U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND
ARMY RESEARCH LABORATORY

Human Agent Interactions for Intelligent Weapons Systems

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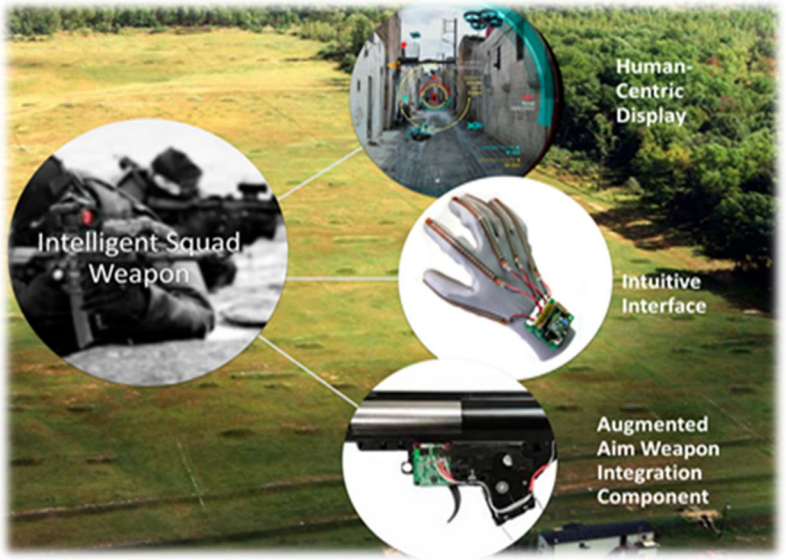
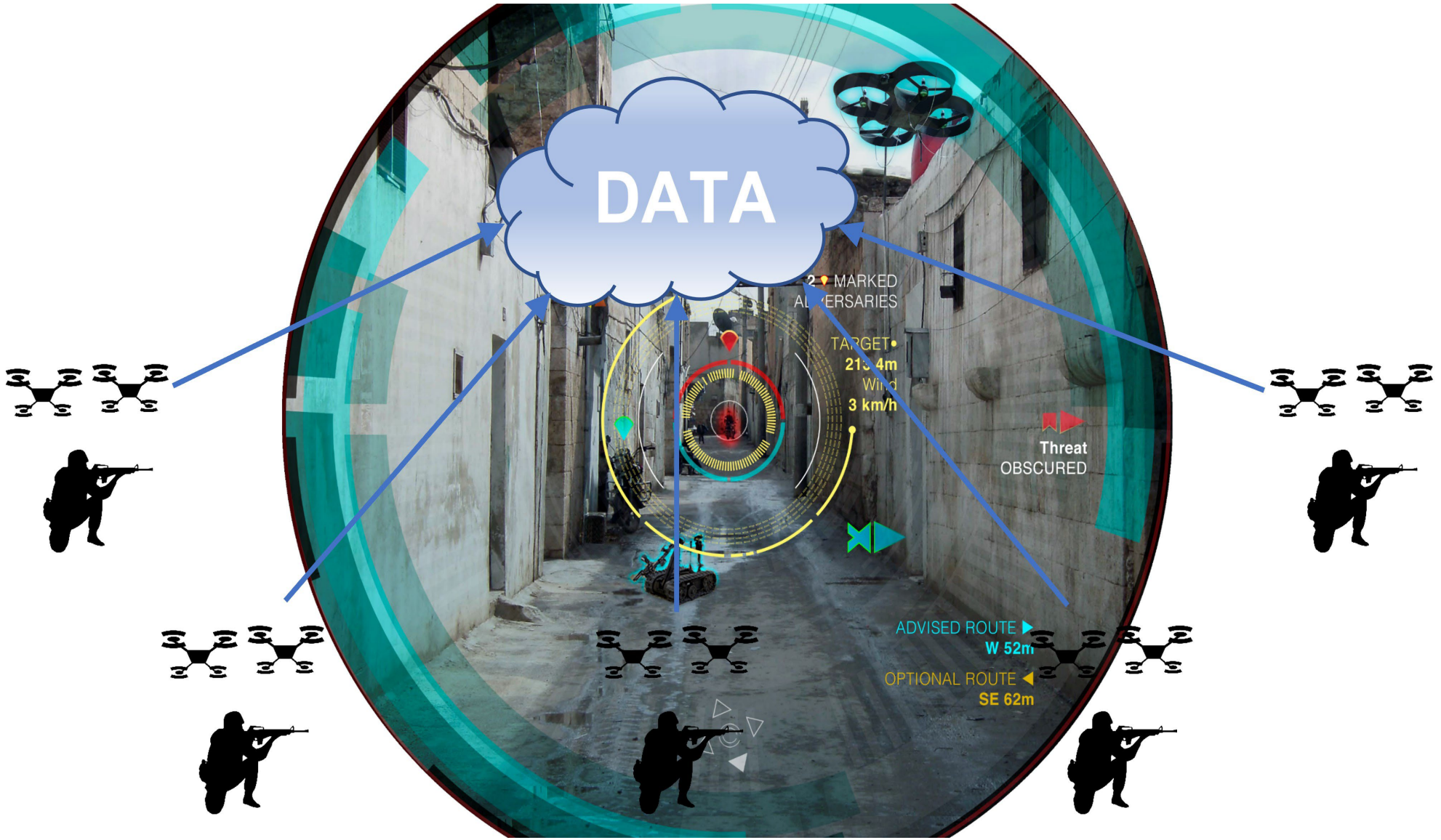
OPPORTUNISTIC SENSING OF HUMAN AUTONOMY INTERACTIONS FOR INTELLIGENT WEAPONS SYSTEMS

- **Big Army Picture**
  - Develop intelligent fire control systems with enhanced target acquisition and situational awareness capabilities to enhance Soldier lethality with individual weapons.

