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DIRECTED ENERGY DEFENSES AGAINST SMALL COMMERCIALLY AVAILABLE UNMANNED AIRCRAFT SYSTEMS

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2017 ASSOCIATION OF OLD CROWS EW EUROPE CONFERENCE

OLYMPIA, LONDON, 6-8 JUNE 2017

Use of Department of Defense imagery throughout this briefing does not constitute or imply endorsement

INTRODUCTION

“Drones Are Still Flying Dangerously Close to Airplanes and Airports”

http://www.cumberlandtrialjournal.com/drones-an-aerial-view-of-the-future-of-unmanned-aircraft-systems/
http://fortune.com/2016/03/28/drones-flying-too-close-airplanes-airports/

COMMERCIAL AIRLINERS AND AIRPORTS HAVE LONG BEEN A TARGET OF TERRORISTS ATTACKS

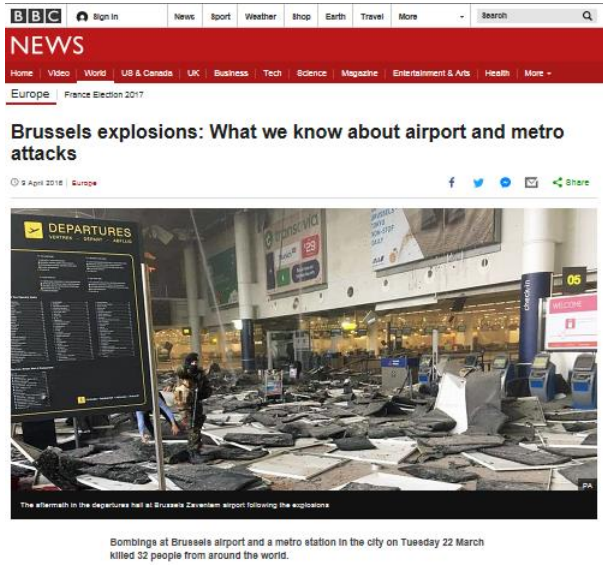
News › World › Africa

Isis plane attack: Egypt admits 'terrorists' downed Russian Metrojet flight from Sharm el-Sheikh for first time

Officials had previously denied Isis claims of responsibility and an Egyptian report claimed there was no evidence of 'terrorist action' in December

134 shares

Russian Emergency Situations Minister Vladimir Puchkov (4-L) and unidentified officials near a piece of wreckage of Russian Metrojet Airbus A321 at the site of the crash in Sinai, Egypt EPA



BBC NEWS

Europe | France Election 2017

Brussels explosions: What we know about airport and metro attacks

Bombings at Brussels airport and a metro station in the city on Tuesday 22 March killed 32 people from around the world.

BBC NEWS

Europe | France Election 2017

Securing airports from attacks: Is it mission impossible?

By Richard Westcott
Transport correspondent, BBC News

Turkey's Ataturk airport is a major transportation hub

"What has changed in recent years is the suicide element. That's difficult to counter, if people are willing to blow themselves up".

- Terrorists are inclined to attack airports because of their symbolism as an international hub with many international travelers, internal security check points, and large economic impact
- Psychological return of an airport attack amplifies previous incidents, shakes confidence
- Fact: Every counter-terrorism move results in a counter-move to defeat security
- Small Unmanned Aircraft Systems (sUAS) (or Drones) have the potential to bypass all existing physical security measures

The time is NOW to address this threat before it fully emerges.

http://esnews.bah.com/small-commercial-unmanned-air-systems-an-amazing-technological-advancement-and-a-growing-threat-to-civilians-and-military-operations/#more-375

SMALL UNMANNED AIR SYSTEMS (sUAS)

- U.S. Federal Aviation Administration (FAA) Guidelines:
  - Weigh less than 55 lbs, including everything that is onboard or otherwise attached to the aircraft
  - Operated below 100 miles per hour
  - Operated below 400 feet above ground level
  - Typically operate under "See and Avoid" principles within "line of sight" to the operator
- Amazon begins *Prime Air* drone delivery trial in the UK Dec. 2016[2]
  - Maximum capacity of 5 pound package
  - Currently in *beta* trials with "beyond line of sight" capability

