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Development of Standardized Test Methods for Quantitative Small Arms Flash Measurements

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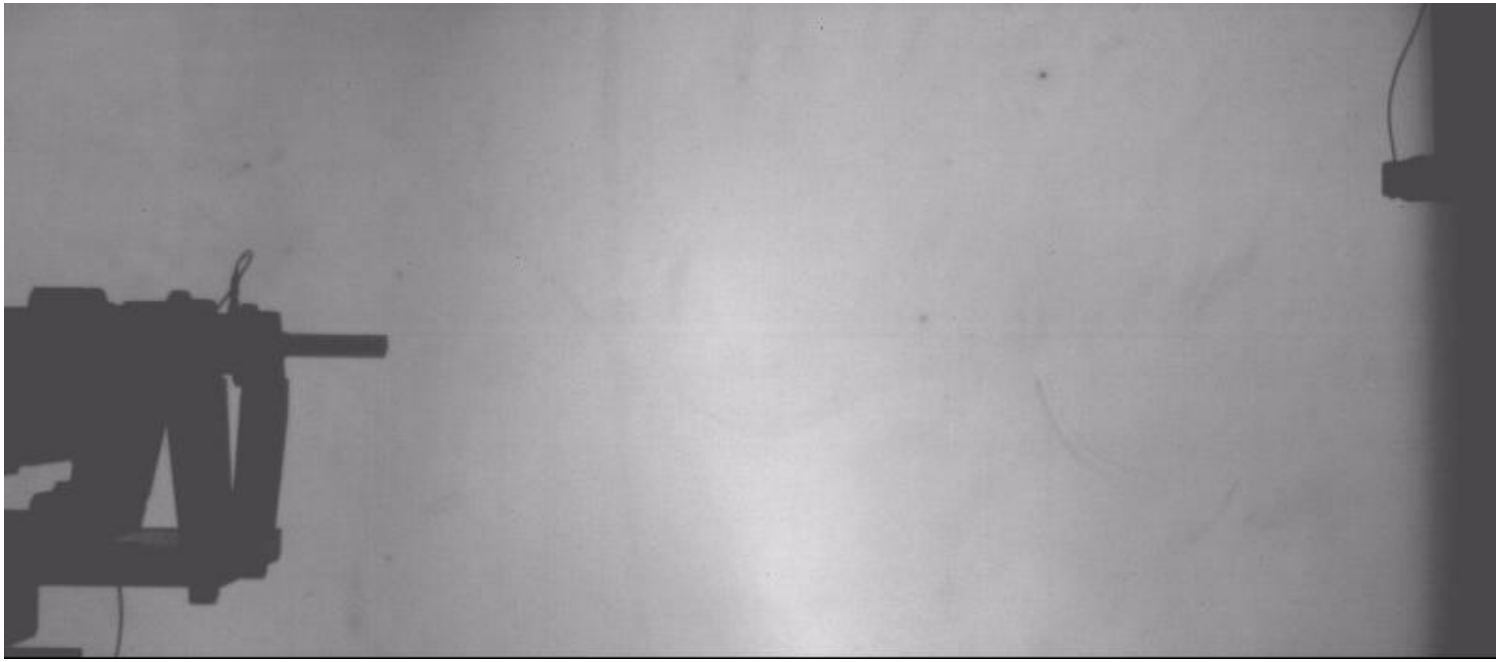
Project Objective

