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Development of Standardized Test Methods for Quantitative Small Arms Flash Measurements

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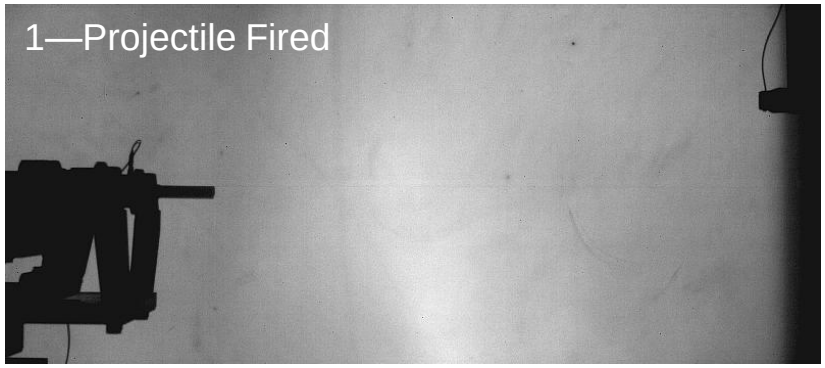
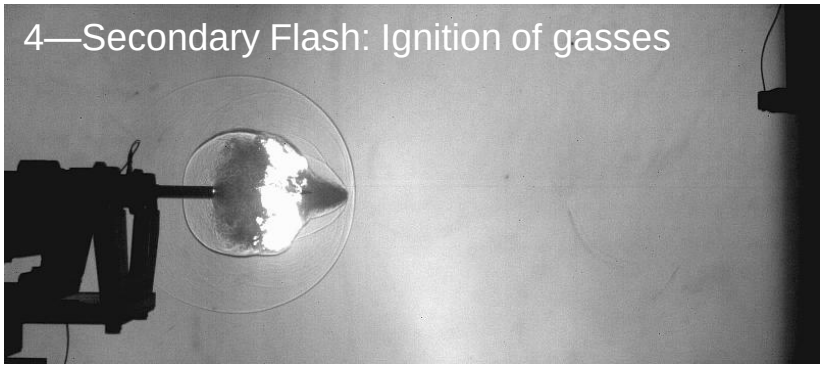
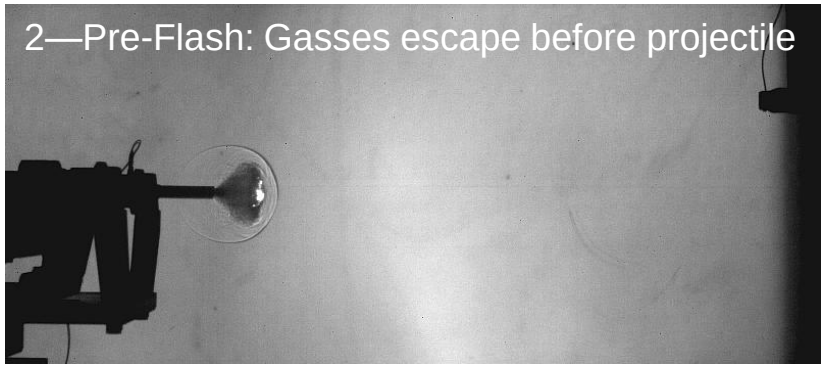
Project Objective

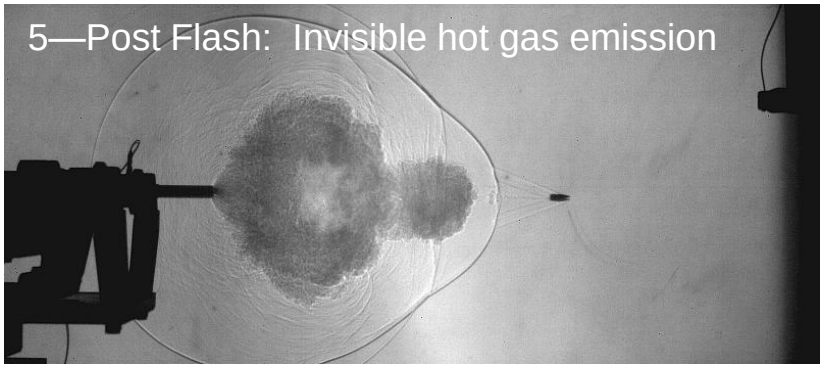
- Current flash measurement methods rely on still (long exposure) photography
  - Qualitative assessment of performance
  - Poor calibration/standardization
- Objective: Develop and evaluate quantitative small arms muzzle flash measurement methods—emphasis on suppressed weapons
  - Effort part of NATO Army Armaments Group (NAAG), Land Capability Group Dismounted Soldier Systems, Suppressor Team of Experts

