Test and Evaluation/Science and Technology Program

Advanced Instrumentation Systems Technology (AIST)

Stereo Camera Optical Tracker (SCOT)

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ITEA Las Vegas Instrumentation Conference

11 May 2016

Test & Evaluation Need

- **Warhead characterization is ubiquitous across the services**
- **Static test methods developed in the 1960's largely unchanged**
  - **Fragments captured and manually retrieved from bundles, measured and weighed**
  - **Capture solid angle decreases with increasing charge size**
- **Time-of-arrival screens measure fragment average velocity over distance traveled**
  - **Rarely correlates velocity information with specific fragment (e.g., with mass)**

Standard Approaches are Manually Intensive and Only Provide a Subset of Data Desired for Accurate Modeling

Long Term Goal for Arena Testing

Replace

with

cameras & automated data reduction/analysis software

Significant Test Set-Up & Data Reduction Savings While Providing a More Accurate Characterization of the Weapon's Debris Field

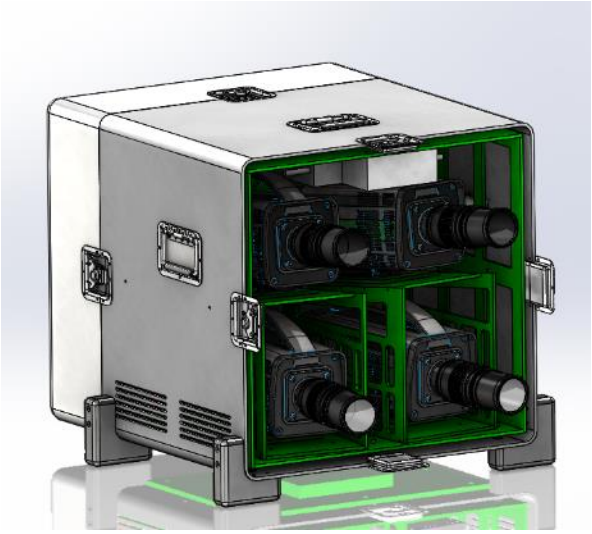
Advantages

- **Complete hemispherical coverage**
  - **More accurate fragment distribution measurements**
  - **Time-dependent fragment trajectory measurements → In-flight drag measurements**
  - **Can measure fragment velocities behind the pressure wave**
- **Correlate individual fragment velocities with size/mass → Energy & momentum**

Imagery-based methods have potential to provide more information, faster, and cheaper than current data collection methodologies

SCOT Project Description

Stereo Camera Optical Tracker (SCOT)



- **Develop, demonstrate, and transition a stereo camera system able to measure fragment 3D velocity and mass.**
  - **In a 45-degree arena segment, achieve < 25% velocity accuracy on 50% of the debris field sized 0.6 cm or greater.**
- **Exploit improved tracking algorithm performance to reduce hardware cost associated with measuring a large volume at high-resolution**
- **System components:**
  - ✓ **Two 4-focal plane, high-speed cameras**
  - ✓ **COTS high quality optical lenses**
  - ✓ **Stereo tracking & debris sizing algorithms**
  - ✓ **Fully automated data reduction and analysis**

SCOT Project Specifications

Parameter	Current Performance Level	Current Target	Ultimate Goal	Achieved
Arena Test Coverage	Sector coverage limited by arena size (1)	45-degree sector	Full Hemisphere	171-degree sector (7)
Resolution	Discriminate 5 cm or larger fragments (2)	Discriminate 0.6 cm or larger fragments	Discriminate 0.25 cm or larger fragments	0.6 cm or larger fragments(5)
% Fragments Tracked	<15% of Total Fragments Collected from Bundles	50% in sector	90% in hemisphere	>80% (5,6)
Velocity Accuracy	± 10 % average at panel, no size/mass correlation(3)	± 25 % time profile, correlated with size/mass(4)	± 10 % time profile, correlated with size/mass(4)	< 5% (5)
Focal Planes per Camera	1	4	4	4(5)
Size, Weight, and Power	Large catch panel array (~100's of kg)	2 camera systems & 2 laptops (10's kg)	2 camera systems & 2 laptops (10's kg)	4 Cameras and 2 laptop(7)
Environmental Conditions	Daytime, clear visibility, dry	Daytime, clear line-of-sight, dry	Daytime, clear line-of-sight, dry	Daytime, clear line-of-sight, dry(7)
Test Set-up	days/weeks	8 hours	2 hours	6 hours(7)
Test Reporting	weeks	8 hours	2 hours	< 1 week

