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ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NJ

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Propellant Analysis in support of Low Observable Tracer (LOT)/One-Way Luminescence(OWL) Efforts

1-3 June 2015

Presented By: Matthew Horch
ARDEC Project Officer, OWL

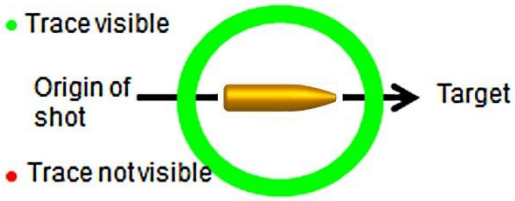
Agenda

- Overview of the OWL program
- Introduction to barrel spectrum testing
- Device design and test setup
- Generated data and analysis
- Future testing
- Summary
- Acknowledgements
- Questions

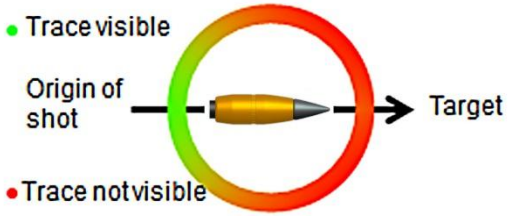
Overview of OWL Program

Visual Signature Comparison

Current Tracer

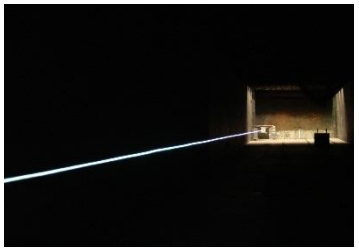


Visual Signature with Current Tracers



Approximate Visual Signature with One Way Luminescent Tracers

LOT/OWL Concept



Operational/Training

- **Increases soldier's survivability**
  - Substantially reduces signature of tracer
- **Greater lethality for belted ammunition**
  - Tracer round gains lethality component
- **Trajectory Matching for ball and tracer rounds**
  - Minimal material exiting the round
- **Potential elimination of range fires due to tracers**
  - Training uptime increased
- **Potential for every round to trace**

Operational/Training

- **Potential increase in soldier aim/effectiveness**
  - Faster point of aim corrections
  - Follow every round to impact
- **Potential addition of a new capability to rifle/carbine weapon systems**
- **Potential elimination of night vision equipment white-out**
  - No pyrotechnic causing intense signature

Overarching goal of OWL is to Integrate a non-pyrotechnic, one-way visible, full day/night tracer into current ammunition production products in order to improve warfighter capability, reduce logistical burden, and reduce ammunition cost.

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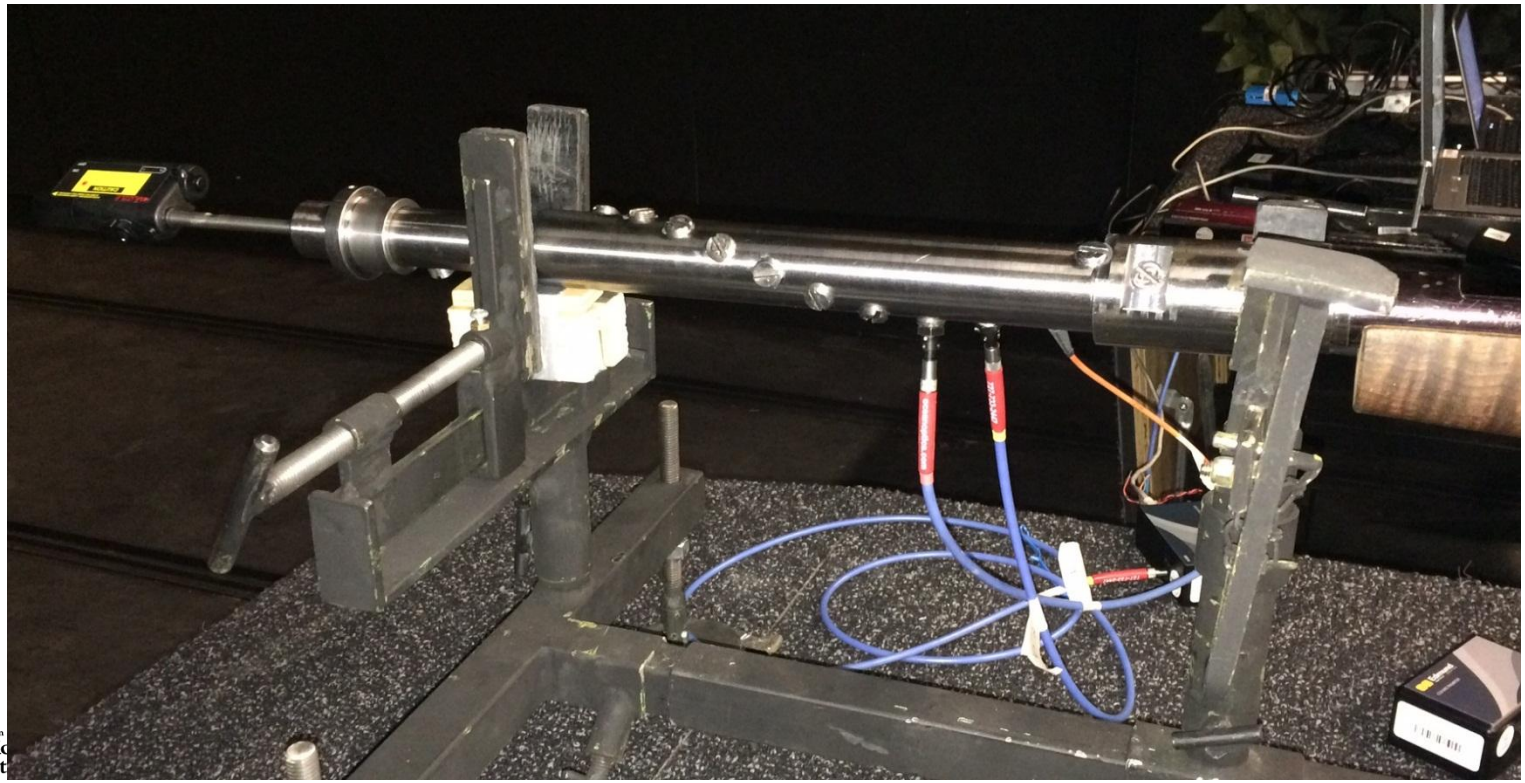
Introduction to Barrel Spectrum Testing