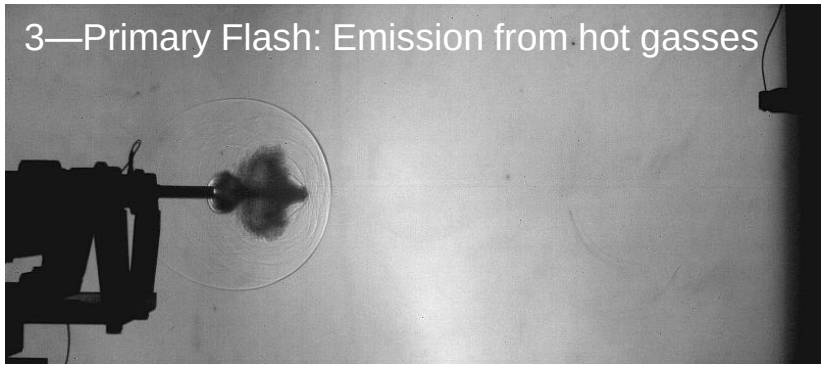
Stages of Muzzle Flash









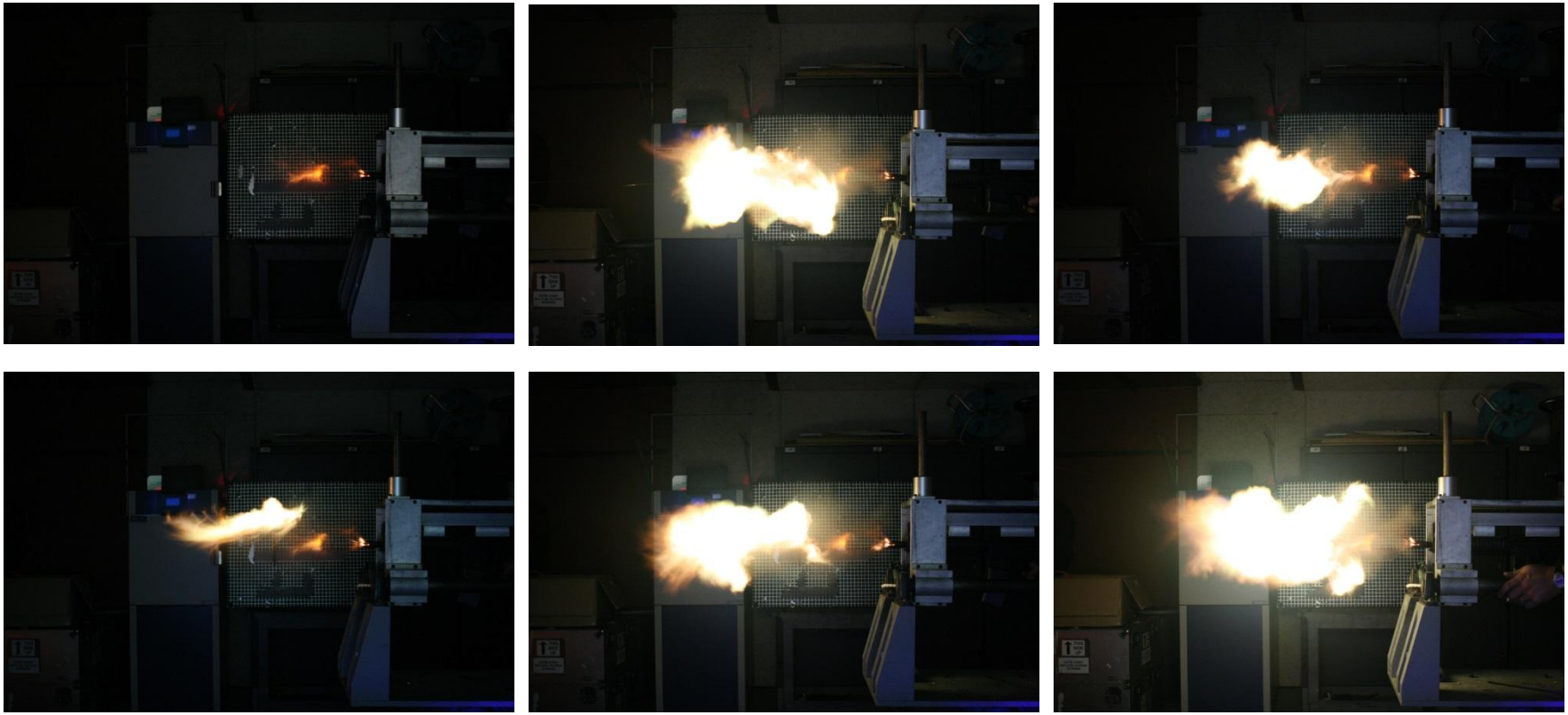


- Still images captured using high-speed shadowgraphy

Images courtesy Army Research Laboratories Aerodynamics Experimental Facility

Photographic Flash Characterization

- Currently preferred method for flash characterization
  - Quantification is difficult using uncalibrated cameras
  - Limited to visible flash (using consumer cameras)



Comparison of Available Methods

Critical Requirements:

- Reliable calibration
- High sensitivity
- Temporal resolution
- Multiple spectral bands

Secondary Concerns:

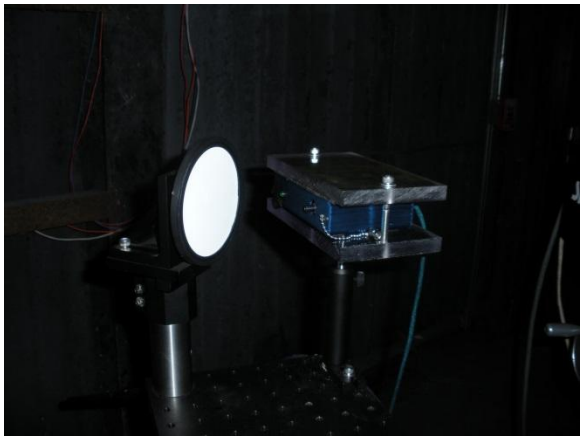
- Shape/size images
- Low cost (relative)
- Easy to use

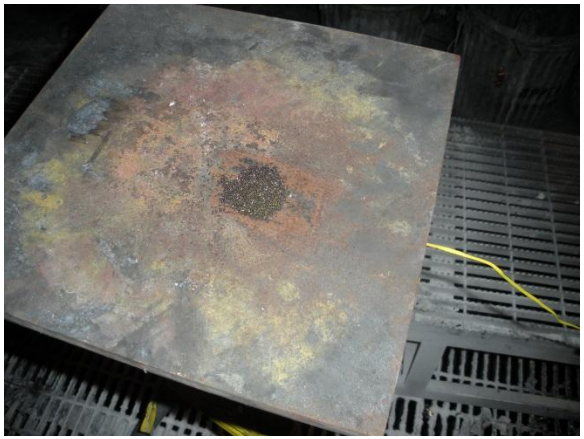
	Still Photography	H.S. Photography	Radiometry	H.S. Spectrometers
Reliable intensity measurement	✓	?	✓	✓
High sensitivity	✓	X	✓	X
Large dynamic range	✓	✓	✓	✓
Temporal resolution	X	✓	✓	?
Multiple spectral bands	X	X	✓	✓
Shape/Size measurement	✓	✓	X	X
(Relatively) Low Cost	✓	X	✓	?
Ease of operation/maintenance	✓	?	✓	X

Open Powder Burn Emission

Objective: Determine visible & IR spectral regions of interest

- Measure combustion emission spectra of various propellants
- Visible and MWIR Emission Measured
  - Spectraline High Speed MWIR Spectrometer: 1.2-4.8 μm
  - StellarNet Blue Wave Visible/NIR Spectrometer: 350-900 nm
- Powder Samples burned on steel plate
  - Ignited by electric match





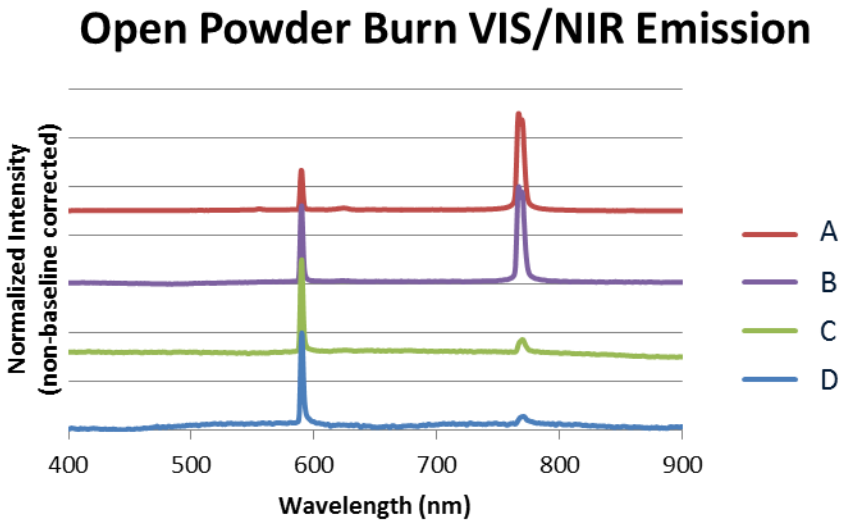
Open Powder Burn Emission

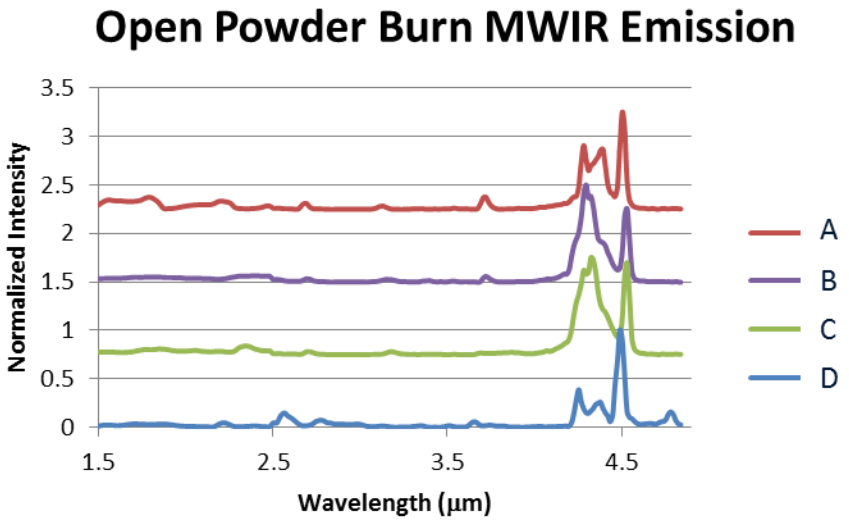
Visible/NIR

- Emission dominated by:
  - Sodium: λ = 589.0, 589.6 nm
  - Potassium: λ = 766.5, 769.9 nm
- Propellants show different intensities and peak ratios
  - Expected based on different formulations

