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Capability Needs for Testing Counter Small Unmanned Aircraft System (CSUAS) Systems

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Discussion Topics

- The Emerging Threat
- Example of CUAS Testbed
- Examples of Test Capability Needs
- Concluding Comments
- Questions

What is a Small Unmanned Aircraft System?

- Latest DoD term is Unmanned Aircraft System (UAS)
  - Previously identified as unmanned aerial vehicle (UAV) or unmanned aerial system (also UAS)
  - Rotary-wing, fixed-wing, and hybrid aircraft

Rotary Wing: DJI Phantom

Fixed Wing: Parrot DISCO

Hybrid: xCraft X PlusOne

- Includes non-military aircraft (civil use, hobby, commercial, etc.)
- Commonly identified as “drones” in the media
- “Small” refers to:
  - Class 1 UAS (0-20 lbs)
  - Class 2 UAS (21-55 lbs)

SUAS Characteristics

- Weigh less than 55 lb (~25 kg)
  - However, most model aircraft weigh less than 5 lb (~2 kg)
- Have a diameter less than 2 ft (~60 cm)
- Normally have a maximum average speed of 35mph (52 ft/s or ~16 m/s)
  - Small fixed wing and hybrid UAS may reach 60 mph (73.3 ft/s or ~27 m/s)
- Fly at altitudes ranging from 1.5 ft (~50 cm) above ground to 19,800 ft (~6,000 m) above sea level
- Hover vertically with a precision of +/- 3” (~10 cm)
- Fly more than 20 minutes with a standard battery
- Carry a payload weighing at least 2 lb (~1 kg).

Hubsan X4 H107
(mini quadcopter)

DJI Phantom

Proliferation and Improvements

- Global drone shipments reached about 4.3 million units in 2015, up from 1.6 million units in 2014*
- This surge in sales has led to substantial investments to improve payload capacity, advanced aerodynamic performance, advanced avionics, advanced control systems, and use of smartphone and/or tablet control systems
- Prices have fallen just as dramatically as sales have risen
- Bottom Line for UASs:
  - Easy to buy
  - Performance is improving dramatically
  - Cost has dropped significantly
  - Millions of them around the world

* Venture capital firm Kleiner, Perkins, Caufield, and Byers

Examples of Improvements (DJI Phantom 4)

- Old Flight Modes: GPS Waypoints, Home Lock, and Point of Interest
- Improved Flight Modes
  - Obstacle avoidance – An array of ultrasonic rangefinders (aiming left, right, forward, backward, and down), vision sensing, and onboard processors
    - Vision sensing – Integrated visual cameras running computer vision algorithms
  - Tap fly – Tap in a general direction on the screen and the Phantom 4 will fly there
  - Follow me – Linked to mobile device. Both must have strong GPS signals
  - Active track – Track subjects automatically (without using a GPS reference) by using advanced image recognition algorithms. Use it to effortlessly orbit around subjects
  - Sport mode – Can increase speed to 45 mph, ascend and descend at speeds of 30 feet per second and 13 feet per second, respectively
- Battery life is improving. With a 5,230 mAh battery, the Phantom 4 can last a little under a half hour in regular mode

Examples of Improvements (Parrot and Teal)

- Parrot S.L.A.M.dunk
  - Development kit for obstacle avoidance, autonomous flying, 3D mapping, or using the on board stereo camera and sensors for data gathering
  - IMU, ultrasound, magnetometer, and barometer
  - Fish-eye stereo camera that shoots 1,500 x 1,500 resolution at 60 fps
  - SLAM = Simultaneous Localization and Mapping

- Teal racing drone
  - 70 mph
  - Company's founder and CEO, George Matus Jr.
    - 18 years old

Mode of Use: Single UASs

Manual Remote Control

Clear Line of Sight

Remote Control (Line-of-Sight)

Teleoperation

Some Separation

Remote Control (Non-Line-of-Sight)

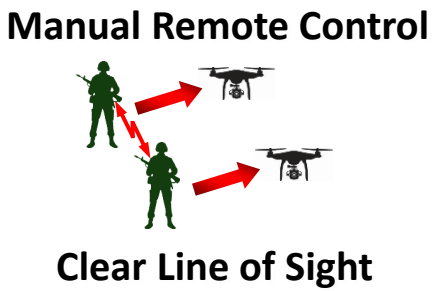
Initial RF Link for Mission Orders

No Link

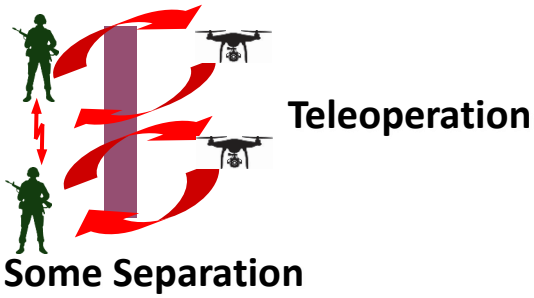
MISSION

Semi/Full Autonomy

Mode of Use: Coordinated Single UASs



Remote Control (Line-of-Sight)

