Multi-Domain Human-robot Teaming Sandbox (MDO-HuRT-S)

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Robotics Research Center
Electrical Engineering and Computer Science (EECS)
United States Military Academy
West Point, NY
August 10, 2022

About West Point

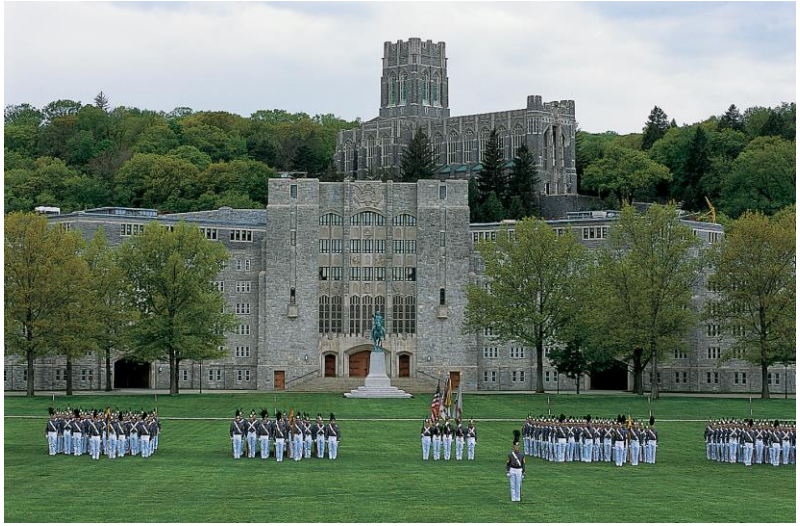
4348
Total Enrollment

36
Majors

26
Research Centers

7:1
Student to Faculty

Along the Hudson River, 50 miles north of New York City



Mission is "to educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country and prepared for a career of professional excellence and service to the Nation as an officer in the United States Army."

UNITED STATES MILITARY ACADEMY
WEST POINT.

Academic Friendly Gateway

Department of Electrical Engineering and Computer Science

Educate Future Leaders

ACADEMIC

EDU

Dean

CME … EECS … BS&L

RRC

- Teach academic courses
- Academic research

MILITARY

GOV/MIL

Commandant

DMI

- Military Training
- Previous real-world experience
- Realistic feedback

UNITED STATES MILITARY ACADEMY
WEST POINT.

Robotics Research Center

Department of Electrical Engineering and Computer Science

Mission

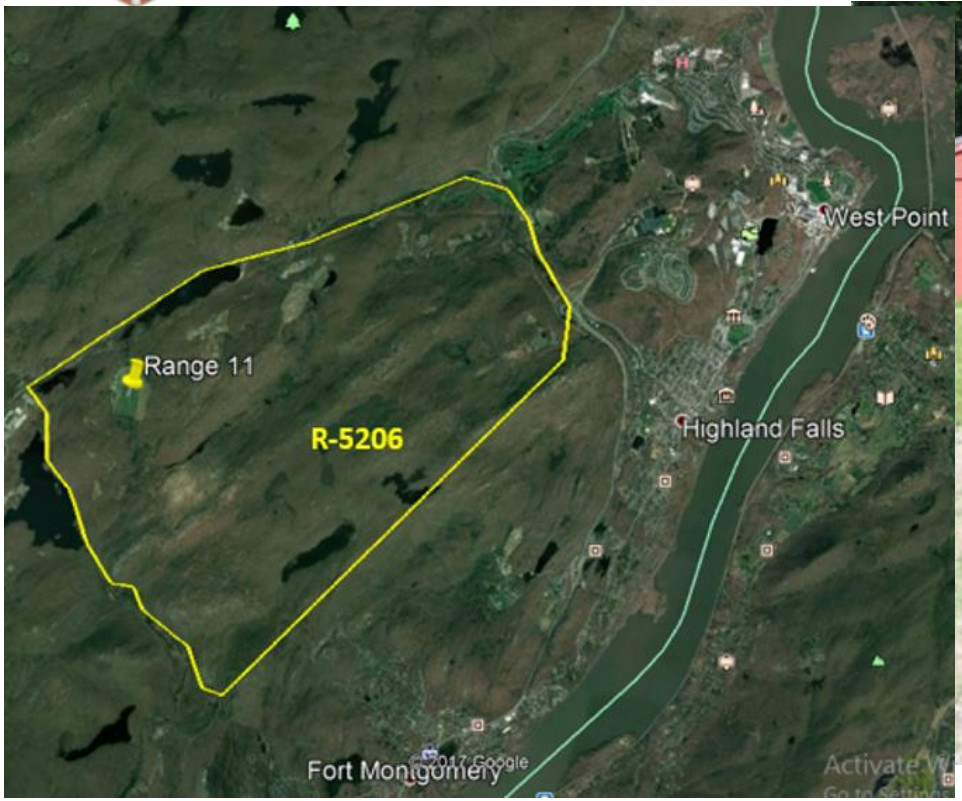
To provide cadets and faculty the opportunity to perform basic and applied research in robotics to prepare them to lead in an Army more reliant on artificial intelligence, machine learning, and autonomous systems.

