CASPR™ Overview

CASPR™

- Thunderbolt's Common Autonomous Sensors & Platform Readiness Framework (CASPR™) is a patent pending Modular Open Systems Architecture (MOSA) battle management aid that is scalable and highly configurable.
- CASPR orchestrates people, sensors and unmanned vehicles (UxVs) to complete mission tasks like resupply, overwatch, reconnaissance and CUAS.
- Originally developed for first responders, CASPR is currently being enhanced under Army and Navy contracts to support crewed-uncrewed teaming and CUAS capabilities.
- CASPR enhances a team's capabilities by integrating existing currently unintegrated or under integrated low-cost systems like hand-held EW CUAS systems, tactical sUAS and small mobile CUAS ELINT and radar systems.

CASPR™

Operator

Asset

- Operator Initiated Tasking
- Mission Task Management

- Asset Control and Status
  - Human to Human
  - Autonomous / Common Controllers

Sense

Orchestration

- Manage Mission Task Lifecycle
  - Asset Selection
  - Persistence/Aggregation
  - Operator Interface

Mission Tasks

- Sensor Initiated Tasking
- Sensor Data

- Mission Task Execution

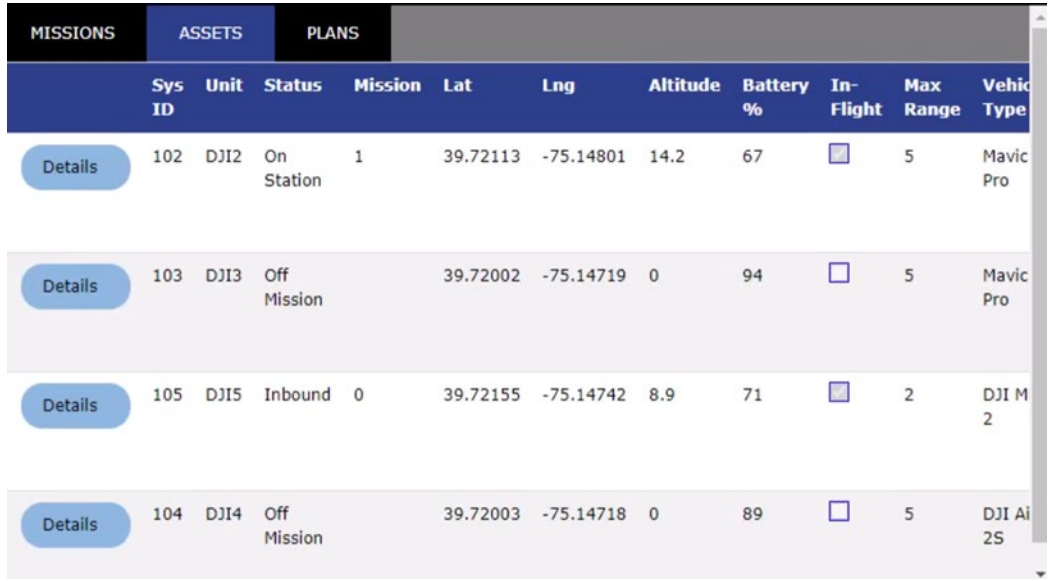
- Recon
- Overwatch
- CUAS
- Resupply
- Visual ID
- Comms
- Leapfrog

- Sensor Data
- External Controls

External COP/C2
(e.g SSDS, Aegis, Minotaur, ATAK, IBCS)

Asset Orchestration and Persistence

- CASPR can select an asset to meet specific mission without understanding the specifics of the underlying platform.
- If the designated platform/effector or sensor is lost, another platform needs to satisfy that mission.
- CASPR will task the next available platform to fulfill the mission task – a next person up mindset.
- CASPR™ will evaluate available assets and pair two together to accomplish the aggregate mission tasks.
- Create virtual assets composed of dozens of platforms that represent their larger manned counterparts.



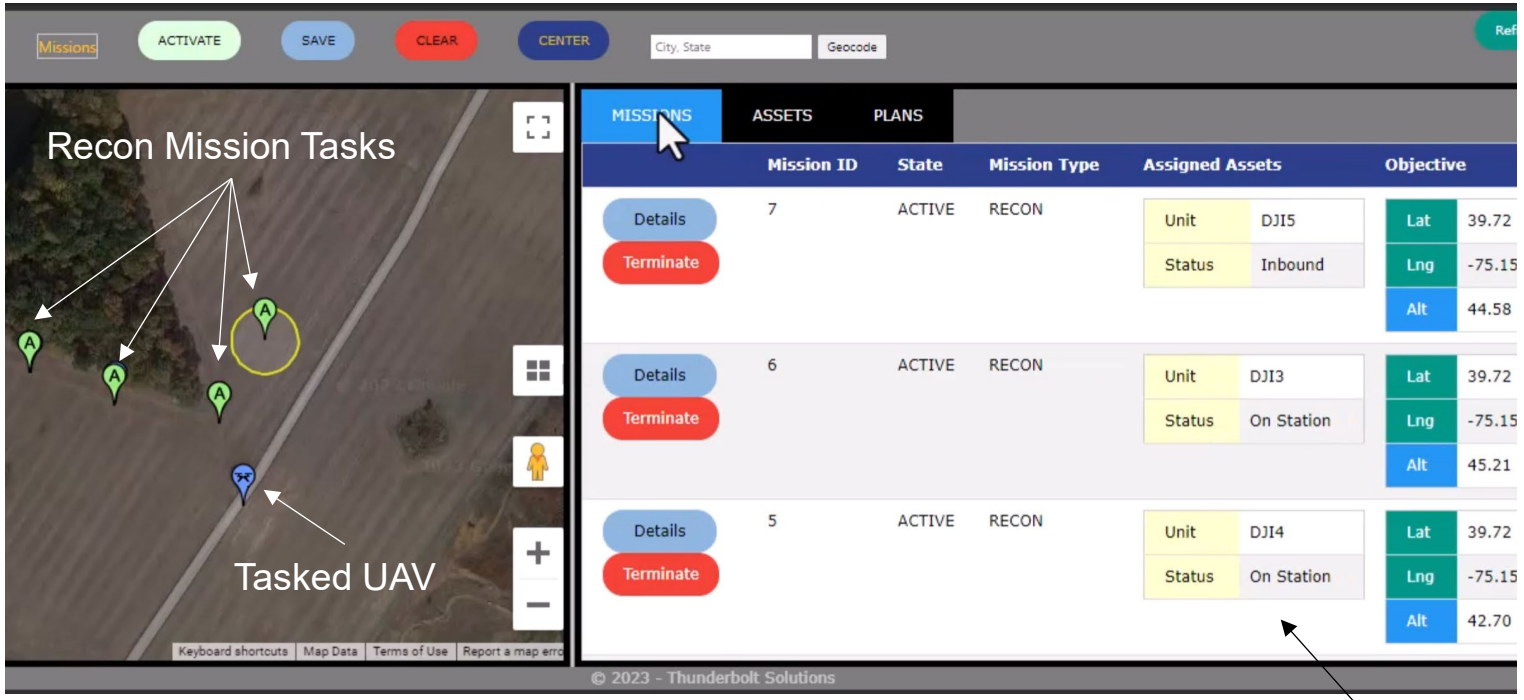
	Sys ID	Unit	Status	Mission	Lat	Lng	Altitude	Battery %	In-Flight	Max Range	Vehic Type
Details	102	DJI2	On Station	1	39.72113	-75.14801	14.2	67	☐	5	Mavic Pro
Details	103	DJI3	Off Mission		39.72002	-75.14719	0	94	☐	5	Mavic Pro
Details	105	DJI5	Inbound	0	39.72155	-75.14742	8.9	71	☐	2	DJI M 2
Details	104	DJI4	Off Mission		39.72003	-75.14718	0	89	☐	5	DJI Ai 2S

CASPR™ Asset Roster Display with Asset Status Information for Asset Management

Asset Orchestration Focuses on Completing Missions Using All Available Assets

Complex Mission Behavior Planning - Mission Composition

- Tasks can be combined to support more complex behaviors and mission objectives.
- For example, we might want to establish a forward deployed sensor picket consisting of 4 ISR platforms (See Figure).
- Mission Tasks can be executed in real-time or saved as part of a planning activity.
- Individual mission tasks like sensing and force projection can be combined to support complex mission sets like anti-air warfare.
- Layered Approach to Asset Orchestration Supports Complex Mission Behavior Planning



Sensor Picket – 4 Simultaneous sUAVs

Mission Task List

Mission Composition Supports Both Asset Command and Control and Complex Mission Behavior Planning.