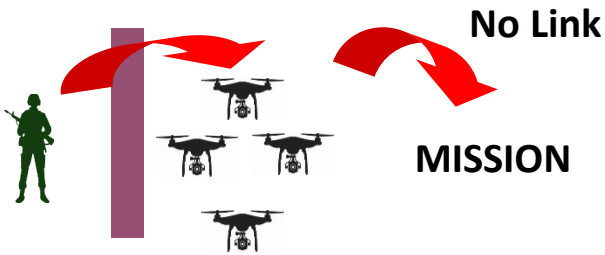


Remote Control (Non-Line-of-Sight)

Semi/Full Autonomy

Modes of Use: Swarms and Collaboration

Initial RF Link for Mission Orders

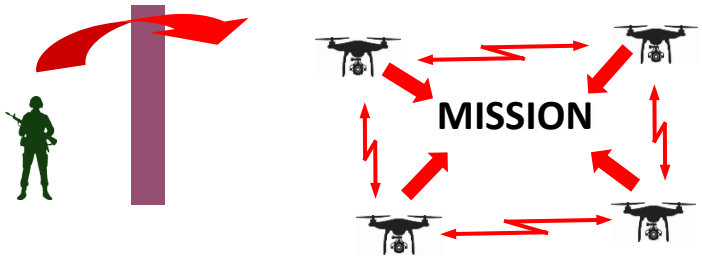


Semi/Full Autonomy

Swarm

Initial RF Link to one or more UASs for Mission Orders

Not Linked to the Operator



Full Autonomy

Collaboration

Why a Threat? (1 of 2)

- Weapon Mode
  - Can carry weapons
  - Because of weight and inertia, the platform itself might be enough to cause significant damage to a warfighter or soft target.
  - Can be fitted with an external or embedded explosive designed to explode on impact
    - Contrary to the past, when our warfighters might find an improvised explosive device (IED); now, IEDs will find our warfighters
  - External payloads can be used to drop explosives or for disseminating biological or chemical agents from an altitude that minimizes detection and direct engagement

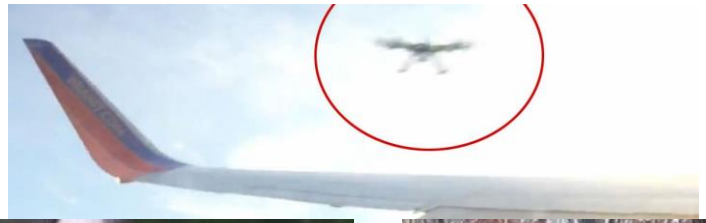
Why a Threat? (2 of 2)

- Non-weapon Mode
  - Can be used for reconnaissance, targeting, counter-surveillance, and even for jamming radio frequency signals
    - Russians are employing as many as 16 different types of UASs in the Ukraine
    - Russians are flying UASs in pairs and are using them with great effect to locate and target Ukrainian units

Growing Concern

Who flew drone over Bangor submarine base? Navy wants to know

Originally published February 25, 2016 at 1:53 pm *Updated February 26, 2016 at 9:52 am*

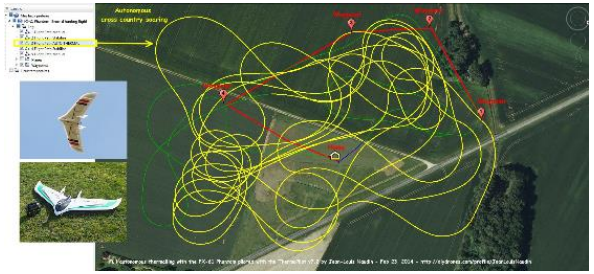


Threat for DHS

- Currently
  - Customs
    - Contraband across borders
  - Prisons
    - Contraband flown over prison walls
  - Forest Fires
    - Aerial firefighting inhibited
  - Airports
    - Threat to take-offs and landings
  - Sensitive areas
    - White House, nuclear power plants, etc.
- Other threats????