Research Priorities

1. Enhance cadet education
2. Develop faculty professionally
3. Address important issues facing the Army and Nation
4. Strengthen partnerships

River Courts

Training Ranges

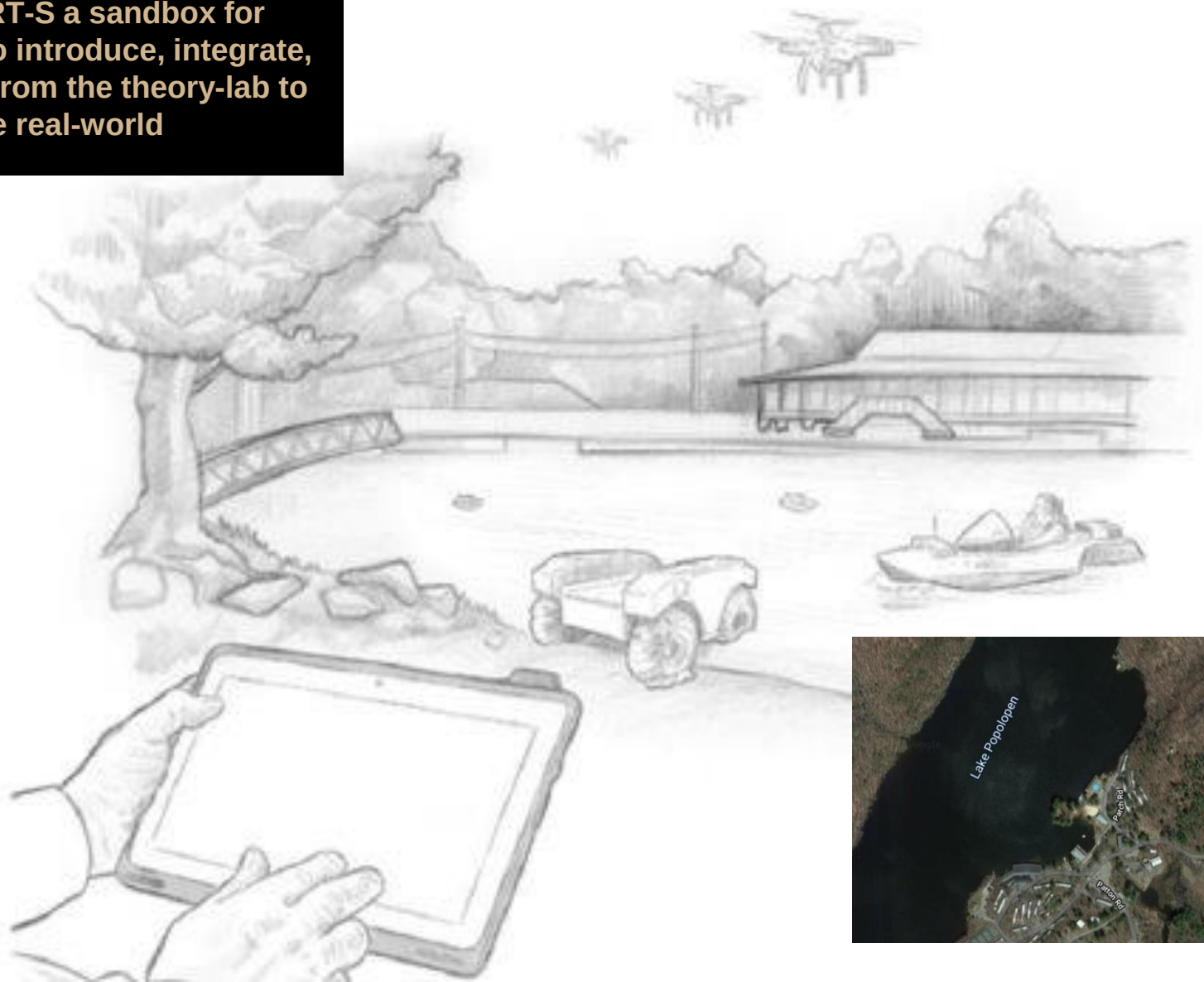


MDO-HuRT-S

(Multi-domain Operations Human-Robot Teaming Sandbox)

Department of Electrical Engineering and Computer Science

MDO-HuRT-S a sandbox for academics to introduce, integrate, refine work from the theory-lab to the real-world



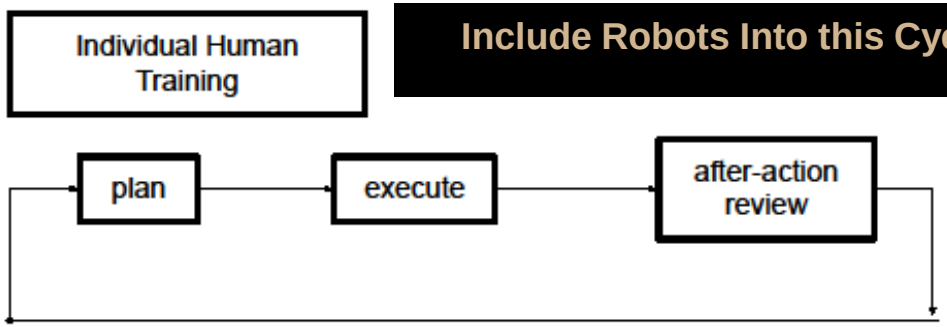
Research Vision

(MDO-HuRT-S)

Department of Electrical Engineering and Computer Science

Dr. Michael "Misha" Novitzky's Research Vision:
Enable organic local unmanned assets at the squad and team level (does NOT require higher echelon approvals or comms).