Sales Forecast Summary (1)
Million sUAS Units

	2016	2017	2018	2019	2020
Hobbyist (model aircraft)	1.9	2.3	2.9	3.5	4.3
Commercial (non-model aircraft)	0.6	2.5	2.6	2.6	2.7
	2.5	4.8	5.5	6.1	7.0

Small UAS are a rapidly evolving and highly proliferating potential threat

(1) Source: Federal Aviation Administration, Advisory Circular: Small Unmanned Aircraft Systems (SUAS), 21 June 2016
(2) https://arstechnica.com/business/2016/12/amazon-prime-air-trial/

PROS AND CONS OF sUAS

RECORDS | PRODUCTS | BUSINESS SOLUTIONS | NEWS | ABOUT US | GET IN TOUCH

Intel launches 500 drones into sky and breaks world record in spectacular style

By Rachel Swatman | Published 04 November 2016

Police departments are using drones to find and chase down suspects

At least 160 police and fire departments acquired drones in 2016, more than in the past three years combined

Terrorists could use drones to destroy critical infrastructure: Interpol

Other tactics they could adapt include hacking attacks and armoured vehicles loaded with bombs

IANS | United Nations
February 14, 2017 Last Updated at 12:24 IST

DEFENSE SYSTEMS

CYBER DEFENSE
MOBILE
RESOURCES
EVENTS

UAS & ROBOTICS

An emerging threat: Small drones as flying IEDs

BY KEVIN MCCANEY • OCT 09, 2015

ars TECHNICA

BIZ & IT | TECH | SCIENCE | POLICY | CARS | GAMING & CULTURE | FORUMS

I'M HUNTING ~~WABBITS~~ DRONES —

Amazon begins Prime Air drone delivery trial in the UK

First customer received drone-delivered Prime Air order in just 13 minutes.

Drone-photography company fined $200,000 by FAA

Bart Jansen, USA TODAY   Published 1:16 p.m. ET Jan. 17, 2017 | Updated 1:41 p.m. ET Jan. 17, 2017

