

OFFensive Swarm-Enabled Tactics (OFFSET)

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Program Manager

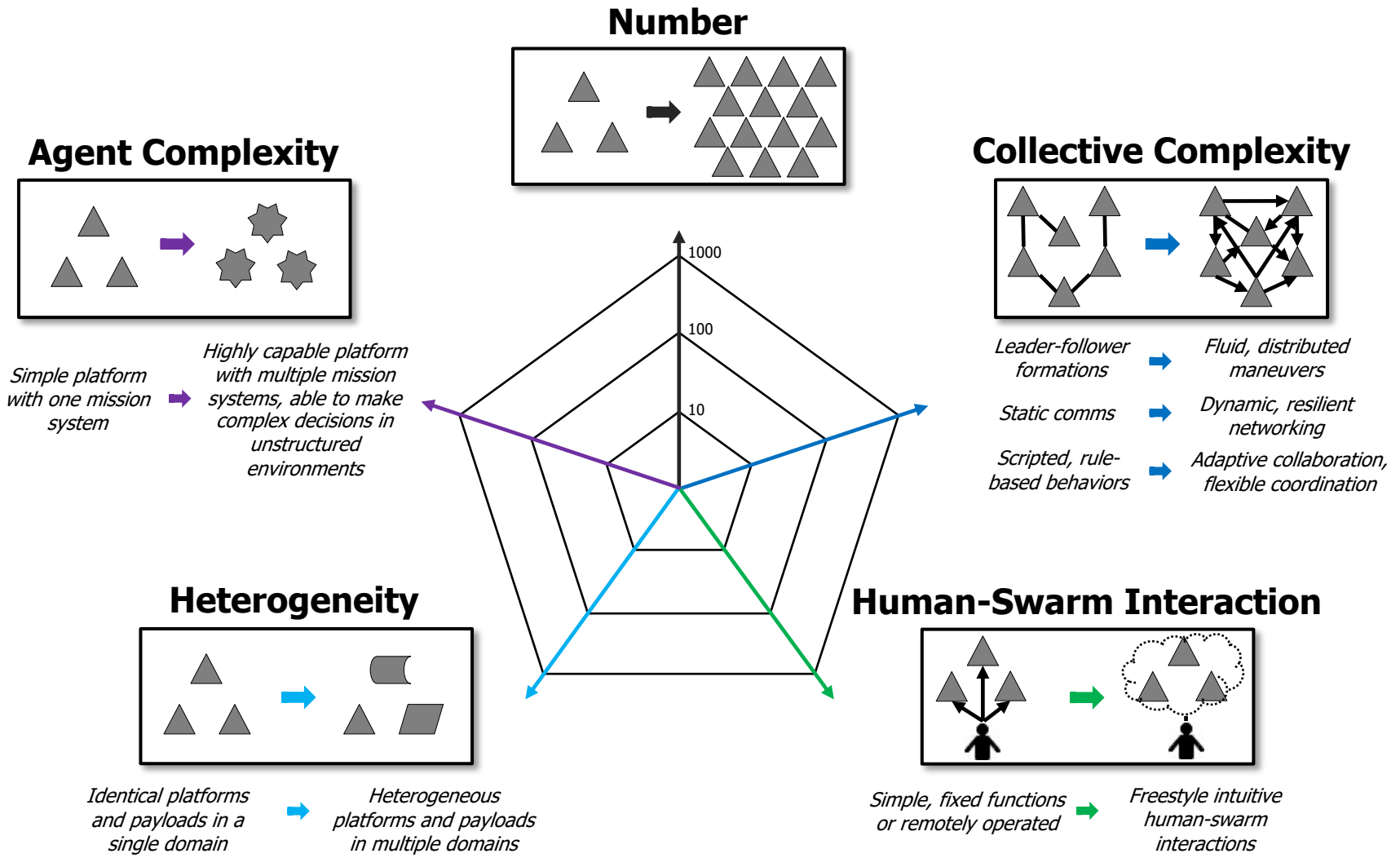
Tactical Technology Office

Defense Advanced Research Projects Agency

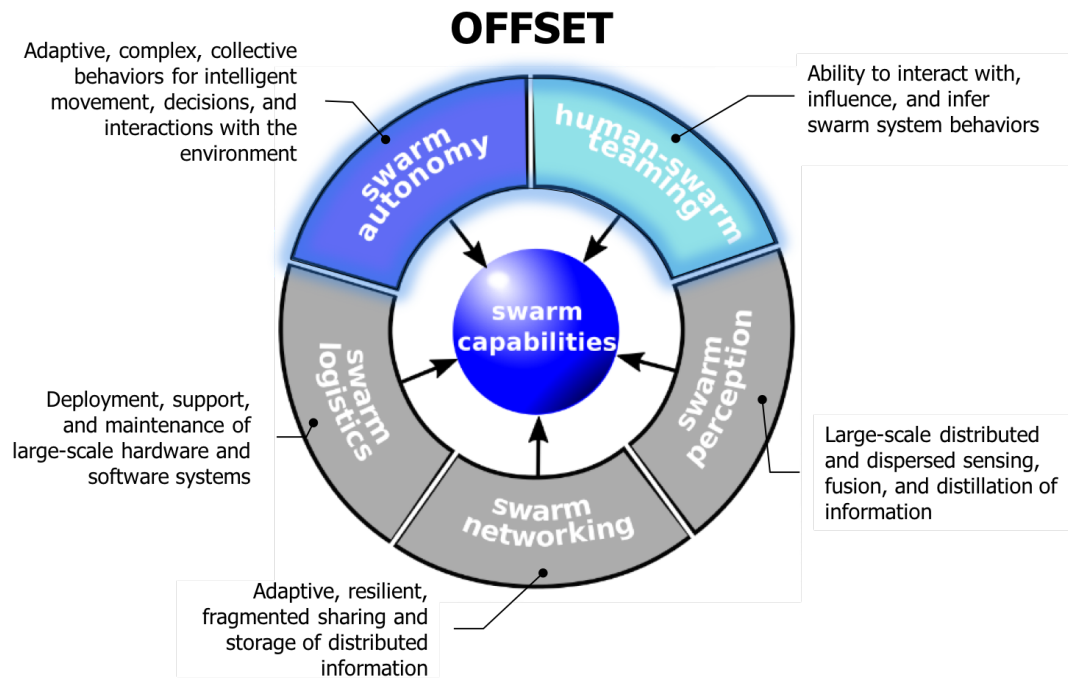
Briefing for the Naval Counter-Improvised Threat Knowledge Network