Research Challenge: break the current standard of high human workload/cognition such as hands on teleoperation of small unmanned assets. (At the squad and team level, each operator is significant man power.) Achieve this by incorporating levels of robot autonomy that are integrated into the plan, execute, AAR cycle of human missions.



Include Robots Into this Cycle!

Universal device(s) for mission planning, execution, AAR.

Required to design autonomy and interfaces:
1) translate plans to executable commands
2) execute plans with little oversight
3) integrate and adapt at AAR feedback

UNITED STATES MILITARY ACADEMY
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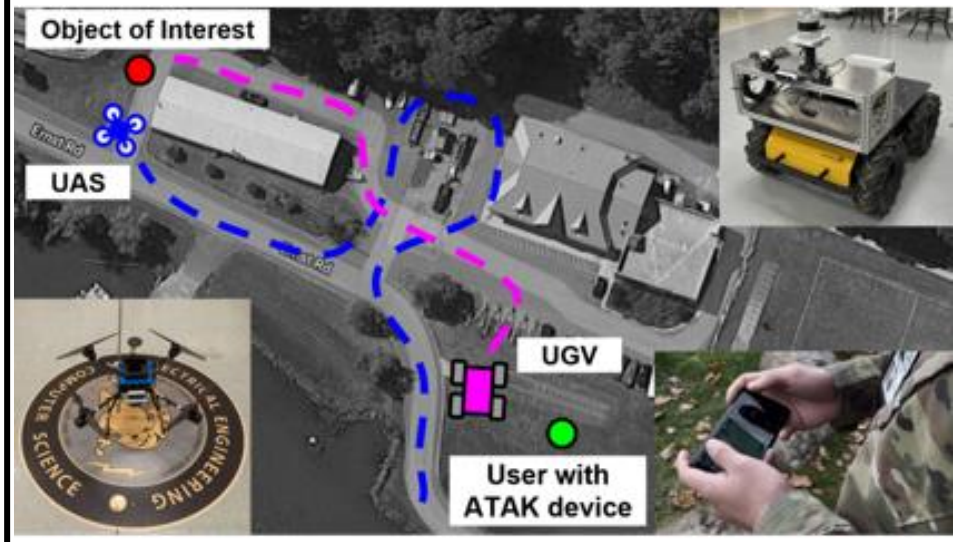
DCIST (Distributed and Collaborative Intelligent Systems and Technology

Department of Electrical Engineering and Computer Science

Objective: An implementation and integration of the ATAK operator interface for coordination between DCIST autonomy stack enabled vehicles for aided threat recognition in autonomous route reconnaissance

DEVCOM ARMY RESEARCH LABORATORY

Sponsor: DTRA, ARL
Collaborators: MIT, Penn, UCSD

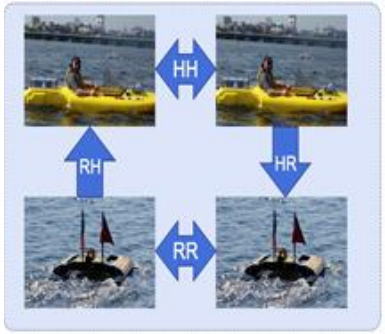


Approach:
Integrate autonomous air and ground vehicles leveraging DCIST capabilities for the purpose of aided threat recognition. Operators will interact with their autonomous teammates using the Android Tactical Awareness Kit (ATAK).

- Aid human decision making in threat engagement
- Leverage autonomy for threat identification, engagement, and battle damage assessment.
- Enable faster and more accurate decision-making for soldiers with air and ground autonomous robot assets.

5th Gen/Next Gen Networks: Resilient Online Multi-Agent Machine Learning

Revision Date: 20220808



Maturing AI for human-bot teams

Tech / Product / Objective:

- **OBJECTIVE:** Leverage an internationally unique testbed to support multidomain heterogeneous human-bot teams supporting multi-domain operations to conduct 5th Gen and Next Gen experiments
- **APPROACH:** Leverage Aquaticus technical capabilities to establish an open-source sandbox extensible to search and rescue experiments:
  - Work with faculty and staff from USCGA and MIT-LL to apply baseline computer vision object recognition models from sparse datasets, enhancing to advance algorithms
  - Explore multi-agent computer vision models during search and rescue scenarios
  - Implement and inform resilient multi-agent algorithms including BBC and hashgraph
  - Integrate MeshMANET radios to explore RF EW resiliency
  - Experiments to demonstrate resiliency during multi-robot on-water search and rescue

The So What:

- Fusion of multi-modal information from multi-agent robot interactions requires awareness of sensor and M/L model performance, modeling of relative position and corresponding uncertainties and new methods to enhance resilient operations in contested environments

Key Participants:

- USMA, USNA, USAFA, USCGA, MIT Lincoln Lab (support CG)
- Broadband commercial communications (through CRADA with USEI to provide 5th Gen points of presence at USAFA, USNA, and USMA)
- Mesh MANET commercial radio support for human-bot teams
- Monterey Phoenix – Computable Models of Command Intent