1) The current JTCG/ME methodology assumes symmetry on the roll axis of the munition. Typical coverage angles are on the order of 30 degrees. Larger sample angles require taller bundles and panels.

2) State-of-the-art camera (1000 frames per second with 40 meter full field-of-view)

3) This accuracy represents the average velocity measurement accuracy measured at the time-of-arrival detection screens, which capture data on a small number of fragments. Individual fragment characteristics are not correlated with the velocity measurements.

4) This accuracy represents the measurement accuracy of the instantaneous velocity profile of a large number (50% of those with diameter greater than 0.6 cm, within the 45 degree arena sector) of tracked fragments that includes estimates of fragment size and mass

5) In simulation

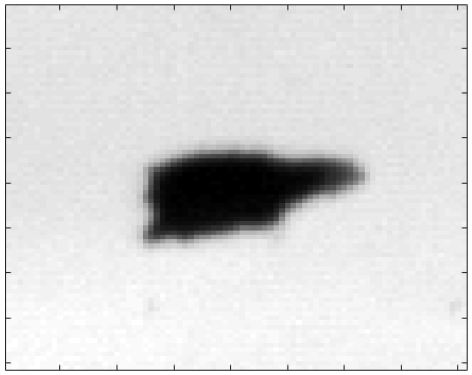
6) 2000 Frames per Second, 180º arena sector; % meeting or surpassing velocity accuracy specification

7) Stereo camera set-up at Eglin AFB CSOP tests.