March 18, 2021



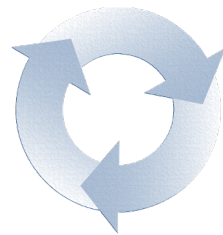


Discover innovative technologies to enable **large-scale teams of air and ground robots** to support **small-unit forces** operating in **complex urban environments**

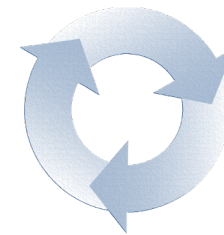


Objective Capability
Seize key urban terrain
4-6 hours
Approx. 8 square city blocks

Vignette 1
Isolate an urban objective
15-30 minutes
Approx. 2 square city blocks



Vignette 2
Conduct an urban raid
1-2 hours
Approx. 4 square city blocks



Objective Capability
Seize key urban terrain
4-6 hours
Approx. 8 square city blocks



Highlights from recently completed OFFSET FX-4 @ Joint Base Lewis-McChord, Washington

<https://www.darpa.mil/news-events/2020-09-18>

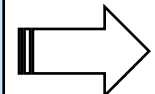
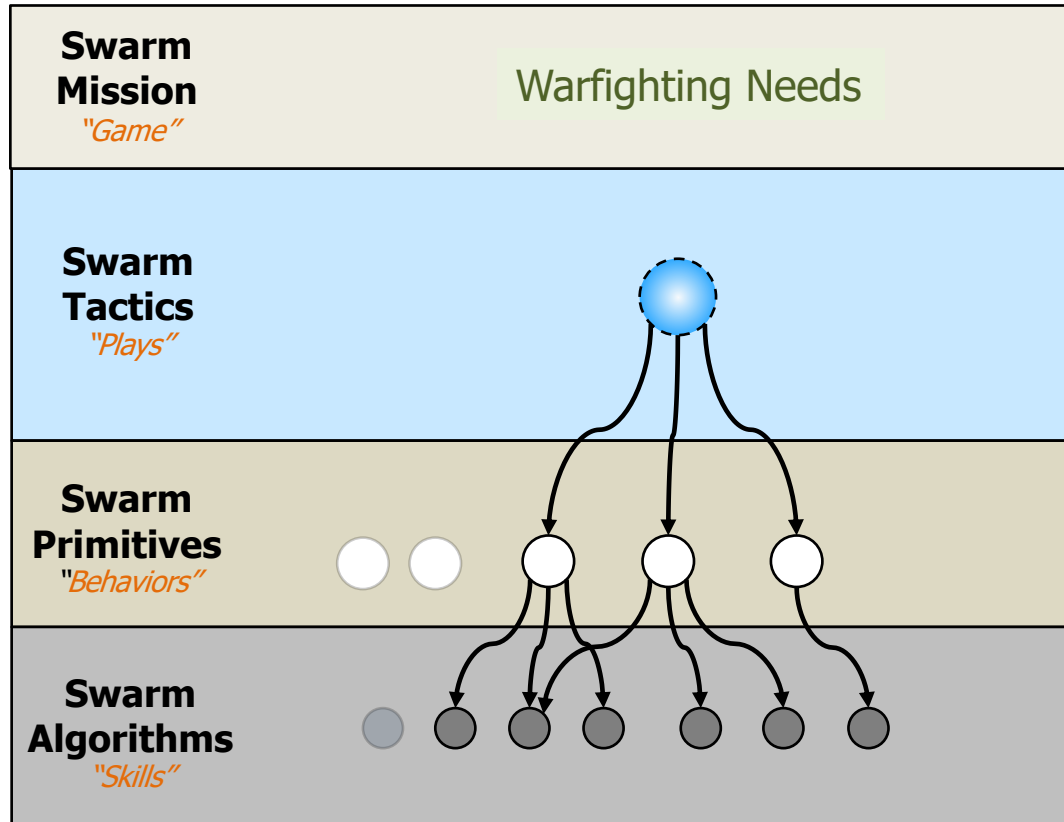
Swarm Tactics

Swarm Systems Architectures

Scalable Swarm Simulators

Modular Swarm Testbeds

OFFSET Focus



NORTHROP GRUMMAN



Rapid Integration Swarm Ecosystem (RISE)