Search and Rescue Research Objectives

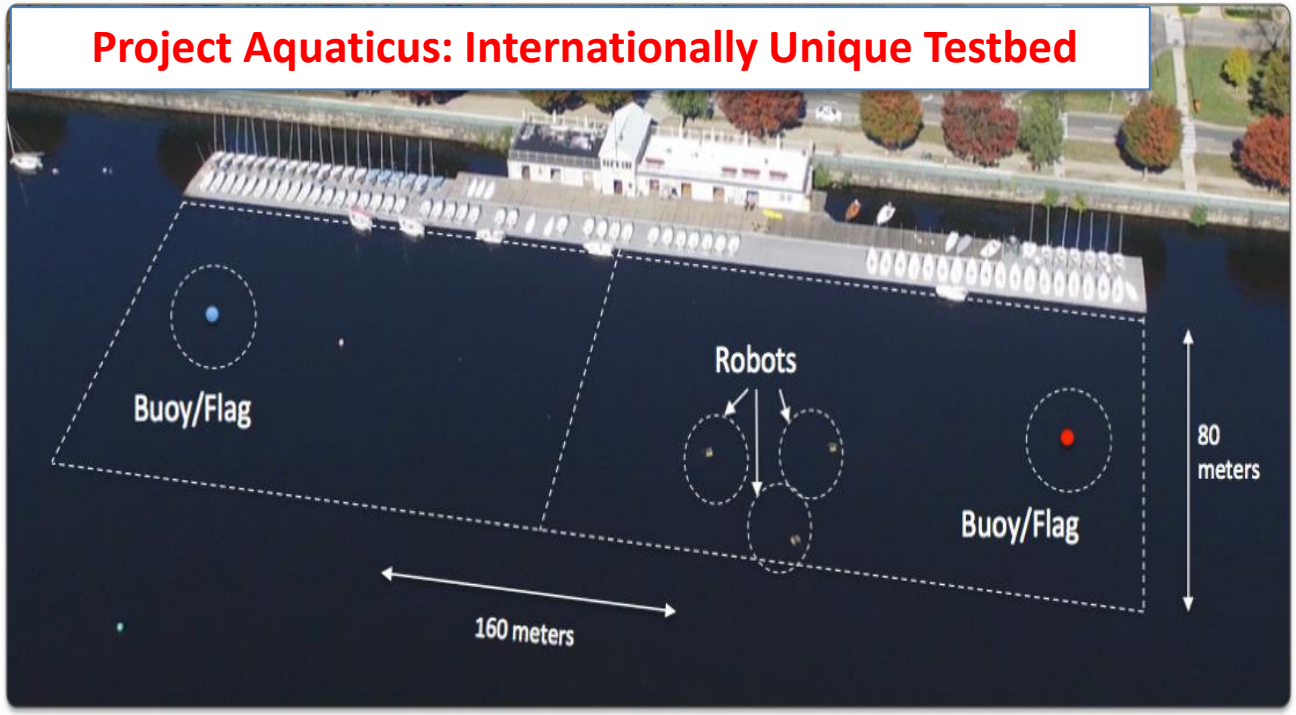
•Perform communications experiments in sharing MDO-HuRT-S sensor flows among Service Academies and international robotics laboratories.

•Demonstrate use of distributed ledger technology (DLT) for maturing resilient trust of cyber-physical systems (CPS) state estimates via international HADR/SAR experiments:

- Sandbox for heterogeneous human-robot teaming
- Sandbox for multi-domain human-robot teaming, including robot swarms
- Sandbox to work with national and international standards bodies for human-robot teaming for military operations, particularly HADR/SAR experiments
- Creation of a national capability for the maturity of AI for military applications
- Creation of an interface definition for multi-domain human-robot teaming experiments and a report detailing how other laboratories can participate in IEEE-sponsored joint human-robot experiments, particularly for HADR/SAR open-source operations
- Framework for measuring utility of multi-agent AI/ML-enabled platforms to assist in meeting command intent for small-unit combat operations

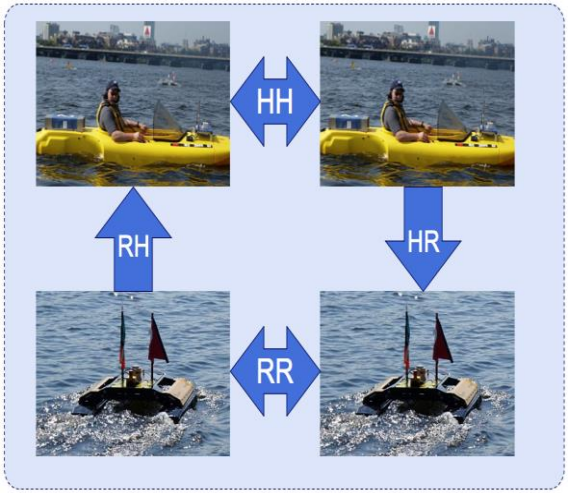
Previous Sandbox Experience

Project Aquaticus: Internationally Unique Testbed



Massachusetts Institute of Technology

2015-2019



Standard Team: mixed human-robot teaming

Objective: Human-robot teams playing games of capture the flag. Research human-robot trust, cognitive load, and robot autonomy.