- 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

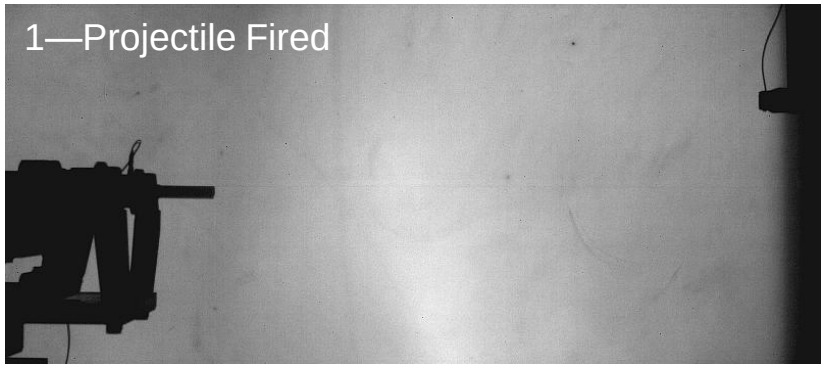
Stages of Muzzle Flash

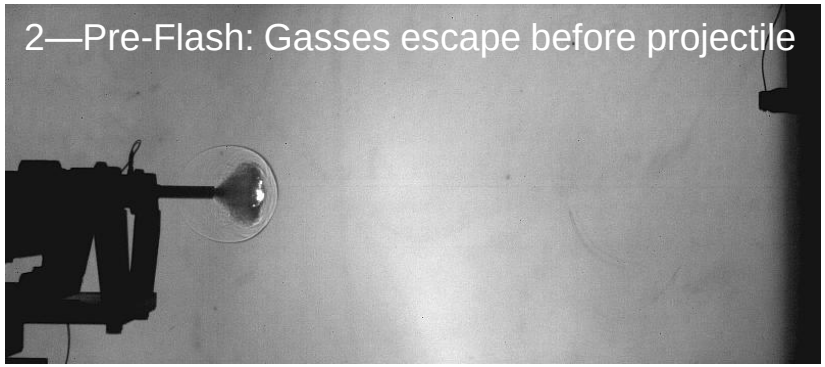


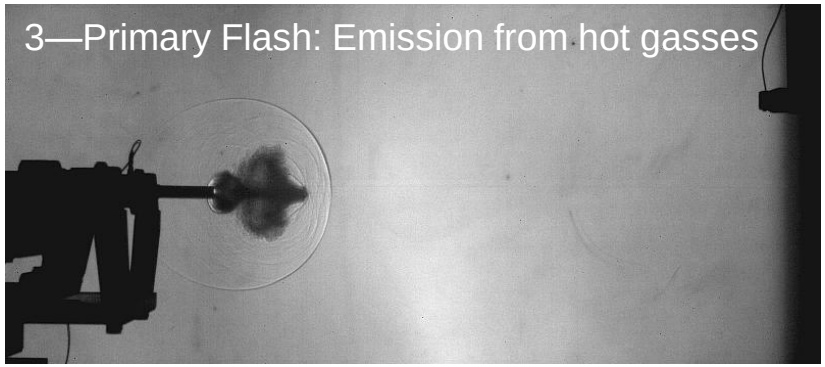
Video courtesy Army Research Laboratories Aerodynamics Experimental Facility

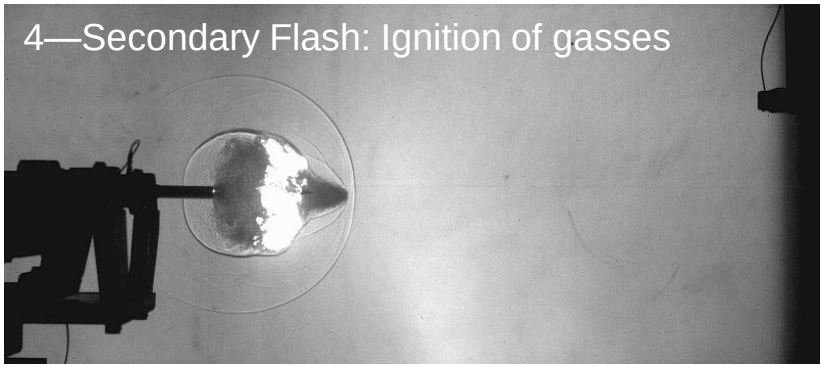
- Pre-Flash: Propellant gasses exiting barrel prior to projectile
- Primary Flash: Propellant gasses which drive projectile from barrel
- Secondary Flash: Combustion of propellant gasses after mixing with O_2
  - Highly variable, and VERY bright relative to other events
- Post Flash: Emission from latent hot gasses