Task Aggregation

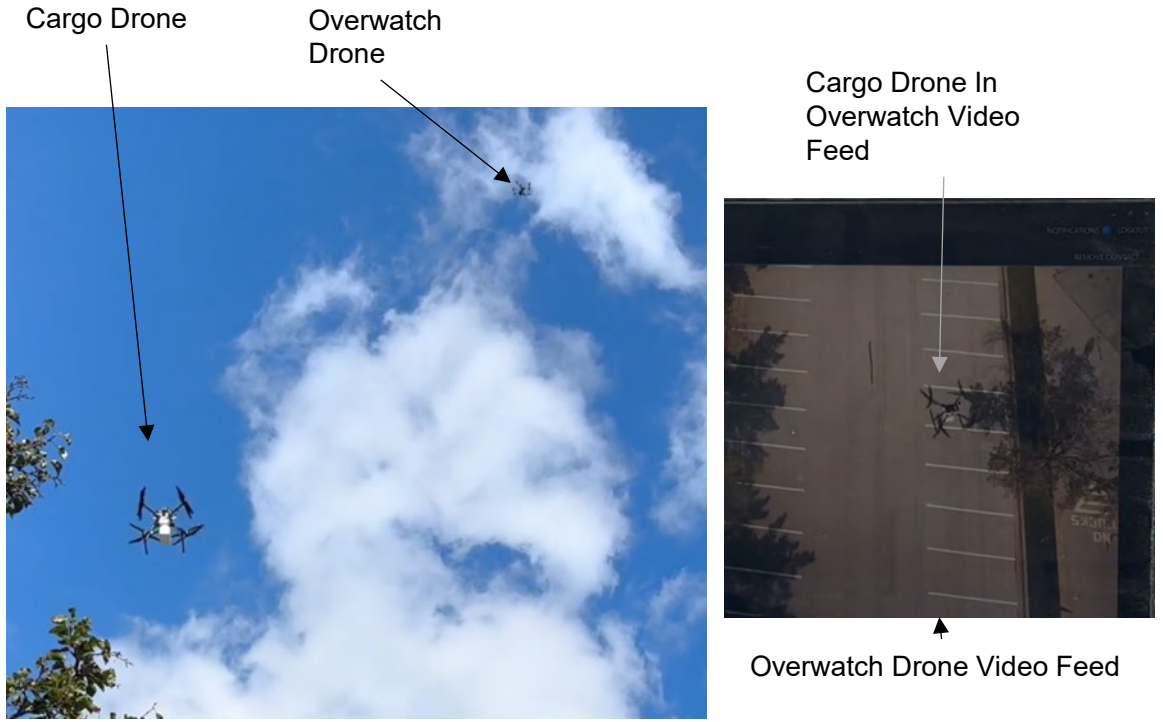
- CASPR™ can combine similar mission tasks into more complex behaviors like an ISR picket.

- Individual Mission Tasks can be aggregated to perform more complex behaviors.

  - For Example, an operator can combine a Resupply Task with an Overwatch Task.
  - This provides the drone operators or commander with situational awareness.

- CASPR™ orchestrates available assets to accomplish the aggregate mission tasks.

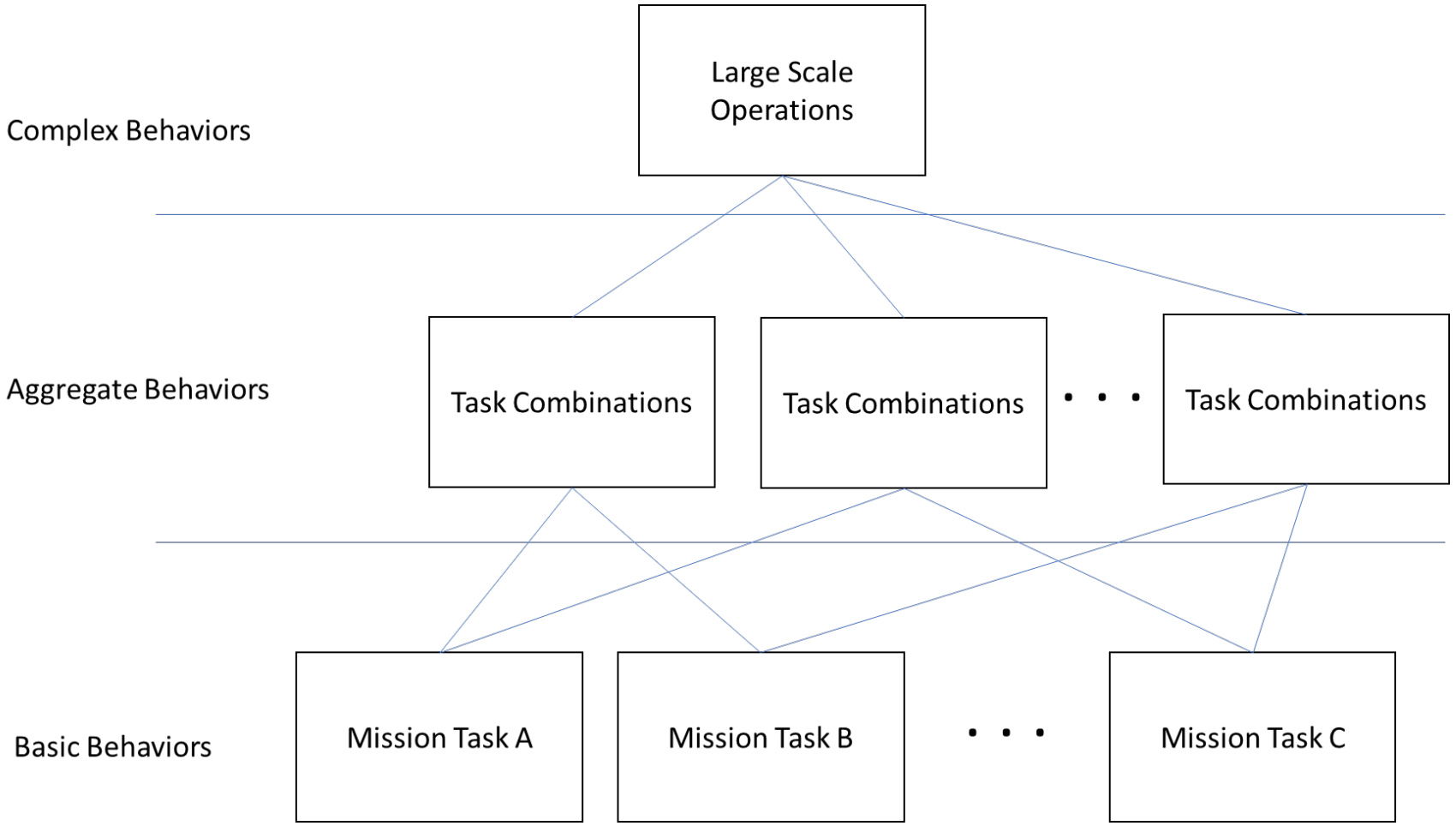
- Software enabled optimization of assets to perform equivalent function of complex platforms.



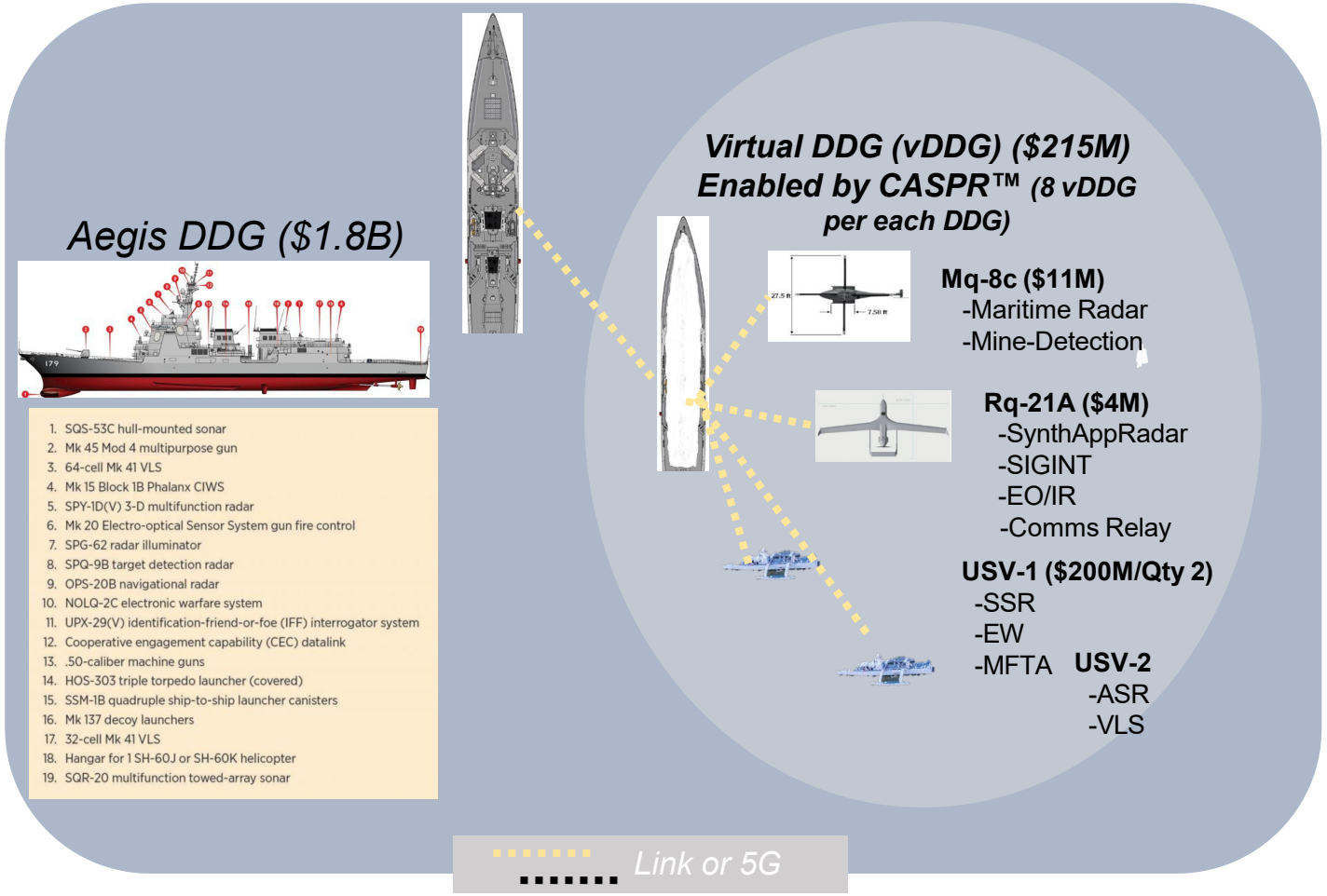
Live Resupply With Overwatch Mission Task Execution