8) Single channel low resolution prototype

Phase 2 Updates

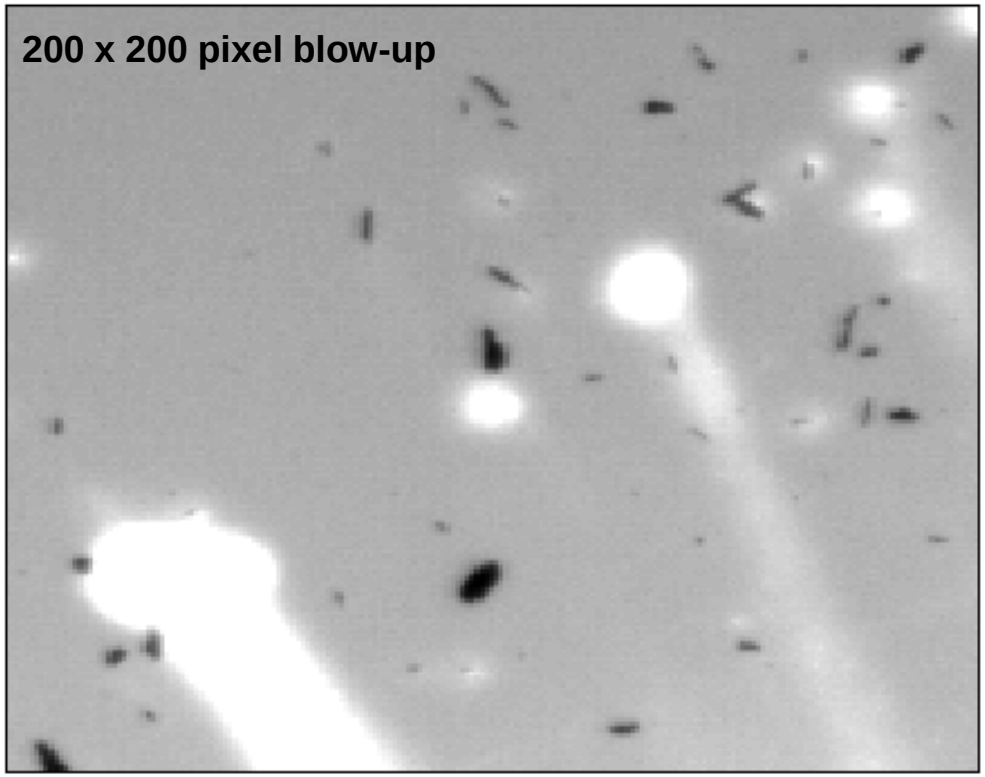
Measurement Volume Challenge



- **"Resolving" a 6 mm fragment limits total FOV ~ 12 x 12 meters with a single state-of-the art, large format, high-speed camera**
- **Accurate fragment kinematic state retrieval requires a finite number of measurements**

SCOT System Employs Multiple Registered Cameras to Meet Measurement Volume Challenge

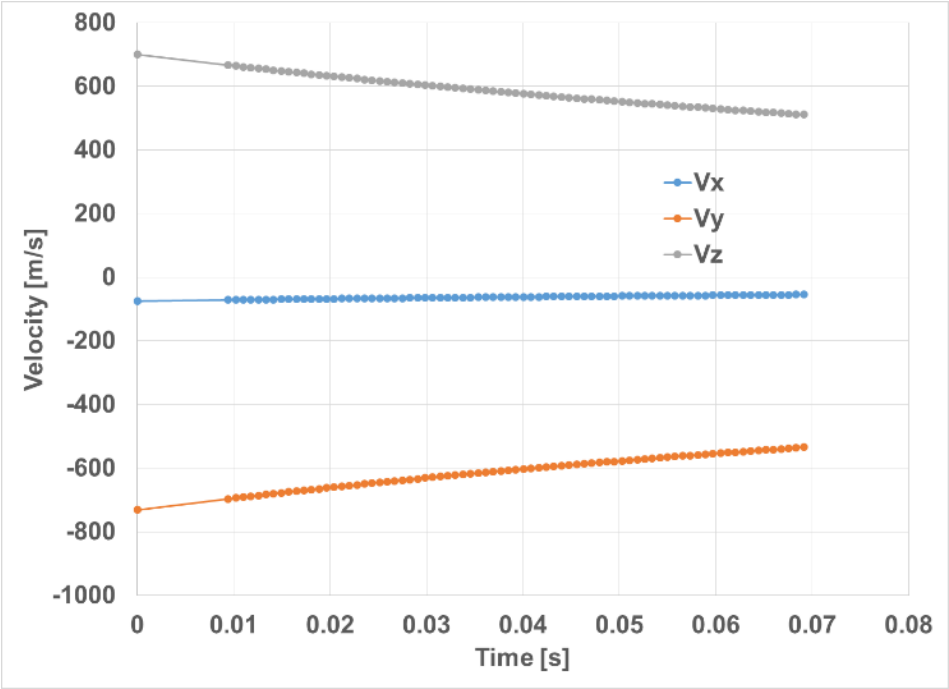
Measurement Assignment Challenge



- **Measurement-to-track assignment in a cluttered environment**
  - **Camera-to-camera correlation**
  - **Frame-to-frame correlation**
- **Irregular, rotating, supersonic fragments can exhibit some unusual motion**
  - **Increases uncertainty in frame-to-frame position prediction**
  - **Increases uncertainty in unsynched camera-to-camera correlation**

Torch Has Developed Automated Image Processing and Track Filtering Algorithms to Solve These Challenges