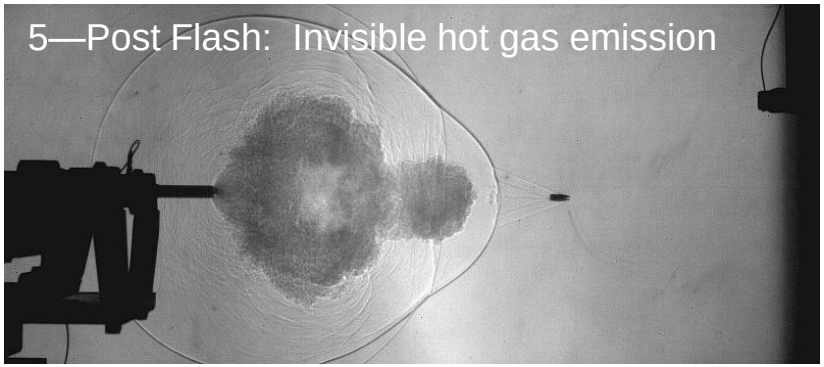
Stages of Muzzle Flash









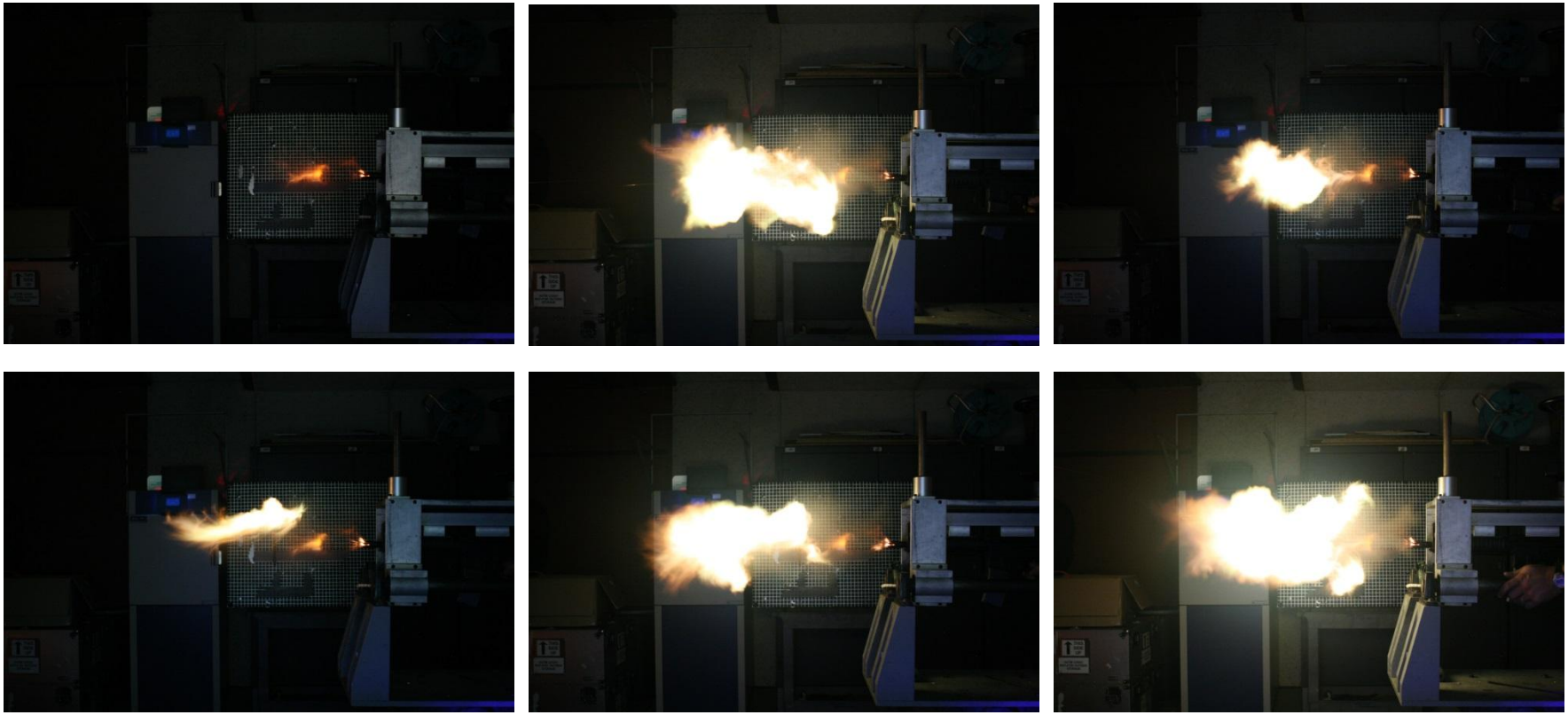


Images courtesy Army Research Laboratories
Aerodynamics Experimental Facility

- Still images captured using high-speed shadowgraphy

Photographic Flash Characterization

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



Proposed Quantitative Method

Proposed Quantitative Flash Intensity Measurement Method:

- Measure brightness using calibrated radiometers
  - Record instantaneous radiant intensity using photodiodes & DAQ module
  - Calculate total in-band energy from temporal response
    - For fast events like muzzle flash, this is the most important value
- Record long-exposure picture of flash event
  - Will be used for comparison with historical data & quality control, but not quantification of flash intensity

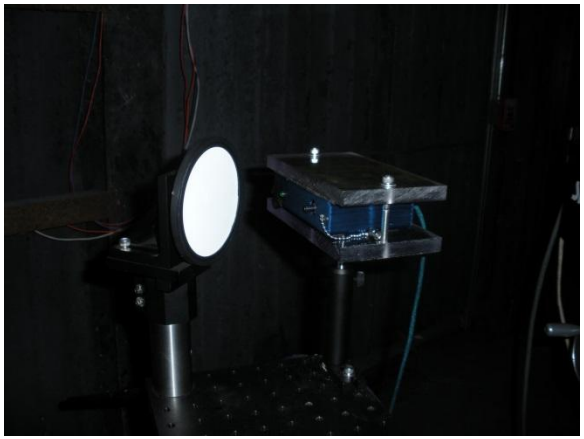
Benefits:

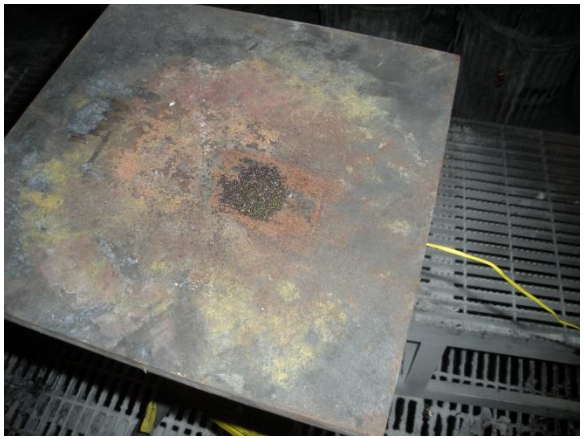
- Enables quantitative vs. subjective performance metrics
- Instrumentation independent intensity values
  - Improves comparison between different test results from different labs
- Simultaneous measurement in multiple bands is possible
  - Invisible emission occurs during firing, even when no visible flash is apparent
  - Proliferation of electro-optics makes non-visible bands increasingly important
- Consistent with upcoming NATO STANREC procedures