Countering Isn't So Easy (1 of 2)

- **Detection** is very difficult
  - UASs are small, fly at low altitudes, and have highly irregular flight paths, and can range in speed from zero (hover) to close to 65 ft/s (~20 m/s)



  - Small UASs can take advantage of the significant amount of background clutter (e.g., birds, trees, urban structures) and non-line-of-sight movement

Countering Isn't So Easy (2 of 2)

- Once detected, **neutralizing** a small UAS is a separate challenge
  - DoD has been developing kinetic, directed energy, electronic warfare (EW), and cyber defenses against UASs, but mostly for UASs larger than model aircraft
    - Recent experiments are focusing on small UASs
  - Extremely difficult to use kinetic counters, especially small arms, to shoot down a single, small, highly-dynamic (agile), fast-moving, low-flying UAS
  - EW counters are neutralized by emerging autonomous flying capabilities

- Swarming UASs can be employed to overwhelm most kinetic counters
  - DARPA initiating projects focused on swarms of drones
  - Collaborative operations make it even more difficult

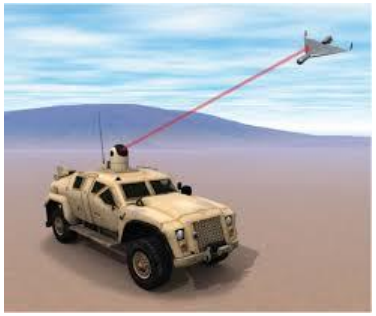
- Often, a CUAS system costs significantly more than the individual UASs being countered
- Any CUAS system developed for dismounted infantry must place minimal space, weight, power, and cognitive complexity demands on the infantryman

Examples of Detection Systems

- Human Sight/Hearing
- Radar
- Lidar
- Optical
  - Daylight camera
  - Near Infrared (night)
- Audio/Ultrasonic
- WLAN (RF sensing)

Examples of Neutralization Systems

- Kinetic effects
  - Directed energy attack (laser, high-power microwave, electromagnetic pulse)
  - Solid particle attack (munitions, air-to-air UAS)
  - Physical control (nets)
  - Birds (hawks, eagles)



- Non-kinetic effects
  - RF jamming
  - GPS jamming
  - Cyber manipulation/control

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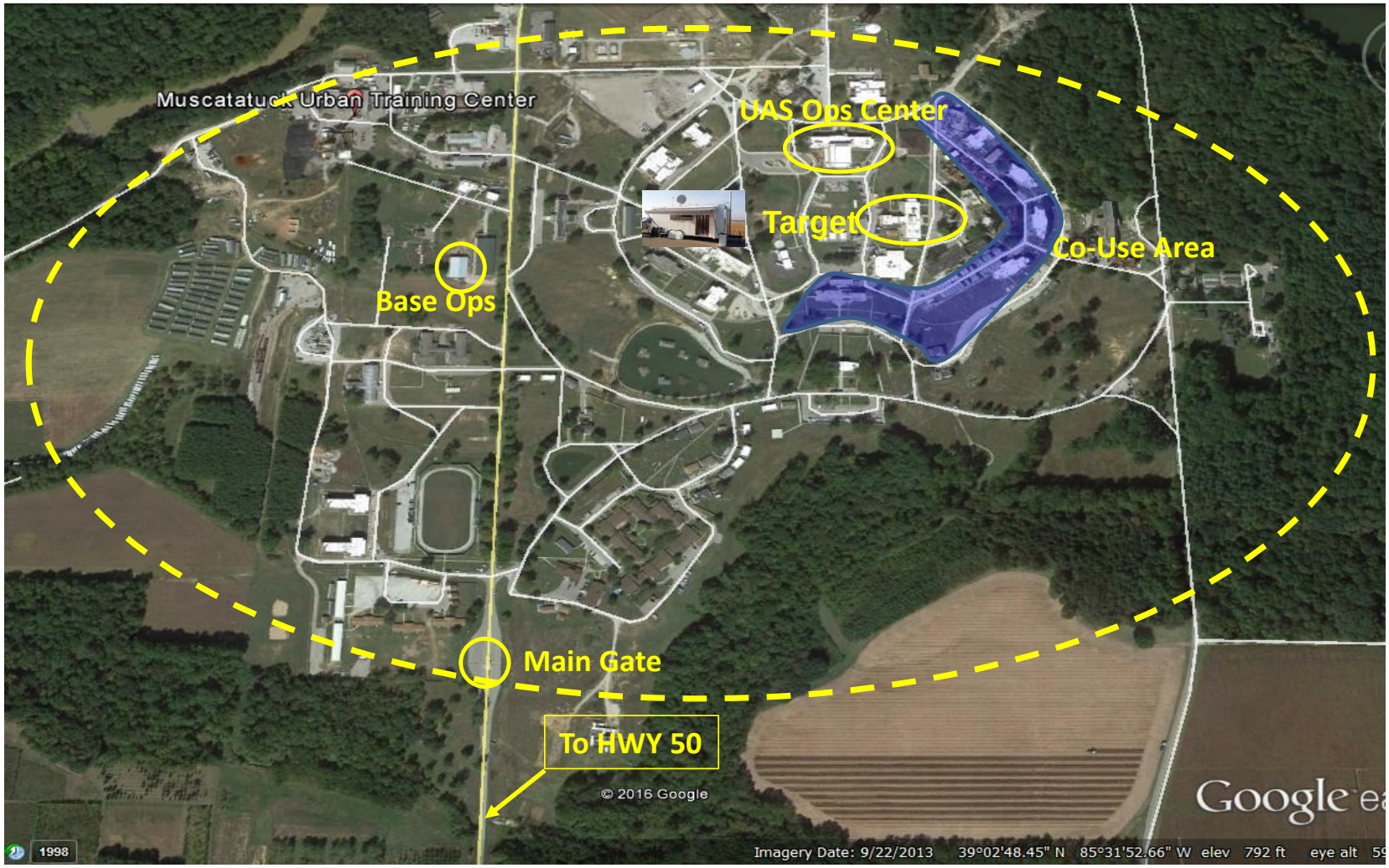
Example of CUAS Testbed

