies from 20 to 400 kW/m^2 (SNL)**
  - **Credible accident scenario**
    - **50, 75 and 100 kW/ m^2 have been selected**
    - **Lower flux and longer times represent conservative approach**

Controlled Heat Flux Device

Insertion Assembly

Test Article

Test Articles

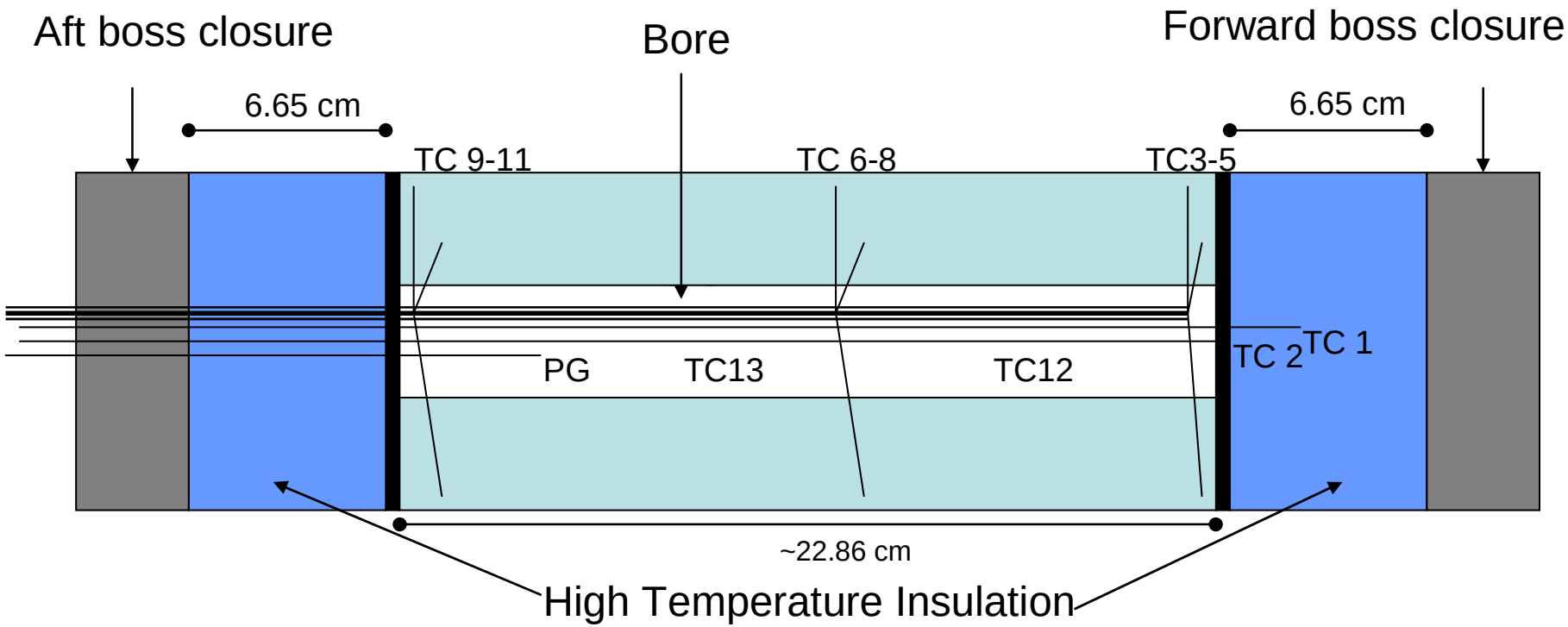
- **Two types of Test Articles**
  - **Tactical Rocket Motor**
    - **0.3175 cm Wall thickness**
    - **Stainless Steel**
    - Composite
  - Large Diameter Rocket Motor
    - 1.27 cm Wall thickness
    - Aluminum
    - Composite
  - **Thermal Properties consistent with configuration**
    - **EPDM insulator with HTPB liner**

Test Matrix

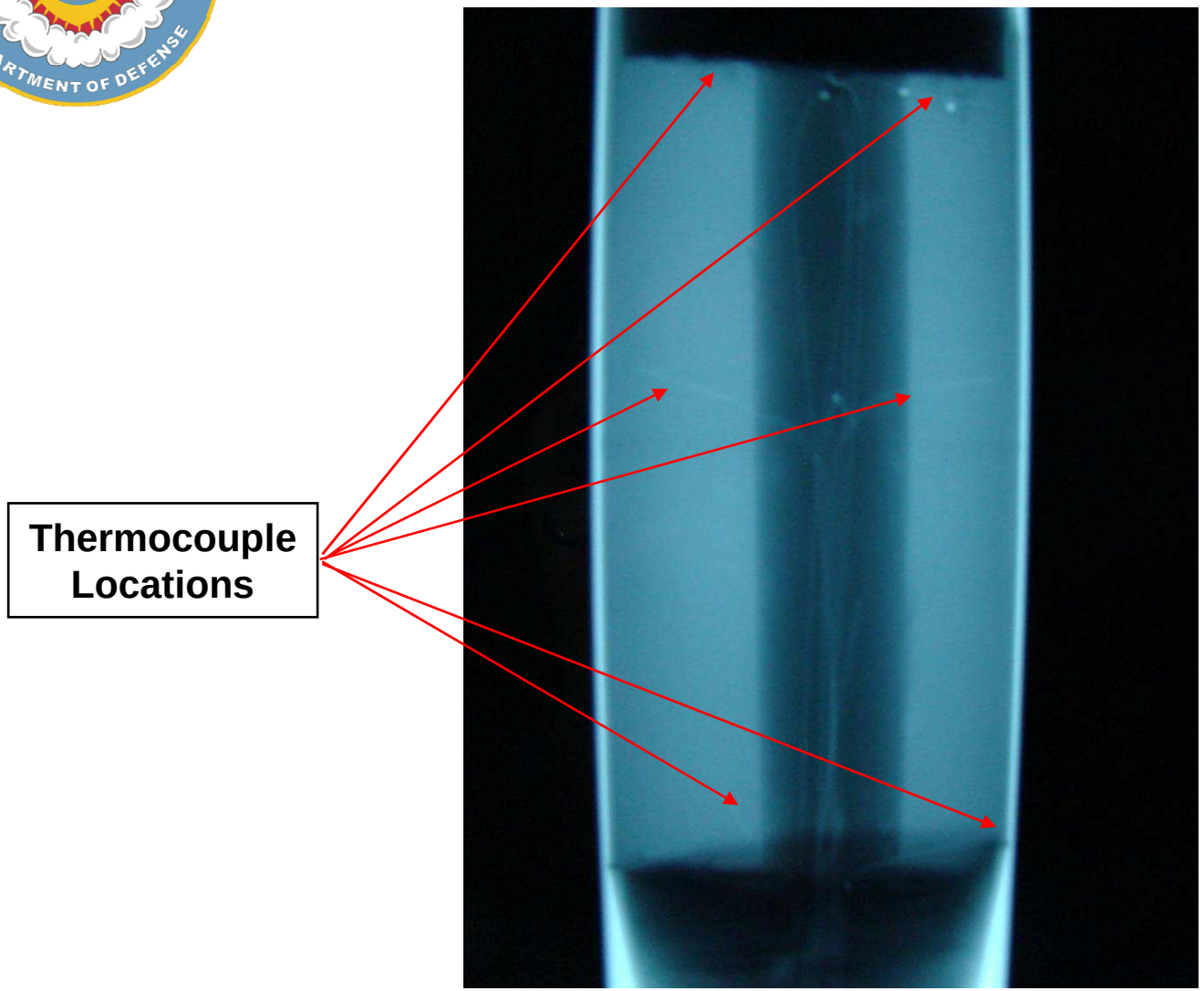
Test Asset	Propellant Geometry	Propellant	Test Location
0	End Burner	1.3 Fast Burning Propellant	CHFD
1	1.27 cm bore		
2	3.81 cm bore		
3			
4		Fielded Propellant	
5		1.3 Fast Burning Propellant	Liquid Fuel Fire