- In order to help drive technology solutions, ARDEC needed to determine and, more importantly, characterize the energy available within the system
  - Allowed for better understanding of the energy to be utilized
  - Provided areas of energy gaps
  - Helped to re-evaluate potential concepts based on available energy
- It is known that there is intense heat, pressure, and light during an initiation event
  - Only pressure is collected on a regular basis (EPVAT testing)
  - Some thermal studies have been performed, but are based on legacy or commercial propellants
  - Only light/wavelength studies ARDEC has seen, have been for muzzle flash work

Internal barrel temperature and light/wavelength characterization during propellant initiation and propagation have not been fully captured, recorded, or characterized

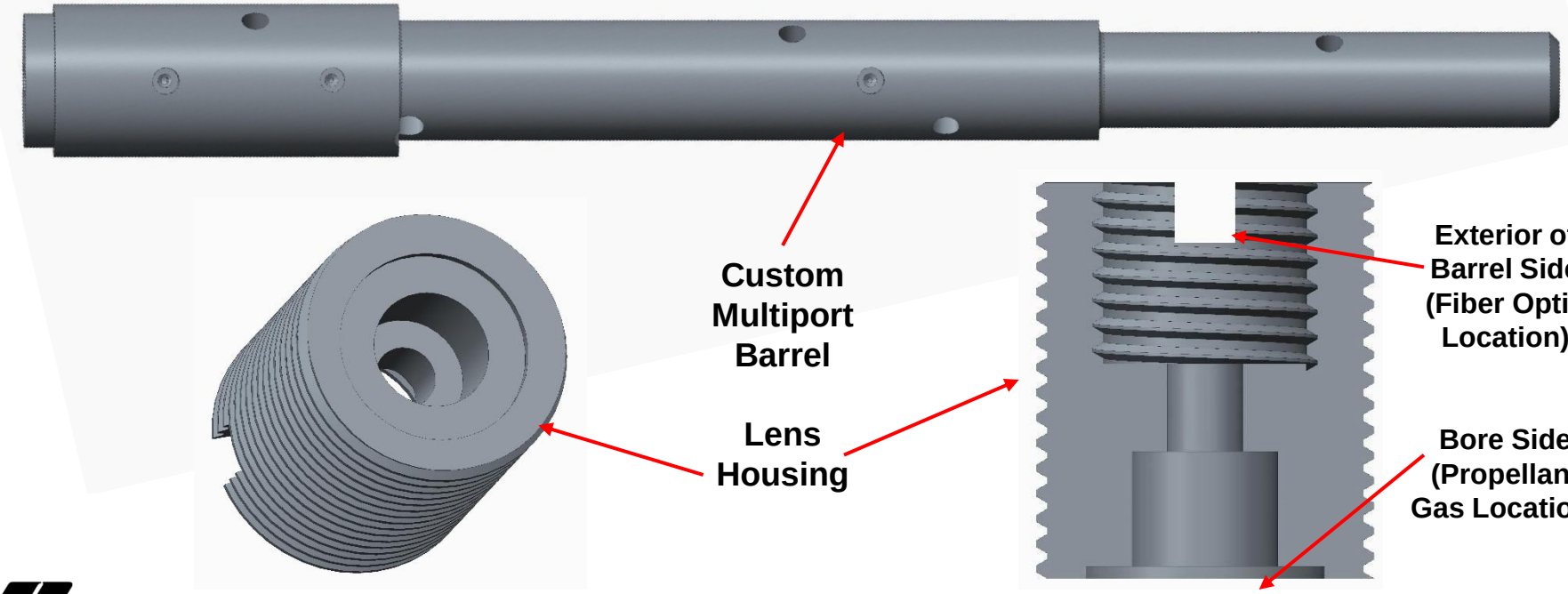
Device Design and Test Setup

- List of key items utilized:
  - Custom multiport barrel
  - Visible and IR spectrometers
  - Various focusing lens
  - Fiber optic cables
  - Custom lens housing
  - Custom barrel plugs
  - Software for analysis