Drones smuggling porn, drugs to inmates around the world

Published April 17, 2017 · Fox News

Use of weaponized drones by ISIS spurs terrorism fears

FOX NEWS channel

U.S. COMPANIES DEVELOP DRONES TO FIGHT TERRORISM

AMERICA'S NEWSROOM

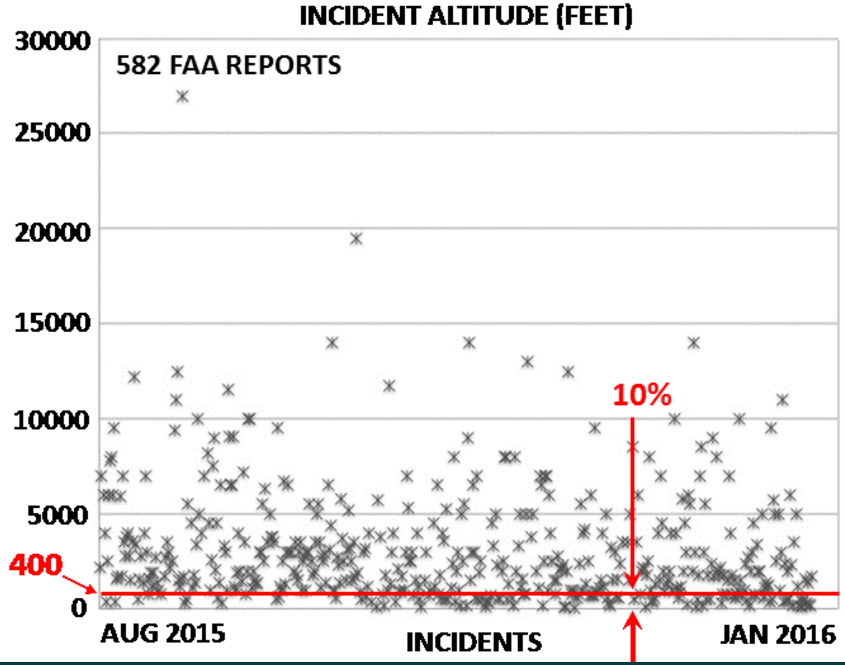
sUAS OPERATIONS IN VICINITY OF AIRPORTS

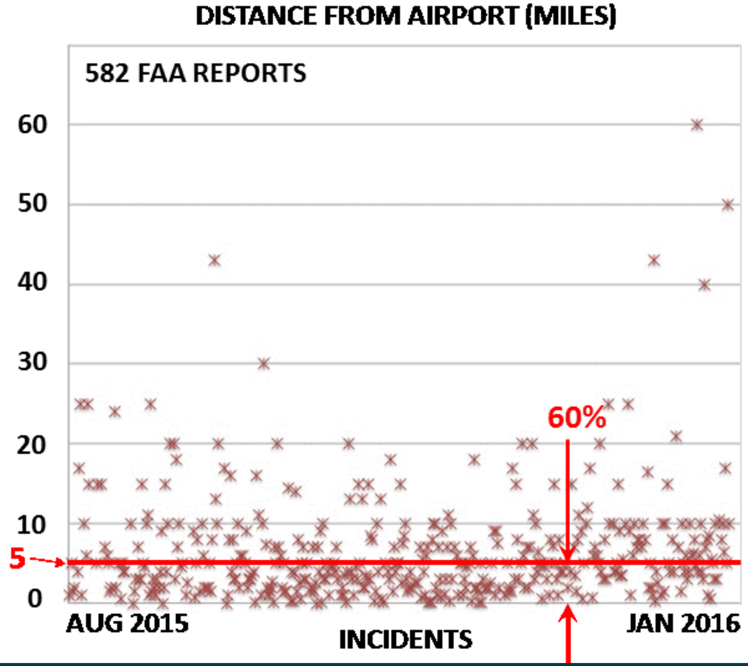
https://www.digitaltrends.com/cool-tech/drone-plane-encounters/

PROBLEM STATEMENT

- sUAS have become widely available for commercial industries and hobbyists
- As sUAS costs decline, operations will become more widespread and present increasing risks to airfield operations; whether through enthusiasm, ignorance, or malicious intent
- This brief will explore the detect-to-engage kill chain and feasibility of utilizing directed energy technology to neutralize sUAS threats operating in proximity to civil aerodromes

U.S. FAA Published Restrictions on sUAS Flying Above 400 feet, and Within 5 miles of Airports





Proliferation Trends for sUAS Present Increased Risk to Air Operations;
Directed Energy Technologies can Help Mitigate Potentially Catastrophic Collisions

http://dronecenter.bard.edu/analysis-3-25-faa-incidents/

MID-AIR COLLISIONS WITH sUAS IN EUROPE AND USA[(1)]

Date	Airspace type	Altitude in ft	A/C type	Aircraft Registration	Drone type	Aircraft Damage	Comments
30/08/2015	Unknown	2500	Grumman AA-1	N3LY	Unknown	None	RPAS struck u[illegible]arriage
30/04/2015	Controlled airspace	700	Robin DR 400-180	[illegible]	SAS W[illegible]g	[illegible]raping on win[illegible]	[illegible] airspace unknown - final approach - exact altitude not available
05/04/2015	G	[illegible]	Pioneer 30[illegible]	G-OPFA	V[illegible] Ray X, S037996	Scuffing and scraping (GBP 1 400)	Uncontrolled airspace
14/[illegible]10	[illegible]ontrolled [illegible]	50	Sh[illegible] [illegible]750	N28KT	AJ Slick model airplane	Lower left wing crushed aft to the main spar	Video
03/08/1997	[illegible]	<650	Grob G 109B		Dingo	Destroyed	2 fatalities

Only (5) Known Collisions,
All “General Aviation” Aircraft,
All with Suspected/Known Fixed-Wing UAS