MOOS-IvP

DARPA

Office of Naval Research ONR Science & Technology

Battelle

DEVCOM ARMY RESEARCH LABORATORY

TTCP AISC OAI Pillar

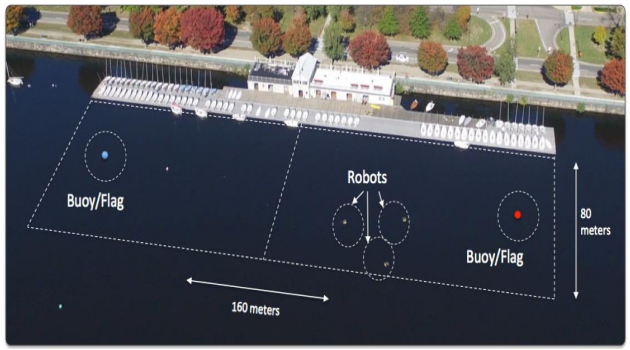
The Technical Cooperation Program (TTCP)
Artificial Intelligence Strategic Challenge (AISC)

Australia, Canada, New Zealand, UK & US (FVEYs)

Accelerate transition of AI solutions into the hands of coalition Armed Forces for tactical edge decision making in multi-domain urban-littoral operations.

Opposed AI Pillar to study teams of artificial agents in contested environments using Project Aquaticus testbed.

OUSD R&E



MIT

West Point

Establish Aquaticus at West Point
~$500k (FY21) Purchase of 8 Searobotics ASVs
~$400k (FY22) Personnel and Site Logistics

Aquaticus@West Point

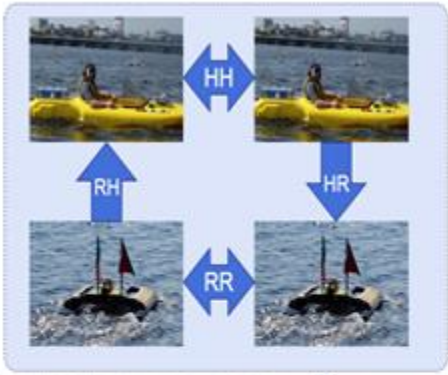
Department of Electrical Engineering and Computer Science

Project Aquaticus Summer 2022

7 Interns high school – undergraduate

- Assembled the MDO-HuRT-S dock
- Familiarized with MOOS-IvP
- Formed Monterey Phoenix (MP) teams
  - Expanded MP model of game & SAR
  - Prototyped MP to MOOS-IvP interface
  - Enabled MP generation of finite state machine model of human-robot teaming task at hand (experiment with cognitive load)

Aquaticus Interns support first live Aquaticus competition at West Point



Maturing AI for human-robot/human-bot teams

OUSD R&E

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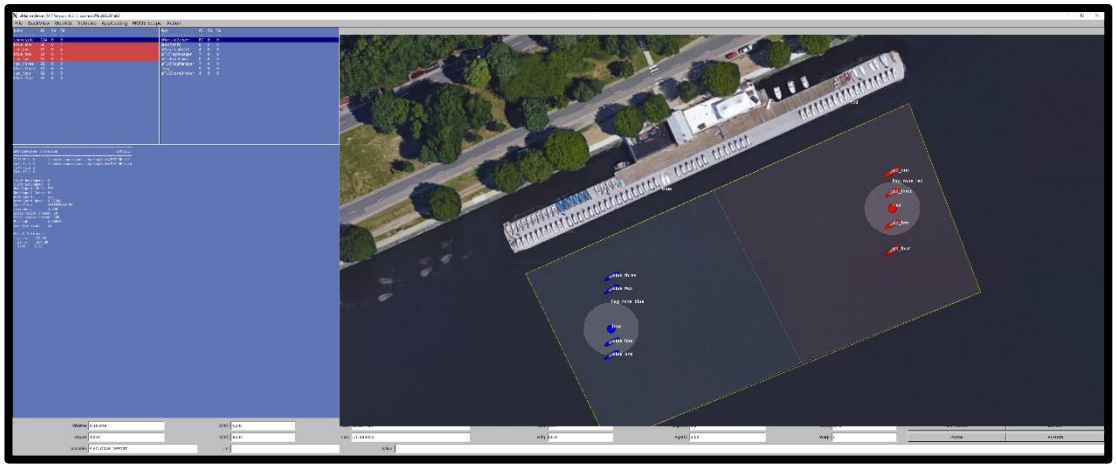
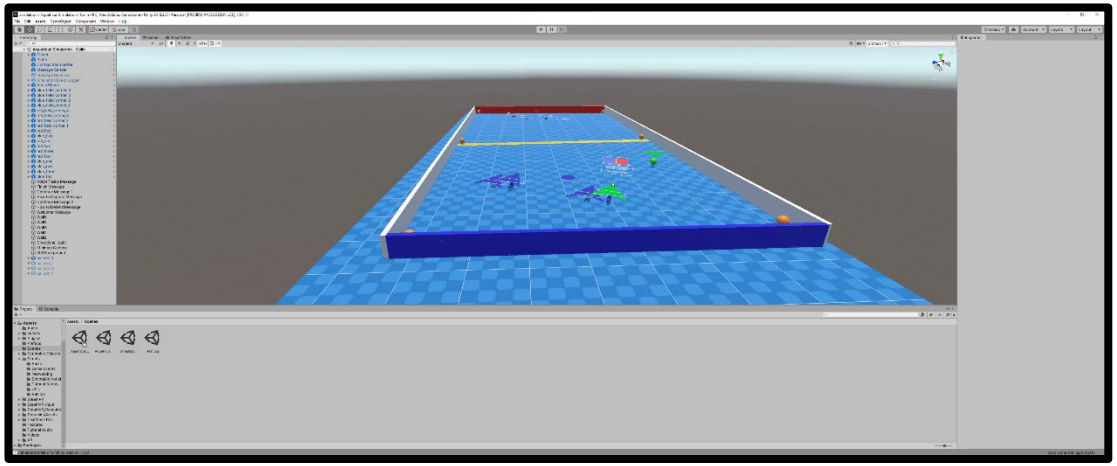
Virtual Reality