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





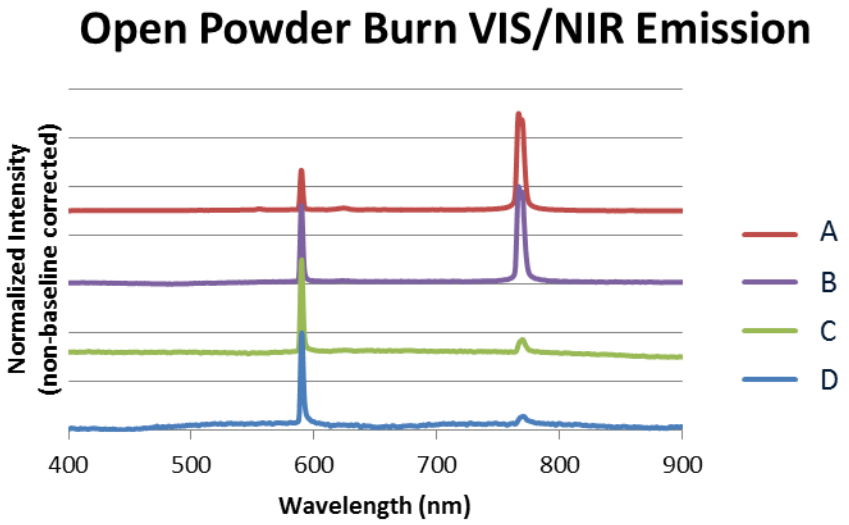
Open Powder Burn Emission

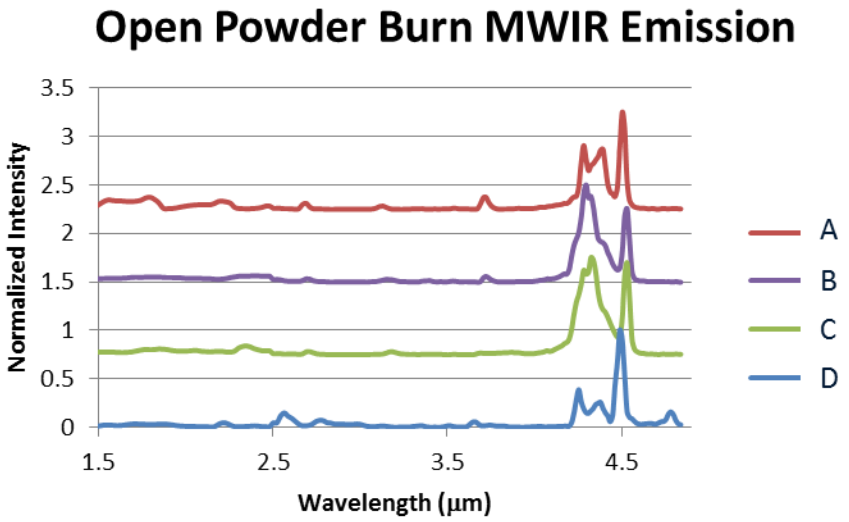
Visible/NIR

- 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

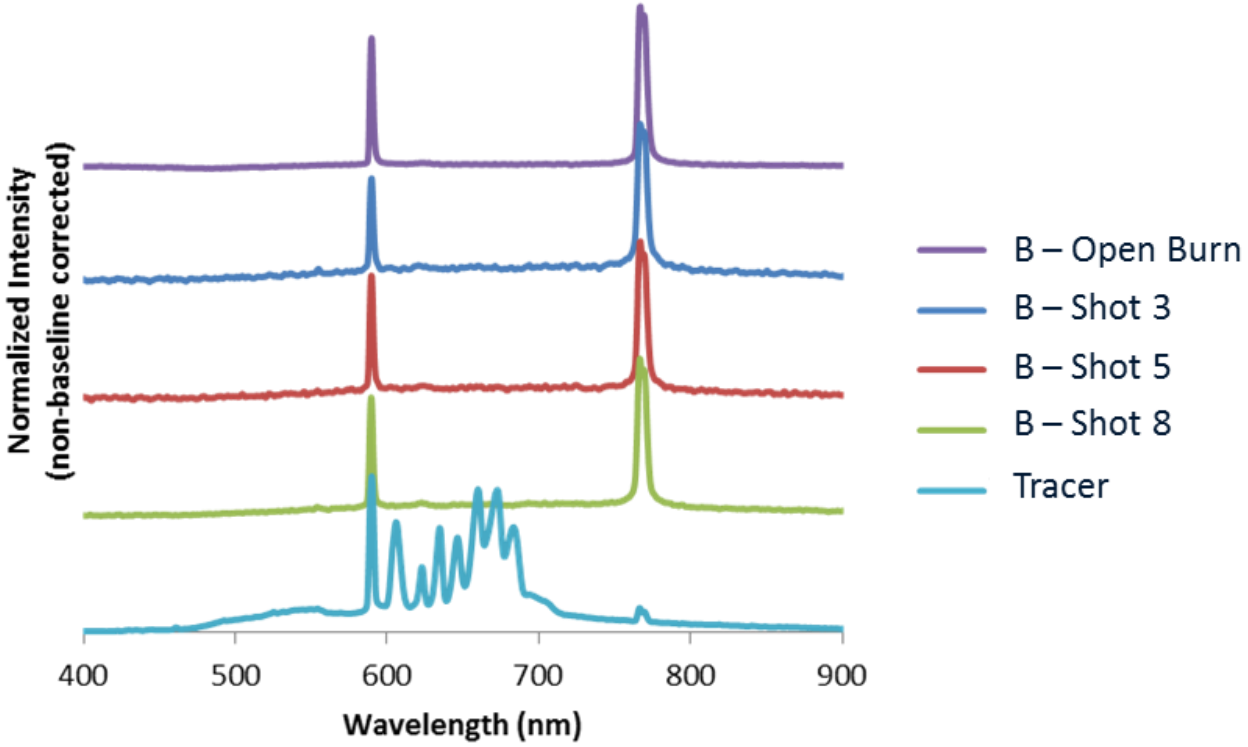
- Emission dominated by CO_2
  - Other species may provide "fingerprints" for different propellants
- Relatively Low resolution of spectrometer prevented definitive chemical assignment