OFFSET Swarm Systems Integrators

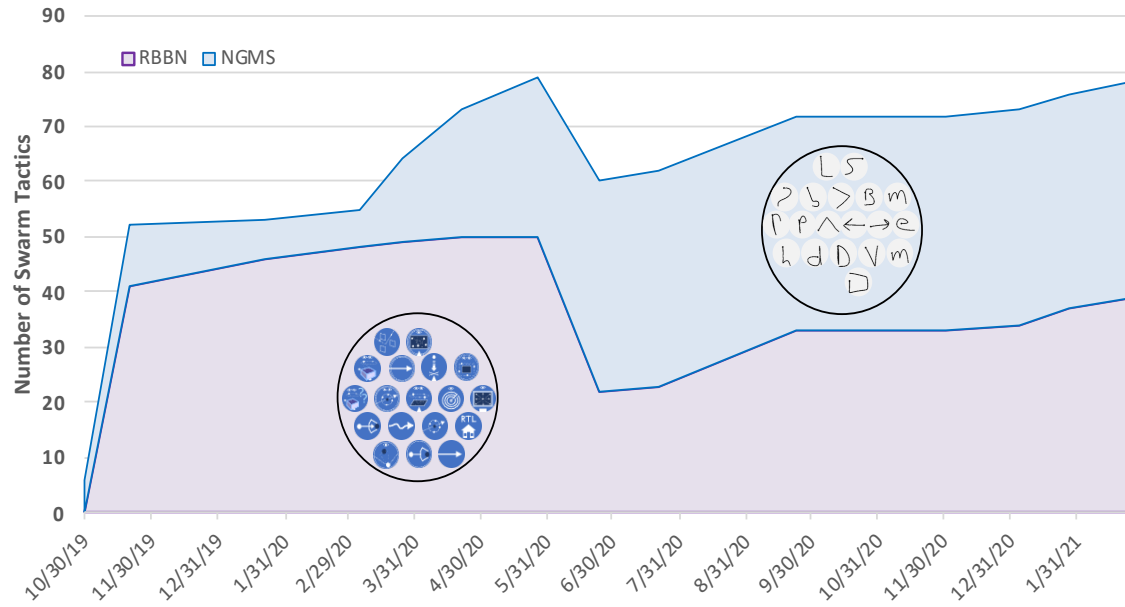


Command and Control of Aggregate Swarm Tactics (CCAST)



OFFSET Impact: Software Repository of swarm tactics code, user tutorials, and developer documentation

Swarm Tactics Count Evolution

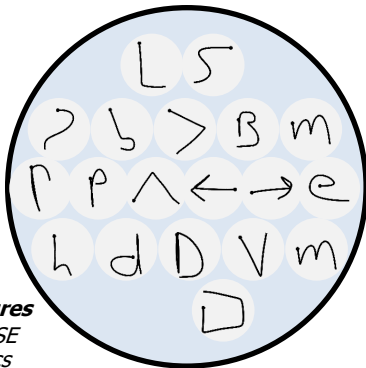


RISE Swarm Tactics Exchange

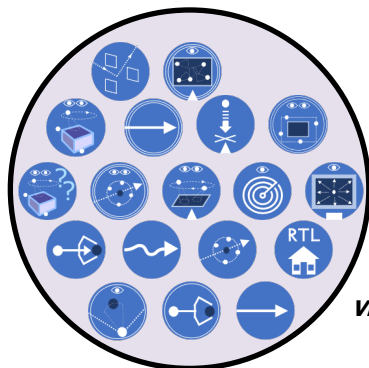
- | | | |
|--|--|--|
| <ul style="list-style-type: none"> • Examine Objective • Follow Route • Hold Position • Hover Above Current Location • Inward Scan • Move To • Multi-agent inward scan • Overhead scan • Ring around POI • UAV Test POI • RADAR scan for ST-MTRI • Safe Land • Sector split leader follower | <ul style="list-style-type: none"> • Platform test • Building scan • Waypoint navigation/POI • Tornado scan • Hover • Ring around POI • Overhead Scan • Multi-agent inward scan • Examine Object • Safe Land • Outdoor to indoor transition • Indoor exploration • Artifact handler | <ul style="list-style-type: none"> • Artifact secure • Building perimeter scan • Outdoor exploration • GPS to indoor explore • GPS to indoor non-explore • Indoor ramp traversal • Leader follower (follower) • Leader follower (leader) • Platform Test • Approach area • Breach Building • Waypoint Navigation/POI • Approach target area leader follower |
|--|--|--|

CCAST Swarm Tactics Exchange

- | | | |
|--|---|--|
| <ul style="list-style-type: none"> • Add To Replacements • Amass • April Tag Scan • Area Survey • Cordon Area • Cordon Building • Explore • Explore Building • Flock To LLA • Follow Object • Gather Ground Imagery • Go To • Go To – Complex | <ul style="list-style-type: none"> • Interact • Interact Go To • Join Quick Reaction Force • Land In Area • Land In Place • Look At • Maintain Proximity to AT • Patrol • Process Obstacles • Proximity • Relieve agent • Rendezvous at Point • Report Objects | <ul style="list-style-type: none"> • Return To Launch • Revive at Medic • Route Nav • Split • Stage In Area • Stop • Stop/Estop • Surveil Ground • Surveil Object • Surveil Area • Transition To Region • Watch Entry Points in Zone • Designate Quick Reaction Force |
|--|---|--|




Sketch gestures for NGMS RISE swarm tactics



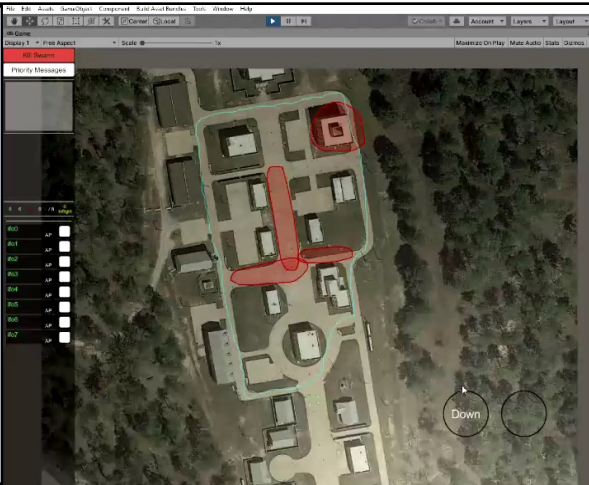
Virtual reality icons for RBBN CCAST swarm tactics