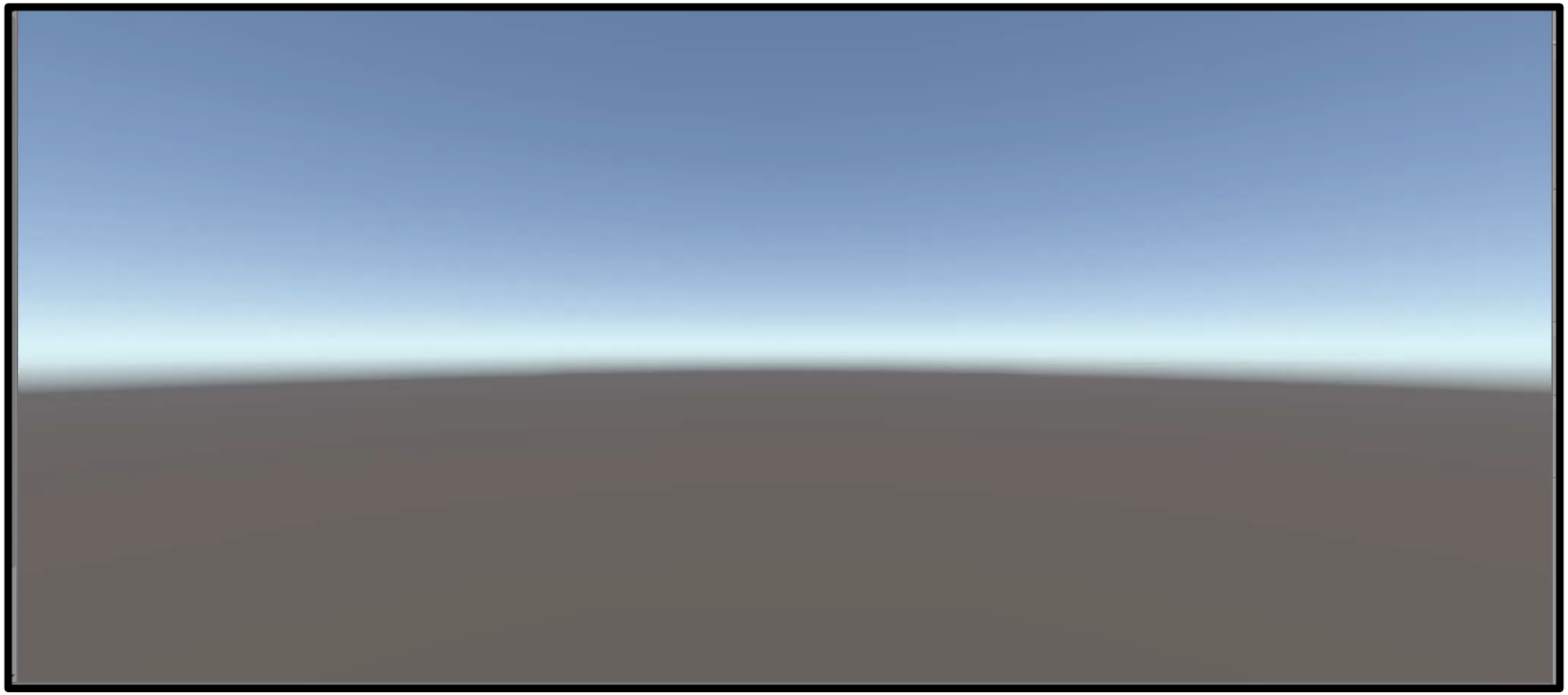


Screenshot of 2D Aquaticus Visualization (moos-ivp)



Screenshot of 3D Aquaticus Visualization (Unity Game Engine)

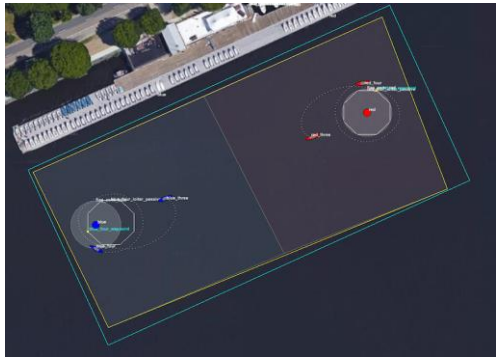
VR Video



Tutorial Gameplay – Phase I: Boat Maneuver

Topics

Machine Learning: Using MOOS-IvP pLearn autonomous vehicles can learn behavior for opposed environments.