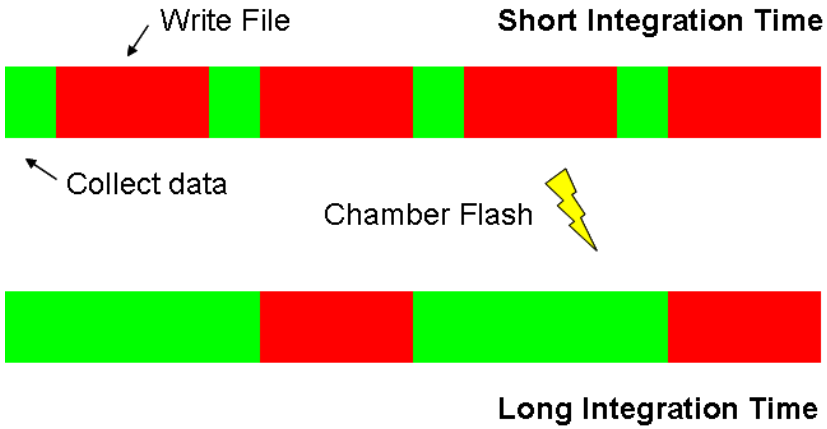
Device Design and Test Setup

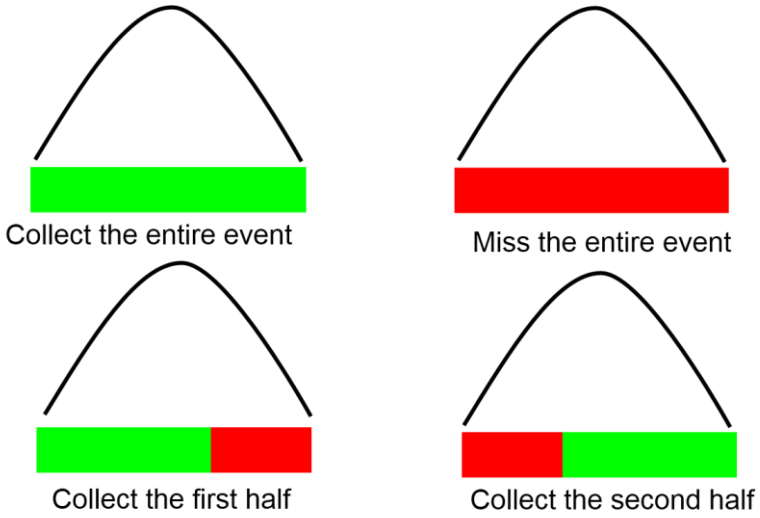
- ARDEC based design off of EPVAT style barrel with custom port sizes and locations down the barrels
- Custom housings needed for collected light & wavelength data as propellant propagates
- Special lenses were also created to insure multiple uses without breaking



Device Design and Test Setup

- During testing, it is critical to capture the event, however based on software limitations it is difficult to collect every event (ARDEC is currently at an ~75% capture rate)
- Spectrometer collects data for length of integration time (green) and then writes the data (red)
  - Data is not collected during the writing phase
  - New software is available to reduce read/write times (non-data collection)
- Some concern that long integration times will reduce overall intensity of captured wavelength
- There is a potential to miss part of the event depending on read/write iteration