Overhead Scan




```
parameters = [
  Altitude
  Cell Size
  Agent Count]
```

Description: Fly UAVs over area to find artifacts

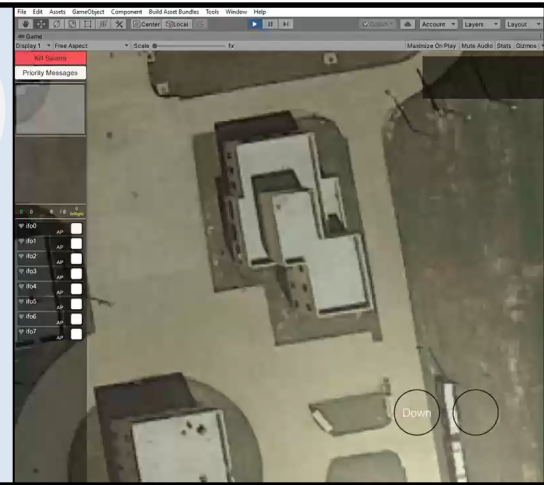


Multiagent Inward Scan

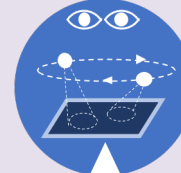


```
parameters = [
  Starting Altitude
  Level Count
  Distance Between Levels
  Agent Count
  Outward]
```

Description: Use multiple UAV agents to scan enclosed area specified by path stroke.



Surveil Area

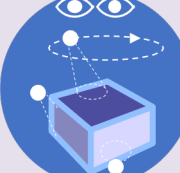


```
parameters = [
  Polygon
  Agent(s)
  Concluding Action]
```

Description: Command wildcard agent(s) to travel to user input area

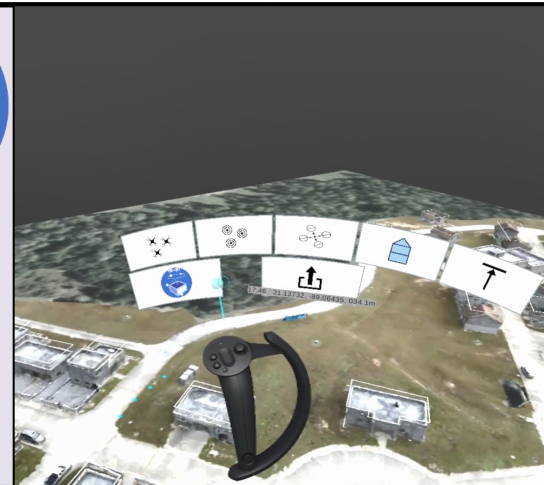


Surveil Object



```
parameters = [
  Building (spatial database)
  Agent(s)
  Concluding Action]
```

Description: Command agent(s) to travel to and surveil an object in the spatial database



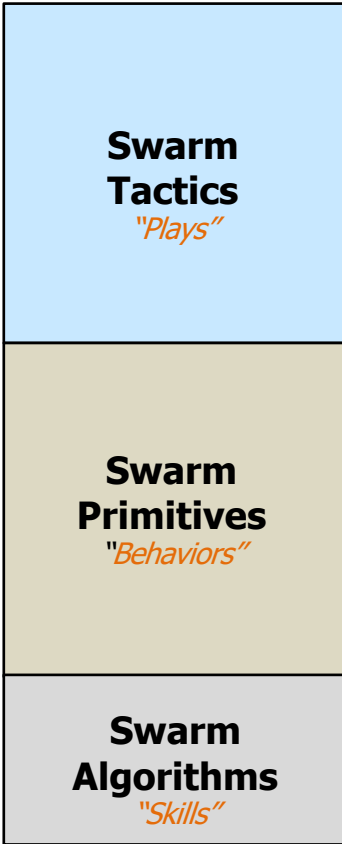
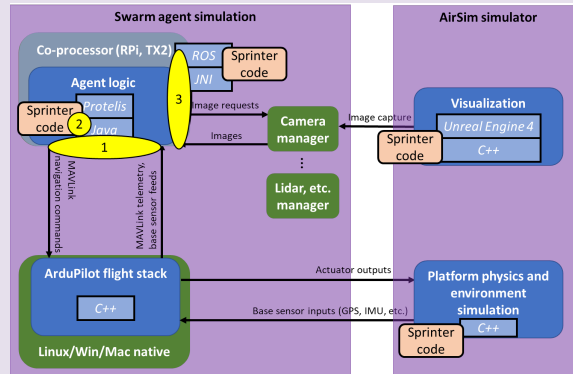
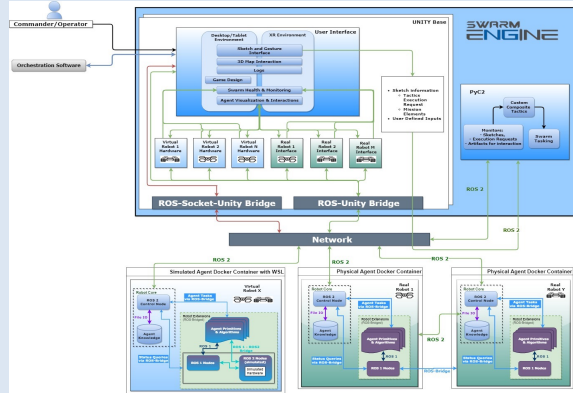
Swarm Tactics

Swarm Systems Architectures

Scalable Swarm Simulators

Modular Swarm Testbeds

NORTHROP GRUMMAN



Fact 1: real-world missions requires *composability*
Different approaches, different assumptions, different context