Test Article

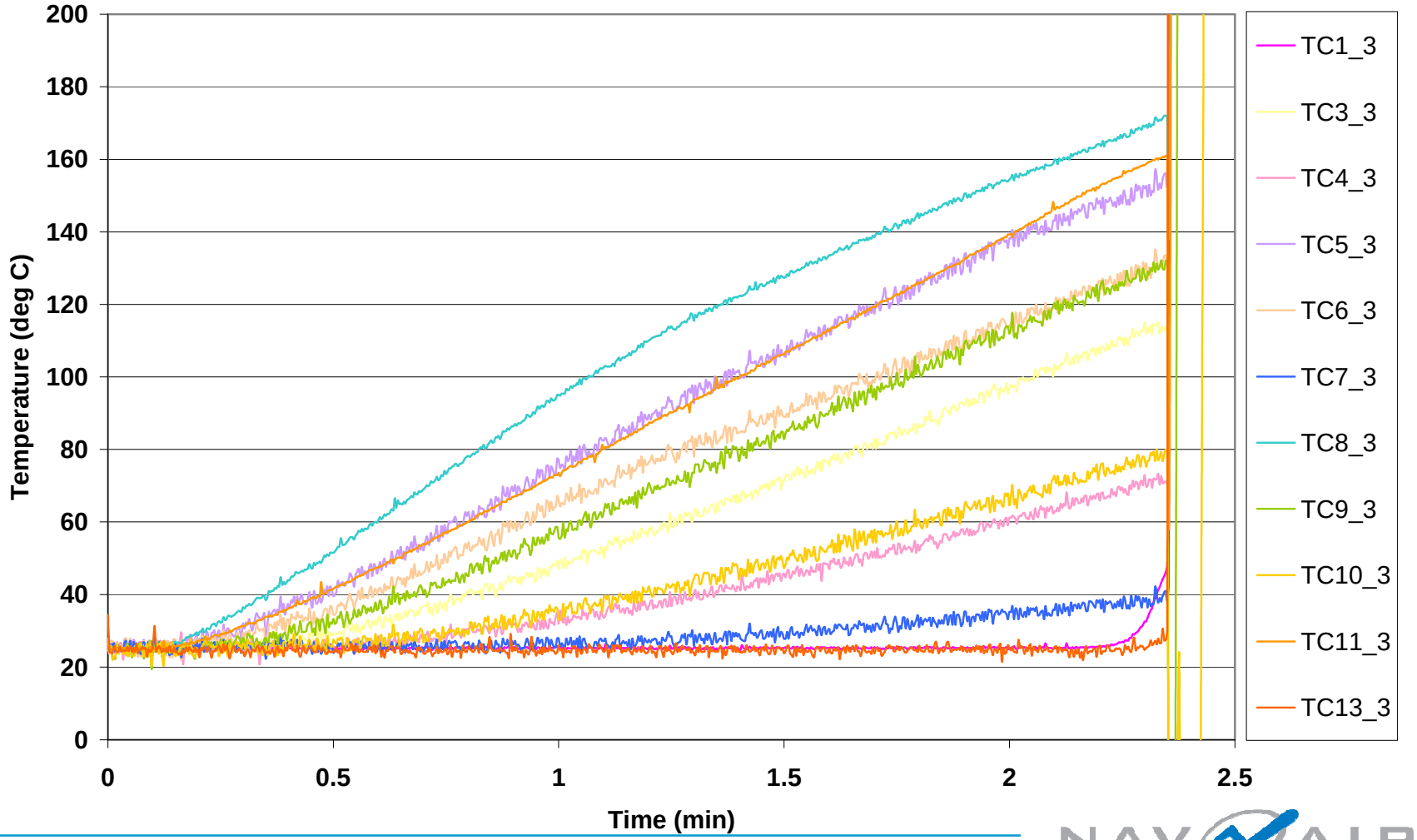
Interior Schematic



X-ray of Test Article



Thermocouple Response of Asset 3



Results

Thermal Stimulus

Thermal Stimulus

- Time to Ignition
  - CHFD
    - 141-145 seconds
  - Liquid Fuel Fire
    - 136 seconds
  - 8 seconds (6%) Difference
- Internal Thermal Couple Temperature
  - Similar temperature response