Task Aggregation Is a Force Multiplier to Achieve More Complex Missions

Mission Task Hierarchy



CASPR™ End Goal - Virtual Platforms



A CASPR™ Virtual Platform is a geographically dispersed set of assets orchestrated to perform the same missions as their larger manned counterparts to provide:

- Increased Standoff Range
  - High Value Assets can Operate Further from Danger
- Persistence Of Capability/Improved A0
- Reduced Costs
  - Platform Cost
  - Staffing Efficiencies
- Scalable
- Multi-Echelon
- Platform-agnostic

Architecture and Components

CASPR™'s Modular Architecture

Commander

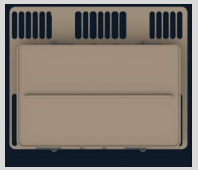
CASPR Command (Mobile Command Kit Or Laptop)

Drones (examples)

Alta-X(Resupply)

DeltaQuad (Recon)

Sensors (examples)



EchoGuard

Bellringer CUAS ELINT

RAPTAR (Laser Designator)

Over 300 Additional Sensors Integrated

- ADS-B and AIS
- Seismic
- Magnetometer
- Passive Infrared
- Ground Radars
- Weather
- Industrial Gas
- CBRN: Blister/nerve, RAD/NUC
- Signal Intelligence
- Gunshot Detection
- MWIR/SWIR
- Thermal
- COTS Electro Optical cameras
- Cognitive (e.g. facial recognition)
- License Plate Recognition
- ELINT: AirWarden, Bellringer, Drone Scout
- Radar: EchoGuard,EchoShield
- UAV Image recognition

- Tasking
- Telemetry
- Sensor Data

Planning/Fusion/Orchestration Engine

- Mission Command
- Mission Management
  - Recon, Overwatch, Resupply, CUAS, Leapfrog, Visual ID, Comms
- Asset Status
- Sensor Data Fusion and Distribution

UxV Plugins

Common Controller Env Plugin

Rules Engine

Web Display

Sensor Plugins

- Sensor Data
- Mission Events

Service Plugins

Edge or Cloud Services/ Data Streams (e.g. AI/ML)

Dismounts, Operators, Drone Operators

COP/C2 Plugins

COP/C2 (e.g. Minotaur, ATAK, SSDS, BC3)

Virtual Aegis Weapon System (Q2 2025)

- Mission Tasking
- Wearable Sensors

CASPR Mobile

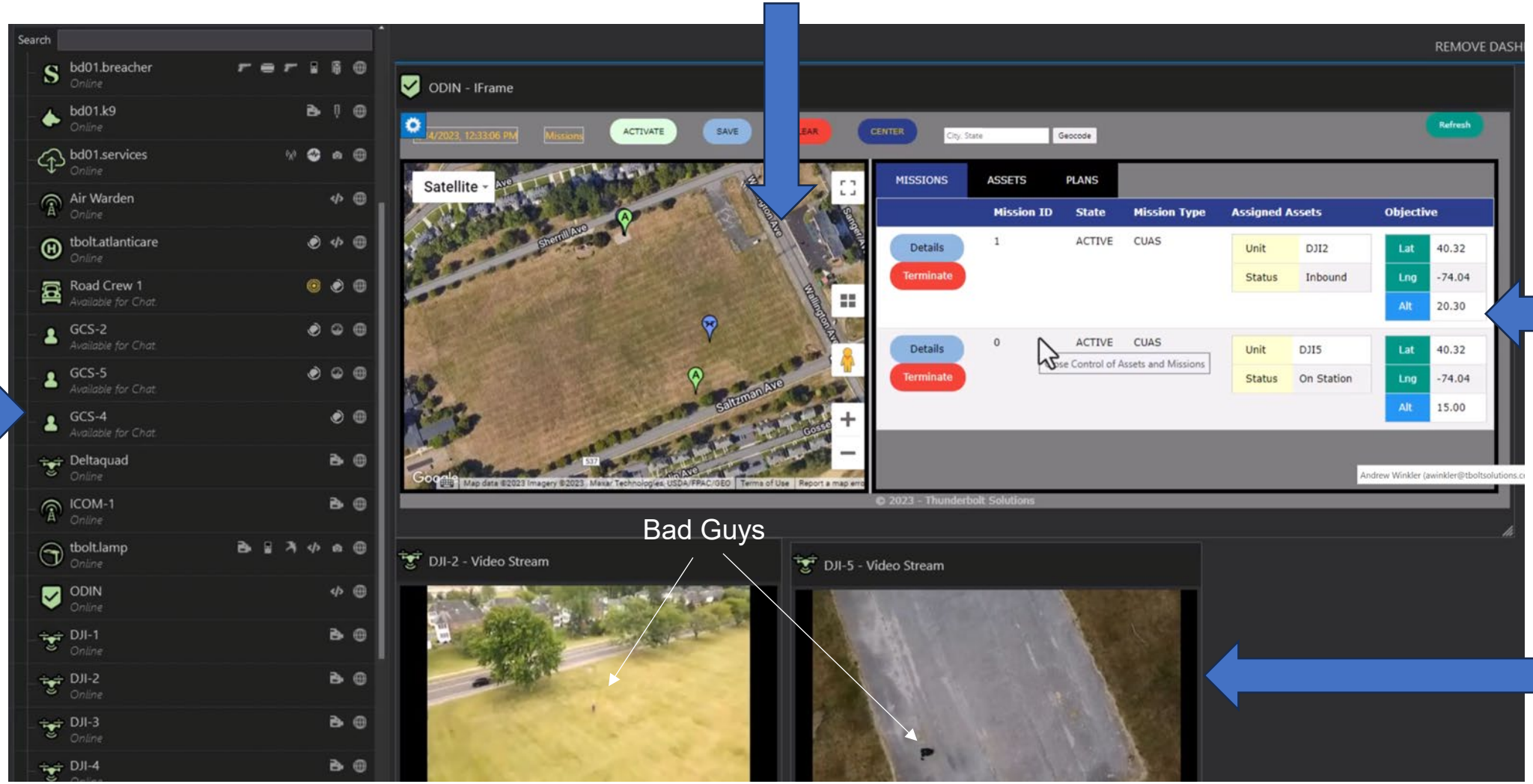
Autopilots Supported

- **DJI**
- **Ardupilot**
- **Pixhawk**
- **Auterion**

Common Controllers

- **Kinesis (AeroVironment)**

CASPR™ Mobile Command



Screenshot of Live CUAS Testing where CASPR™ was autonomously sending drones to locations of drone operators identified by a AirWarden a CUAS COMINT Platform.

CASPR™ Mobile App

Situational Awareness
- Displays Sensor Data from Sensor Sources and Mission Tasks

Tactical Presence
- Location, network location, device health, and end-user status fused and self-synchronized to provide complete awareness of every endpoint.

Location Services
- Precision geospatial location sharing for outdoor use, inertial navigation location for subterranean use, and beacon support for GPS denied environments.

FIPS 140-2 Security
- Information security at rest and in transit using military grade FIPS 140-2 certified cryptography for authentication and encryption.