U.S. NAVAL RESEARCH LABORATORY

NPS PRAESTANTIA PER SCIENTIAM 1909

AR/VR HRI: Leveraging augmented and virtual reality for training human-robot teams, lowering cognitive load, and establishing tactical judgement.

HRI: Multi-modal human-robot interaction in stressful environments.

Research Topics

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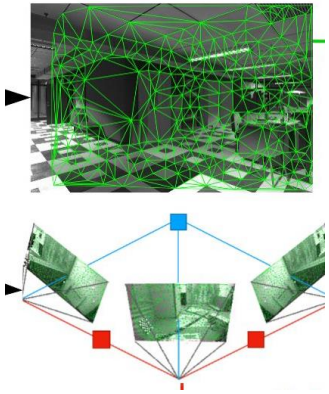
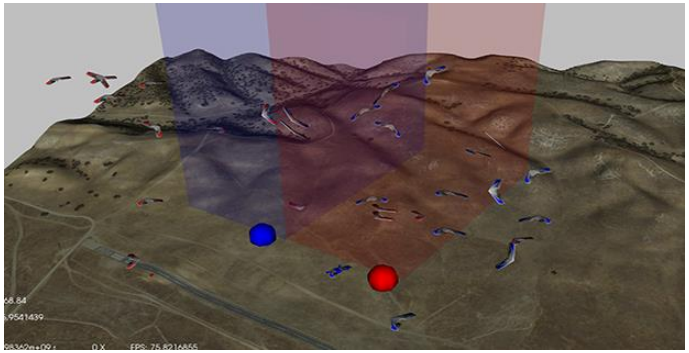
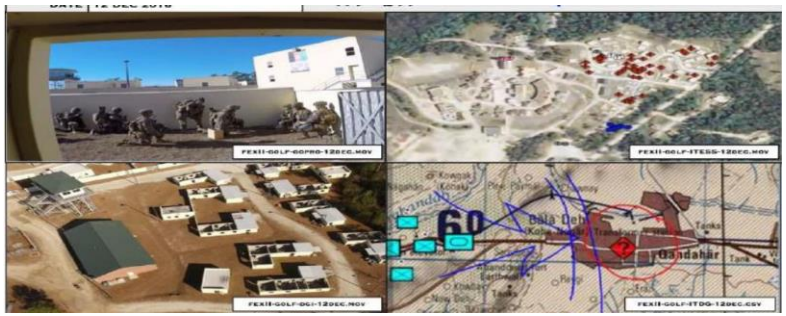
GPS-Denied Environments:
Exploring simultaneous localization and mapping (SLAM) and Visual Inertial Odometry (VIO)





SWARMS vs SWARMS:
Autonomy for multi-robot teams in contested environments

Human-robot Teaming:
Planning -> Execution -> After Action Review



ITDG

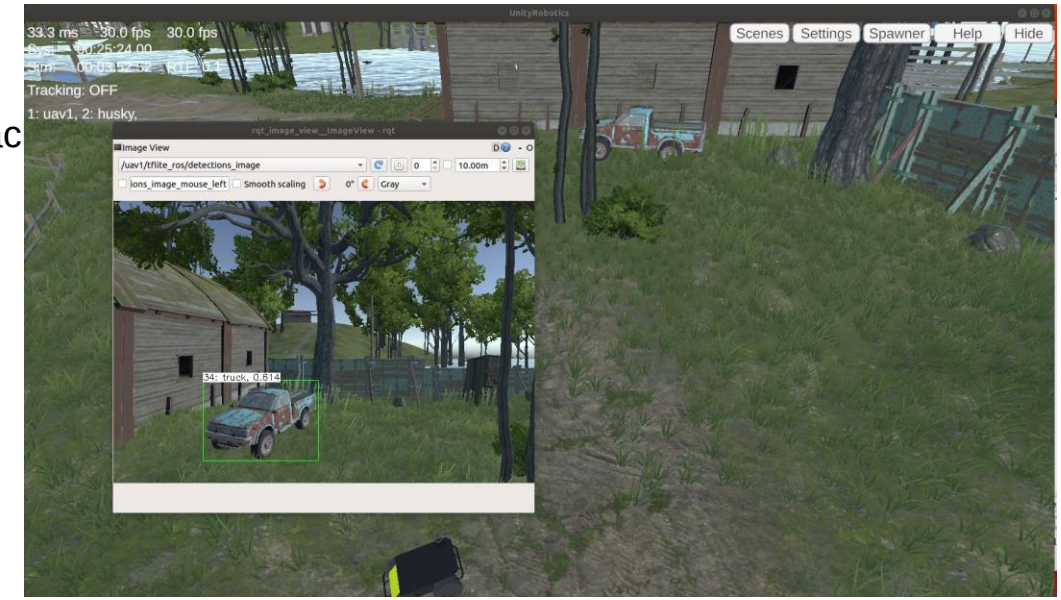
Simulation

Unity:

Part of the ARL-DCIST sim tools

ARL-DCIST Phoenix Ground Autonomy stac

ARL-DCIST Air Autonomy stack



DMI Sim Center:

State of the art facilities

Close to actual deployment

Current Sandbox sUAS

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Range Restrictions for sUAS:

- <= 20 lbs total weight
- FAA class G airspace
- Restricted mil airspace
- Have Certificate of Authority (COA)
- Have airworthiness approval
- Department of the Army approval
- 400ft AGL

Regular use:

- 10 areas approved for flight
- Max 48 hour advance notice prior to lift off

ModalAI m500

ATAK: GoTenna Pro + Samsung S21

FLIR Black Hornet

Parrot Anafi

Skydio X2

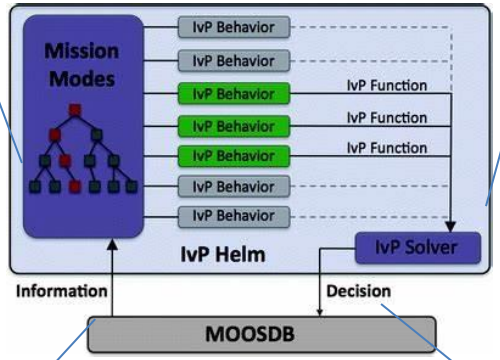
Custom F450/650

MOOS-IvP Across Sandbox

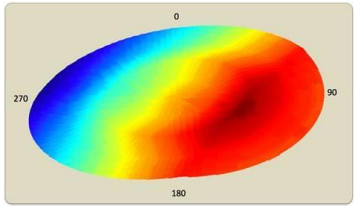
Department of Electrical Engineering and Computer Science

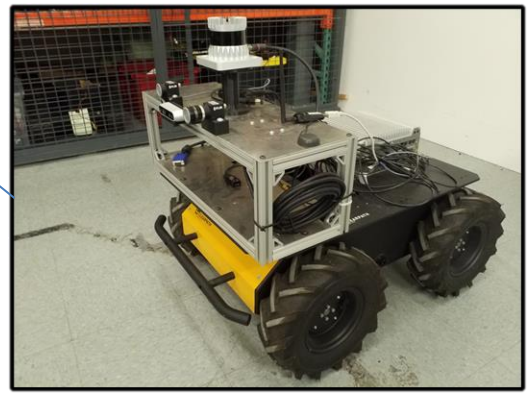
Clearpath Warthog

Boston Dynamics Spot



Custom F450/650





Boston Clearpath Husky

Cross Campus Collab

Cyber Research Center

- D5: deceive, degrade, deny, disrupt, destroy
- Spoofing of signals
- Attack/Defense of networks
- Target identification and digital recon
- Mission assurance

Photonics Research Center

- Below-the-horizon laser applications
- High Energy Laser effects on UAS and counter-battery
- Laser countermeasures of EO sensors
- IR Laser target designation

Future Collaborations

Accessible: Government and Academic Institutions.

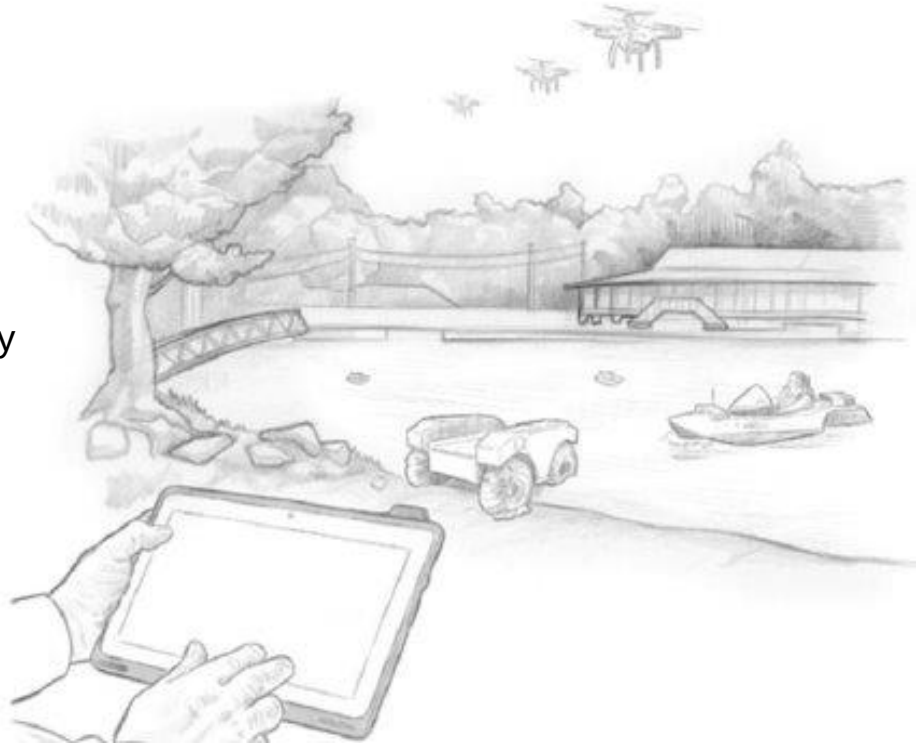
Benefits: Expose future officers to robotics, AI, autonomy that they will encounter during their careers.

Joint Services: Air Force, Army, Coast Guard, and Navy
Interoperability: AFRL, NRL C2 node at tactical edge

Coalition Forces: FVEYs

OSD TRMC: Data Gathering, T & E

JAIC: T & E, V & V



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Massachusetts Institute of Technology

Thank You