Fragmentation

CHFD

4 Metal Fragments Recovered

Liquid Fuel Fire

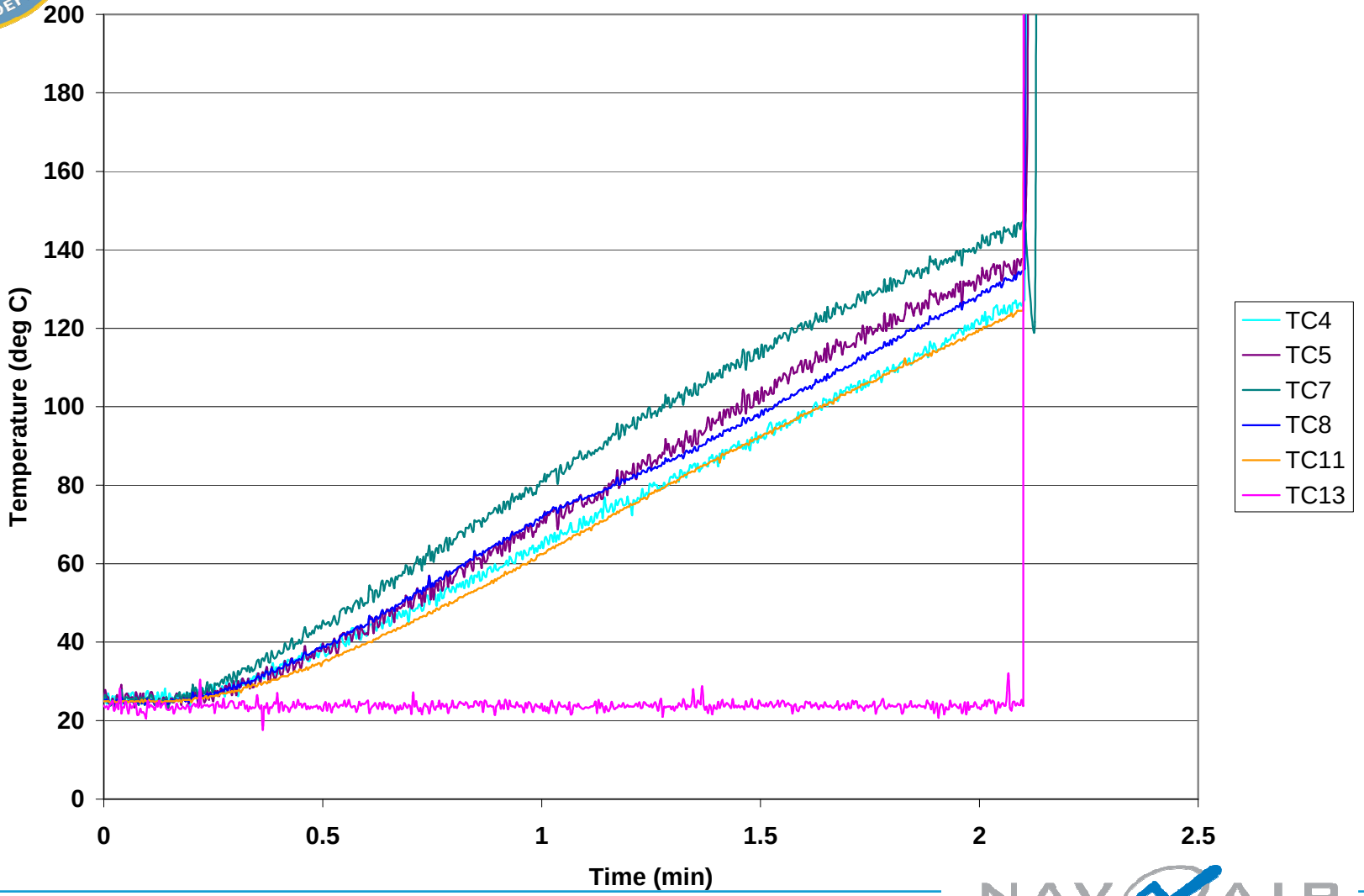
3 Metal Fragments Recovered

Scaling

Scaling Comparison

- CHFD
  - Similar Thermal Properties → Full Scale
  - Time to Reaction
    - 126.18 seconds
- Full Scale – Liquid Fuel Fire
  - 148 seconds
- Difference of 22 seconds (15%)