- **Big Problem**
  - Current AI implementations (in general) for small arms are brittle and narrowly-defined.
    - Example: Aided Target Recognition (AiTR) can break when encountering untrained-for scenarios or adversaries change appearance or tactics.
  - These intelligent fire control systems rely on accurate and robust AiTR.
    - Can't hit what it can't see.
  - AiTR requires large amounts of relevant and accurately labeled data.
  - Obtaining relevant and labeled military data is extremely difficult.
    - Slow and resource intensive model development and deployment process.

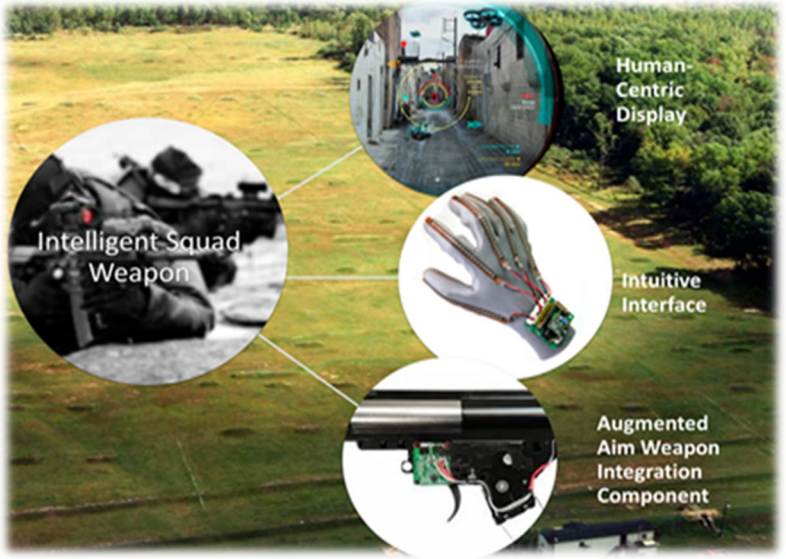


STRATEGIC GOAL – AI ENHANCED SMALL ARMS ECOSYSTEM



OPPORTUNISTIC SENSING OF HUMAN AUTONOMY INTERACTIONS FOR INTELLIGENT WEAPONS SYSTEMS

- **Program Objectives**
  - Address performance gaps in small arms fire control by investigating novel human-in-the-loop mechanisms for adapting aided target recognition.
- **Opportunistic Sensing**
  - Obtaining operational data required for AI/ML algorithms from tasks the operator is already doing, without negatively affecting performance on those tasks or requiring any additional tasks (Lance, et. al. 2020).
- **Improving Small Arms AI through Opportunistic Sensing**
  1. Stabilizing tracking algorithms with multi-sensor fusion
  2. Un-obtrusively collecting in-field data for rapid labeling and model integration
  3. Reduce data requirements for model development
  4. Human-autonomy teaming approaches for mixed-squad small arms ecosystems.



LIMITATIONS IN DISMOUNTED AITR

DEVCOM ARL LIVE FIRE RESEARCH PLATFORM

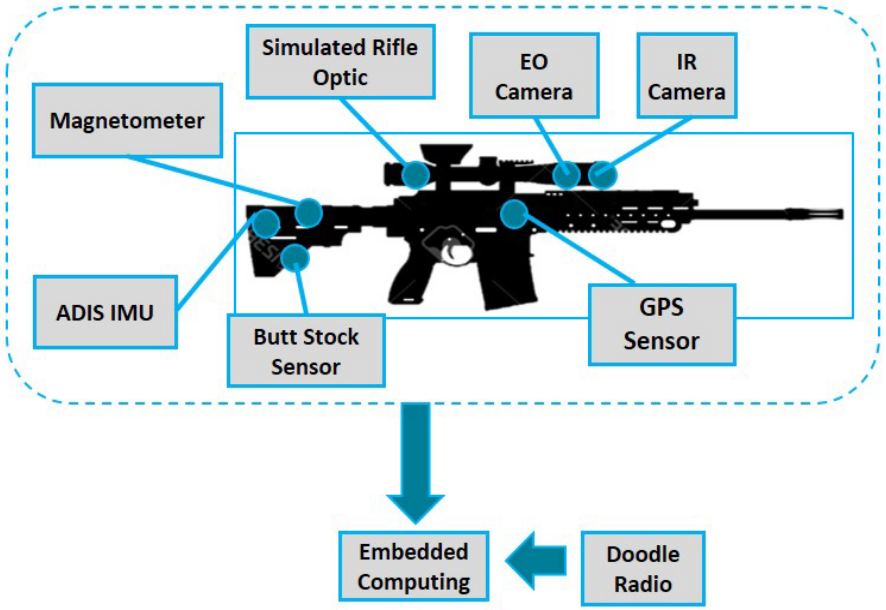
- Can we distinguish operationally-relevant Soldier-weapon behaviors without adding weight or attentional burdens?
- How can we leverage these behaviors?