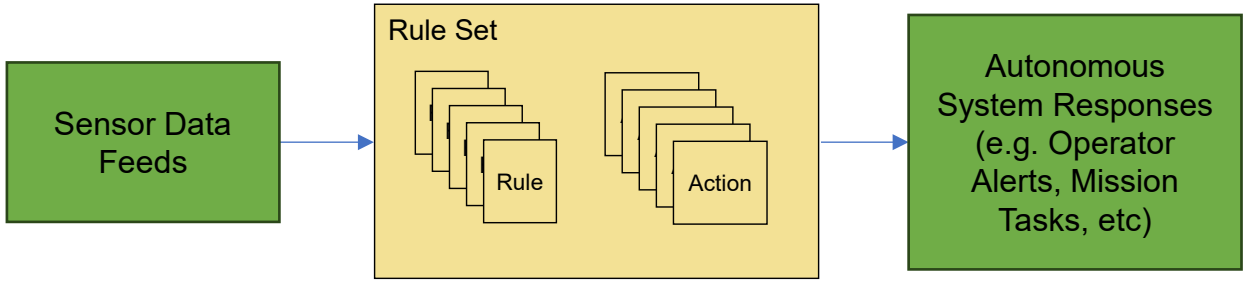
Rapid Adaptation
- Plugin architecture for integration of operator worn or controlled sensors.

Interoperable
- Built on open standards enabling interoperability between agencies and information systems.

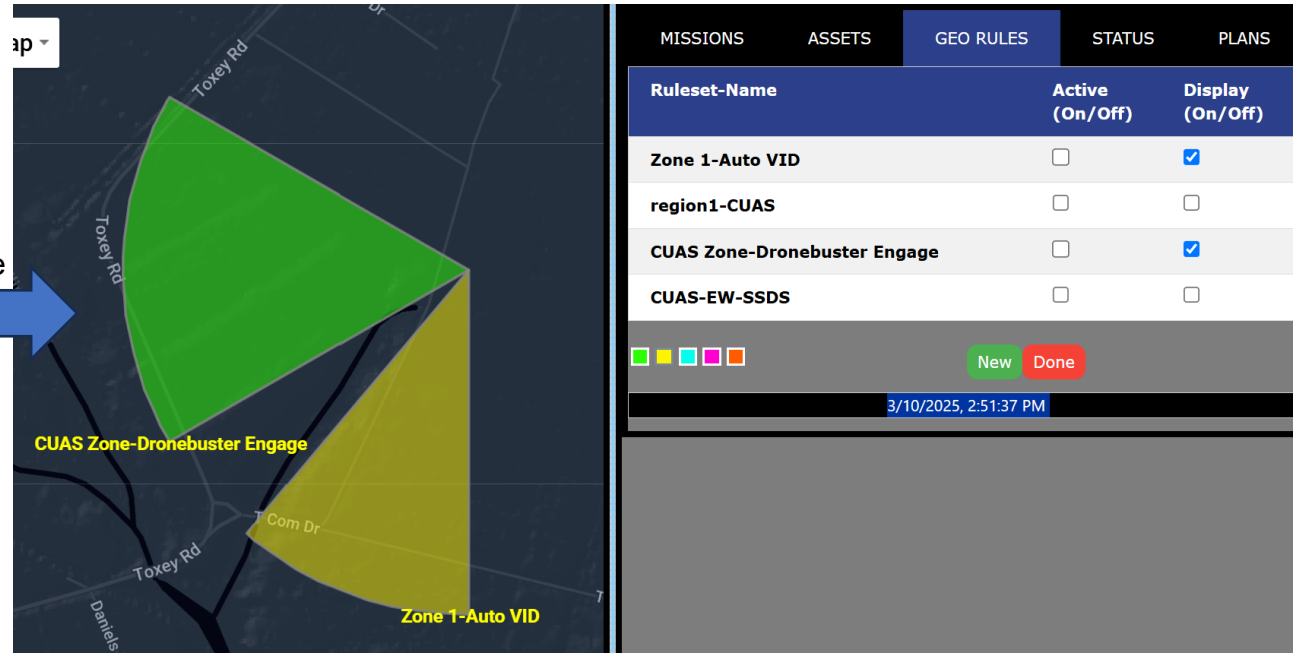
CASPR™ Mobile App Allows Additional Flexibility and Enables Coordination of Mobile and Dismounted Assets.

CASPR™ Rules Engine

- CASPR™'s Rules Engine provides automated decision support for operators.
- Operators Create system behaviors by combining rules evaluating internal or external data with system responses or "Actions".
- Situational Awareness add-on provides standard set of rules to evaluate track kinematics and geospatial geometries.
- Provides evaluation capabilities for complex behaviors (e.g. swarm, convoy, convergence, follow).
- Enables automated decision support to manage operations and workload to enhance decision-making.



User Composable Behaviors



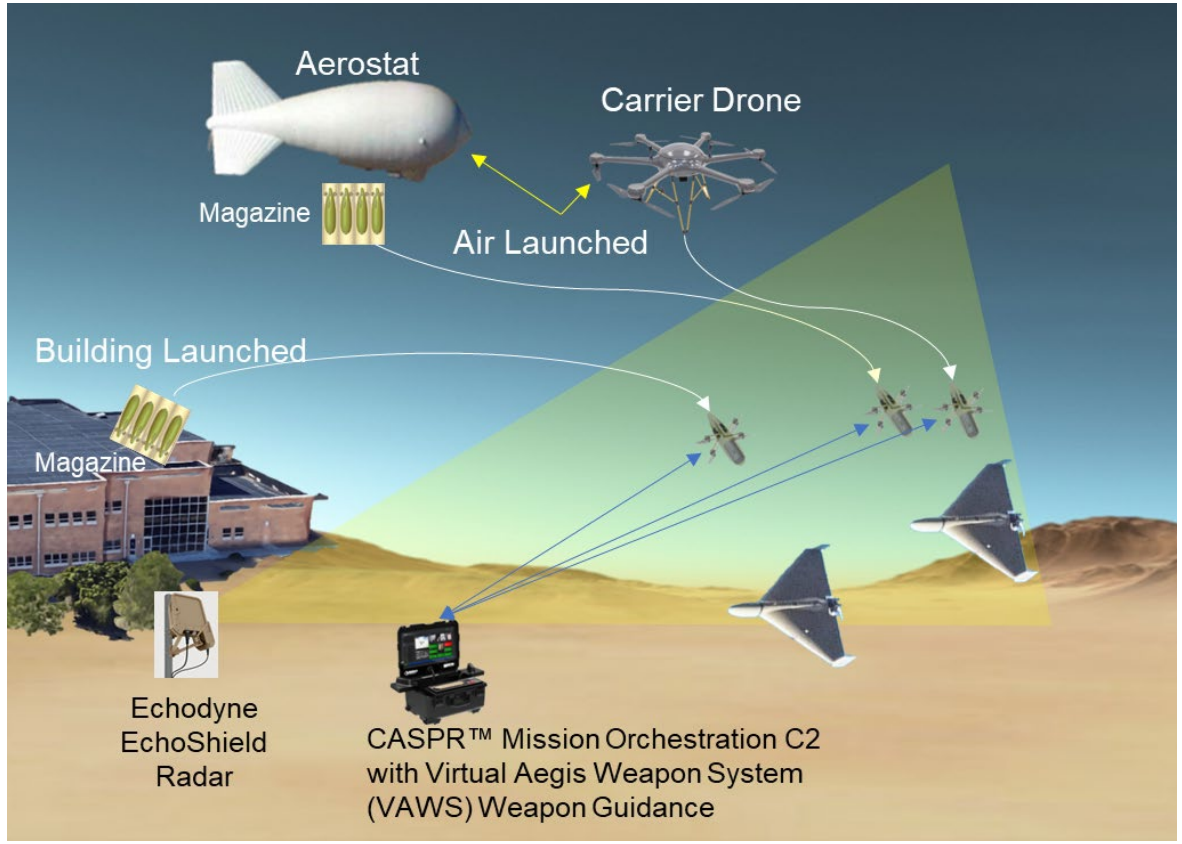
CASPR™ Rules Engine provides and additional layer of capability supporting Complex Mission Behavior Planning and Integration of External Information Streams