Thermocouple Response of Fielded Propellant with 1.5” Bore



Modeling

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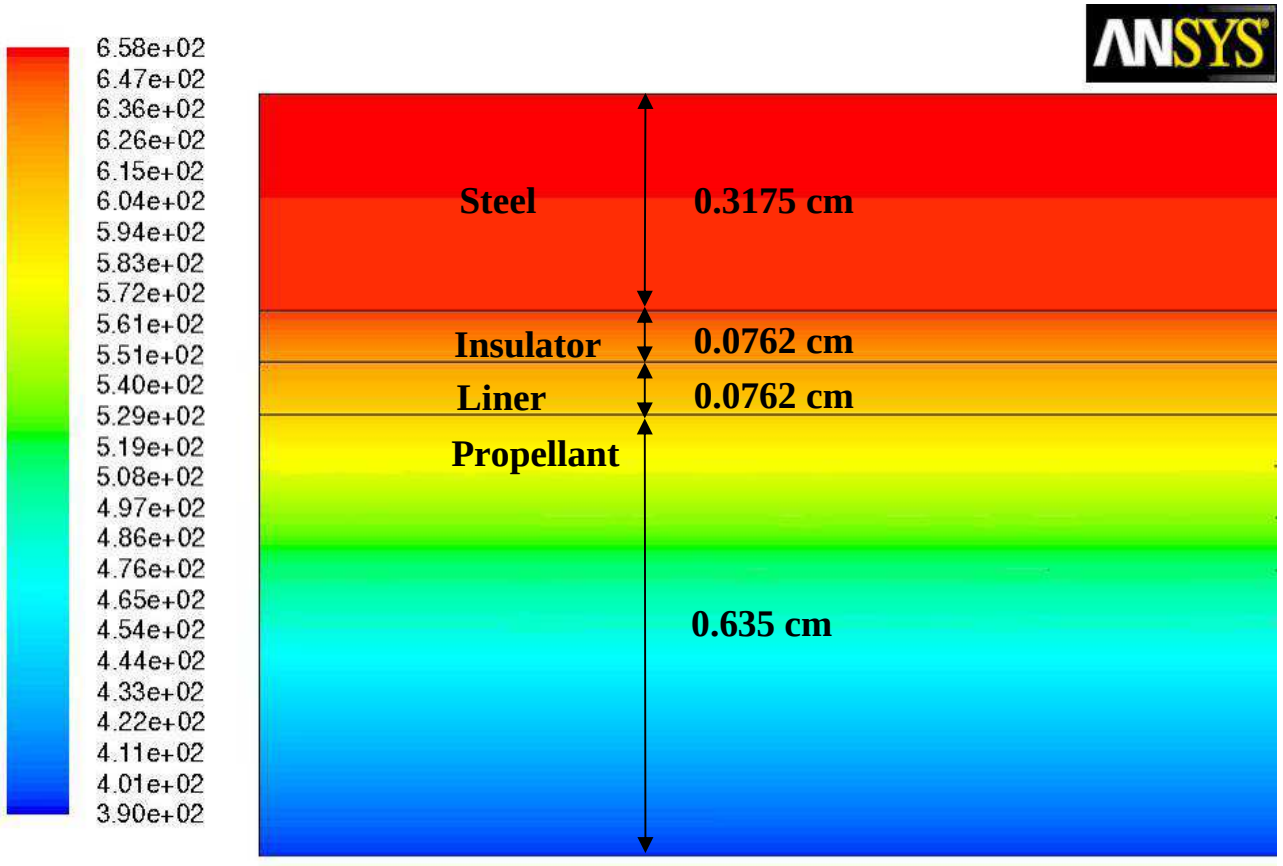
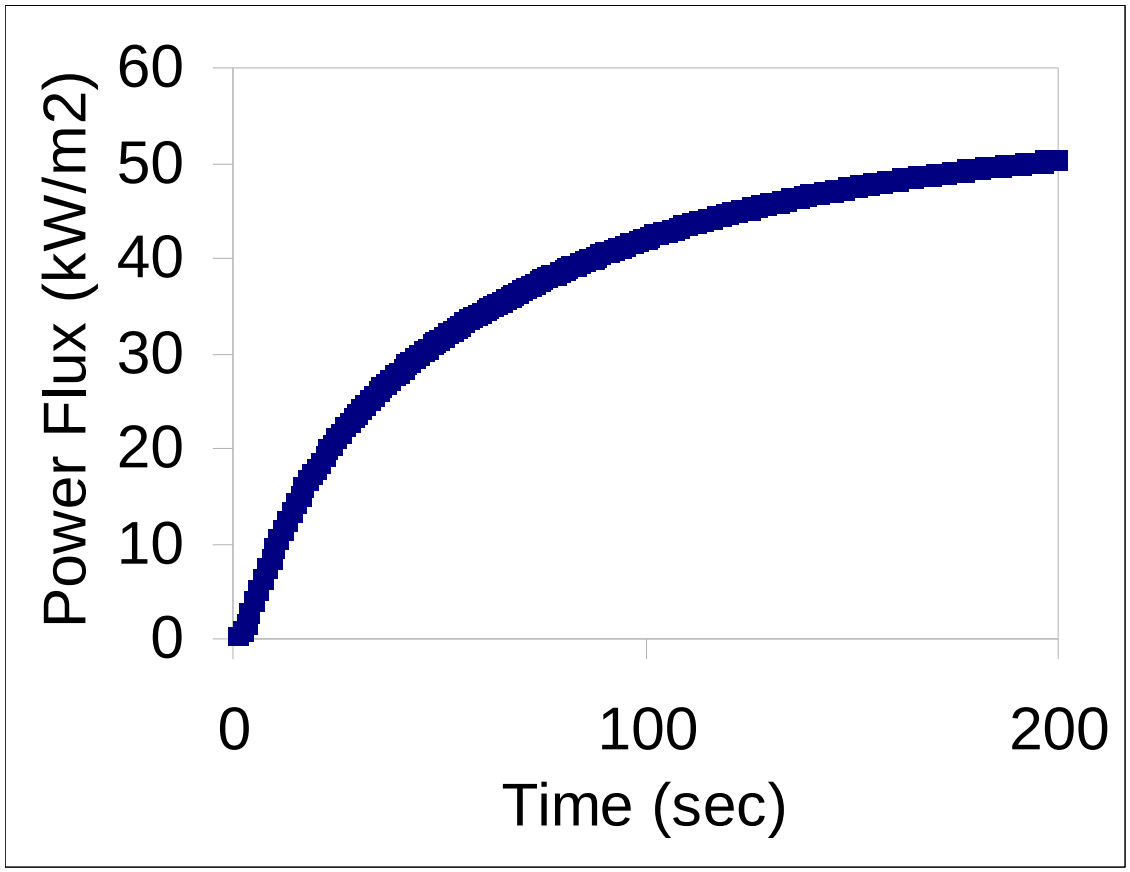
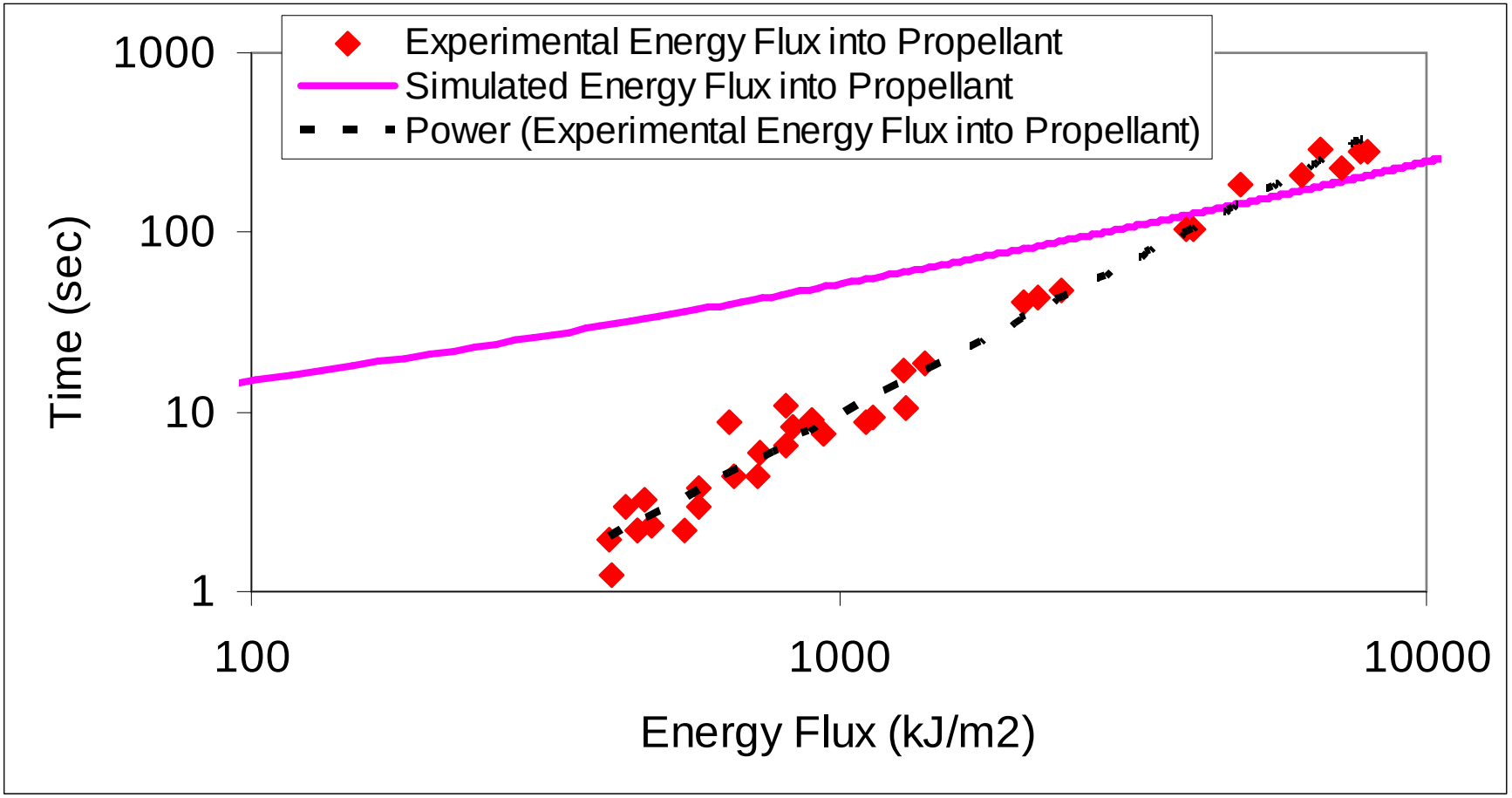
Fluent Modeling after 145 sec