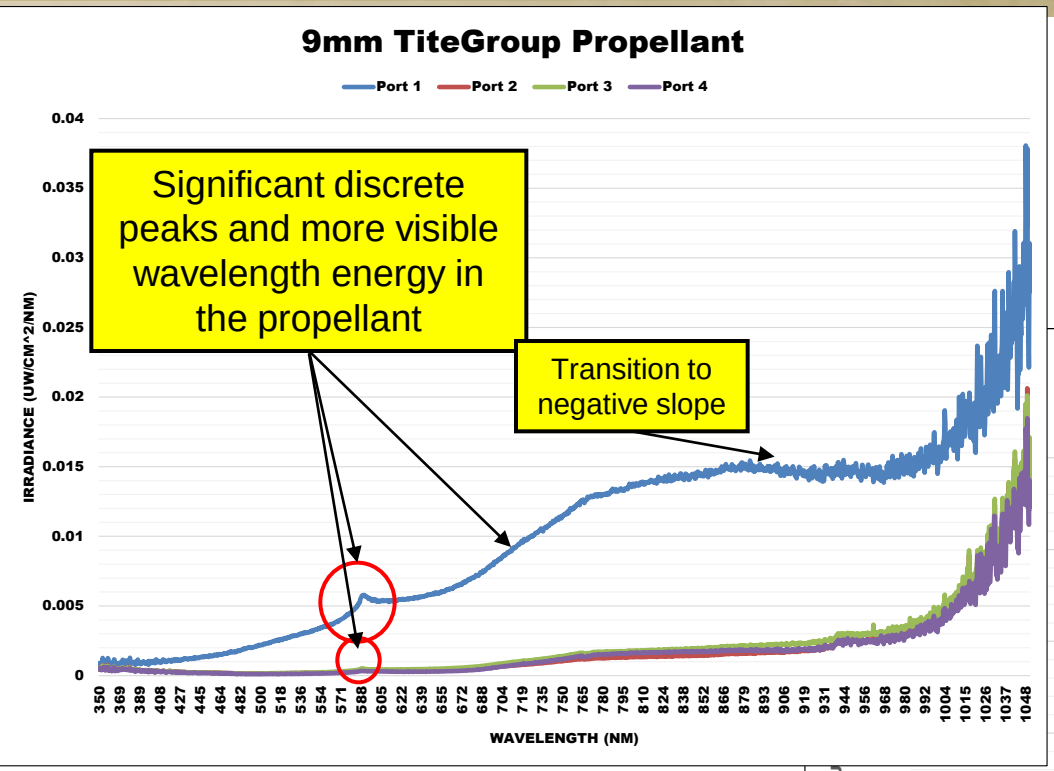


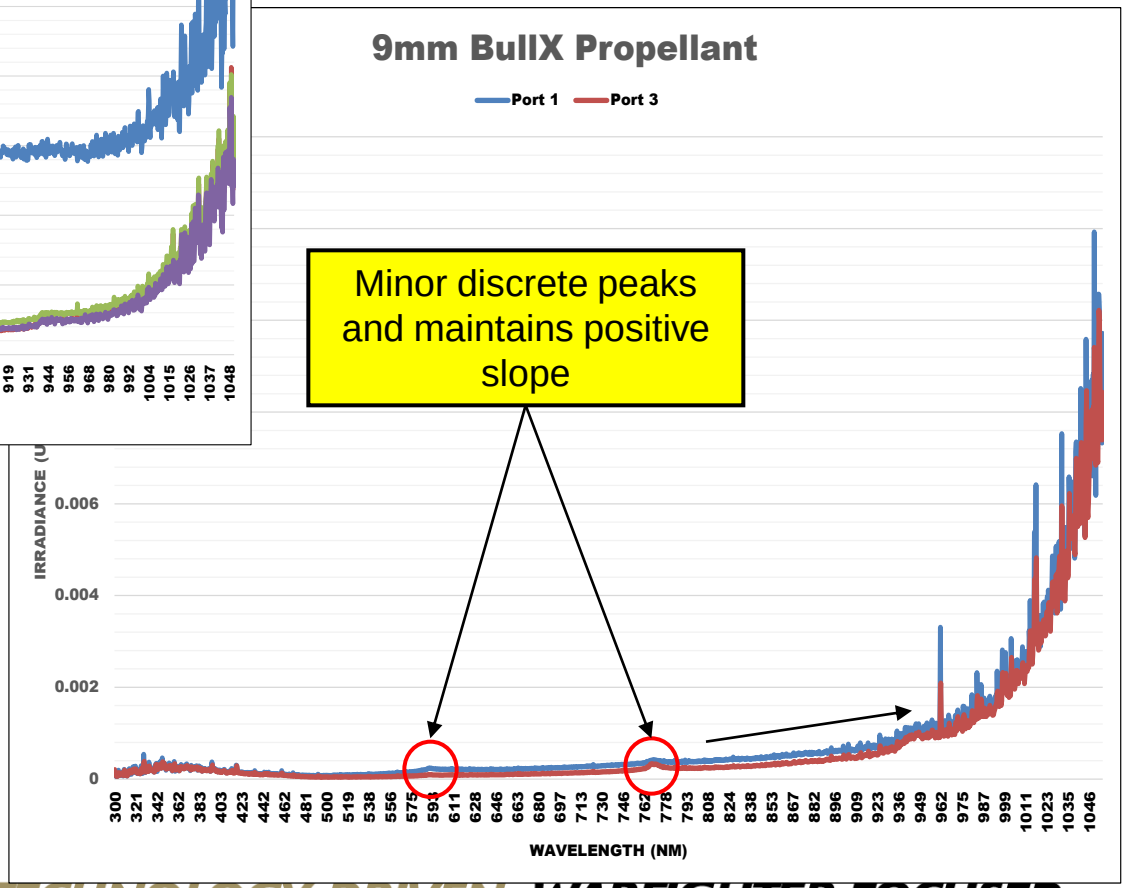
Generated Data and Analysis

- Testing conducted on multiple propellants over last 3 years
- Due to limitations of spectrometers used, data recorded was conservatively screened
  - Data considered unreliable and screened from visible spectrometers
    - Data collected at 400nm and below
    - Data collected at 950nm and above
  - Data considered unreliable and screened from nIR spectrometers
    - Data collected at 975nm and below
    - Data collected at 1650nm and above
- Collected spectrum from 5.56mm – 9mm size calibers, although the OWL effort is focused more on high velocity rifle systems
- Captured light density
  - Units are
    - Y-axis: Intensity ($\mu W/cm^2/nm$)
    - X-axis: Wavelength (nm)
  - Essentially these are photons per unit area i.e. the light density at that specific port location broken down by wavelength