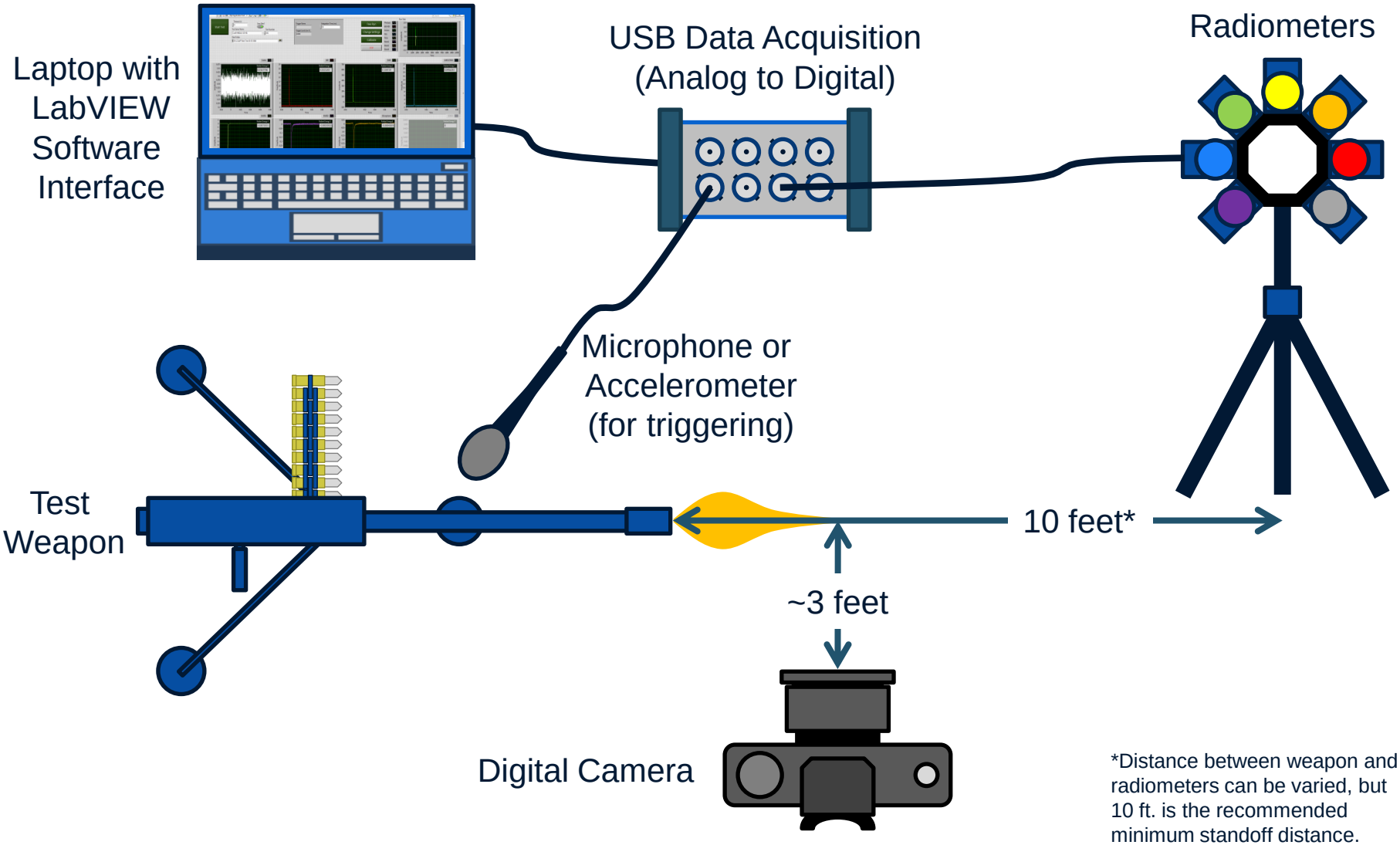


Spectral Flash Characterization

- 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



Simplified Instrumentation Diagram