MWIR

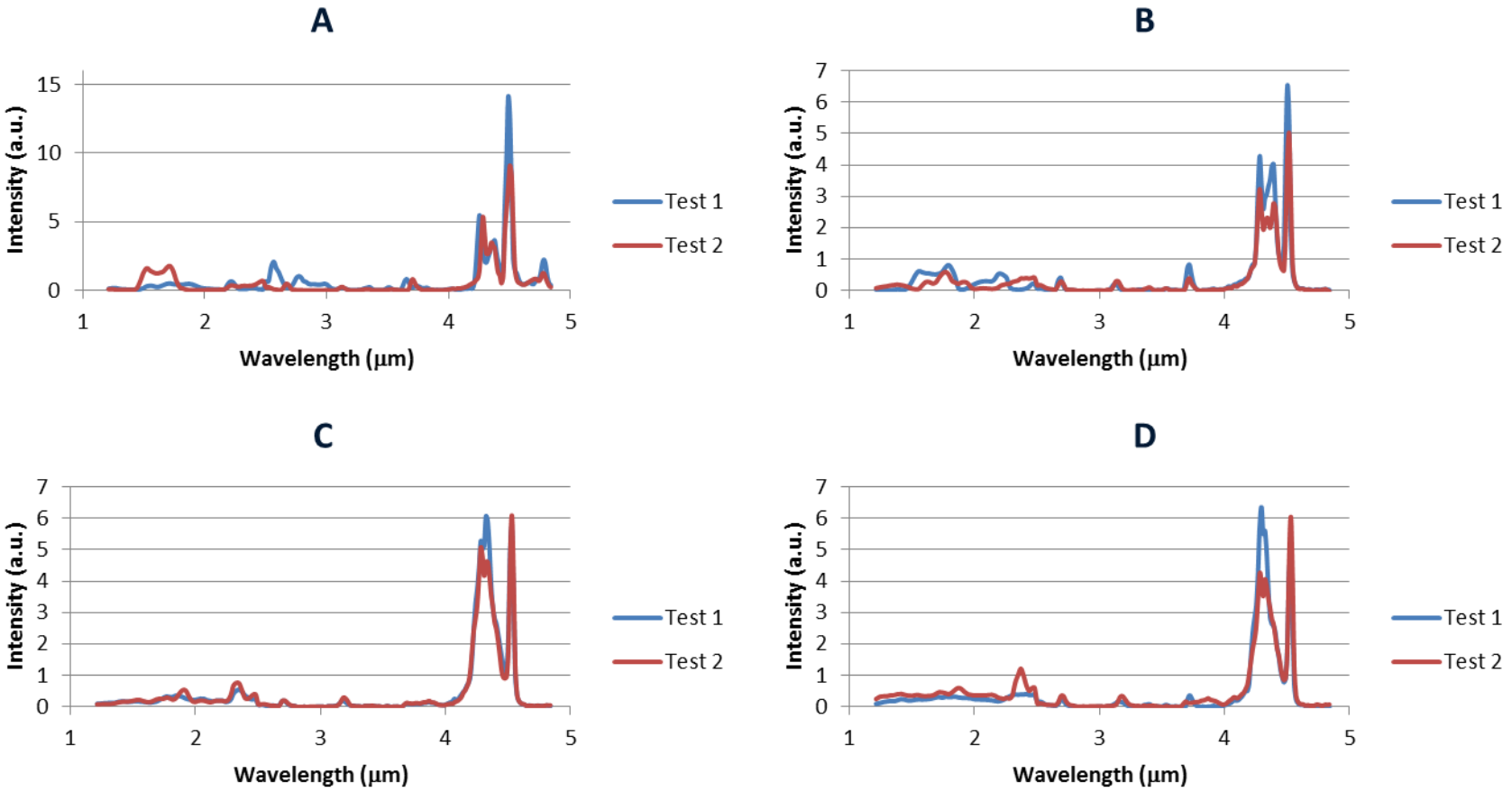
- Emission dominated by CO_2
  - Other species may provide "fingerprints" for different propellants
- Relatively Low resolution of spectrometer prevented definitive chemical assignment





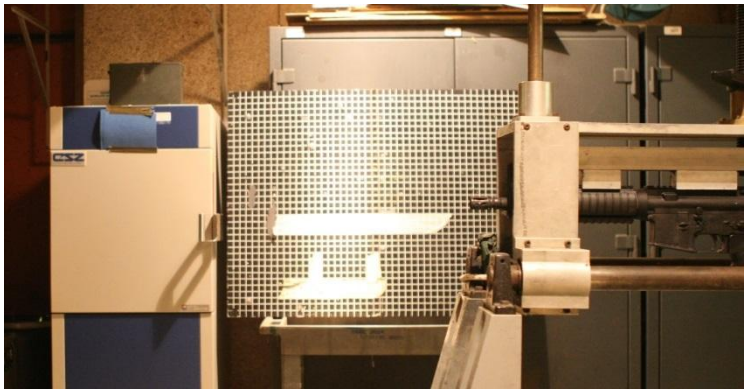
Open Powder Burn Emission

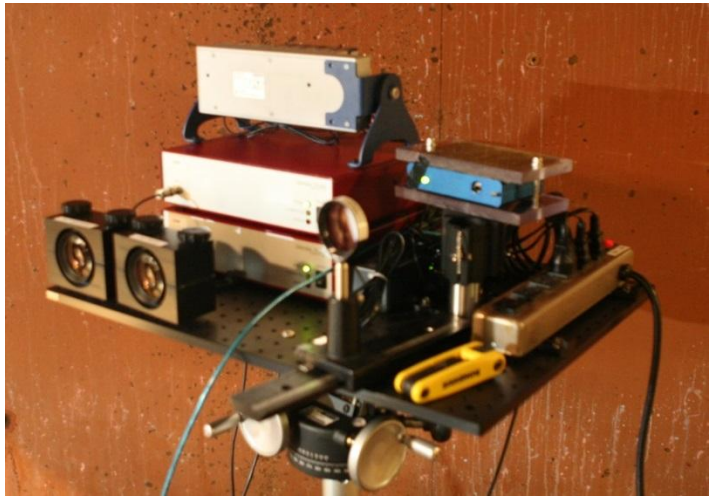
- Major emission features were repeatable
  - Some differences expected due to experimental configuration