Generated Data and Analysis

9mm - Commercial





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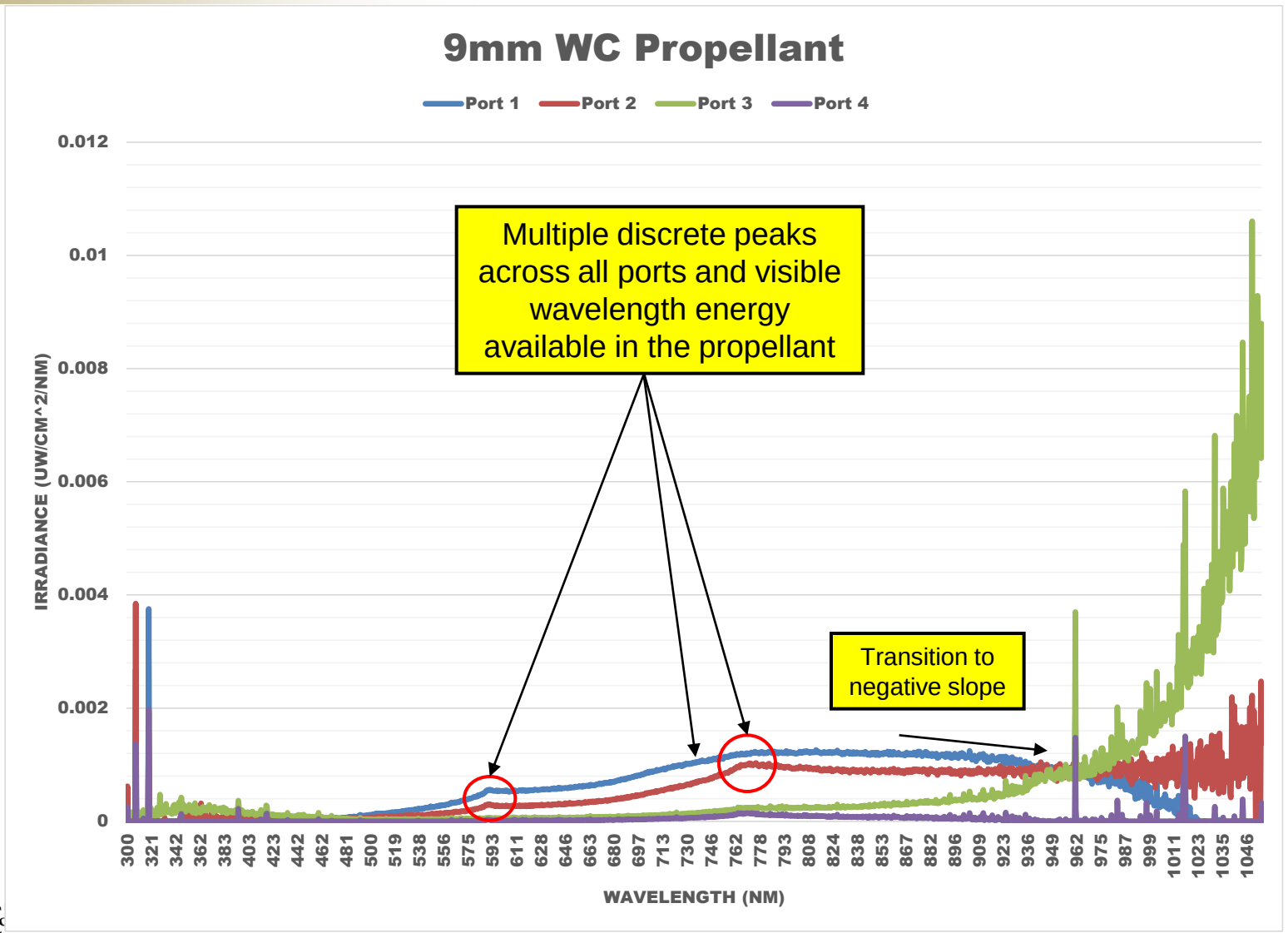
Generated Data and Analysis