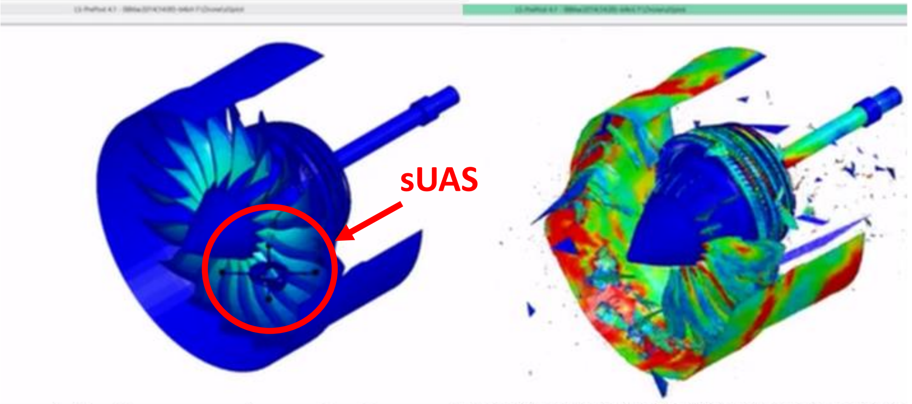
Boeing 737 at Tete, Mozambique

- Suspected sUAS collision occurred on **17 April 2016 when an A320 reportedly struck what was believed to be an sUAS during landing at Heathrow Airport, UK**. Subsequent inspections revealed no damage to the aircraft, and lack of evidence to confirm the presence of an sUAS.
- Suspected collision occurred on **5 January 2017 near Tete, Mozambique. While on approach, the crew of a Boeing 737 reported hearing a crash.** Inspection upon landing revealed several deep gashes in the radome on the aircraft’s nose. While sUAS had been reportedly operating around the aerodrome, Mozambique’s Civil Aviation Authority (ICAM) concluded the radome most likely failed as a result of a structural failure caused by air-flow pressure.

(1) A Safety Analysis Of Remotely Piloted Aircraft Systems 2012 to 2016, ATSB Transport Safety Report. AR 2017 016, Final – 16 March 2017

POTENTIAL CONSEQUENCES OF COLLISION

Crashworthiness for Aerospace Structures and Hybrids (CRASH) Lab at Virginia Tech (sUAS Hits Engine)



http://www.popularmechanics.com/flight/drones/a24467/drone-plane-collision/

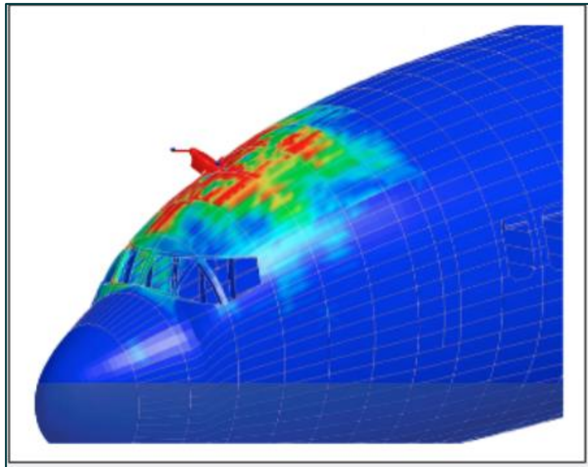


Figure IV.1 A simulation of a drone impact on an aircraft's fuselage

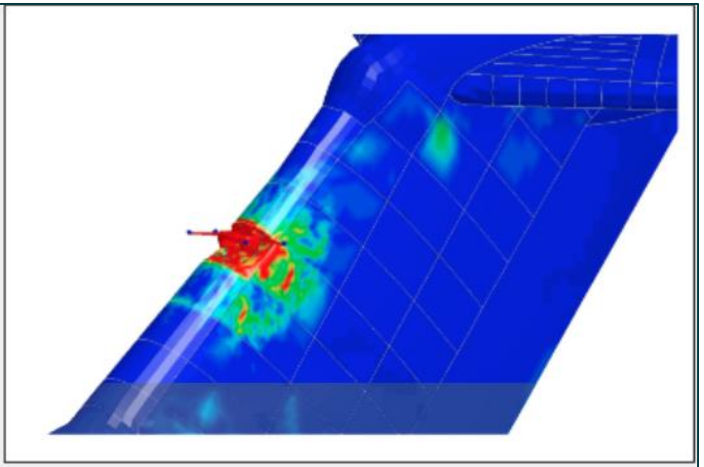


Figure IV.2 A simulation of a collision affecting the tail section of a manned aircraft