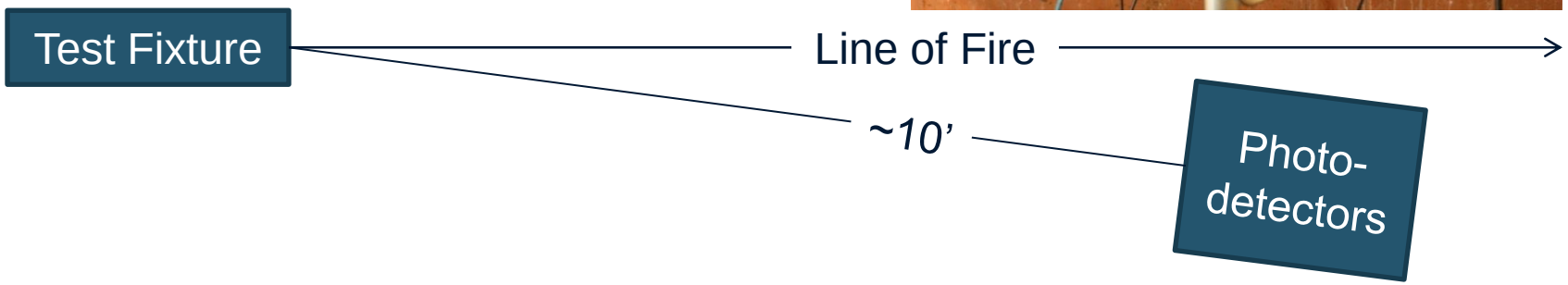


Flash Characterization Equipment

- Temporal flash intensity measurements
  - Gigahertz-Optik TR9600 photodiode amplifiers
    - Interfaced via custom GPIB controller software (LabVIEW)
    - Analog output recorded using National Instruments DAQ system
  - Visible light detector: Silicon photodiode
  - Infrared detector: InGaAs

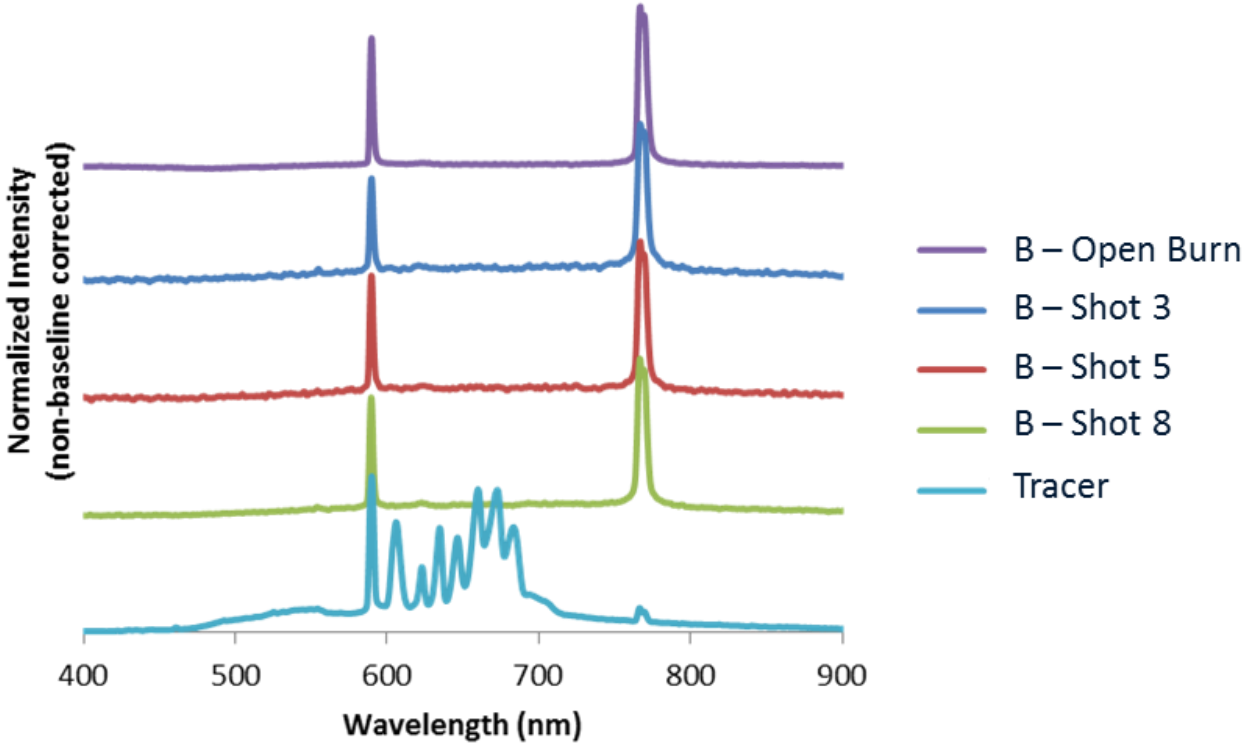






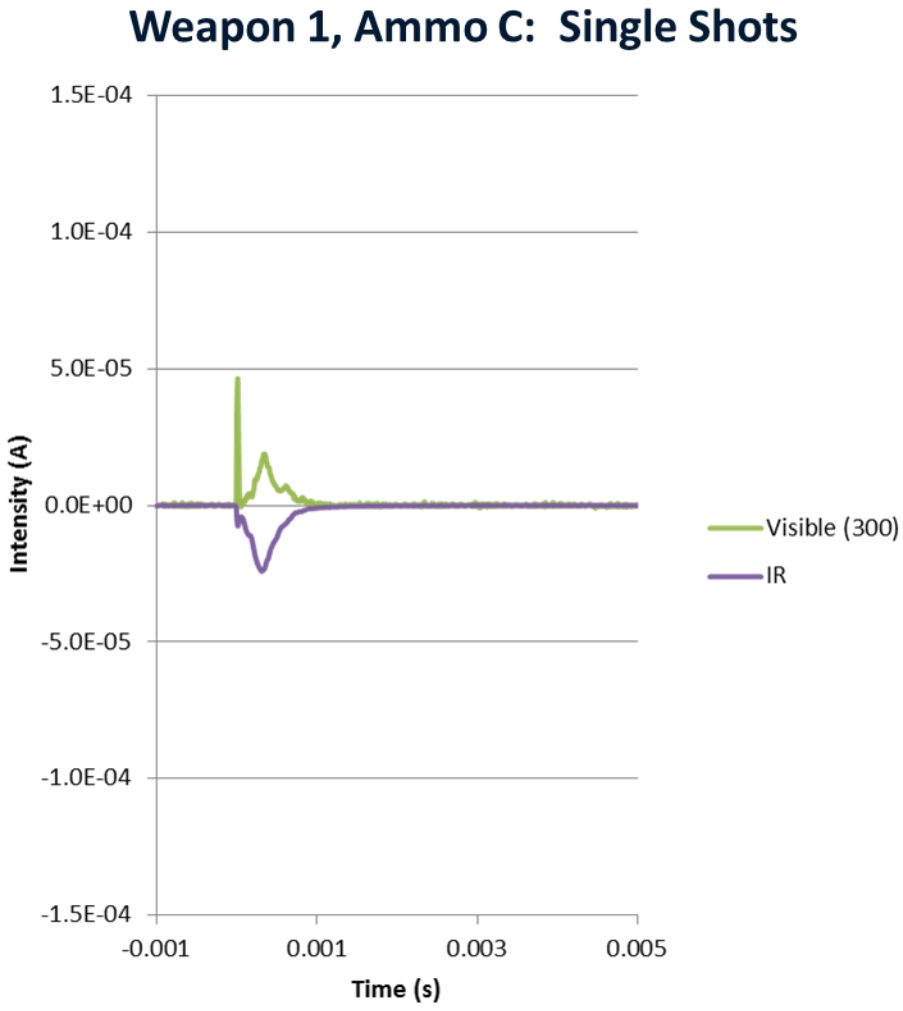
Spectral Flash Characterization

- Spectral emission profiles recorded for various flash tests
  - "B" ammunition used for spectral flash emission tests
  - Secondary flash dominated by atomic emission lines
  - Primary flash was too dim for reliable measurement
  - Tracer rounds produced expected "red" emission lines