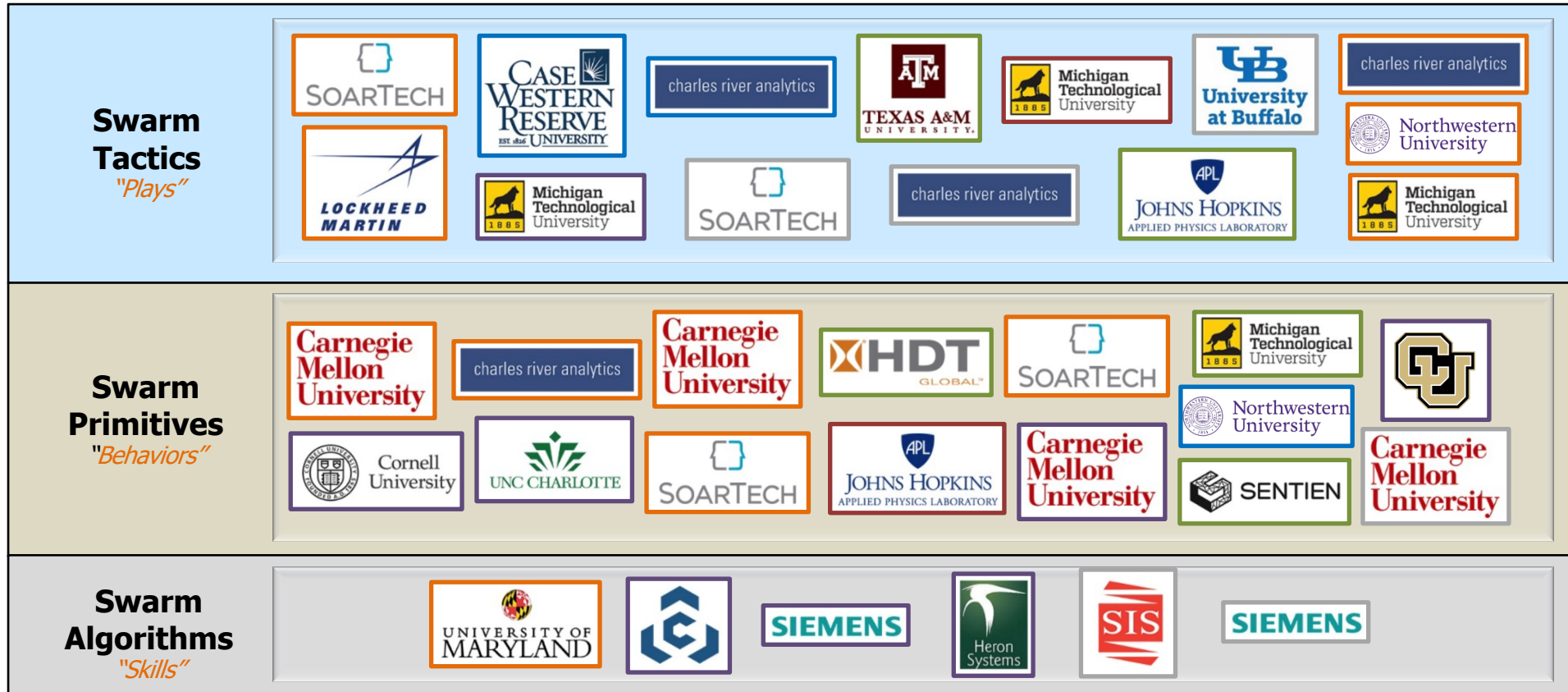
Fact 2: adopting new innovation requires *flexibility*
Novel ideas don't come in just one shape and size (or interface)

OFFSET relies on **composable** and **flexible**
swarm autonomy

swarm tactics | swarm primitives | swarm algorithms

OFFSET Impact: Swarm Sprinter-exercised *design patterns* for how to contribute novel swarm tech through flexible architecture interfaces

“Open architecture” means open to **diverse and flexible pathways** for integrating novel technologies



35 Swarm Sprinter efforts across five Swarm Sprints



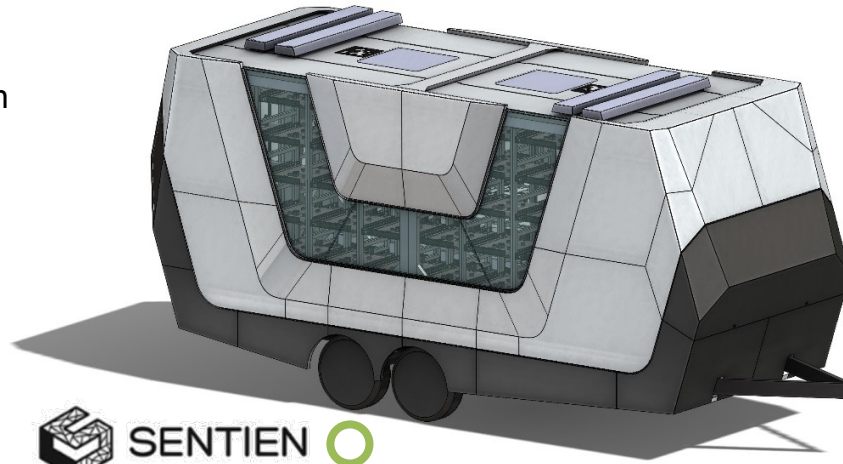
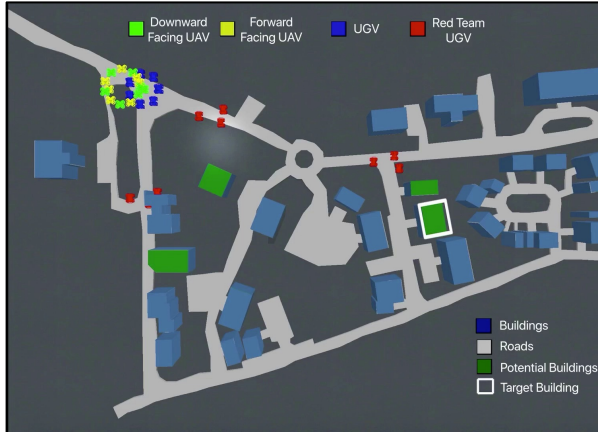
Swarm Sprinters: Spotlights

Swarm Sprint Thrust Areas:

Swarm Tactics Swarm Autonomy Human-Swarm Teaming
Virtual Environment Physical Testbed Applications of AI



ENHANCE: Evolving Neural Architectures with Human Augmented Novelty for Complex Environments