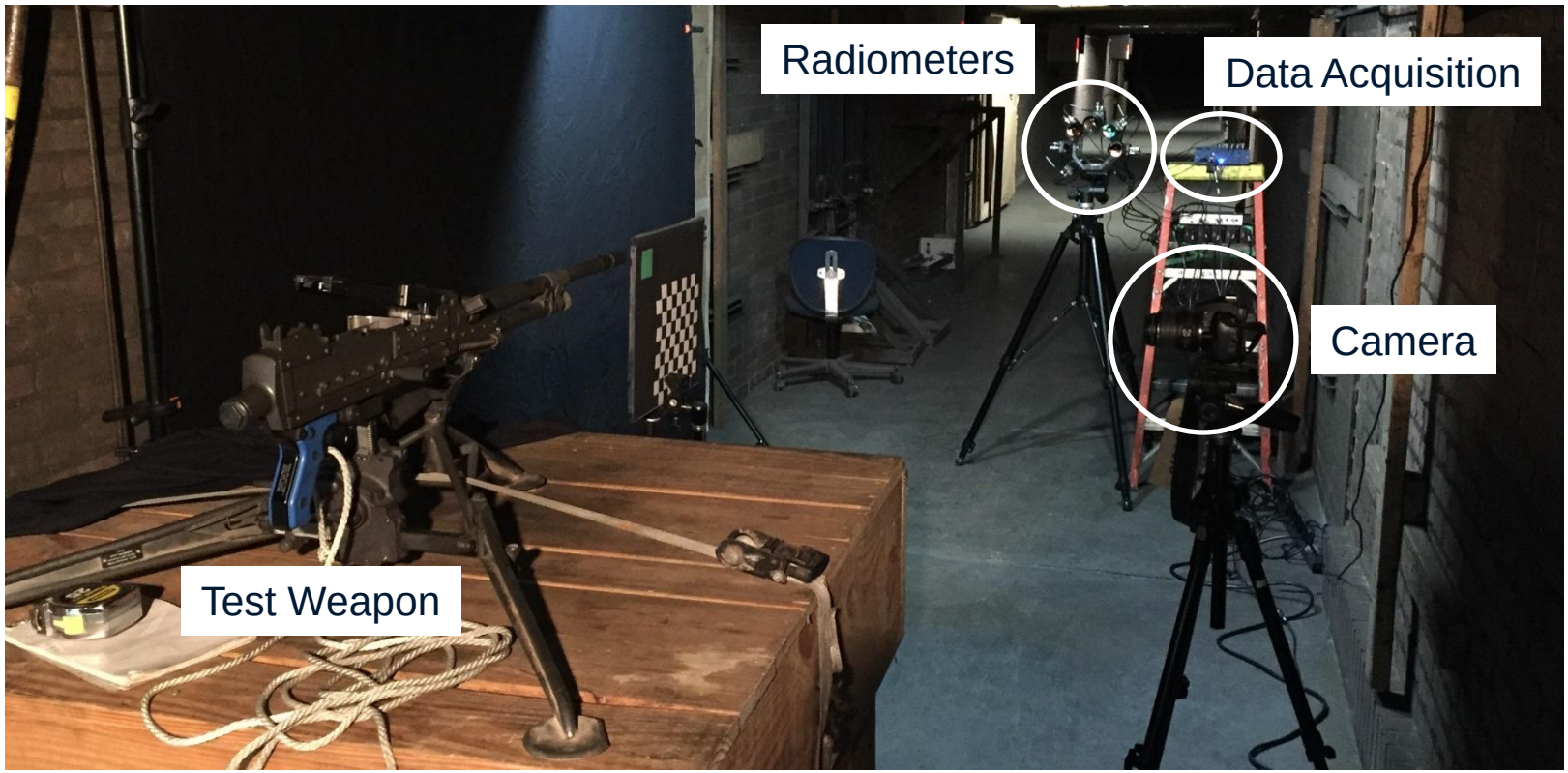
*Distance between weapon and radiometers can be varied, but 10 ft. is the recommended minimum standoff distance.