CASPR Applications

Peregrine - CASPR Orchestrated Low Cost CUAS Interceptor

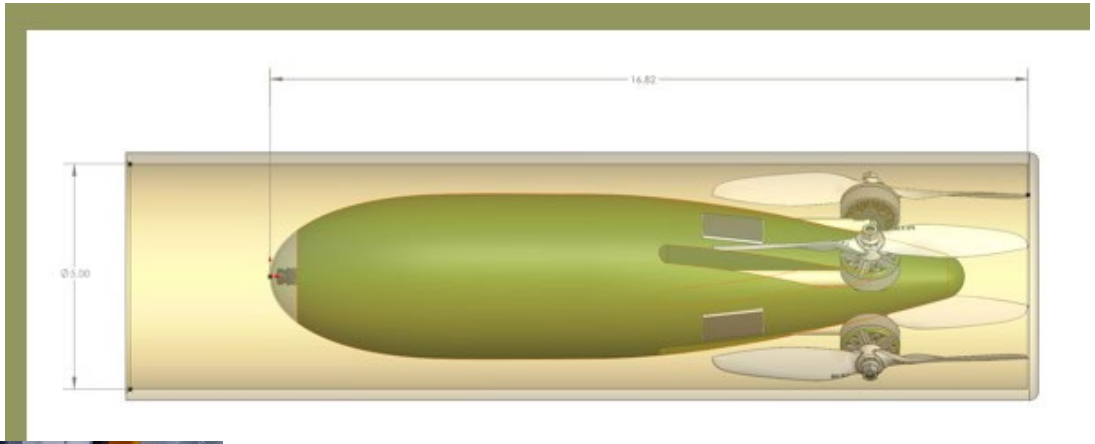
Peregrine

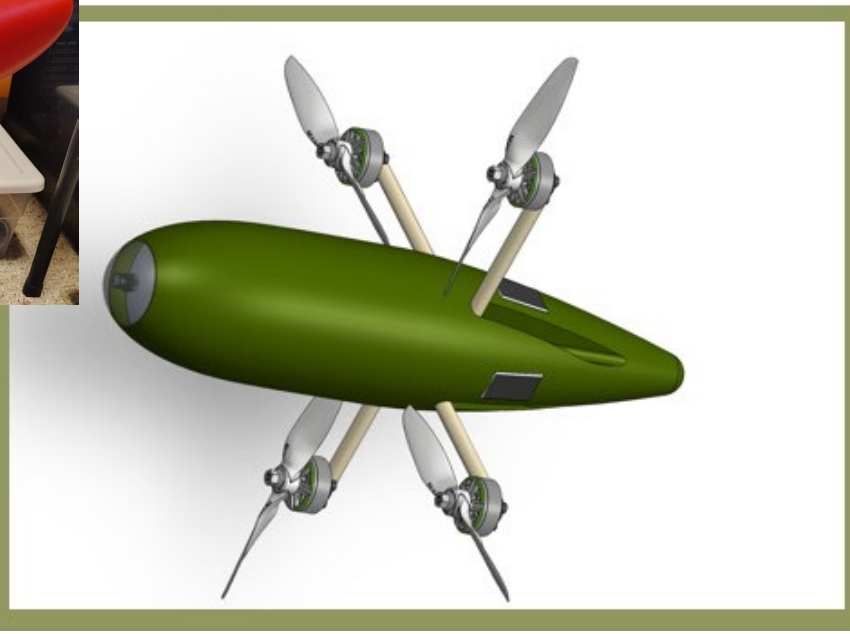
- Peregrine is a low-cost kinetic CUAS interceptor designed for fixed altitude launch from Aerostats, Drones or Buildings.
- Fully integrated fire control system.
  - Echodyne's EchoShield Ku CUAS Radar
  - Range: 100m - 10km (depending on altitude of launch)
  - Virtual Aegis Weapon System (VAWS) technology for interceptor guidance. (Same tech used for Navy Standard Missile Guidance).
- Low-Cost Interceptor
  - $10,000 for Blue - Under $6,000 for partial Blue
  - 8lbs – Current Top Speed 320km/hr, High Maneuverability (7g)
  - Magazines for swarm defeat, multi-salvo
  - Group 1,2 and 3 defeat
  - Kinetic intercept (no energetics) aligns with USC 130i(a)(F) – use of reasonable force to disable/damage/destroy unmanned aircraft
- Ongoing Efforts
  - PD-Aerostats Exercise in Feb 2025 for CUAS In support of CENTCOM JUONS (CC-0587) – Follow-on exercises to add Aerostat Launched Effects Capability Planned but Unfunded
  - Picatinny Arsenal Seed Funding for Interceptor Prototypes and demo support from Autonomous Armaments Tech Division, DEVCOM & Automatic Test Systems Division, ARDEC
  - Interest received from CENTCOM G-2 ISR Task-Force Director and INDOPACOM J81 Innovation & Experimentation Division for sub $15k/round defeat capability.
  - Internal (Self-Funded) Development Continuing In Parallel



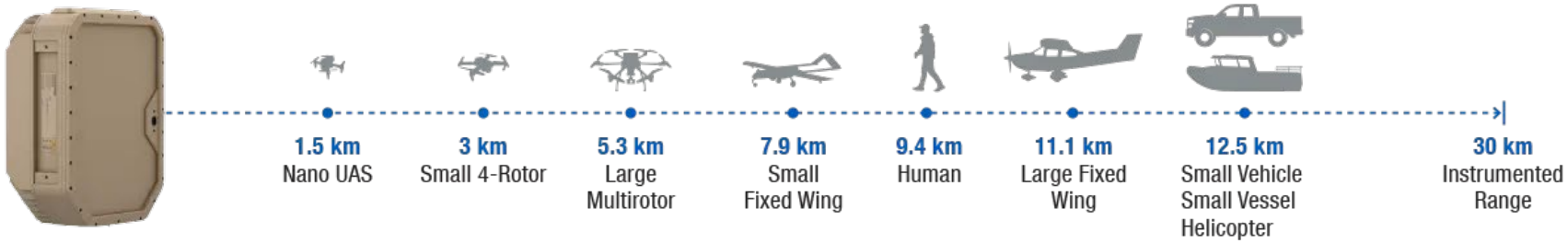
Peregrine Interceptor

- Design evolved from high-speed racing drones.
- COTS Components – Simple to learn and operate
- Current Top Speed 320km/hr
  - Goal Top Speed 460km/hr
  - Capable of 7g maneuvers
  - Impact energy of 14kJ (roughly equivalent to a .50 cal round at muzzle velocity)
- Weight: 8lbs
- Payload capacity allows for a lead slug or tungsten penetrator.
- Spring Powered Tube Launch (10’)
- EOIR Camera
- Encrypted COMS
- IP 54 – Launch canister provides additional environmental protection
- AS9100 Production Facility – Initial Capacity 400/month
  - Full Rate Production 4000/month
- Future Enhancements Would Allow Operation in GPS Denied/EM Hostile Environment
  - Interceptor Guidance does not require GPS data
  - Hardened LPI/LPD Radios would increase cost but allow operation in EM Hostile Environments.
  - Fly By Fiber being evaluated also.
  - Advanced Low-Cost AESA radars becoming available in 2026 that will work in Jamming Environments (Lockheed ZPY-X)





Echodyne EchoShield 4D Radar



- Low Cost* Ku Band Radar Designed for Detection and Tracking of UAS
  - Group 1: 3 km to 5.3 km (-20 to -10 dBsm)
  - Group 2: 5.3 km to 7.2 km (-10 to -3 dBsm)
  - Group 3: 7.2 km to 12.5 km (-3 to 5 dBsm)
- Ground, building or aerostat mounted
- Provides Associated Measurement Report (AMRs) for VAWS processing.
- Software Defined Architecture Allows Rapid Enhancements

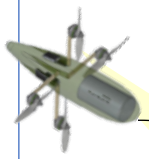
- EchoShield LEVIATHAN Classifier
  - Leviathan is a system to do scalable, rapid-iteration, machine learning classification on the EchoShield radar.
  - Collection of tools and processes to: Collect/store large amounts of real-world data, Accurately label large amounts of data, Train modern deep-learning models in the cloud with No-code deployment of trained models
  - New models with every SW release

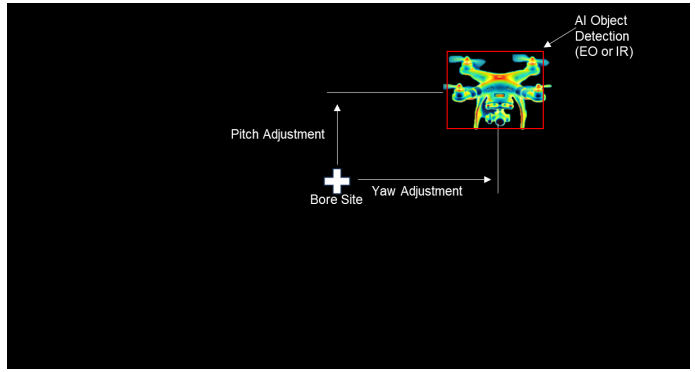
*~8X cheaper then existing Army Ku Radars

- Track While Scan Accuracy: 0.5 deg elevation and azimuth. 3.0m range
- Dedicated Track Accuracy: 0.125 deg elevation/azimuth. 0.75m range.
- Able to Support multiple simultaneous engagements without additional sensor input.