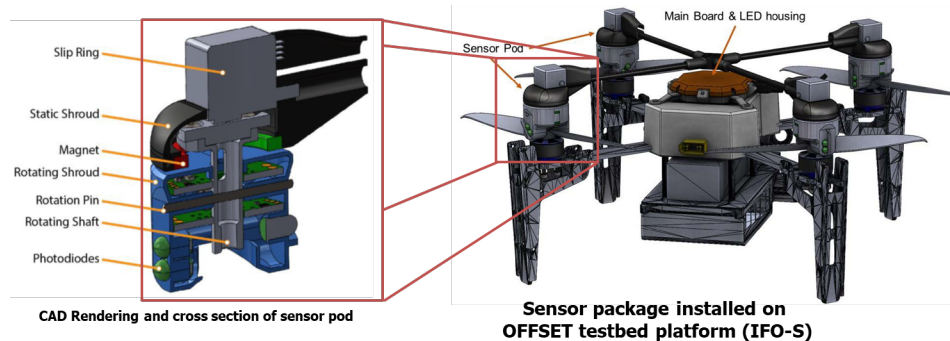
HiveXL: automated 80-drone launch, recovery, charging, and transport



ACCIPITER: Aerobatic Control and Collaboration for Improved Performance In Tactical Evasion and Reconnaissance



Rotor Mounted Bearing+Elevation Sensor



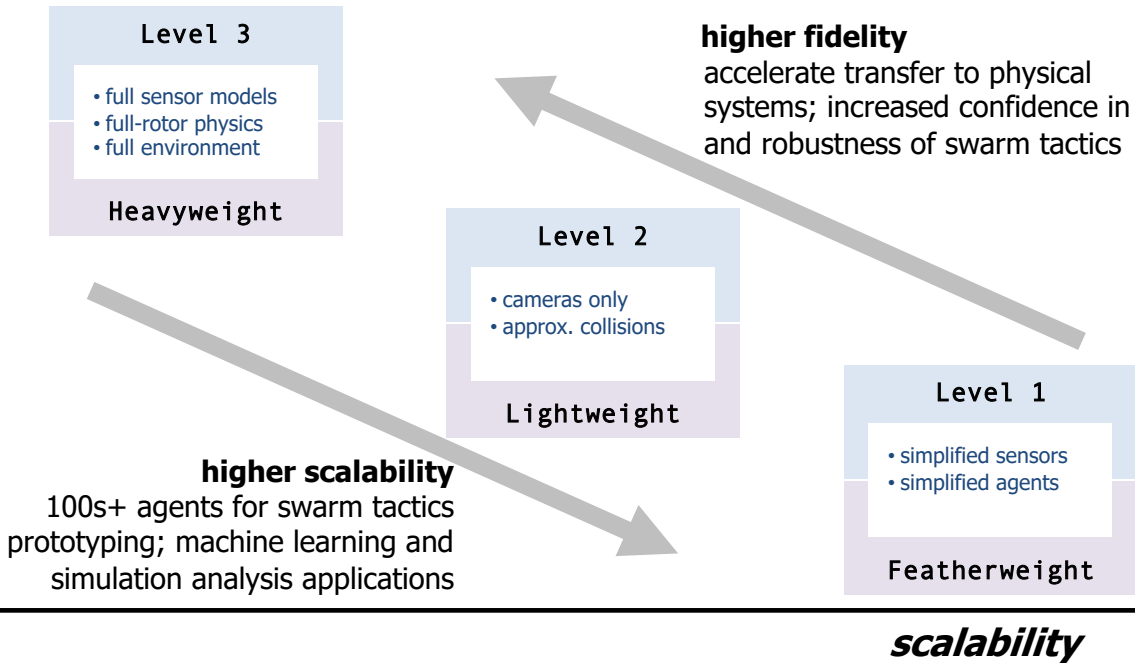
Swarm Tactics

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Modular Swarm Testbeds

fidelity



OFFSET Impact: Two extensible virtual environments for integrated autonomous systems simulation + development + testing