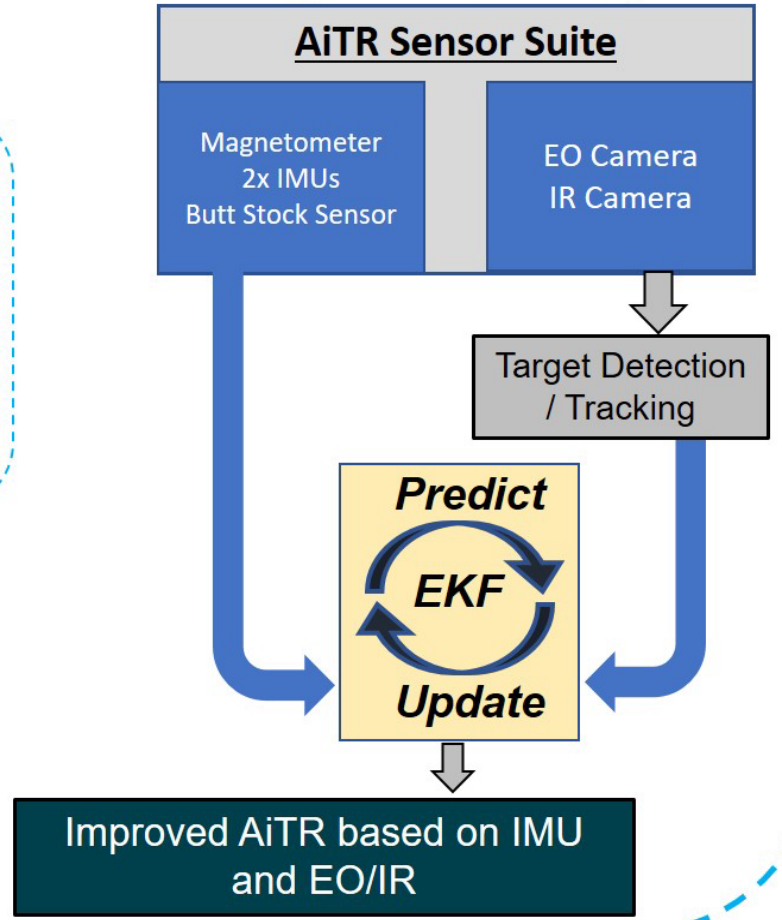
Mimic human activity recognition (HAR) and eye-tracking research.

HAR – using IMU suite to classify body movement and actions

Eye-Tracking Methodologies –
1. Saccade – transitioning aim between targets
2. Smooth Pursuit – aim point tracking moving target
3. Fixation – static aim at stationary target

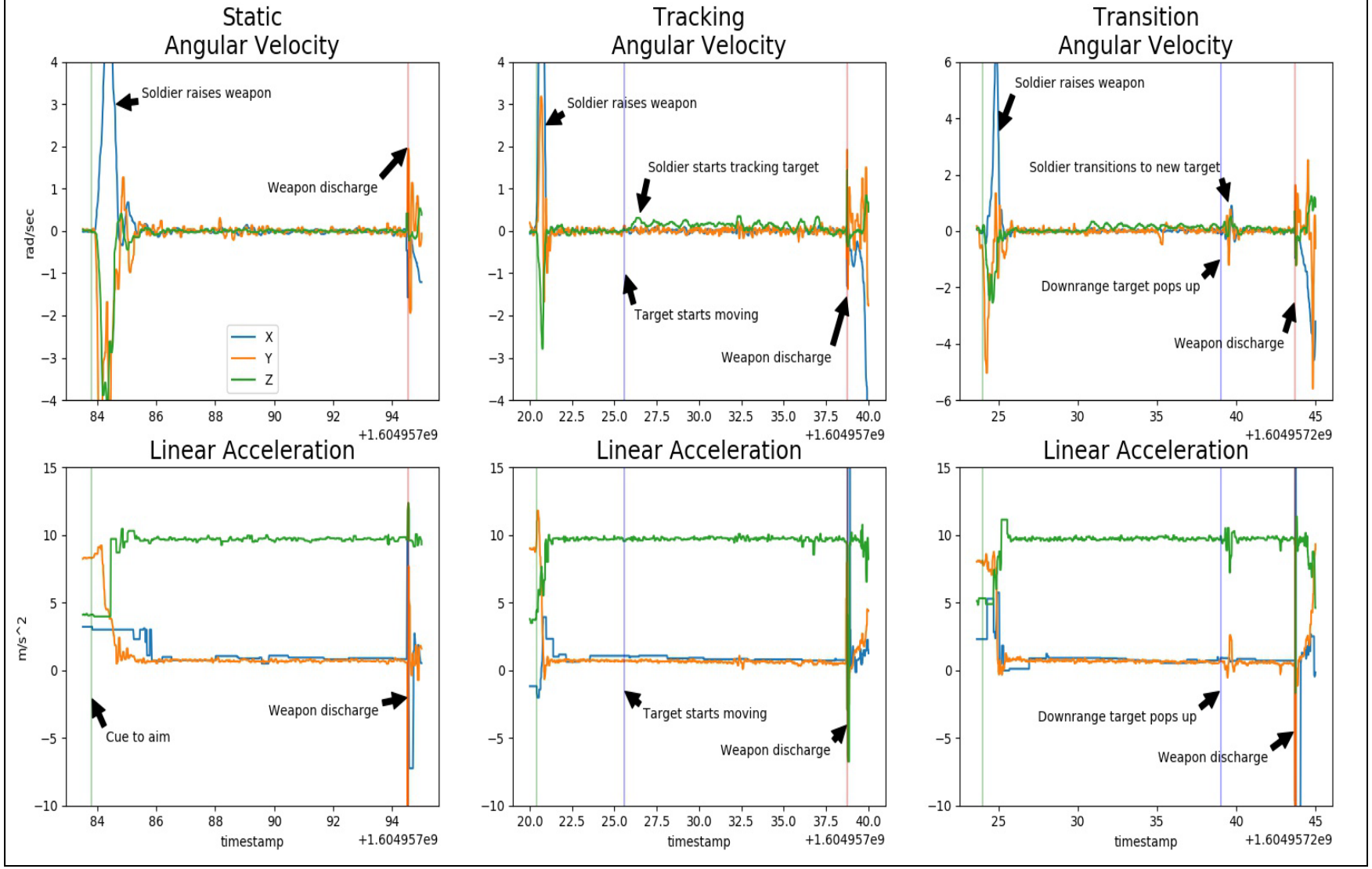
By **fusing** real-time, **opportunistically** sensed data derived from Soldier behavior during **relevant** military operations with AI/ML algorithms, we may **improve** Aided Target Recognition (AiTR).