Automated Data Acquisition Software

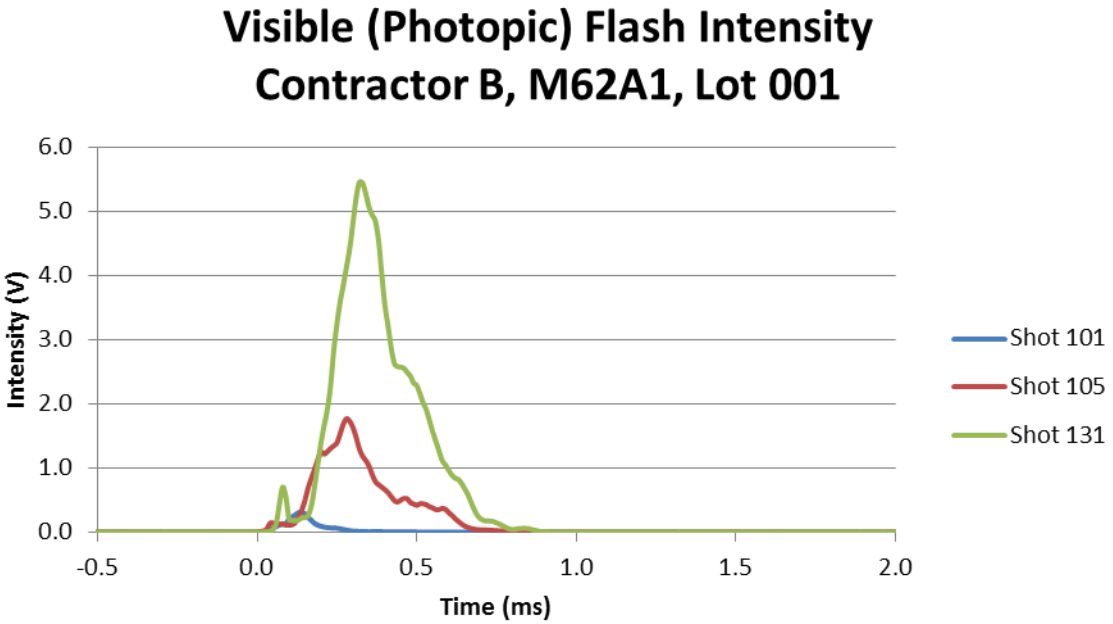
- Simultaneous sampling of 8 channels
  - Up to 100 kHz acquisition rate with external trigger for data synchronization
    - Acoustic, light, or vibration triggering possible
- In-line post processing of data & report generation

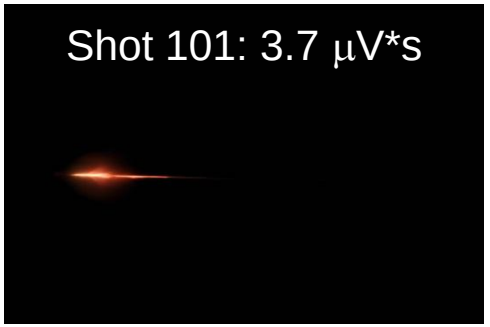
LCAAP Demonstration

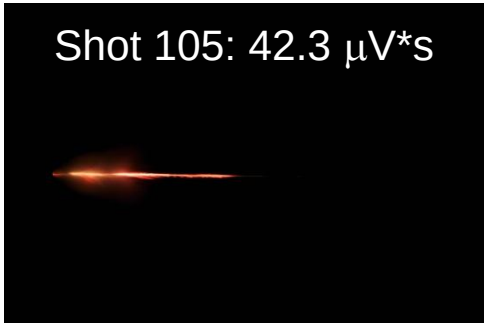
- Radiometers: 10□from the muzzle, ~5° right of the weapon's line of fire
- Camera: ~1□in front of the muzzle, ~1□right of the weapon's line of fire
- Instrumentation was controlled remotely from outside of the firing tunnel

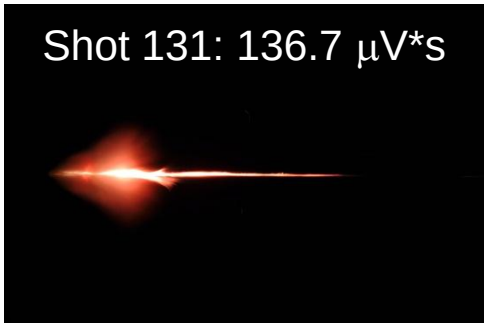


Quantification of Flash Brightness









- Perceived visible brightness can be described as luminous energy (cd*s) for short flashes
  - Repeatable measurement
  - Calibratable
  - Instrumentation independent

*Uncalibrated sample data is shown in volts vs. time for public release. Meaningful data will be reported in cd*s for visible light and Joules for invisible light.

NSWC Crane Demonstration

- Continuation of radiometer evaluation
  - Improved acoustic triggering demonstrated

- Thermal imaging capabilities evaluated
  - Microbolometers
  - Dual-band InSb

Conclusions

- Photometers provide reliable muzzle flash measurement
  - Spectral radiant intensity measurements:
    - Visible, NIR, SWIR, and MWIR detectors available
    - Clearly defines measured intensity (W/sr)
  - Combination of photometry and photography is current path forward
- Demonstrations have shown effectiveness
  - Being incorporated as test capability at NSWC Crane
- Adoption spreading
  - Norway, Canada, Great Britain, ARDEC

- Documentation and validation of NATO standards is ongoing
  - Final procedures established by Fall, 2017