Intercept Concept

- Flight path established using Radar AMR Data
- VAWS used to manage engagement/intercept/weapons solution





VAWS guidance commands can be adjusted to align camera object with interceptor boresight (if seeker is present)

- Kille Dive to Maximize Target Area and Kinetic Energy at Impact
- High Speed and Maneuverability to Counter Collision Avoidance

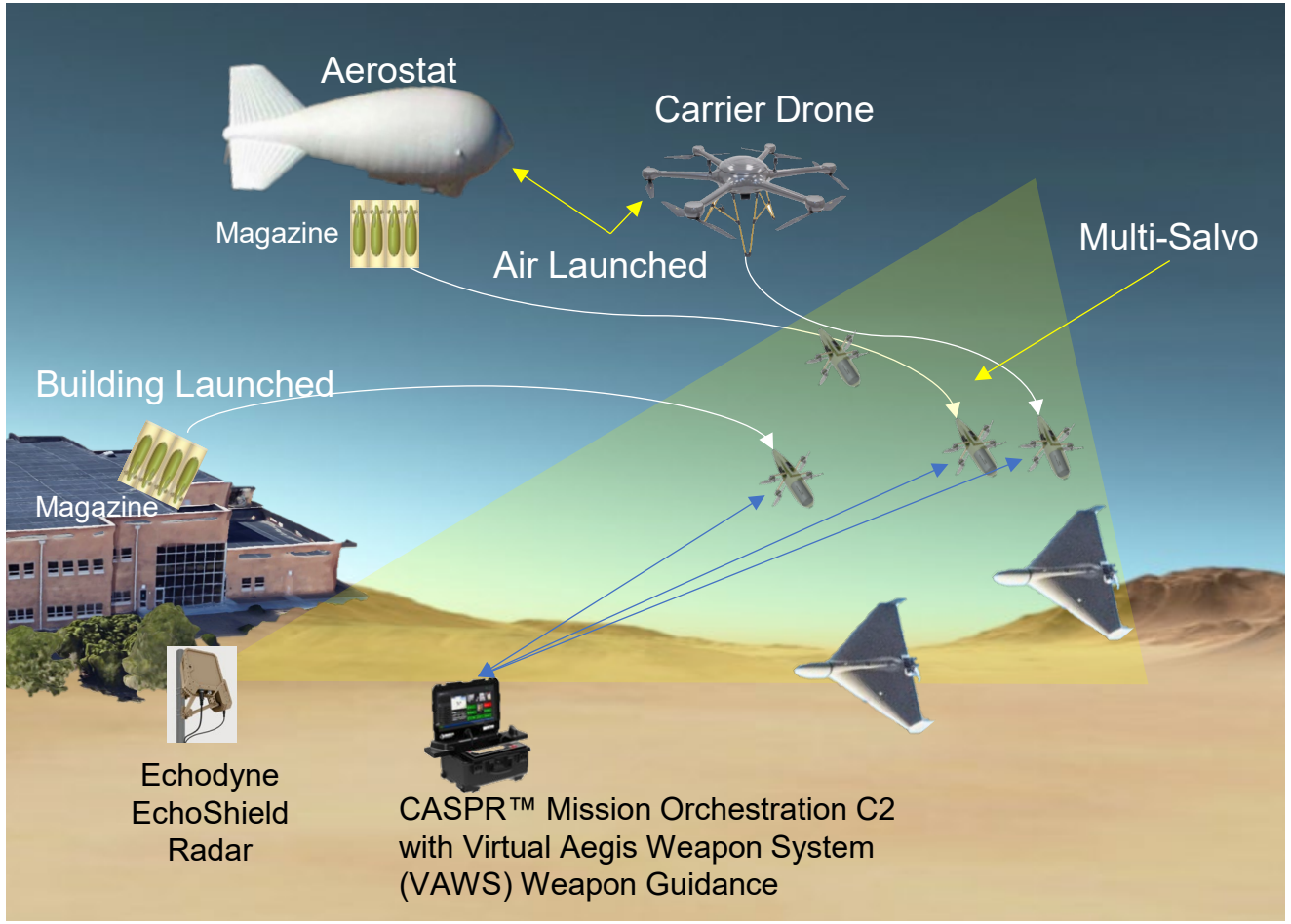
Command Guidance Phase

Up to 10km

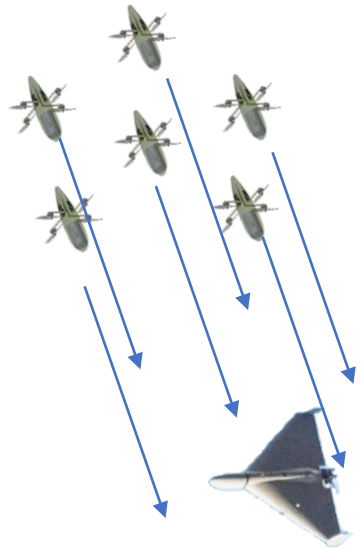
Terminal Homing Phase

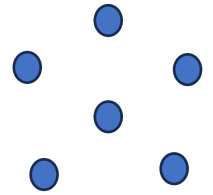
30m

Multi-Salvo



- Multiple drones can be launched and controlled at the same time from magazines of launch tubes.
  - Theoretical limit of 128 simultaneous engagements per system.
    - Dependency on drone controller and radio architecture
- Salvo size dependent on radar resources and magazine size.
- CASPR can be enhanced to use multi-salvo of interceptors in formation to increase probability of kill.
- Can be staged spatially and temporally or both





Head on view

Testing and Production

- Current Development
  - Integration Testing underway
    - Interceptor proxy being controlled using radar AMR data from Echodyne Radar.
  - Initial flight tests scheduled for July/Aug using proxy drones.
  - Seeker Development In Progress – Leveraging COTS And Open Source
  - Two interceptor prototypes under construction for testing in Sept.
- Interceptor Flight Tests
  - Scheduled to Start September.
  - Algorithm and system evaluation and tuning focused.

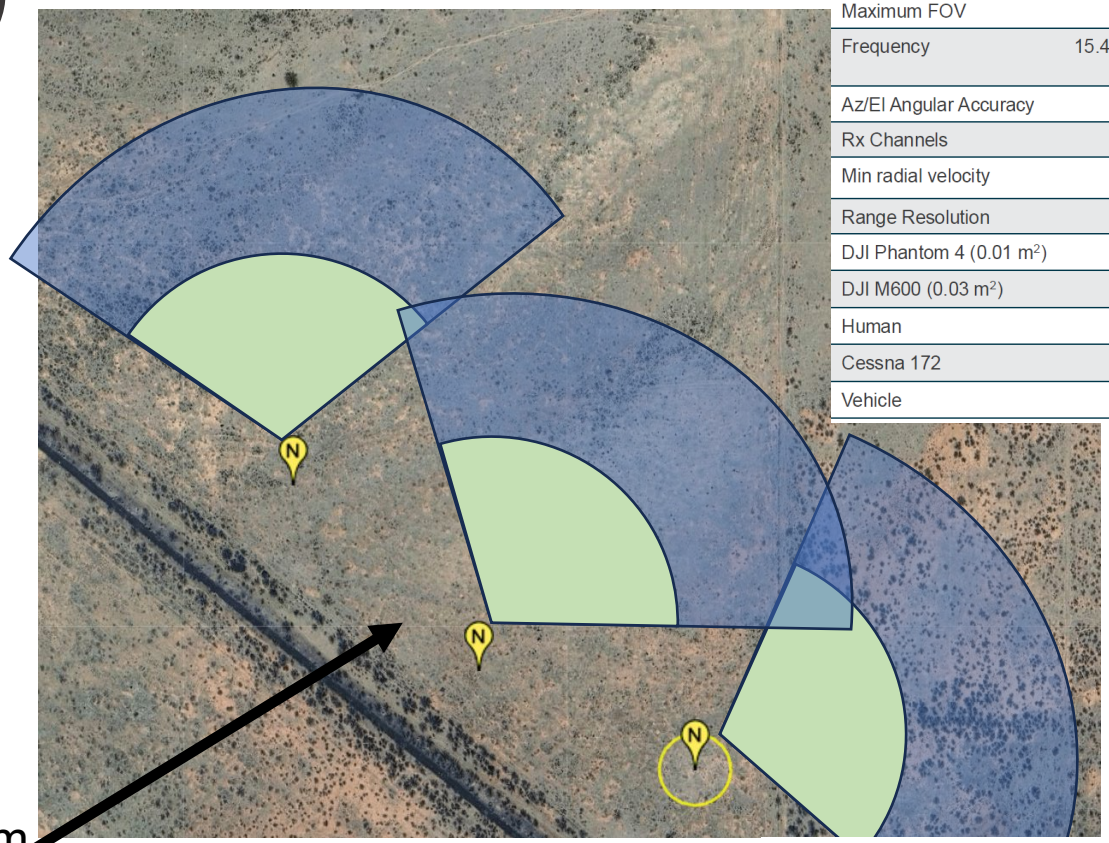
Leapfrog – CASPR Orchestrated Forward Deployable Sensors

Leapfrog

- Leapfrog is the patent pending concept of using CASPR to dynamically deploy sensors using sUAVs.
  - Airborne radar sensors require power, coupled with the power needed for flight, any airborne radar on an sUAV would have very limited flight time (order of minutes).
  - Landing the sUAV and operating the sensor from the ground allows several hours of sensor operation.
  - sUAVs can be repositioned on demand to relocate sensor resources as needed.
  - CASPR provides orchestration and persistence of the desired distributed sensor configuration.
- Leapfrog is not limited to sUAVs. The same concepts can be applied to uncrewed surface and subsurface vehicles.