- Muscatatuck Urban Training Center, Butlerville, IN
  - The 1,000 acre site was turned over to the Indiana National Guard in July 2005 and has since evolved into a full-immersion contemporary urban training environment
  - Over 120 training structures, including collapsed buildings

Example of CUAS Testbed

Example of Size of a CSUAS Systems Test



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Test and Evaluation Needs

- Time, space, and position information (TSPI) systems
  - For target UASs
    - Need 3D location, yaw, pitch, roll, and direction of movement
    - Current approach is to collect GPS data from a UAS's onboard system
      - Significant problem when testing a GPS jammer or testing in a GPS-degraded environment
    - Other TSPI systems have difficulty locating and tracking small UASs, especially threat drones that fly "low and slow" in a cluttered (ground and air) environment
    - Many add-on TSPI systems have space, weight, and power (SWAP) needs that affect the performance of the UASs
  - For attack systems – similar to above
  - For detection systems
    - Need accurate orientation information

Test and Evaluation Needs

- For kinetic attack (e.g., use of shotgun or rifles) – end-game information difficult to collect
  - Need to track small bullets, pellets, fragments, and interactions with targets
- Energy on target
  - Need ability to measure energy (level and duration) on target – especially, if target isn't destroyed
- Cyber attack
  - Need to actually monitor, measure and assess the effect of "cyber-attacks" on software, beyond "we believe it did/did not work"
  - Need to measure effects on target
  - Need to understand Impact of geographical and electromagnetic environments on cyber attack

Test and Evaluation Needs

- Human Performance Testing
  - Need ability to measure visual, auditory, cognitive, and psychomotor mental workloads
    - Operation of SUAS and CSUAS systems can impose significant mental workload
  - CSUAS systems may also increase physical burden of dismounted infantry
- Testing of onboard SUAS functionality/sensors
  - Autonomy
  - Obstacle avoidance capability
  - IMU, ultrasound, magnetometer, barometer

Test and Evaluation Needs

- For safety reasons, most testing is conducted in artificial environments – especially artificial urban environments
  - Normally benign; e.g., lacking electromagnetic (EM) interference, population, active movement of vehicles, overhead electrical lines, wildlife (birds), etc.
  - Have flight altitude restrictions
  - Have RF spectrum management issues
  - May have additional safety issues with use of Directed Energy Weapons
- Training and testing urban facilities do not have high rise structures – can't fully replicate a large city environment
- RF and EM background noise needs to be characterized for various operational environments and then realistically duplicated on test ranges

Test and Evaluation Needs

- Need ability to prevent UASs (especially swarms) from creating an unsafe event – e.g., flying uncontrolled and outside the test area
- Current DoD models and simulations
  - Kinematic models are not designed for, nor function effectively for, the flight dynamics of UASs
- "Standard Representative" scenarios and operational environments need to be defined
  - Being addressed by Service/Agency Red Team efforts
- Are there unique assessment metrics?

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Concluding Comments

- CUAS efforts are ubiquitous across all Services and Agencies
- House Armed Services Committee is concerned
- National Academies Ad Hoc Study Committee to address CUAS at Battalion and Below Operations
  - Search for "National Academies CUAS"

  Or go to:
  - http://www8.nationalacademies.org/cp/projectview.aspx?key=49810


ANY
QUESTIONS
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