9mm - Military



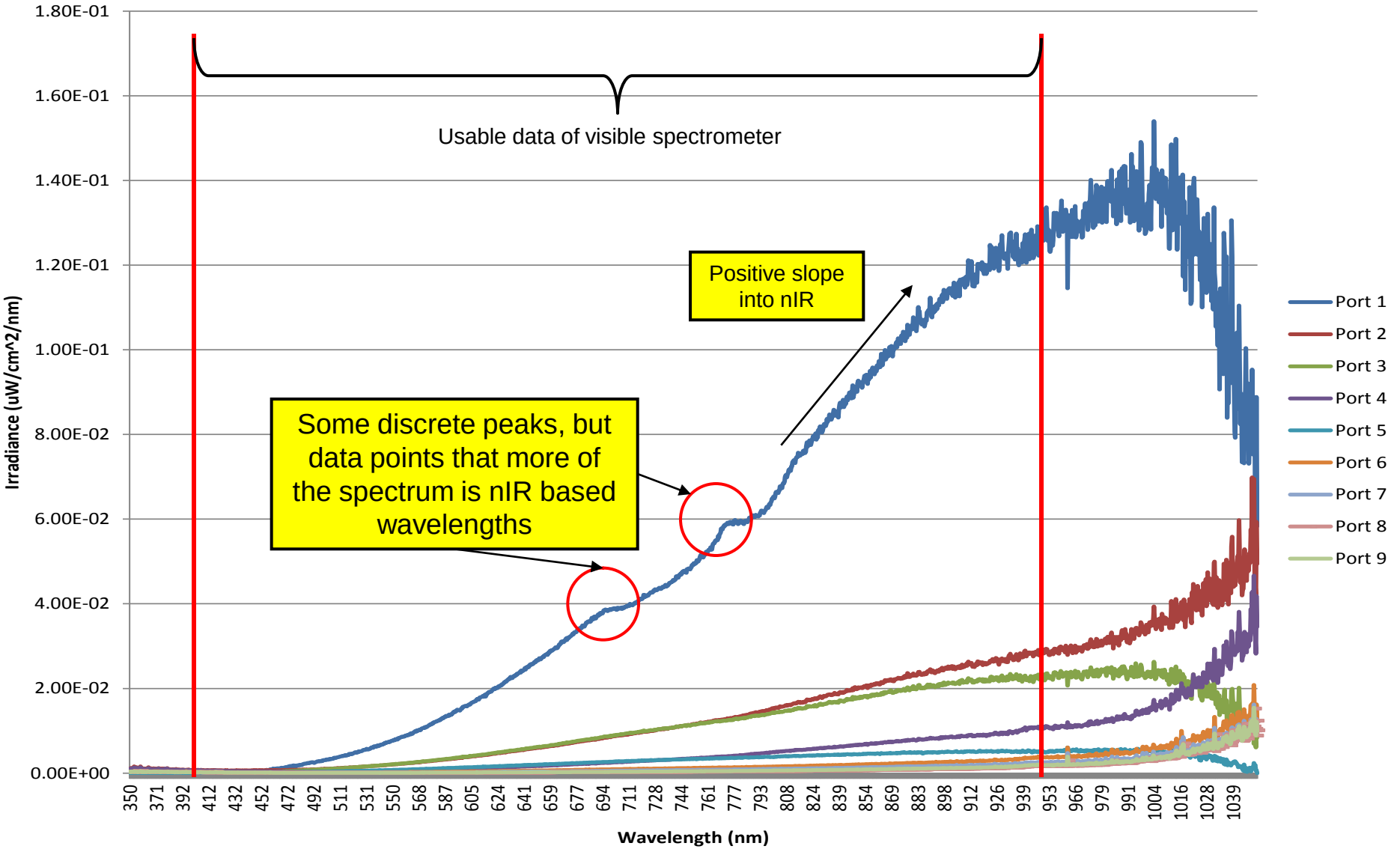
Generated Data and Analysis

9mm Propellant Suite

- All 3 propellants were 9mm, 2 of 3 were commercial propellants for comparison and verification that discrete data could be collected
- IR data was not taken
- Key features seen
  - All propellants provided discrete peaks
    - Discrete peaks are distinct wavelengths specific locations
  - Majority of the propellants have energies in visible spectrum
  - Slope (positive to negative slope) of spectrum
    - Can provide thermal characteristics of propellant
    - If positive only can try and match up known black body curves
    - Negative slope provides a more distinct curve to match to a known black body curve (location of the peak is the key distinction)