OFFSET Virtual Environments





Large-scale swarm mission scenario play

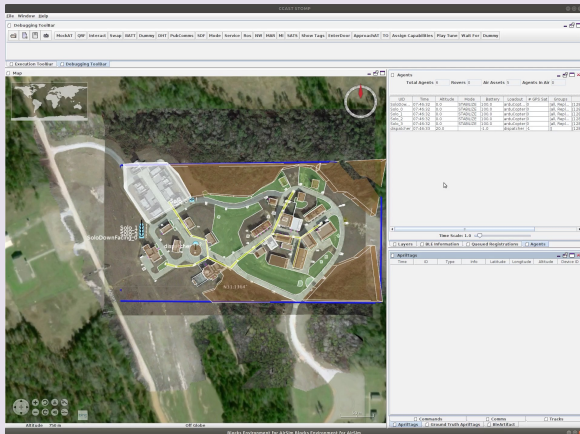


Temporal coverage sensor modeling



Multi-host swarm tactic execution

Variable faster-than-real-time simulation



Field test swarm mission rehearsal



Multi-robot environment interactions



Swarm Tactics

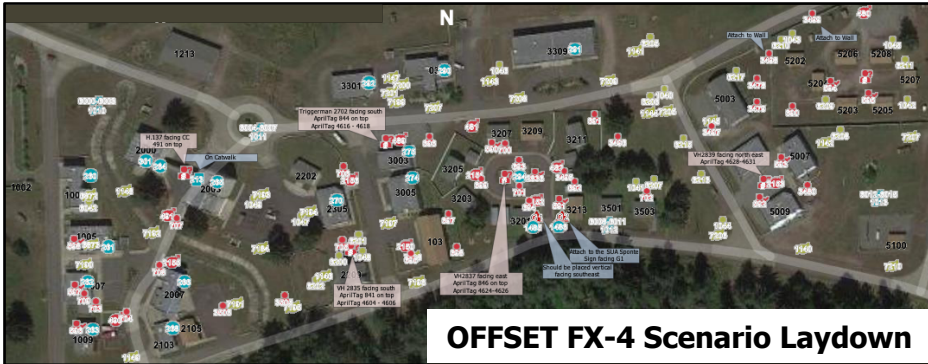
Swarm Systems Architectures

Scalable Swarm Simulators

Modular Swarm Testbeds

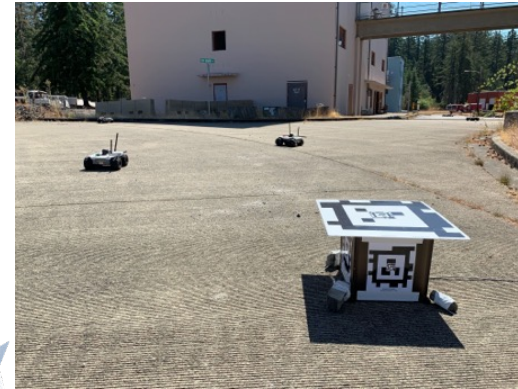


1. Design scenario for offensive urban operations



Joint Base Lewis-McChord "Leschi Town" CACTF

2. Rapidly instrument large-scale urban test sites



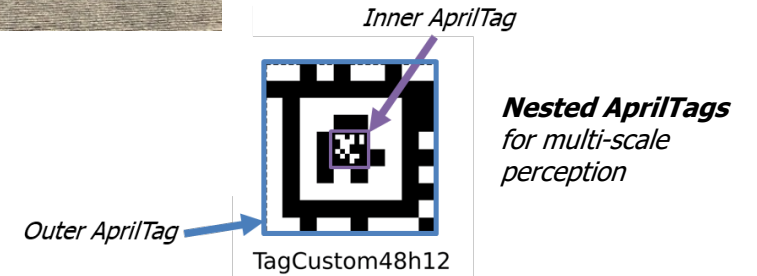
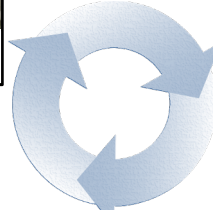
FX-4 Infrastructure Measures

- 5300+ meters of Ethernet
- 600 meters of optical fiber
- 811 Unique AprilTags
- 83 Raspberry Pi Nodes
- 26 network switches
- 14 USG team members

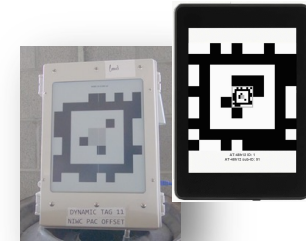
3. Orchestrate and capture real-time assessments of "Swarm Under Test"



Screenshot of networked orchestration software frontend (a.k.a. Mole)



Dynamic AprilTags:
E-ink screens for evolving scenarios



Operational Context		Vignette 1		Vignette 2		Vignette 3	
Representative Mission		Isolate an urban objective		Conduct an urban raid		Seize key urban terrain	
Mission Duration		15-30 minutes		1-2 hours		4-6 hours	
Area of Operations		Approx. 2 square city blocks		Approx. 4 square city blocks		Approx. 8 square city blocks	
Swarm Size		50		100		250	
FX Experiment		FX-1	FX-2	FX-3	FX-4	FX-5	FX-6
Date		Oct 22-25, 2018	June 5-13, 2019	Dec 7-19, 2019	Aug 1-12, 2020	Jan 2021	Jun 27-Jul 14, 2021
Location		 Camp Roberts	 Fort Benning	 Camp Shelby	 Joint Base Lewis-McChord	 Camp Shelby	 Joint Base Lewis-McChord

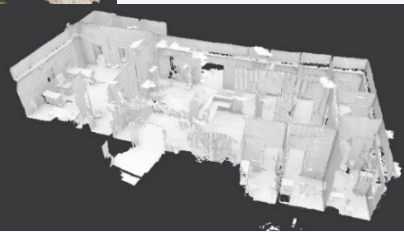
OFFSET Urban Scenario Reference Dataset



High-resolution 3D photogrammetric mesh



*Interior 3D mesh scans of all **33** building interiors in-play*



*Exterior building scan videos (by drone) for all **40** buildings in-play*

Scenario walkthrough videos (outdoor/indoor) of entire test range



What has OFFSET created?

- Library of collaborative autonomy software
- Swarm virtual environments as bridge to real-world
- Unique swarm datasets

What are (actionable) OFFSET lessons learned?

- Define point-of-departure swarm autonomy capabilities
- Seek applications needing high + fast "swarm power"

What comes next after OFFSET?

- Urban maneuver-capable platforms
 - **Still** need agile and adaptable robotic systems
- Swarm logistics enablers
 - On-the-move and/or federated swarm deployment
 - Swarm replenishment, recharge, and recovery technologies
- Counter swarm/autonomy



www.darpa.mil

OFFSET@darpa.mil

www.darpa.mil/work-with-us/offensive-swarm-enabled-tactics

Specification Overview

- PX4 Flight Stack
- NVIDIA Jetson Nano
- Intel RealSense D435
- GPS with Helical Antenna
- CSI/MIPI Camera
- TFMini LiDAR
- Rajant DX2



Capabilities

- Collision Avoidance
 - Static and dynamic
- Scanning Tactics
- Waypoint Navigation
 - Follow Route Tactic
 - POI
 - Hover/Loiter
- Camera Feed & AprilTag Detection – forward & downward
- Depth sensing via RealSense and TFMini LIDAR

Specification Overview

- ArduRover Flight Stack
- NVIDIA TX2
- Intel RealSense D435/D415
- Here2 GPS
- Embedded Wheel Encoder
- RPLIDAR
- Rajant ES1