Power Flux into Propellant



Time Versus Energy Flux into Propellant



Model Prediction of 145 sec

Test Asset	Propellant Geometry	Propellant	Time to Reaction (sec)	% Difference from Model
0	End Burner	1.3 Fast Burning Propellant	123.6	14.76
1	1.27 cm bore		128.6	11.31
2	3.81 cm bore		144.6	0.28
3	3.81 cm bore		141	2.76
4	3.81 cm bore	Fielded Propellant	126.18	12.98

Modeling Reaction Violence

Fragment
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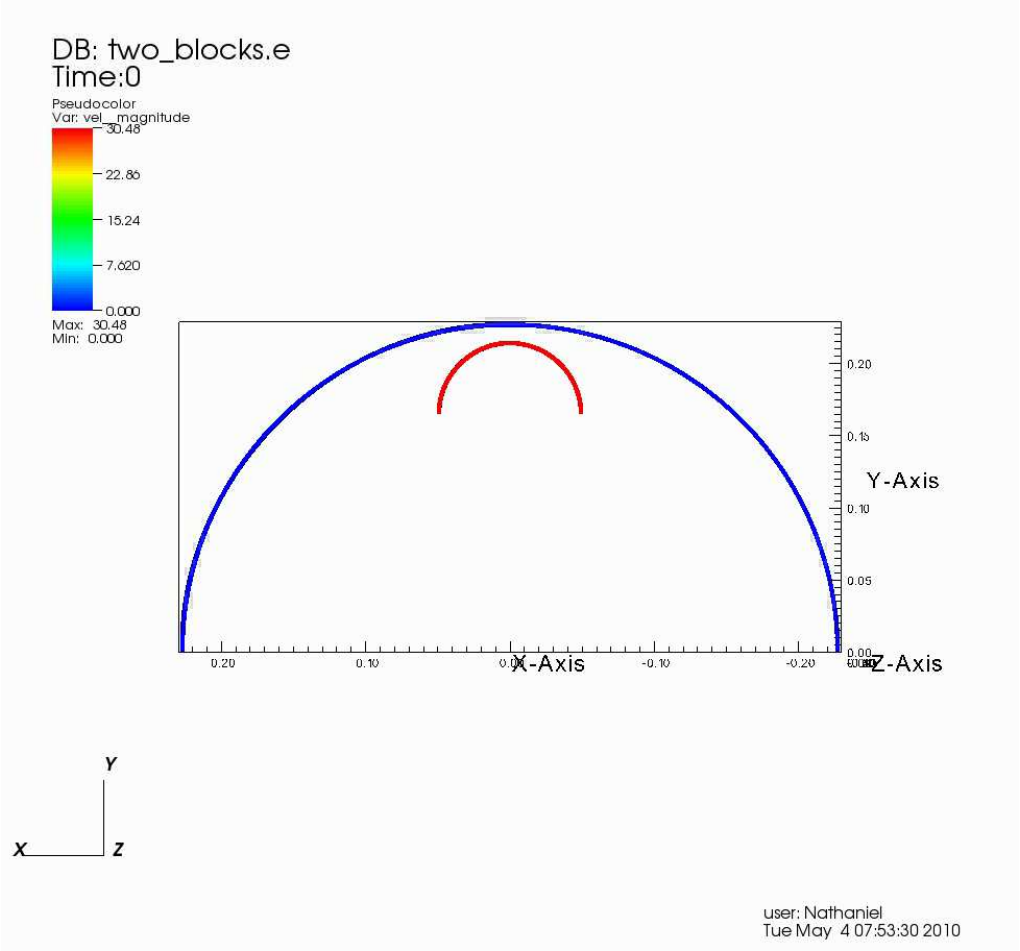


Summary

- **Thermal Apparatus – designed to produce 20-200 kW/m^2**
- **Thermal Stimulus**
  - **Reaction and time to reaction similar between CHFD and Liquid Fuel Fire**
- **Fielded propellant similar thermal and time to reaction to full scale test**
- **Predict time to reaction within 15%**
- **Reaction violence still examining**
  - **Fragment Energy segregate reactions**