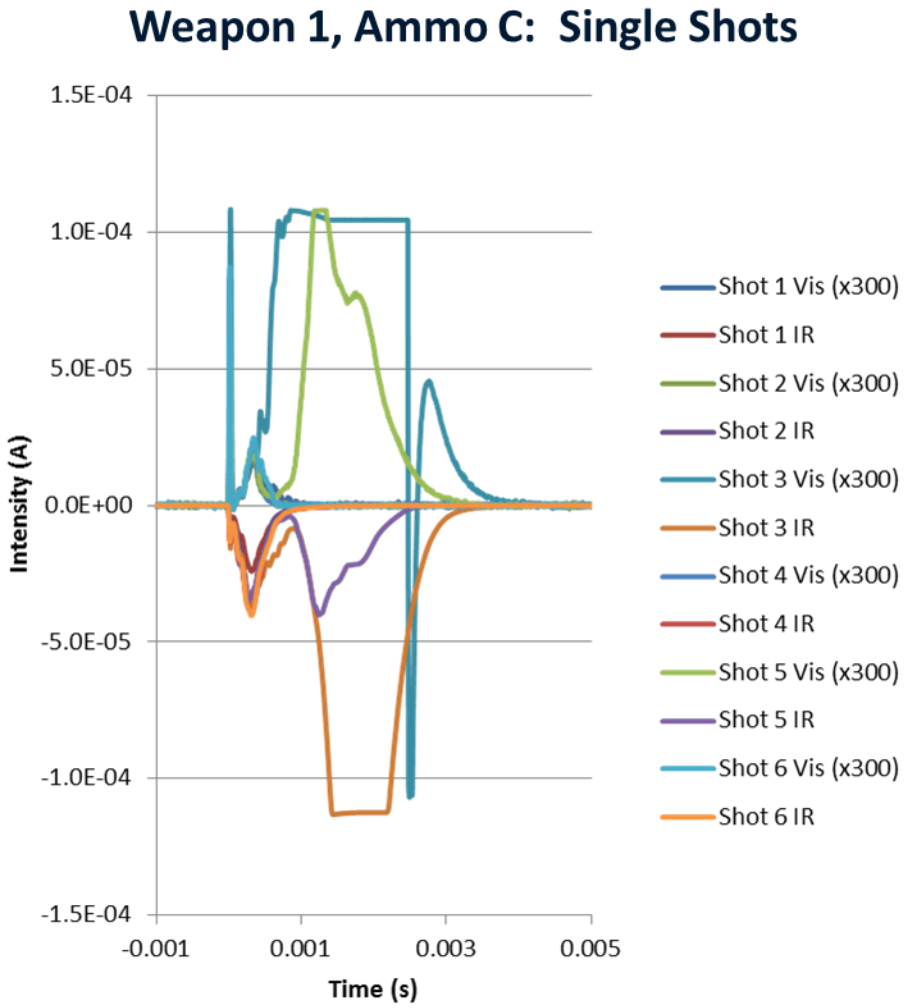
Temporal Flash Characterization

- Test Objectives:
  - Can instrumentation resolve fast features of the flash profile?
  - Can instrumentation quantitatively and repeatably measure intensity of flash profile?
    - Integration yields W/sr
- Notes:
  - Intensities plotted in amps to minimize apparent intensity differences due to amplifier gain settings



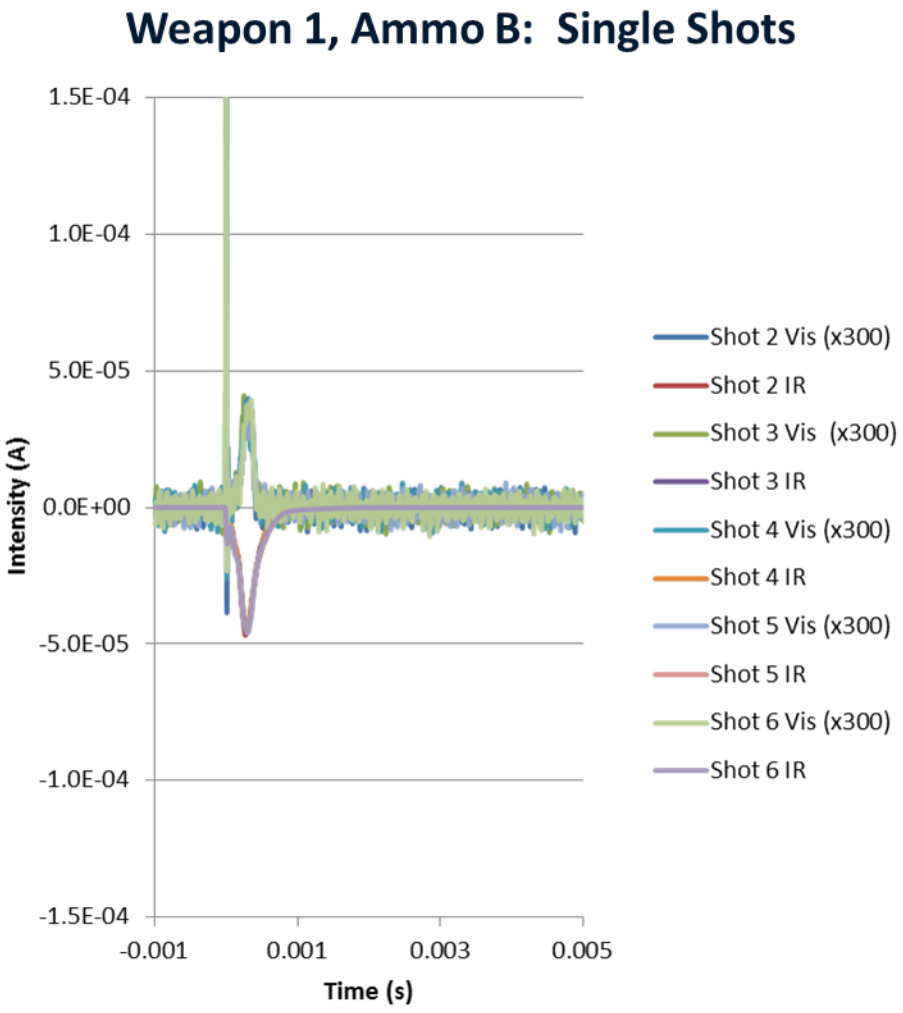
Temporal Flash Characterization

- Expected features observed
  - **Early: Pre-Flash**
    - Consistent profile
    - Bandwidth limiting feature
    - Small total energy emission
  - **Mid: Primary Flash**
    - Consistent duration & intensity
  - **Late: Secondary Flash**
    - Highly variable duration & intensity
- Large variability observed in flash intensities
  - Secondary flash is inconsistent
  - *Visible light level triggering is not reliable*
    - Recommend triggering from either IR or acoustic signal
    - IR triggering used successfully in these tests