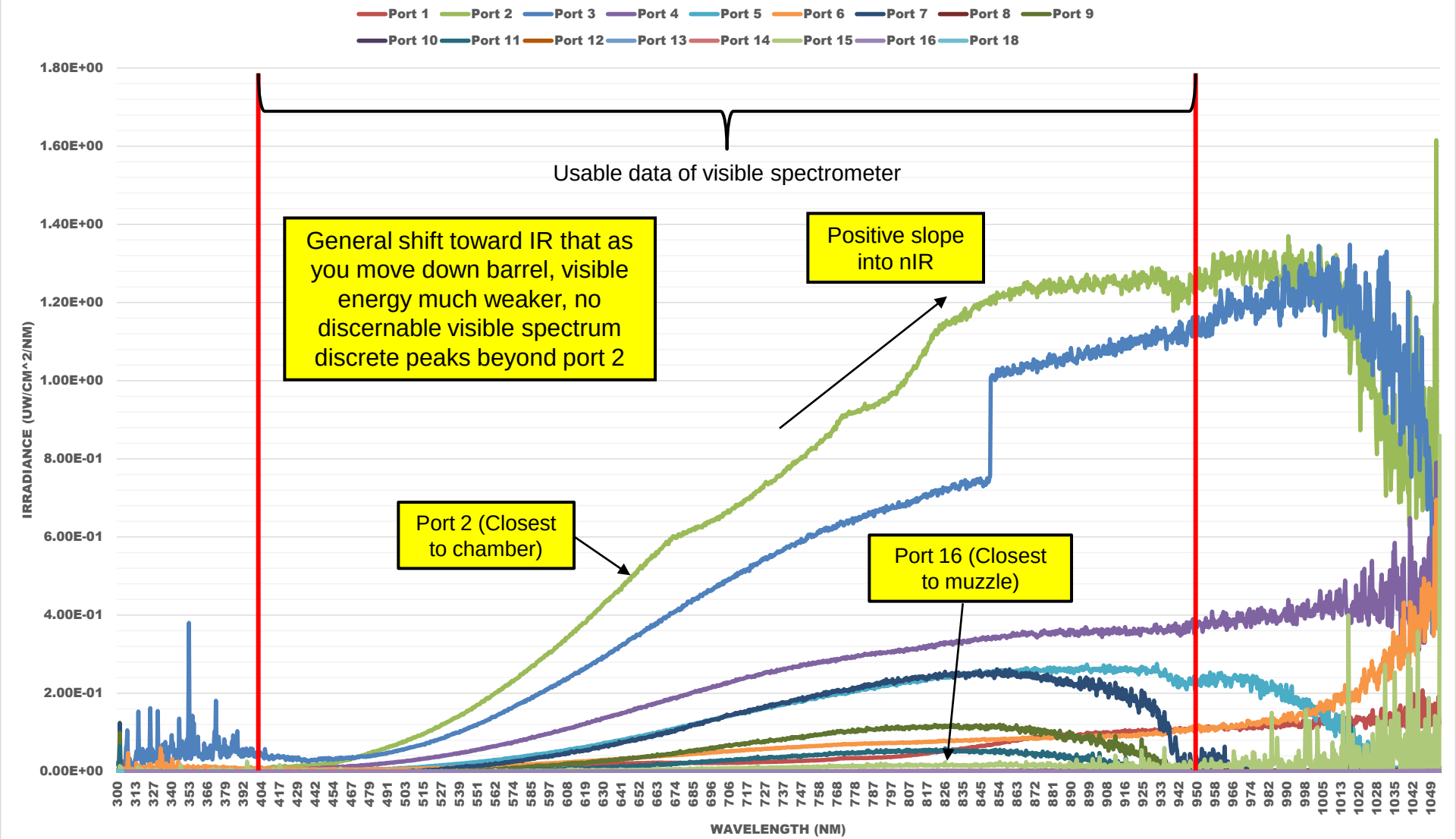
Generated Data and Analysis

7.62mm – Propellant Type A



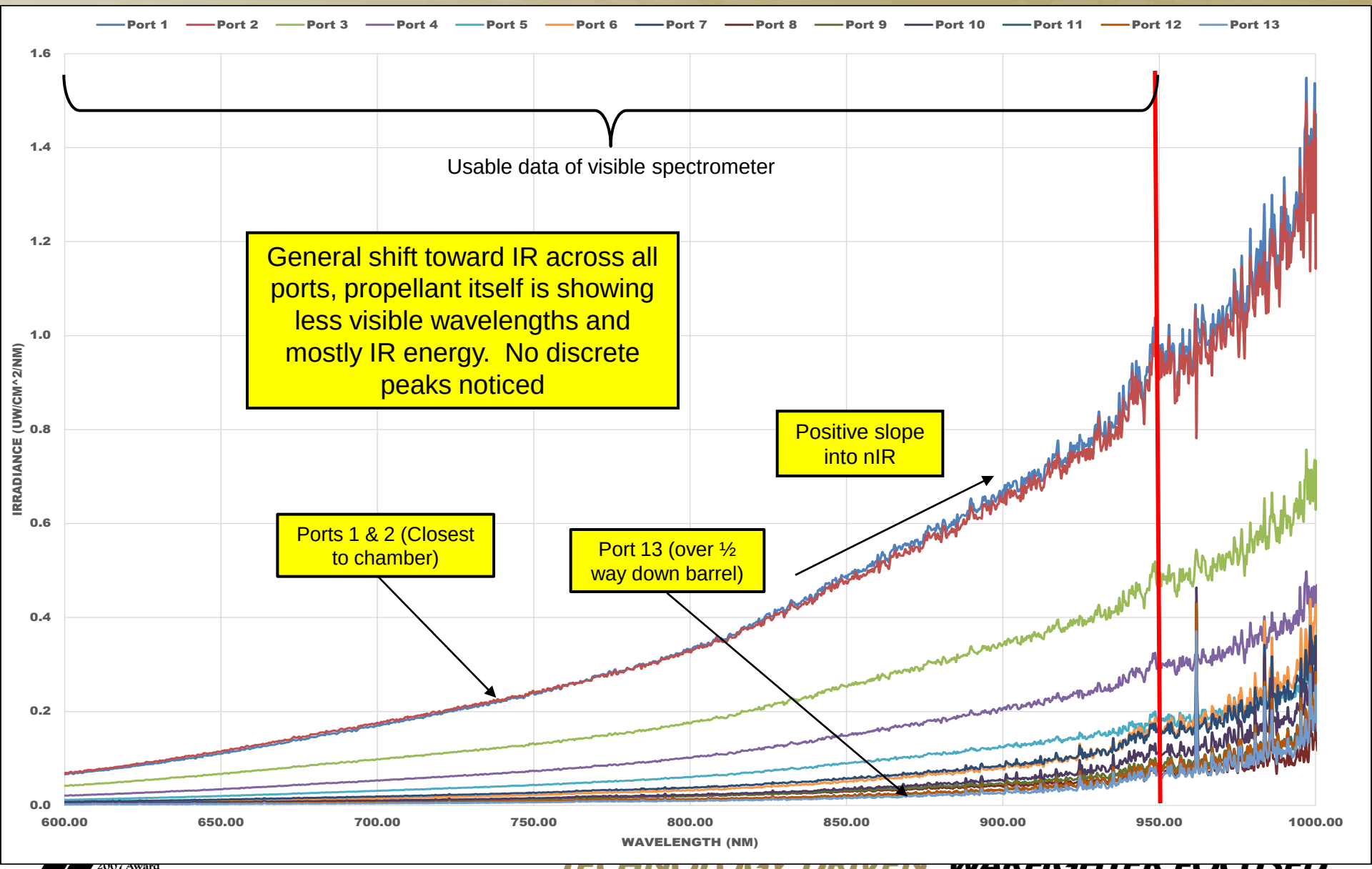
Generated Data and Analysis

7.62mm – Propellant Type B



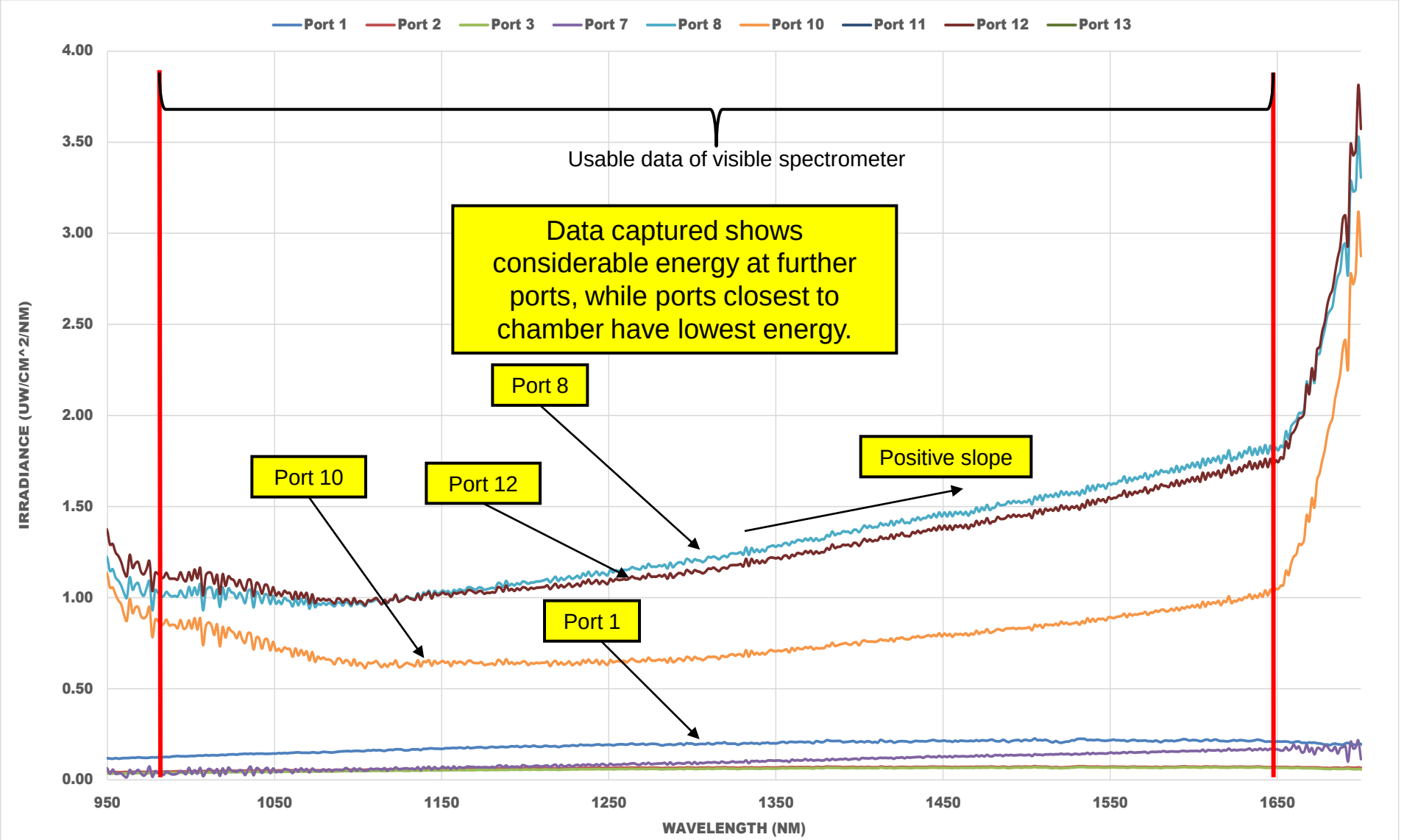
Generated Data and Analysis

7.62mm – Propellant Type C (Vis Only)



Generated Data and Analysis

7.62mm – Propellant Type C (IR Only)



Generated Data and Analysis

7.62mm Propellant Suite

Visible Propellants

- Based on analysis, military has various propellants that show a variety of characteristics
  - Some show clear discrete wavelengths
  - Some show cooling portion of their curves for better thermal analysis
- General trend is more propellants provide IR characteristics than visible, could be considered “hotter” propellants

IR Analysis

- Data is still being collected and is confusing
- When viewing trends from Vis to IR, data (as seen by port location), lines do not match up
- Initial estimates of temperature ranges (based on trying to match known black body curves) are between ~1725^{o}C (3137^{o}F) - ~ 4225^{o}C (7637^{o}F)
- More analysis is needed to complete internal IR curves

Future Testing

- Team is still collecting data and is comfortable with the visible spectrum data
- Have initiated analysis on 5.56mm propellants and have drafted plans to continue testing into larger calibers as the program dictates
  - Purpose would be to:
    - Gather a complete suite of data
    - Determine differences between caliber propellant wavelengths
- Re-look needs to happen at the IR spectrums
  - Ideally would like to get a broader IR spectrometer to capture data into the MW if possible
  - Would allow for better definition of thermal curve/black body analysis

Summary

- ARDEC has built, tested, and verified a unique capability to determine the specific affects of heat and wavelength propagation of propellants as they expand during initiation
  - Materials and equipment used are easily transferrable to different calibers
- 7.62mm rifle propellants have completely different wavelength characteristics than 9mm pistol
- Data collected directly impacts models and technologies the OWL team is building and investigating
- Test setup and analysis show clear differences between all propellant types
  - Equipment used is able to pick up specific differences in all propellants
  - Provides that methodology for testing is sound
  - Improvements can be made in type of electronic equipment used

Acknowledgements

I would like to thank the following for all their support in this effort:

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QUESTIONS?