Acknowledgements

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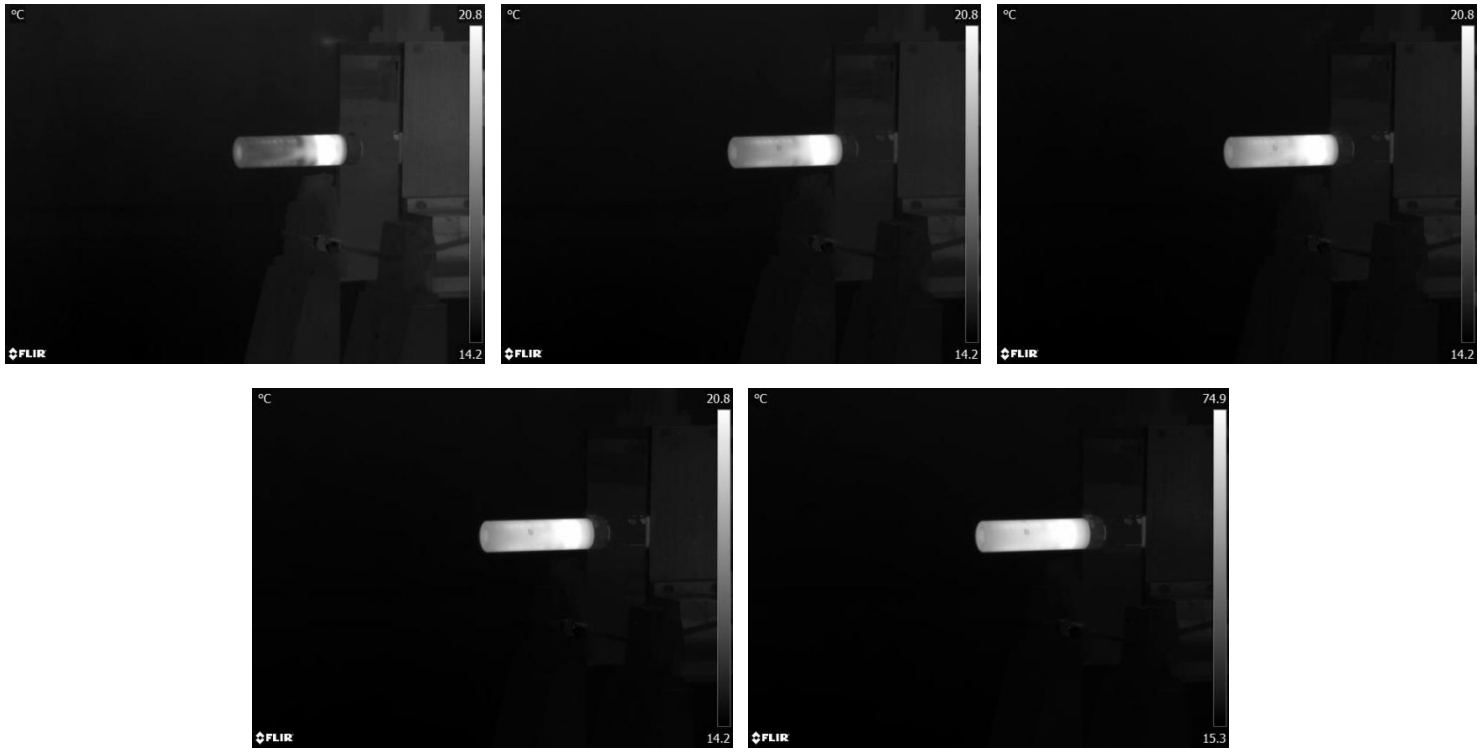
Supplemental Material

Thermal Signature Measurement

- Signature measurement method development ongoing
  - Utilize expertise gained from aircraft signature analysis
  - “Low-cost” microbolometers provide good images
  - Commercial software designed for qualitative imaging
    - JPG file format unsuitable for quantitative analysis
    - Raw output necessary—few software packages include this option



Acronyms & Abbreviations

Abbreviation	Definition
ARDEC	Armament Research Development and Engineering Center, Picatinny, NJ
cd	candela—a measure of visible brightness
COTS	commercial off-the-shelf—items that are readily available for purchase from commercial vendors
CWO	Chief Warrant Officer
DAQ	data acquisition
DRDC	Defence Research and Development Canada
DSSPM	Director Soldier Systems Program Management
ft	feet
Hz	Hertz
kHz	kilohertz
LCAAP	Lake City Army Ammunition Plant
NAAG LCG-DSS	NATO Army Armaments Group, Land Capability Group, Dismounted Soldier Systems
NATO	North Atlantic Treaty Organization
NSWC	Naval Surface Warfare Center
s	seconds
ms	microseconds
SLR	single lens reflex—a type of camera which uses a single lens for composition and imaging
sr	steradian—the solid angle of a conical projection (A full sphere is 4π steradians.)
STANREC	NATO Standardization Recommendation
SYSCOM	Systems Command
ToE	Team of Experts
USB	Universal Serial Bus
USMC	United States Marine Corps
V	Volts
μV	microvolts
W	Watts