Instrumentation by ARL Sensors and Electron Devices Directorate (SEDD)

OPPORTUNISTIC SENSING FOR SOLDIER-WEAPON BEHAVIOR



Soldier aiming tasks

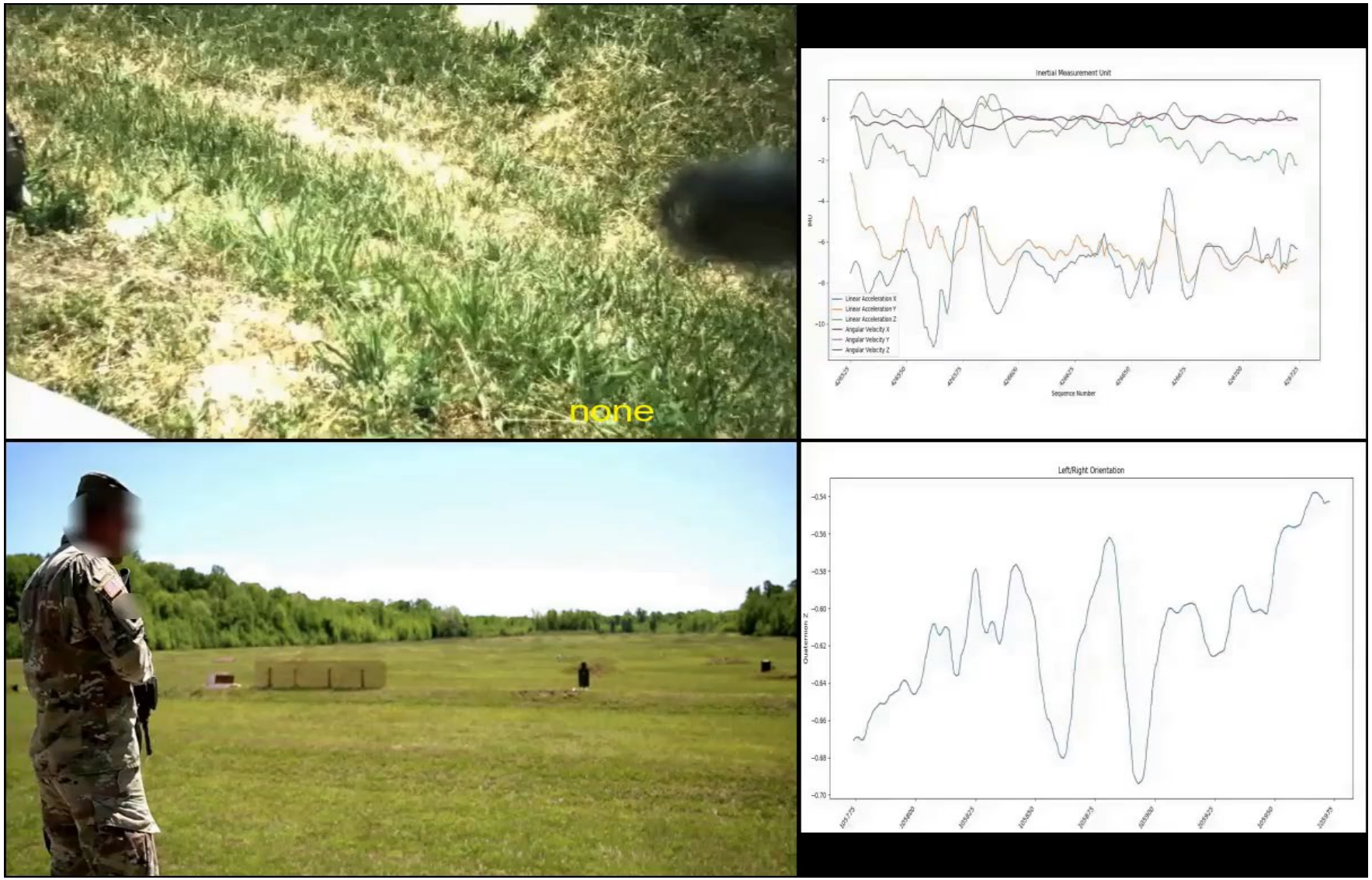
1. Static Aiming
2. Tracking/Smooth Pursuit
3. Transitioning between E-sils