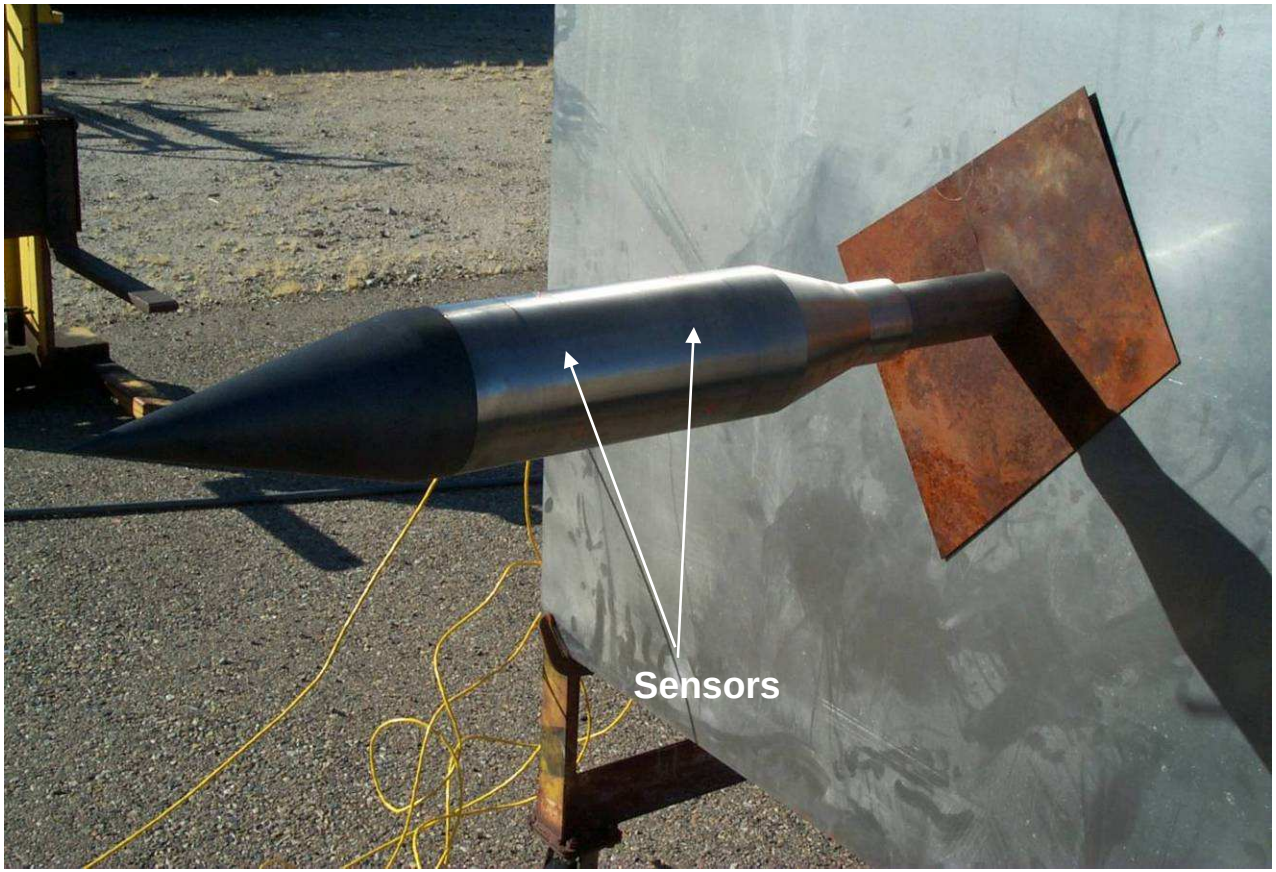
Future Plans

- Perform CHFD methodology on 5 types of hazard response
  - Assess Reaction Violence
- Continue Validation Testing
- Refine Model
  - Material expansion
  - Continued Development of Mechanical Response Model