Temporal Flash Characterization

- Ammunition choice contributes to secondary flash likelihood
  - **Ammo B:** no secondary flash
  - **Ammo C:** frequent secondary flashes
- Note: Pre-Flash intensity was clipped using previous gain settings
  - Amplifier ringing apparent in enlarged plot
  - "Apparent Visible Intensity" calculated from intensity & duration
    - Early "spike" is more intense, but will probably not dominate how bright the flash appears
    - Primary flash is the major contributor to apparent intensity



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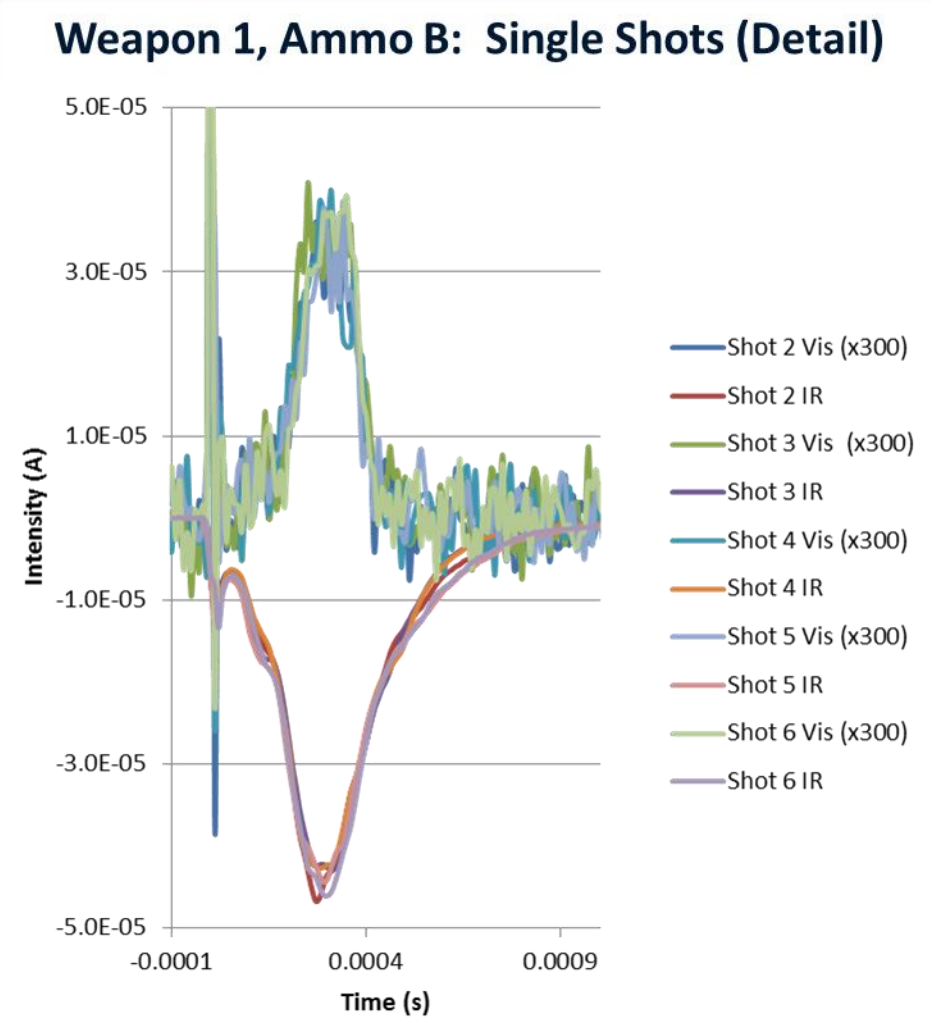
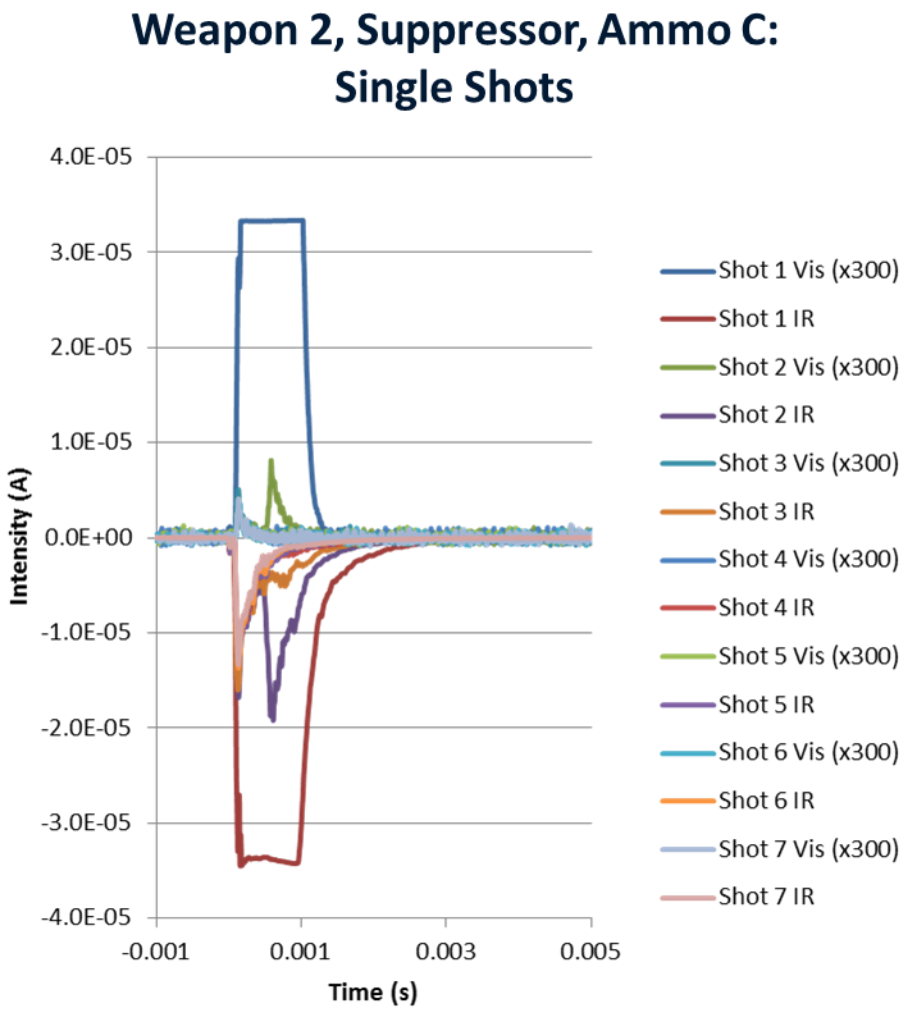