Discrete actions labeled according to IMU data

1. Weapon Raise
2. Static Aiming
3. Transitioning
4. Tracking
5. Weapon Discharge
6. Null or None of the Above

95% accuracy achieved with RFC and real-time classification demonstrated.

OPPORTUNISTIC SENSING FOR SOLDIER-WEAPON BEHAVIOR



Soldier tracking E-sil

- Upper left – barrel mounted FLIR POV with behavior classification
- Lower left – stand off perspective of Soldier
- Upper right – synchronized IMU data streams
- Upper left – Orientation data stream derived by IMU and magnetometer

OPPORTUNISTIC SENSING FOR IMPROVED HUMAN-AGENT INTERACTIONS

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STABILIZE TRACKING ALGORITHMS WITH MULTI-SENSOR FUSION

Classifier + IMU

- Locks bounding box to last known target position within environment

Classifier + Human Tracking

- Locks bounding box to last known target position within camera frame

IN-FIELD DATA FOR RAPID LABELING AND MODEL INTEGRATION (AD-HOC LEARNING)

```
61          while not rospy.is_shutdown():
62              # Training model
63              try:
64                  train_frame = self.q.get(block=False)
65                  if train_frame is not None and train == True:
66                      # Color the esill for re-detection
67                      colored_img = copy.copy(train_frame)
68                      _, box, mask = self.segmentor.detect_esill(train_frame)
69                      self.segmentor.color_esill(colored_img, mask)
70
71                      # Train
72                      self.trainer.train_sample(colored_img)
73                      train = False # activate button press
74              except queue.Empty:
75                  train_frame = None
76
77              # Detection on trained model
78              try:
79                  frame = self.im_q.get(block=False)
80                  if frame is not None:
81                      detect_frame = ImageSegmentation.zoom_and_crop(frame, zoom_size=64)
82
83                      boxes, scores, classes = self.esill_detector.detect(
84                          detect_frame, True)
```

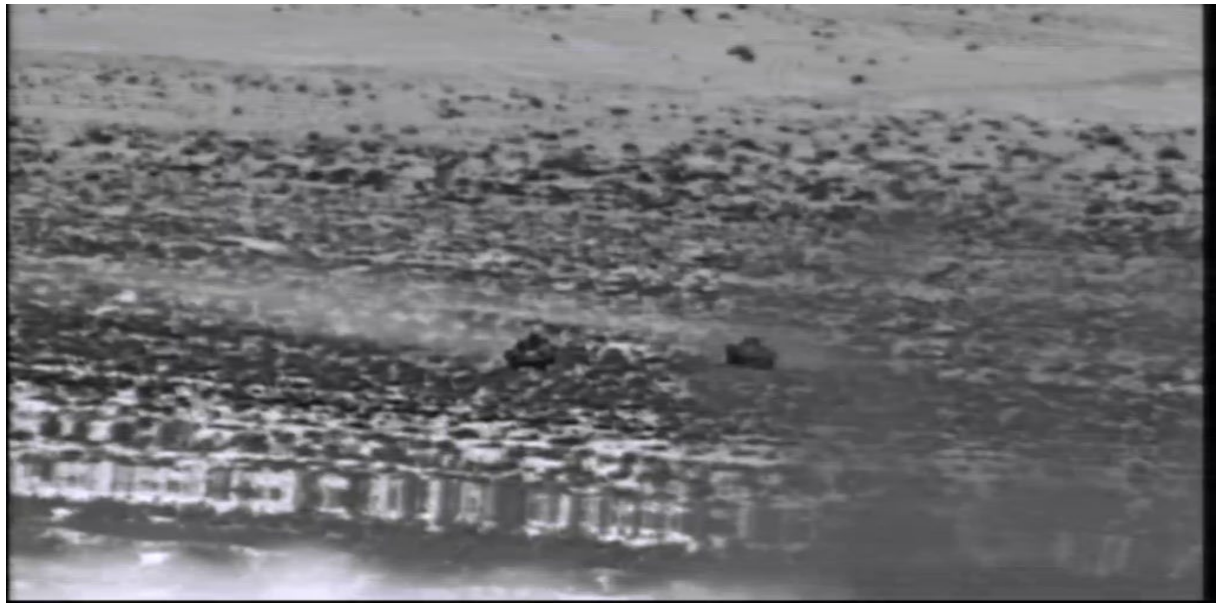
PROBLEMS 5 OUTPUT DEBUG CONSOLE TERMINAL PORTS 6

```
[INFO] [1635925014.939645]: esill detected 115
[INFO] [1635925015.601684]: esill detected 116
[INFO] [1635925015.681070]: esill detected 117
[INFO] [1635925016.054995]: esill detected 118
[INFO] [1635925018.991549]: esill detected 119
^C[monitor_node-3] killing on exit
[esill_detection_node-1] killing on exit
[classification_node-2] killing on exit
shutting down processing monitor...
... shutting down processing monitor complete
done
root@osben-desktop:/app#
```

REDUCE DATA REQUIREMENTS FOR MODEL DEVELOPMENT (FORCE ON FORCE DATA COLLECTION METHODS)

Opportunistically collect data during more dynamic target engagement scenarios with commercially available technology to improve AiTR algorithms.