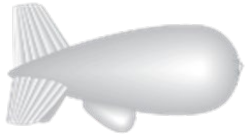
Leapfrog (cont)

Example Leapfrog UAV with R-20 Radar



CASPR Dynamically Positioned Radars

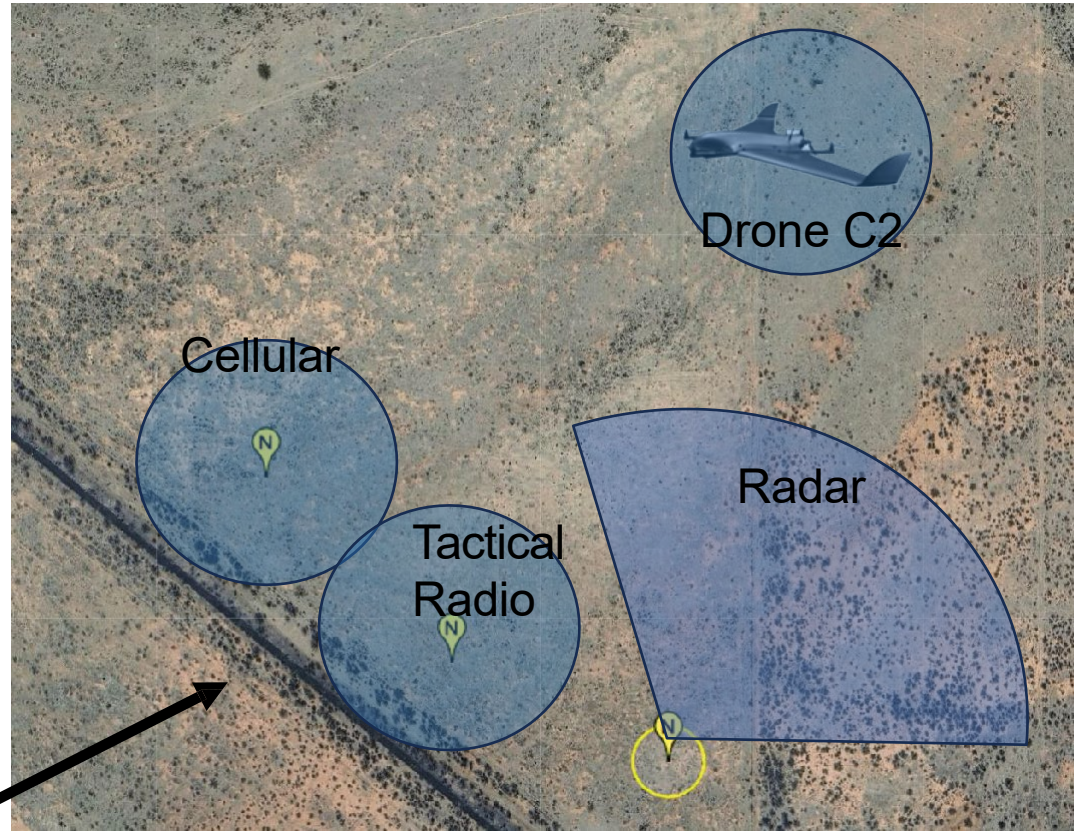
5-10km



	R20	R30	R40˚ (2024)
Technology	FMCW Phased Array		
Maximum FOV	120° x 60°	120° x 120°	
Frequency	15.4-16.7 GHz (Ku Band)	15.4-16.6 GHz (Ku Band)	
Az/El Angular Accuracy	± 2º	± 1º	± 0.5º
Rx Channels	4	16	
Min radial velocity	0.15 m/s or less		
Range Resolution	1-8 m	1-16 m	2-16 m
DJI Phantom 4 (0.01 m^2)	750-1000 m	2000-2500 m	3750-4250 m
DJI M600 (0.03 m^2)	1300* m	3300 m	5000-5500* m
Human	1900* m	5000* m	8000* m
Cessna 172	3000* m	8000 m	13000* m
Vehicle	3000* m	8000* m	13000* m

Leapfrog RF Decoy Orchestration

- Disposable programable radio
  - Low Cost
  - Emulate Multiple RF signatures
    - Tactical Radios
    - Bluetooth
    - Wifi
    - Cellular
    - Radars
    - Drone C2
  - US Manufactured “Blue”



CASPR Orchestration of Dropped or Drone Carried RF Spoofing Devices

“Drone Phone” – CASPR Orchestrated Forward Deployable Emission Free Communications

Comms Mission : The Drone Phone

Emission-less Long-Range Communications System

Ground Controller

Optional FPV

Up to 40km Commercially Available – TTL Variant has 1Mbs/sec bandwidth – single mode fiber supports 100Gb/s

Operators able to connect carried gear (e.g. PPT headsets) directly to comms payload for instant communications

Comms Hub

Fiber Optic Connection

Voice/Voice Over IP

WAN/ Backhaul

Local IP Network

Drones dispatched using Thunderbolt's CASPR™ Asset Orchestration Software

Comms Payload

Voice/Voice Over IP

IP Network

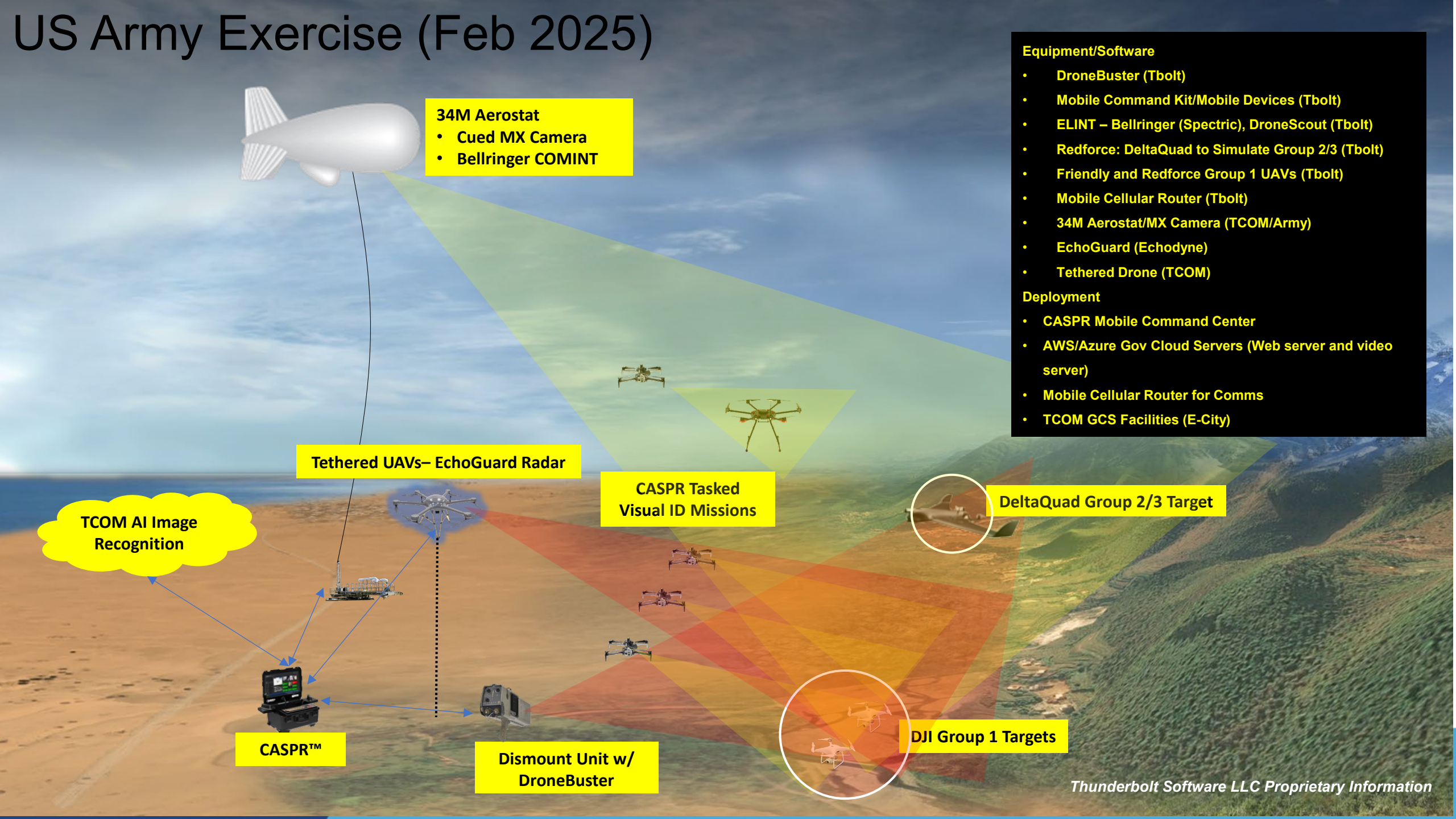
Can be configured on USVs, UUVs and UGVs also.