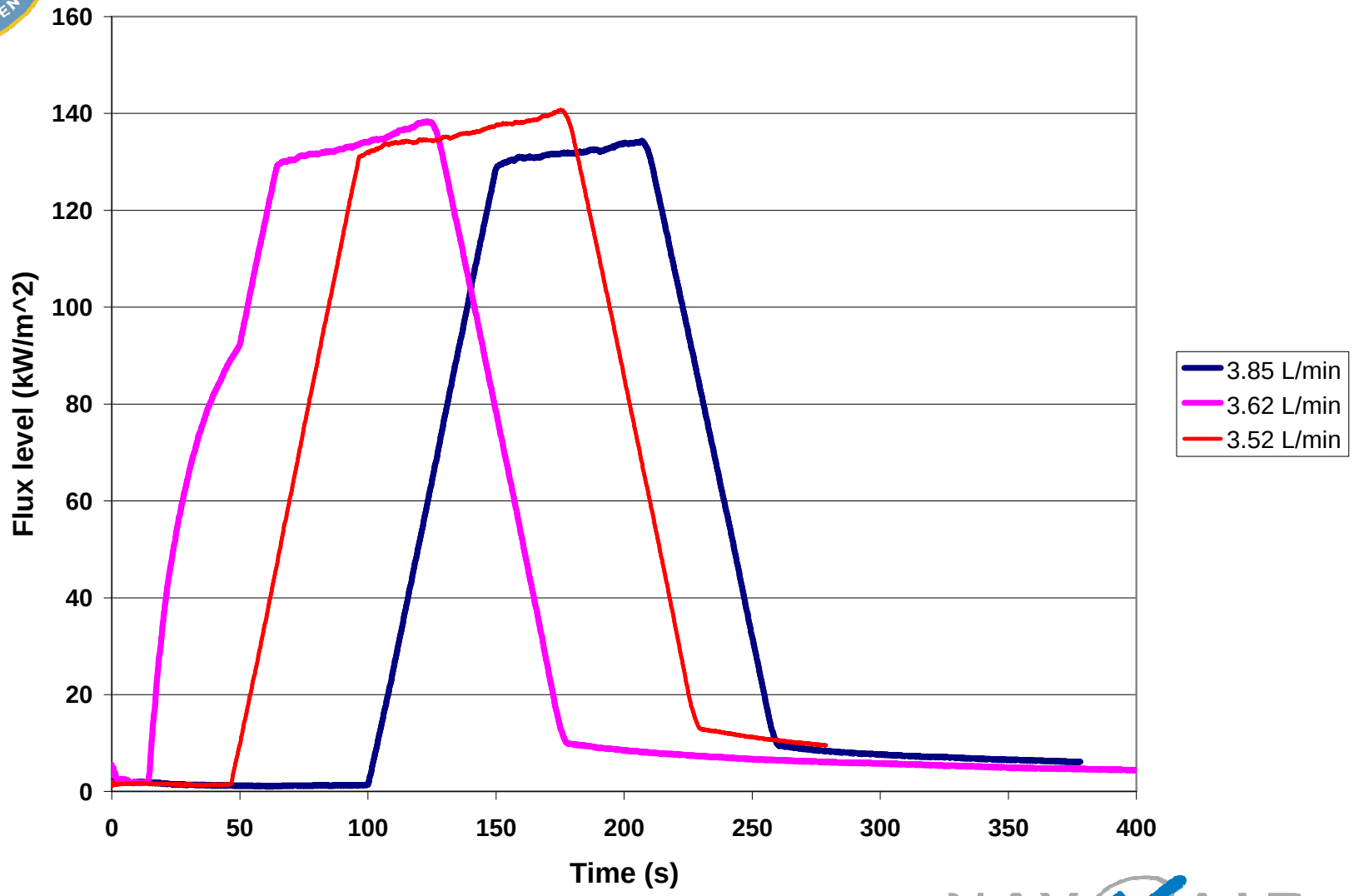
Extra Slides

Combustor at Remote Site

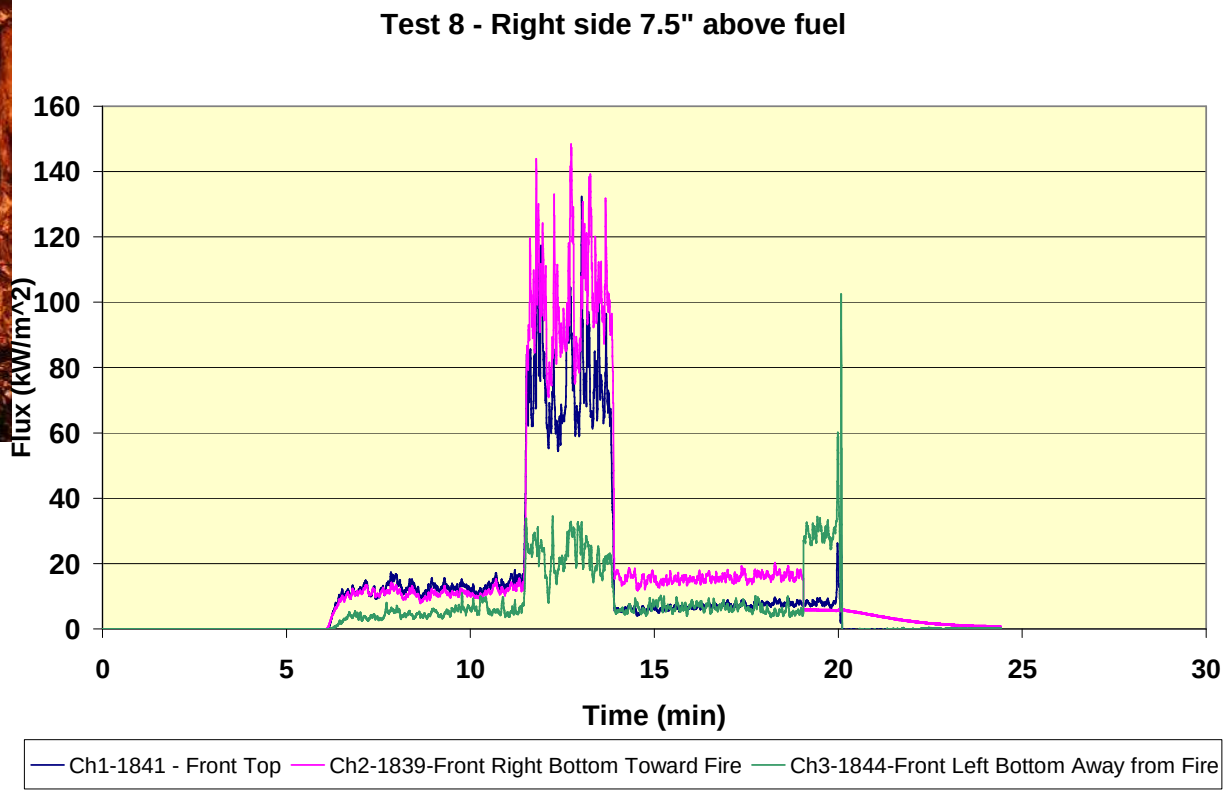
Calibration Device



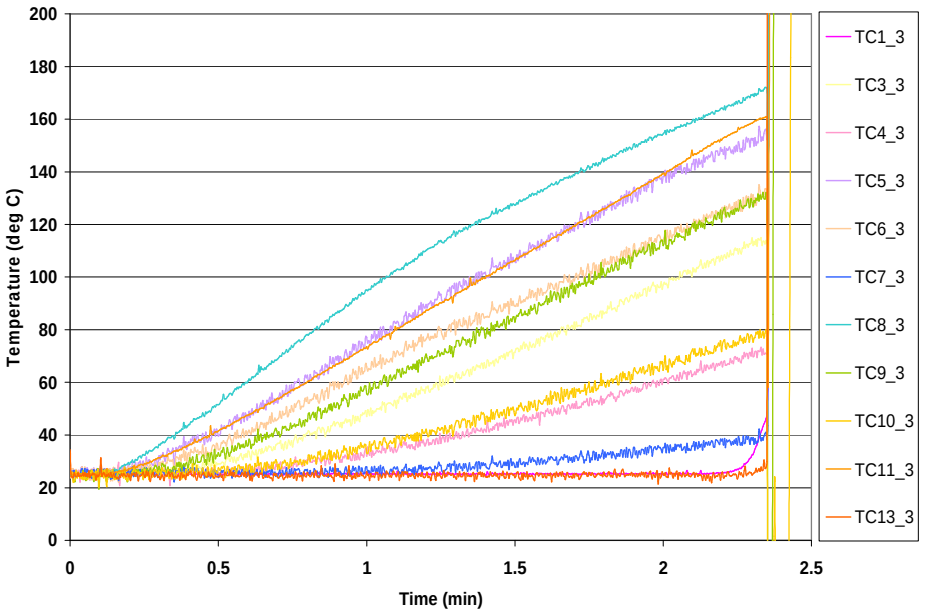
Combustor Calibration – 135 kW/m²



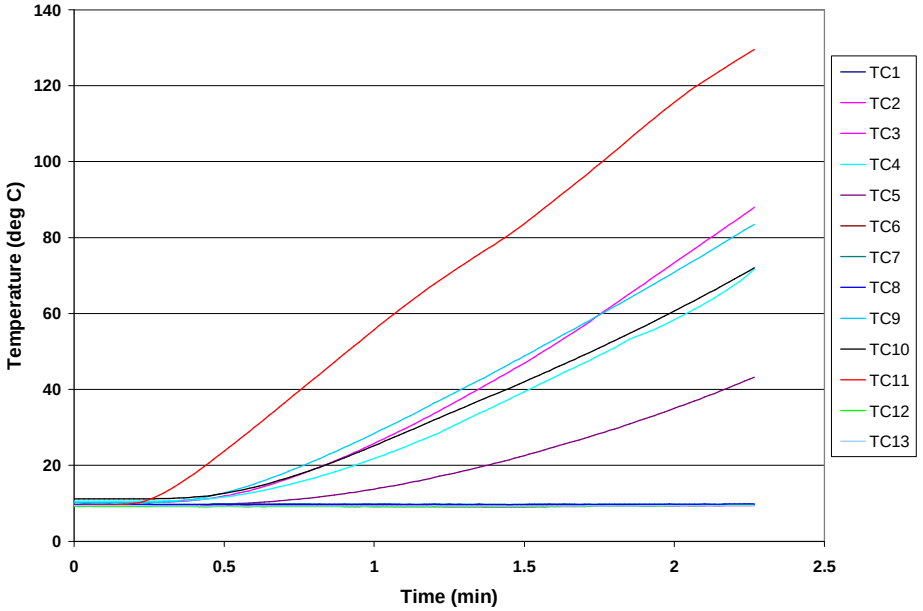
Flux Level Variability 1 m Pool Fire



Internal Thermocouple