Mounted



Mounted Force on Force during NTC OPFOR

- Establishing data pipeline to collect EO/IO and behavioral data using **QinetiQ Inc's Target Engagement Video Capture System.**
- Transitioning data to partners for target model development, AAR development, and system development.

Dismounted

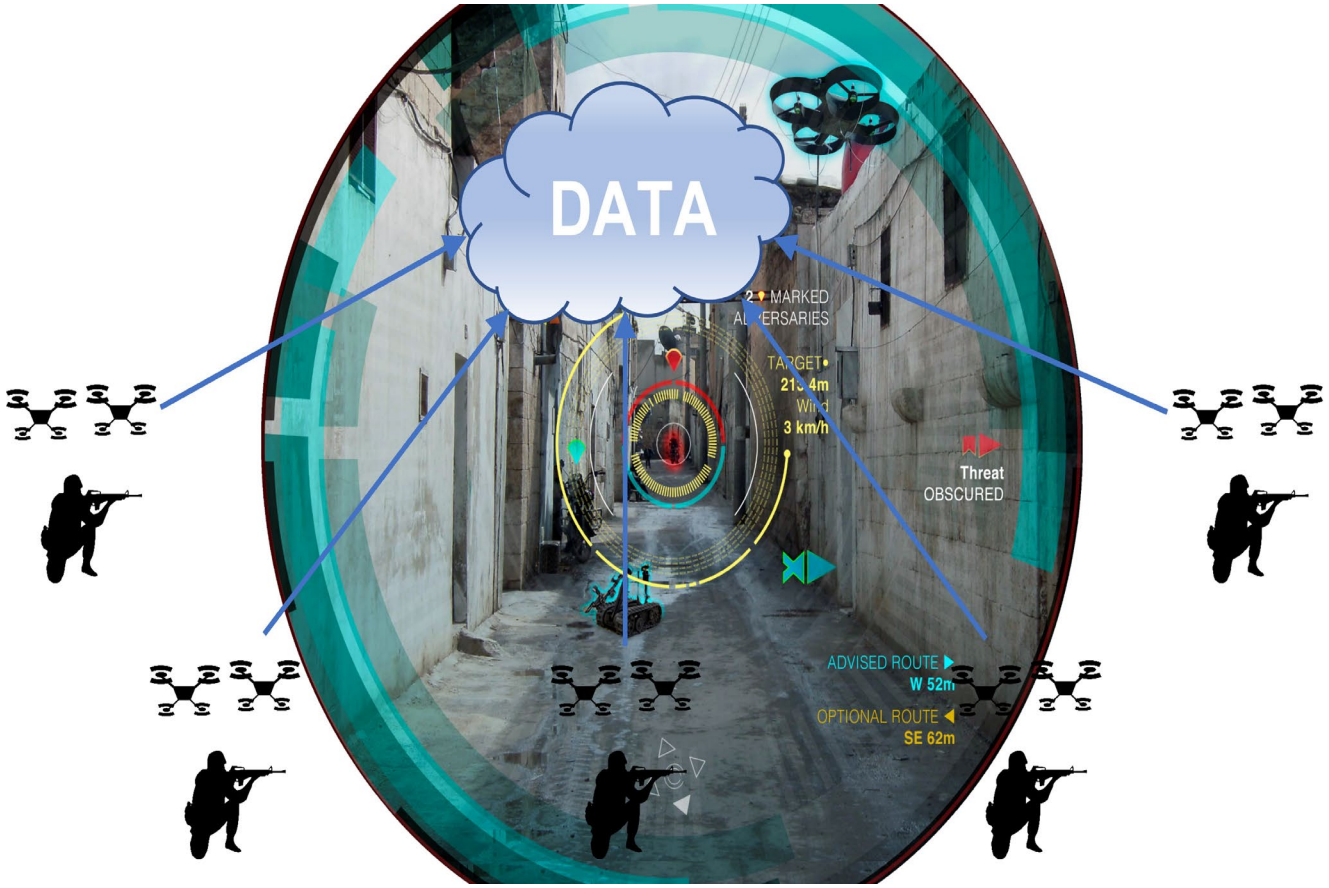
Dismounted Force on Force Scenario

- **FN America VictoR** EO and IMU
- MCOE Maneuver Battle Lab STP

~30,000 frames → 3,000 frames

HUMAN-AUTONOMY TEAMING APPROACHES FOR MIXED-SQUAD SMALL ARMS ECOSYSTEMS

Can we demonstrate human-autonomy teaming approaches?



Wind Estimation Use Case

- Wind is a large unknown factor in ballistic kernel calculations.
  - No current automated implementation to correct aim point (can be done by hand or by intuition).