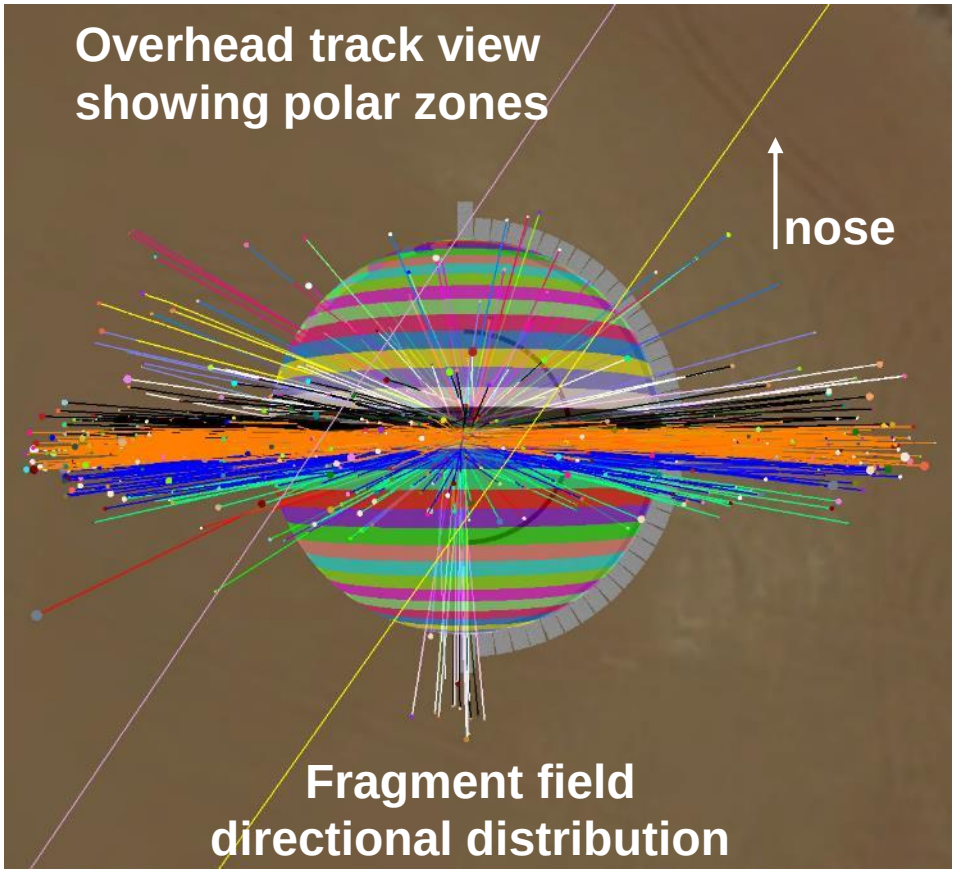
SCOT Data Products

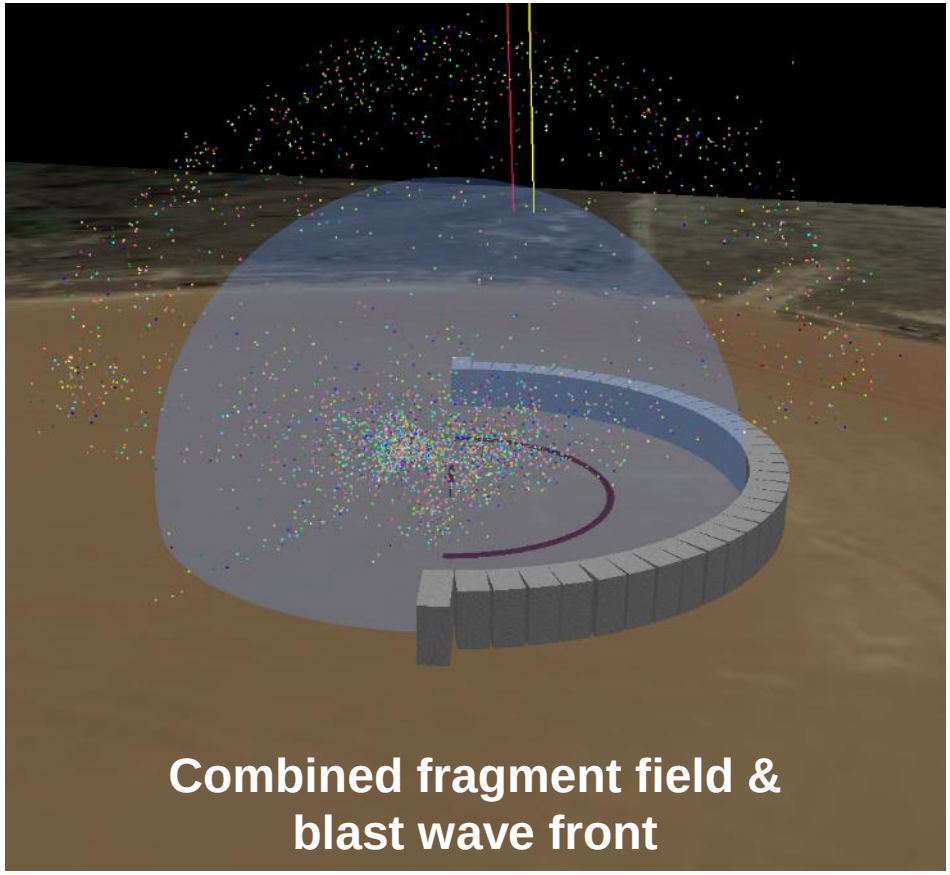


- **3D Time-dependent state estimates: position, velocity, ballistic coefficient**
  - **T0 estimate is critical for accurate warhead fragmentation characterization**
- **Kinematics plus imagery exploited to derive size, shape, mass, and rotation**