Capabilities

- Collision Avoidance
 - Static and dynamic
- Scanning Tactics
 - Area Scan
- Waypoint Navigation
- Depth sensing via RealSense and RPLIDAR
- Indoor Capabilities
 - Building Breaching Tactic
 - SLAM
 - GPS-denied capable
- Camera Feed & AprilTag Detection

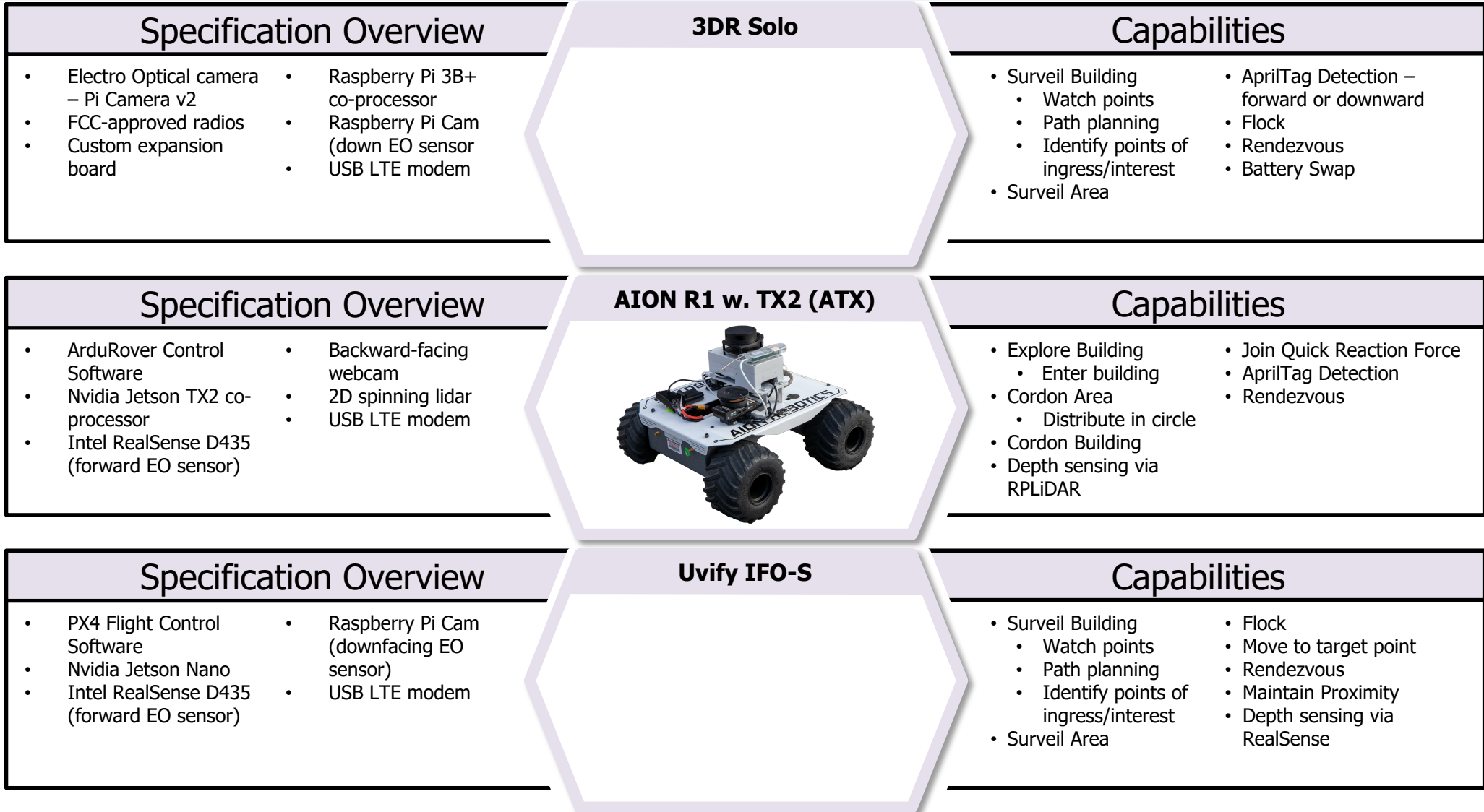
Specification Overview

- ArduPilot Flight Stack
- NVIDIA Jetson Nano
- Here2 GPS
- Downward CSI/MIPI Camera
- Rajant Dual Band mini radio



Capabilities

- Overhead Scan and SA
- Waypoint Navigation
 - Follow Route Tactic
 - POI
 - Hover/Loiter
- Downward Camera Feed & AprilTag Detection



Specification Overview	Modal AI VOXL m500	Capabilities
<ul style="list-style-type: none"> • VOXL Flight Deck with PX4 • GPS/Compass • PWM breakout board • Stereo image sensor • Tracking image sensor • 4K image sensor 		<ul style="list-style-type: none"> • Surveil Building <ul style="list-style-type: none"> • Watch points • Path planning • Identify points of ingress/interest • Surveil Area • AprilTag Detection – forward or downward • Flock • Rendezvous • Battery Swap

Specification Overview	mRo Nano Talon EVO	Capabilities
<ul style="list-style-type: none"> • ArduRover Control Software • Nvidia Jetson TX2 co-processor • Intel RealSense D435 (forward EO sensor) • Backward-facing webcam • 2D spinning lidar • USB LTE modem 		<ul style="list-style-type: none"> • Combat Air Patrol • Surveil Building <ul style="list-style-type: none"> • Watch points • Path planning • Identify points of ingress/interest • Explore • AprilTag Detection

Specification Overview	JHU Custom Fixed Wings	Capabilities
<ul style="list-style-type: none"> • mRo Control Zero F7 • Intel NUC • Ardupilot/ACCIPITER • Basler Dart (EO Camera) • RFD900U telemetry radio 		<ul style="list-style-type: none"> • Multi-Agent Fixed-Wing Building Scan • Multi-Agent Fixed-Wing Aerobatic Decoy