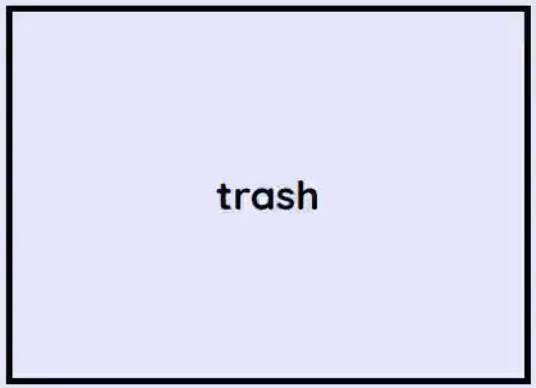
Decision Dominance for MDO Use Case

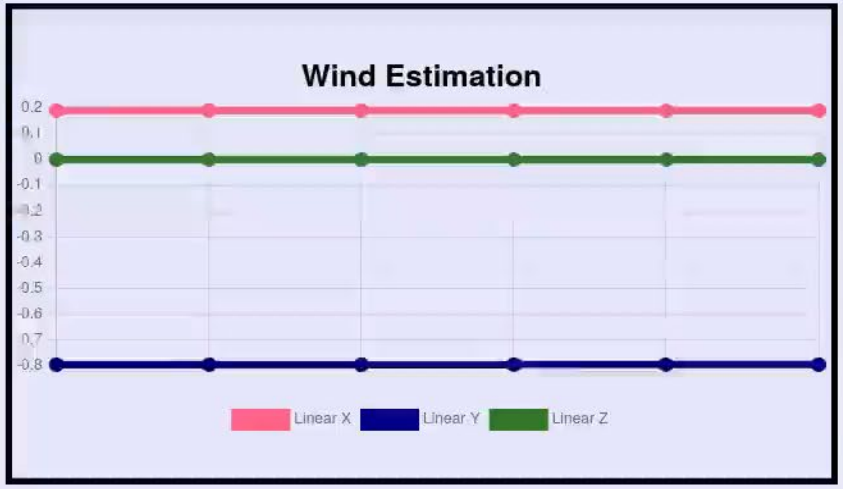
- Aggregating emergent Soldier and squad-level behaviors and distributing to decision making AI tools could increase echelon SA.
  - Currently only limited behavioral and environmental cues are being implemented.