CHFD

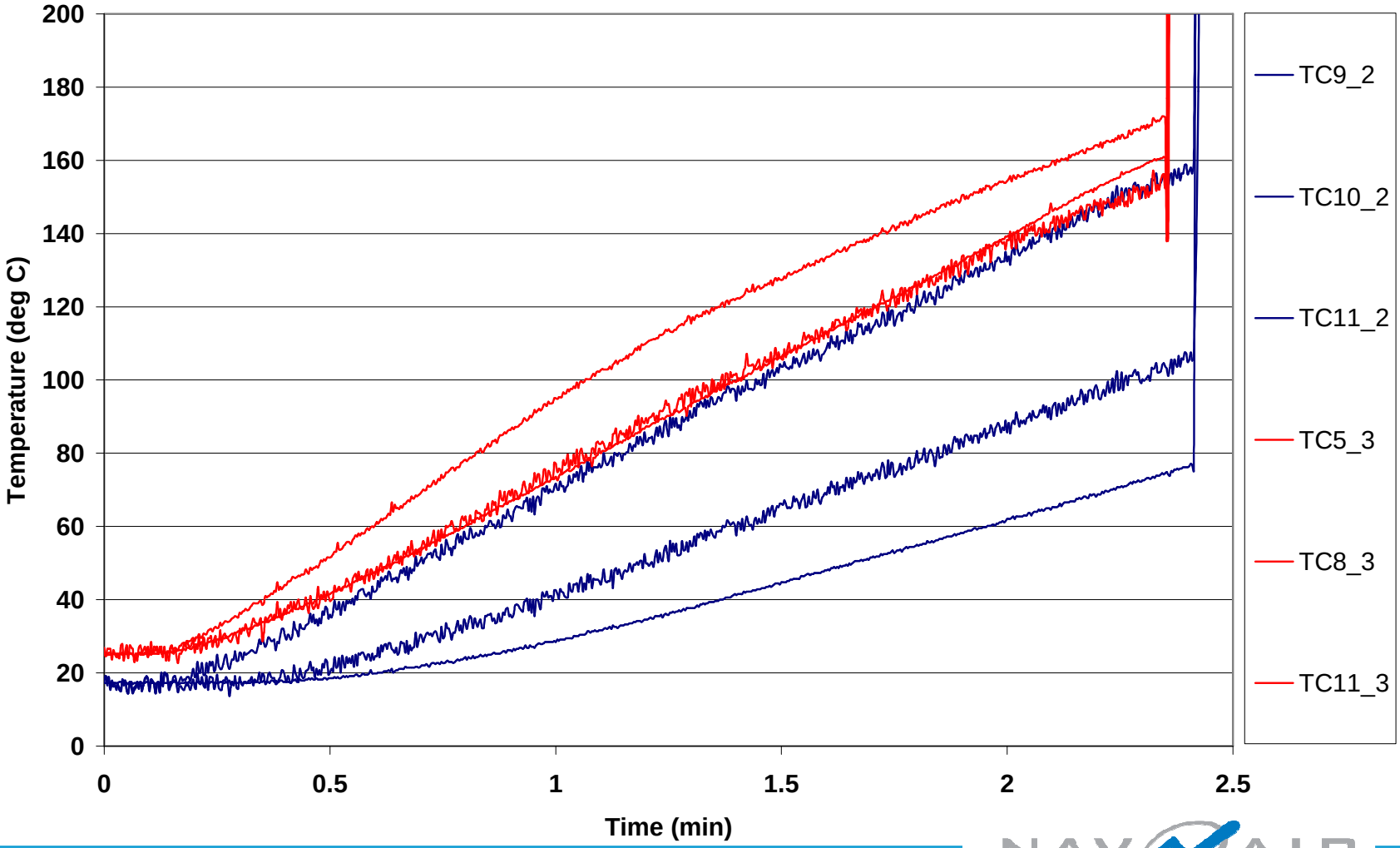


Liquid Fuel Fire

Repeatability

Test Asset	Propellant Geometry	Propellant	Time to Reaction (sec)
2	1.5" bore	1.3 Fast Burning	144.6
3			141

Thermocouple Response of 1.3 Fast Burning Propellant with 1.5” Bore



Fragment Repeatability

Test Asset 2

Test Asset 3