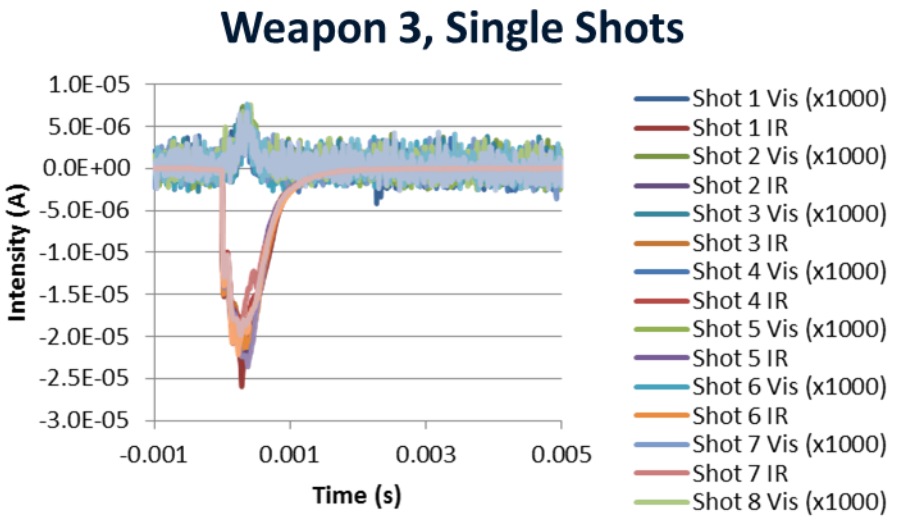
Temporal Flash Characterization

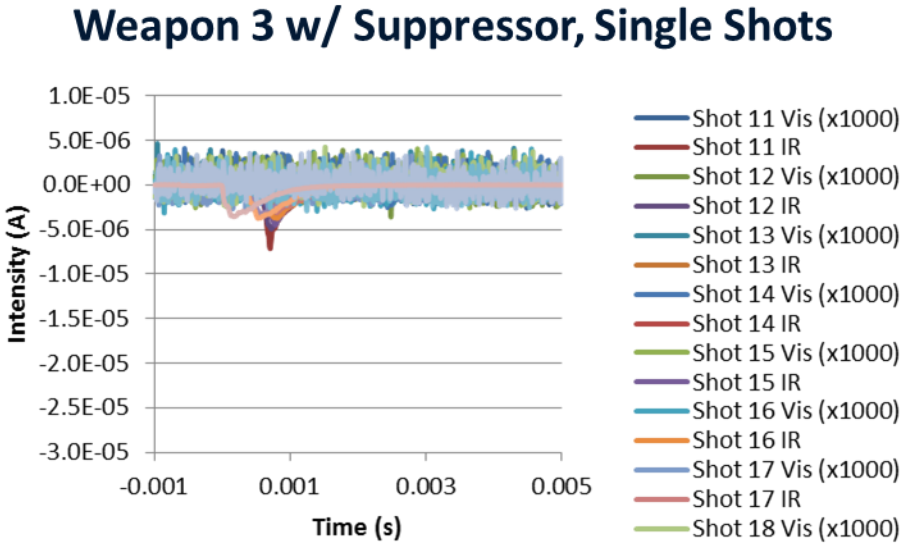
- Addition of suppressors has a major impact on measured intensity
  - Infrared and visible signals both greatly reduced
  - “Cold” shots were much more intense than “warm” shots



Temporal Flash Characterization

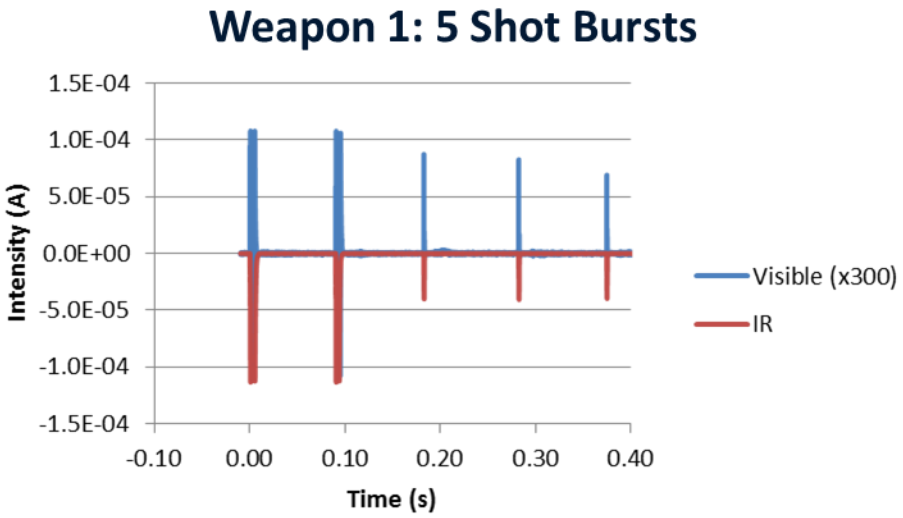
- Different weapons showed different temporal profiles
  - Minimal pre-flash apparent
  - Primary flash was predominant feature
  - Very few secondary flashes were observed (none shown here)
- Addition of a suppressor had a major impact
  - Visible detector was insufficiently sensitive to accurately measure intensity
  - Primary flash apparent to human observers
- Note: triggering timing was inconsistent for this series due to higher-than-optimal threshold value, and can be easily adjusted.

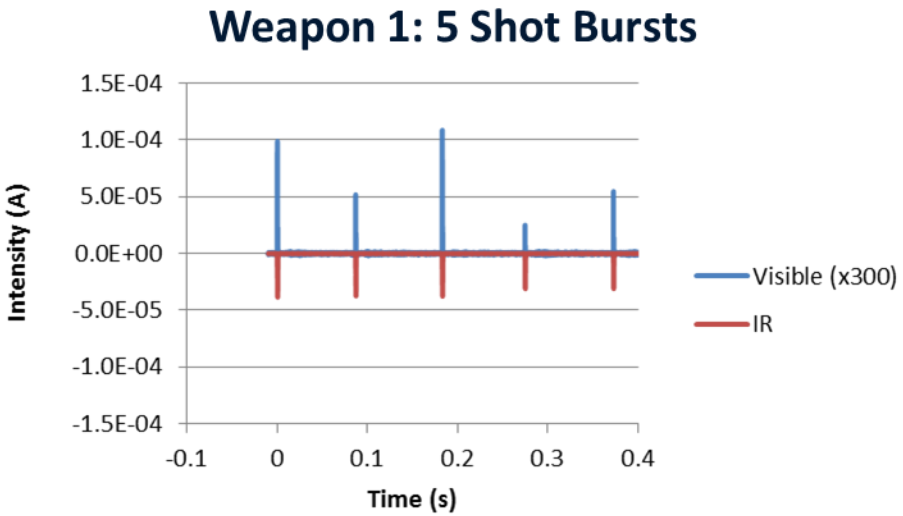




Burst Flash Characterization

- Multi-round bursts were measured
  - Clear temporal resolution
- Unpredictable secondary flash resulted in saturation of some signals in the series
  - High dynamic range detector/amplifier configuration necessary to measure bright and dim events
    - Dual photodiodes/amplifiers with different gain settings may be a solution