SHARING HUMAN-DERIVED OPERATIONAL CONTEXT WITH AUTONOMOUS SYSTEM FOR HUMAN-AUTONOMY TEAMING

HAI2SW Interface

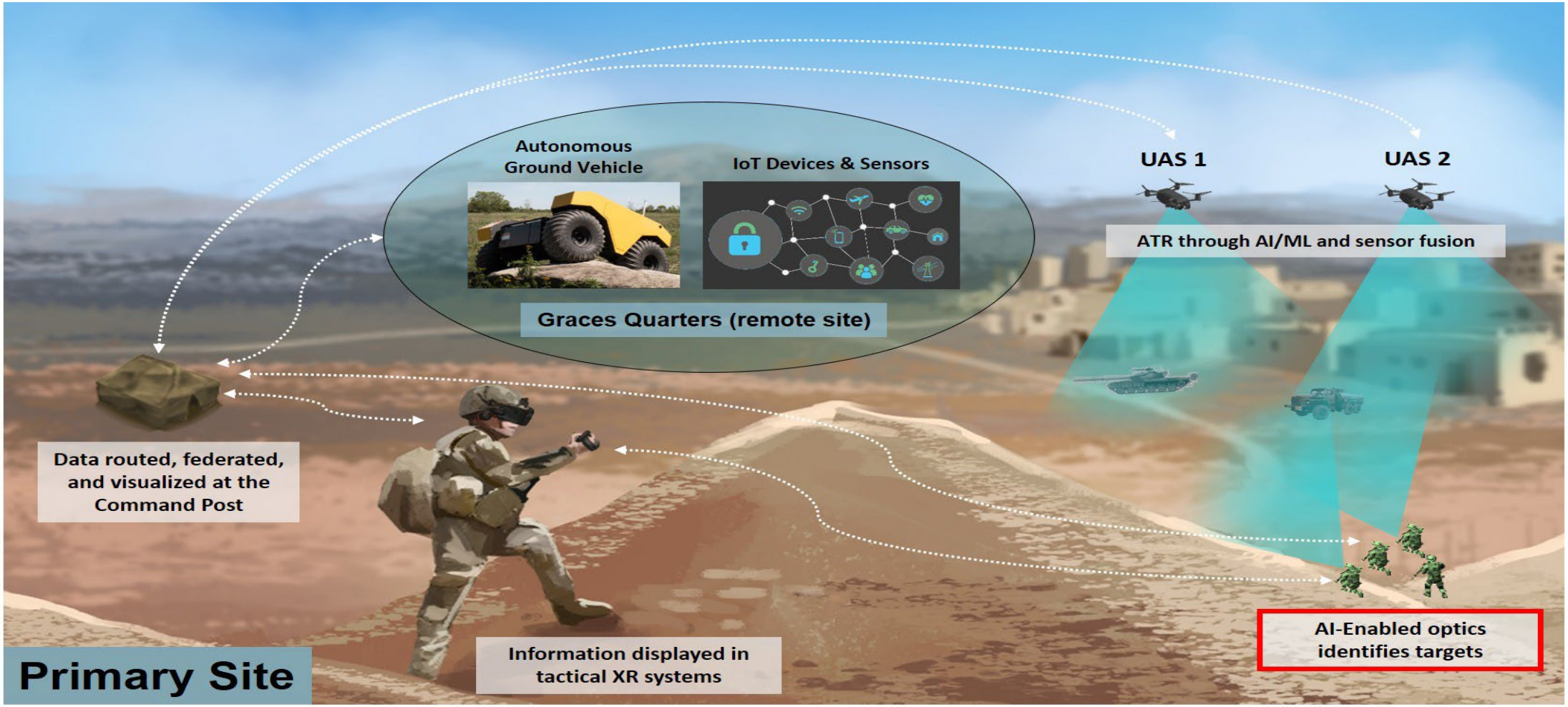
Current Status: Connected





MIXED HUMAN-AI ECOSYSTEMS FOR MULTI DOMAIN OPERATION

Autonomy, Cross-Reality Operating Picture, Optempo Learning Information Sciences (ACROPOLIS) is a tech demonstrator of lower TRL advanced technologies and human agent interfaces to enable situational understanding and target acquisition for dismounted squads/reconnaissance elements feeding into the company-level operating centers.



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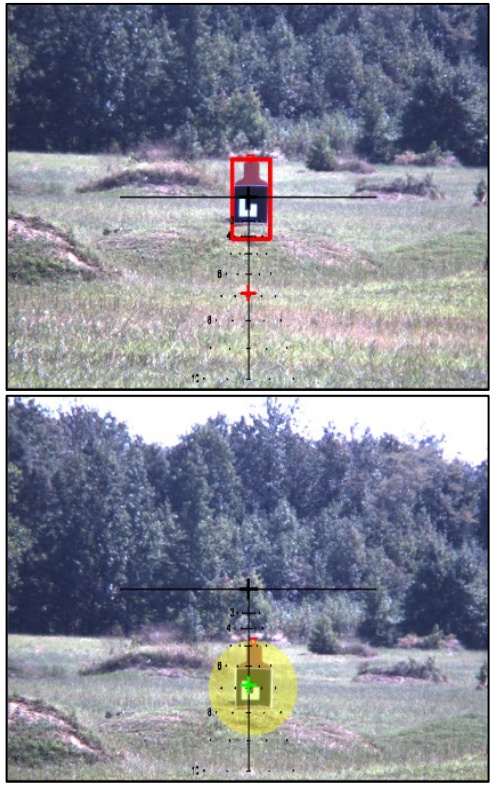
TAKEAWAYS AND FUTURE EFFORTS

By deriving Soldier-weapon interaction behaviors using opportunistic sensing, we can

1. fill fail-case gaps in current AiTR technologies.
2. provide AI technologies context for enhanced learning and model development.

Near Term Efforts

- Assess trade-off between performance metrics with these new intelligent weapon AiTR technologies.
- Incorporate other opportunistic sensing modalities (e.g., eye-tracking in HUDs) for expanding applications.
- Establish novel processes for efficient collection and labeling of data obtained from Force on Force operational scenario.



Methodologies for assessing human-AiTR effectiveness

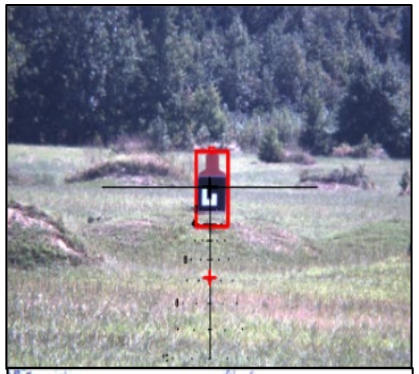
Back up slides

APPROACHES FOR CHARACTERIZING HUMAN PERFORMANCE WITH NEXT-GEN FIRE CONTROL

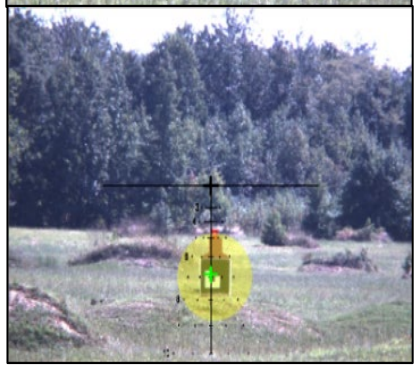
How do you effectively transfer the capabilities of the aim augmentation systems to the Soldier and assess its impact on lethality and probability of hit. A large portion of the error budget in marksmanship is still human error.

Objective - Develop approach to assess effects of aim augmentation fire control and ATR visualization using an augmented trigger system to systematically alter tolerance based on relevant engagement profiles and engagement time.
Outcome - Predict tradeoffs between how precise the aim augmentation is (area on target that will activate the release) and performance to inform implementation in next-gen fire control

AruCo Markers and weapon mounted camera allow for simulation of ATR and ground truth of target location



Correctly classified target (ground truth: threat (red), highlight: threat). Aim point will result in missed target, as indicated by red crosshair



Correctly classified target, using different ATR visualization method. Aim point optimized for center mass hit, as indicated by green crosshair