Comms Mission

- “Drone Phone” Concept Not Limited To Voice Comms
- Combined with Leapfrog
  - Emission free deployment of sensors and decoys
  - Emission free backhaul of sensor data.
  - Potential for Big Pipe for large data rates (e.g. radar data)

PD-Aerostats Exercise in Feb 2025 for CUAS In support of CENTCOM JUONS (CC-0587)

US Army Exercise (Feb 2025)



Equipment/Software

- DroneBuster (Tbolt)
- Mobile Command Kit/Mobile Devices (Tbolt)
- ELINT – Bellringer (Spectric), DroneScout (Tbolt)
- Redforce: DeltaQuad to Simulate Group 2/3 (Tbolt)
- Friendly and Redforce Group 1 UAVs (Tbolt)
- Mobile Cellular Router (Tbolt)
- 34M Aerostat/MX Camera (TCOM/Army)
- EchoGuard (Echodyne)
- Tethered Drone (TCOM)

Deployment

- CASPR Mobile Command Center
- AWS/Azure Gov Cloud Servers (Web server and video server)
- Mobile Cellular Router for Comms
- TCOM GCS Facilities (E-City)

CASPR CUAS Mission Task with Dronebuster

CUAS ELINT
or Radar

Sensor
Cue

CASPR

CUAS Mission Task For
Dronebuster Operator w/
Target Location

CASPR Mobile App

Augmented
Reality Targeting

Friendly and
Hostile Units
overlayed in AR.

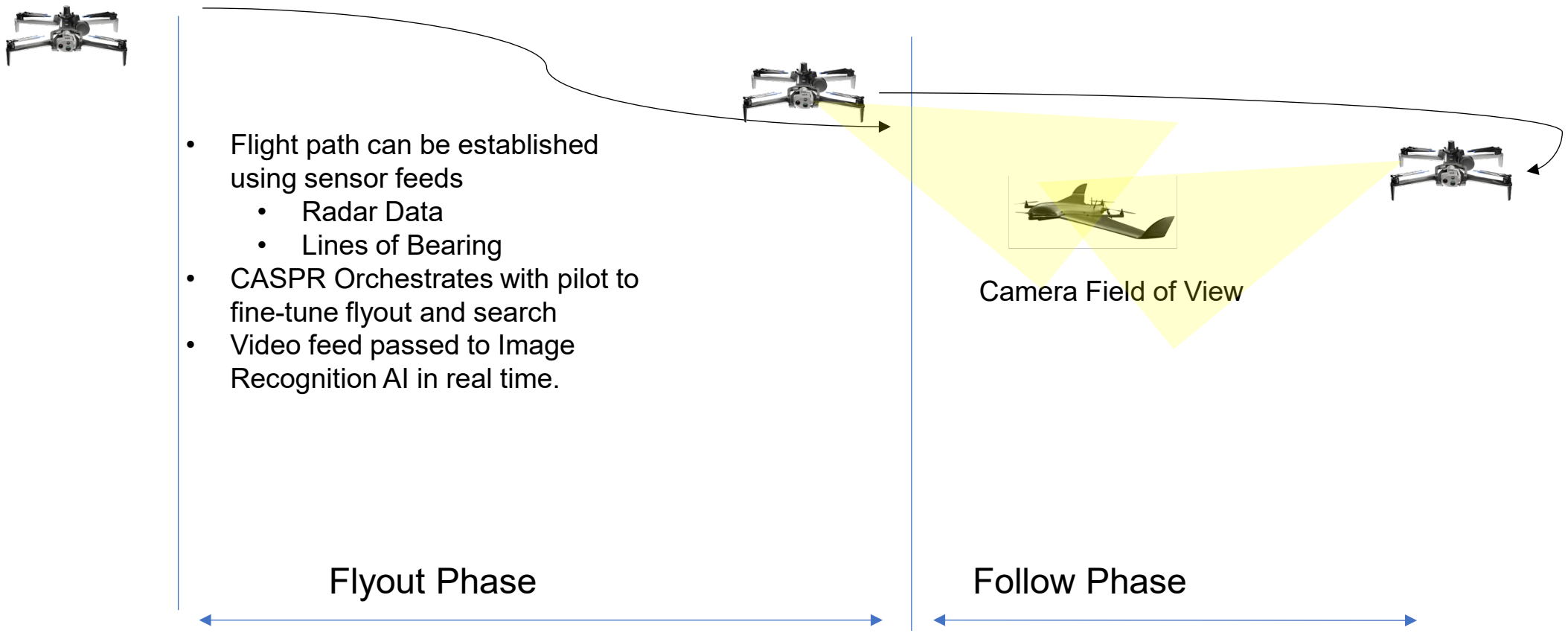
Dronebuster

Visual Range
~100m

Cued Range 1-2 km

10-20x Improved Standoff Range

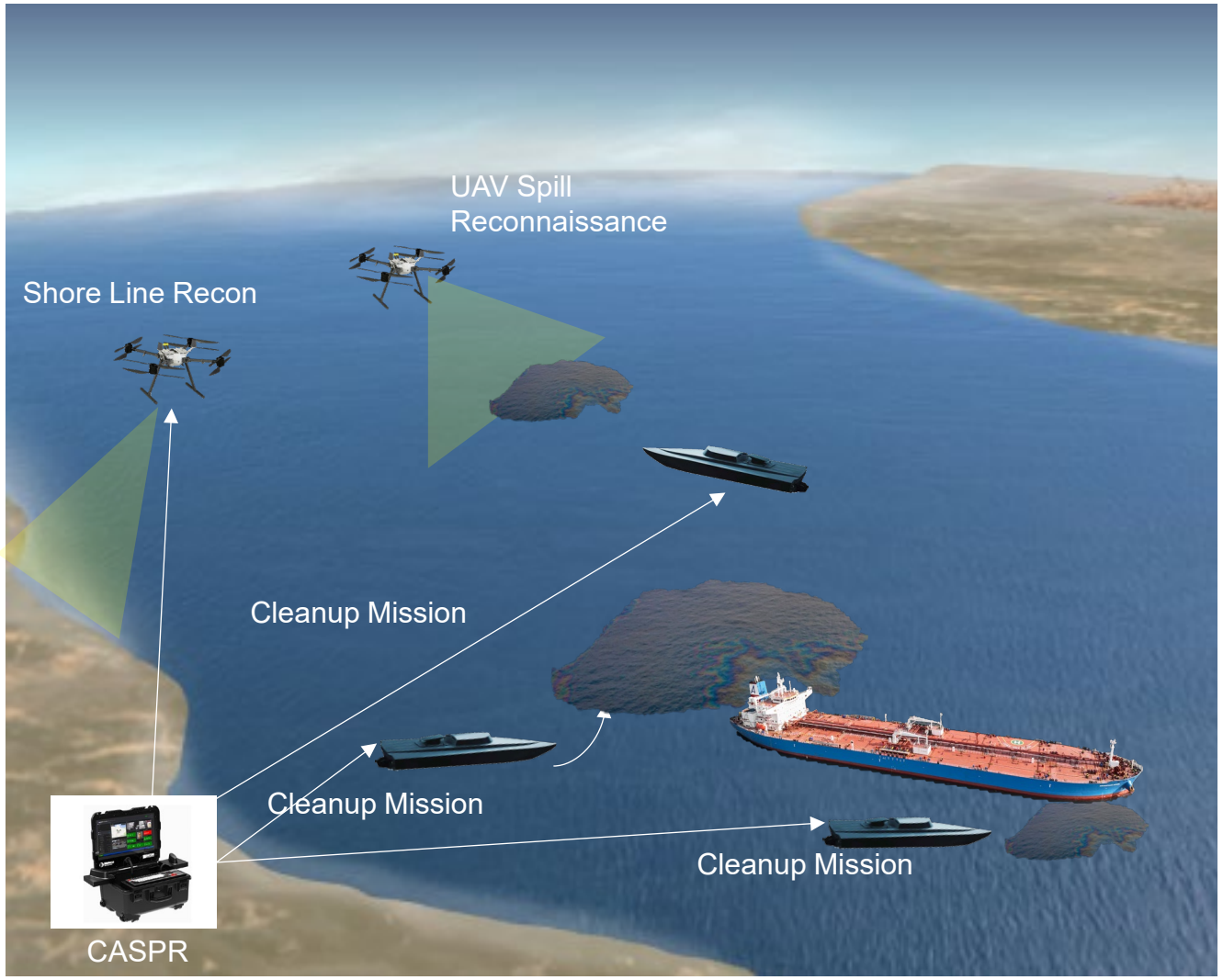
CASPR Visual ID Mission Task



- Flight path can be established using sensor feeds
  - Radar Data
  - Lines of Bearing
- CASPR Orchestrates with pilot to fine-tune flyout and search
- Video feed passed to Image Recognition AI in real time.

Commercial Applications

Maritime Incident Response



- CASPR being utilized by Gallagher Marine to orchestrate multiple assets.
  - Cleanup Vessels
  - Spill/Slick detection
  - Team Communications
  - Federal, State, Local Unit Integration/Coordination
  - Coast Guard Integration/Coordination