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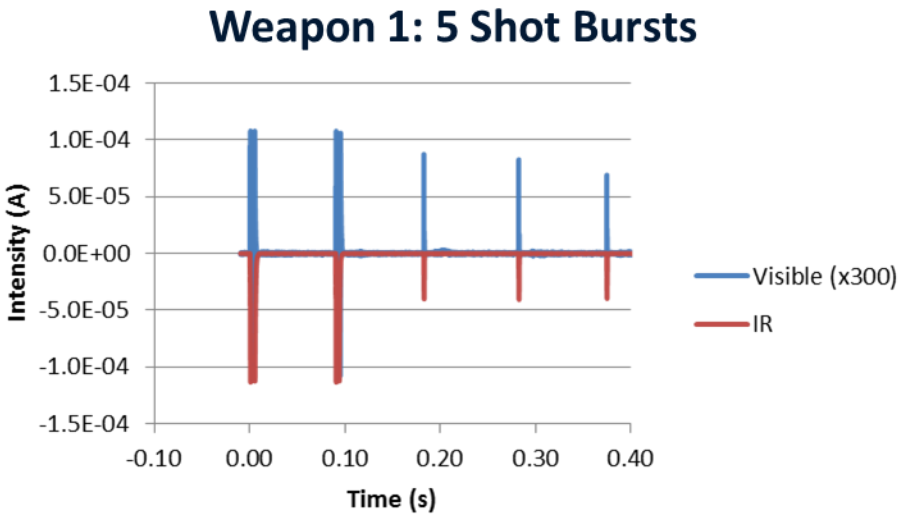
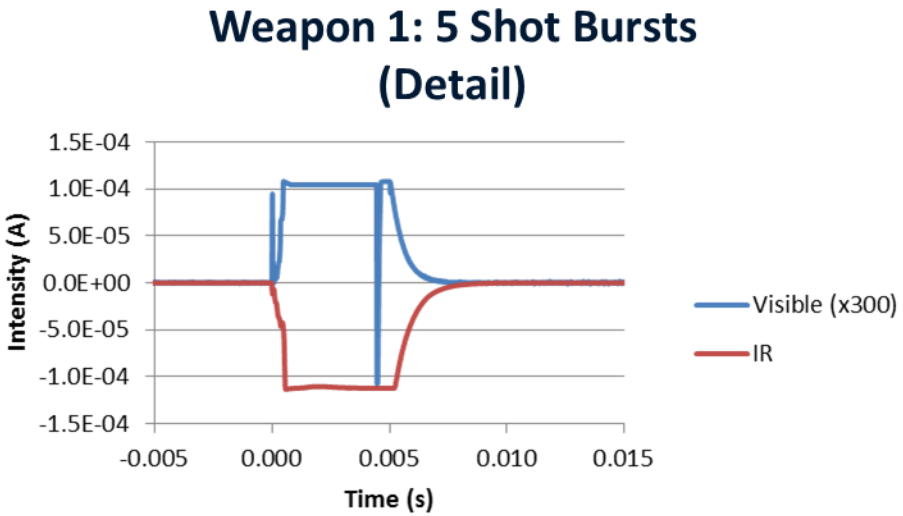
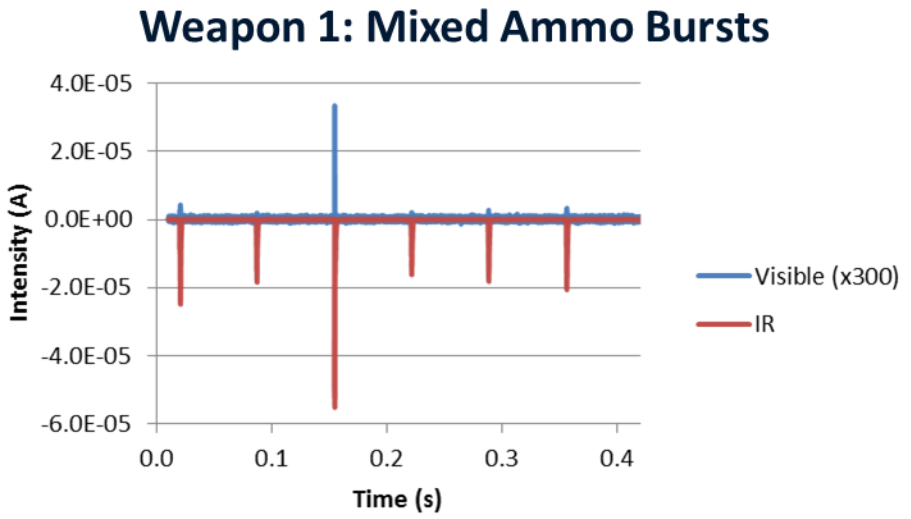
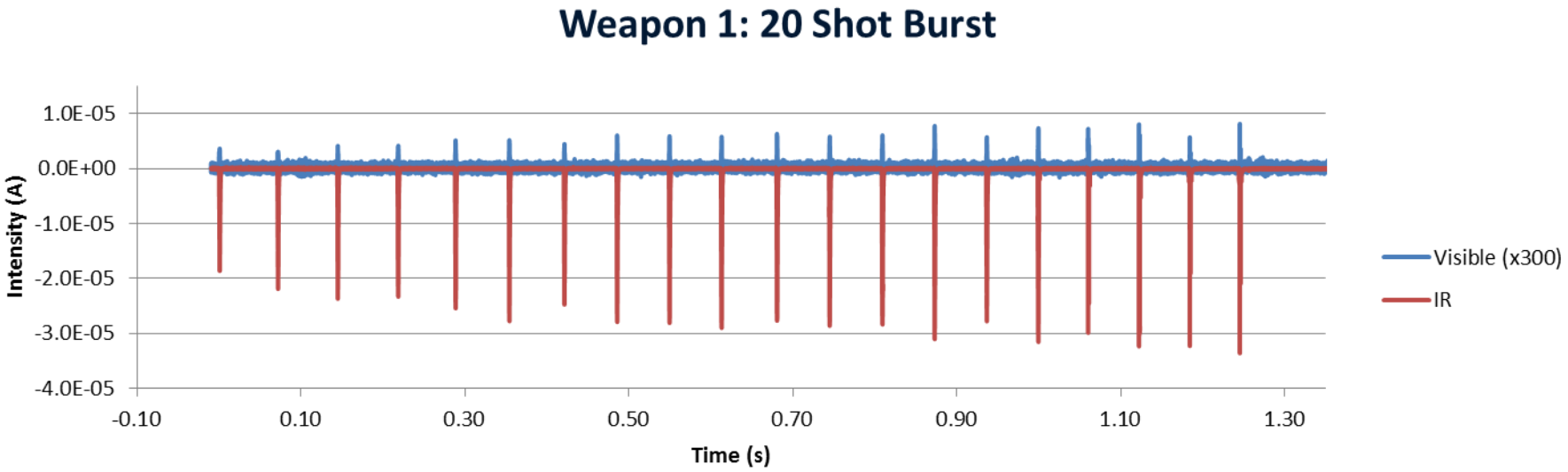




Burst Flash Characterization

- Mixed ammunition burst
  - Shots 1&2: Ammo B
  - Shot 3: Tracer
  - Shot 4-6: Ammo C
  - Ammunition differentiation may be possible
- 20 shot burst
  - Intensity of signal increased through series of shots





Conclusions

- Photometers provide reliable muzzle flash measurement
  - Spectral radiant intensity measurements:
    - Visible, NIR, SWIR, and MWIR detectors available
    - Clearly defines measured intensity (W/sr)
  - Secondary flash creates dynamic range issues
    - “Bright” flashes saturate high-gain detectors/amplifiers
    - Possible solution is multiple detector/amplifiers
    - High sensitivity COTS solutions are being explored
  - Suppressed measurements pose sensitivity issues
    - Evaluation of alternate detectors is ongoing
  - Combination of photometry and photography is current path forward

- Documentation and validation of standards is ongoing
  - Final procedures established by Fall, 2016