Individual Fragment Correlated Position, Velocity, and Area/Mass

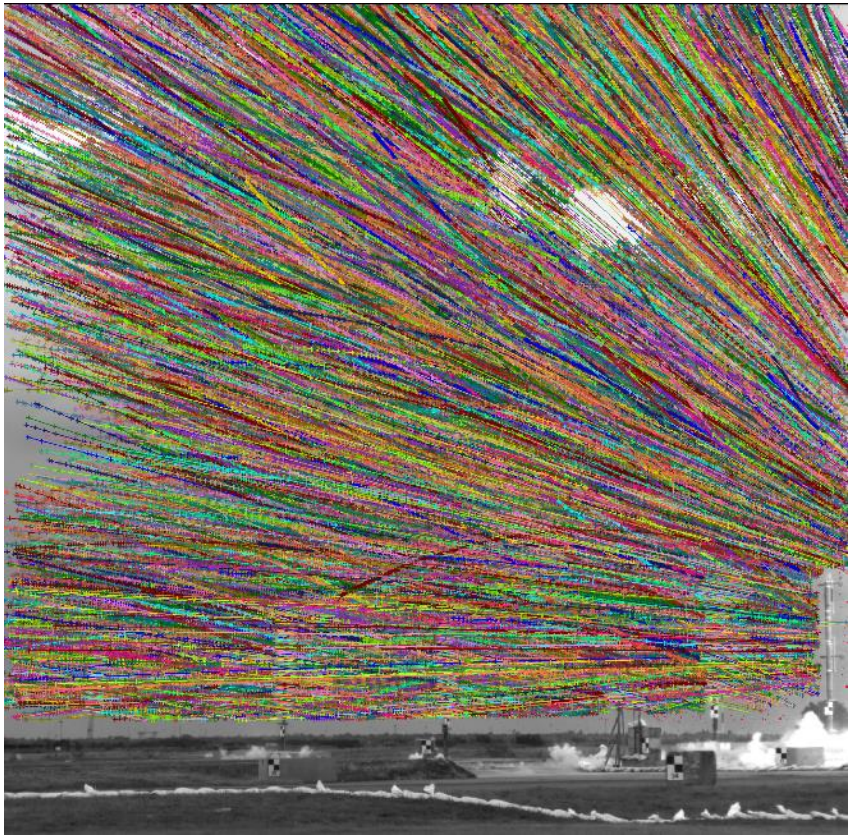
3D Track Visualization Software

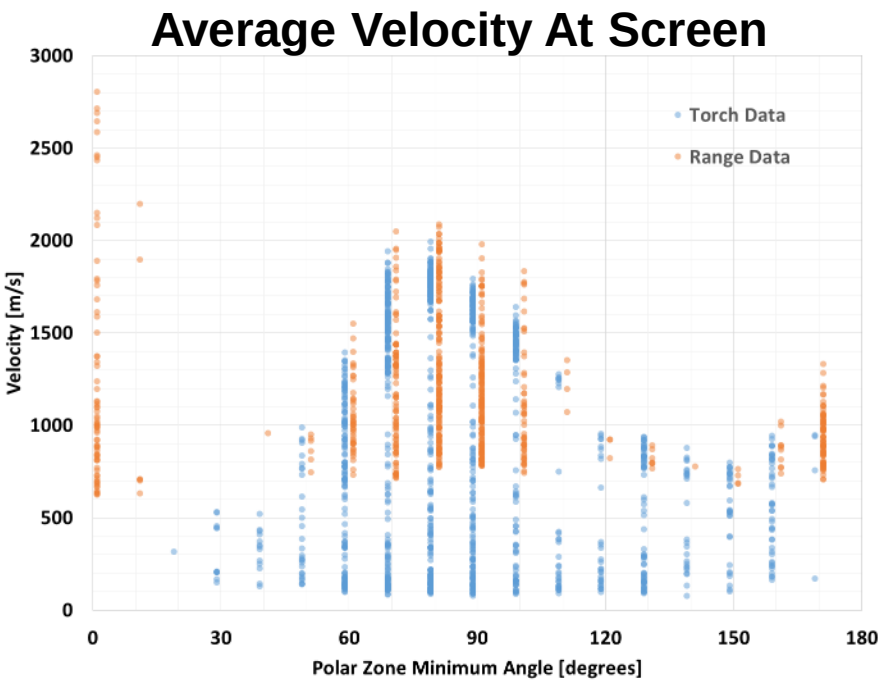




3D Visualization and Analysis Software Provides Comprehensive Picture

Field Testing & Comparison Example





Torch has fielded high-speed COTS cameras in stereo pairs to collect live-fire data to exercise and refine the fragment tracking software implementation

Fragment Tracking Software Demonstrated on Live-Fire Arena Tests

Summary and Conclusions

- **Better warhead characterization techniques are an active research area in the DOD LFT&E community**
- **Torch has demonstrated an integrated imagery-based fragment tracking hardware/software solution for arena test applications**
- **Stereo tracking demonstrated on multiple live-fire tests with good results**
  - **Track velocity estimates show very good agreement with velocity screen data**
  - **Angular distribution comparisons with range data are in excellent agreement**
  - **Significantly increases the number of fragments and the weapon mass characterized compared to standard range instrumentation**
- **SCOT multi-focal plane stereo camera technology in final development phase**
  - **System will be ready for field testing summer 2016**
  - **Improves capability to track small fragments**
  - **Eglin's 96th TW is our primary technology transition partner; 4th quarter 2017**

Improved Warhead Characterization is Critical to Develop Protocols for Next Generation Precision Weaponeering

Acknowledgments/Disclaimer

This material is based upon work supported by the Test Resource Management Center (TRMC) Test and Evaluation/Science & Technology (T&E/S&T) Program through the U.S. Army Program Executive Office for Simulation, Training and Instrumentation (PEO STRI) under Contract No. W900KK-13-C-0019.