Images Courtesy of the Virginia Tech CRASH Lab

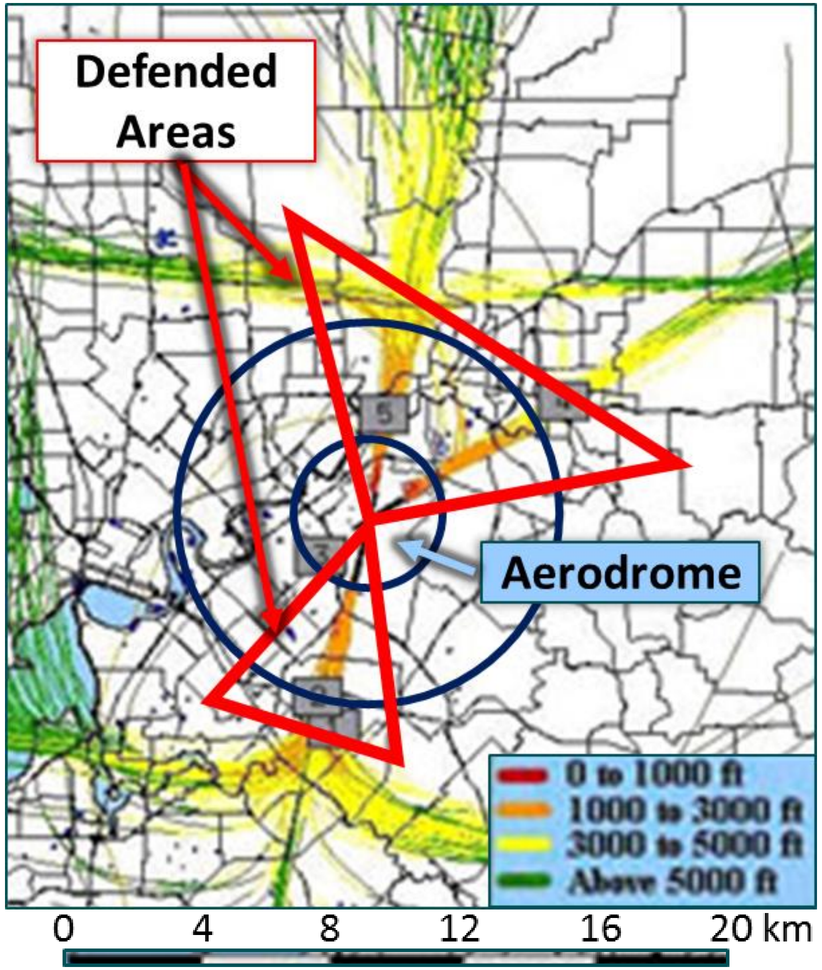
- *Accidental* bird strikes have long been a problem, and have caused considerable damage (i.e., *viscous fluid*)
- Virginia Polytechnic Institute and State University ("VA Tech") researchers have begun analyzing consequences of sUAS collisions with commercial airliners:
  - 8-pound quadcopter can rip apart fan blades of a 9-foot diameter turbofan engine in less than 1/200th sec
  - Professional multi-copter drones (4-5 kg) can cause irreversible damage on primary structures (including flight deck windshield pillars), or catastrophic failure on non-primary structural components (such as control surfaces, radome, etc.)
  - Large and medium sized hobby drones (1-3 kg) can potentially cause critical damage

Due to Damage a sUAS can Inflict on a Passenger Aircraft, Pilots have Made Evasive Maneuvers.

http://www.vtnews.vt.edu/articles/2015/10/102815-engineering-jetenginedronestrike.html

OPERATIONAL ENVIRONMENT

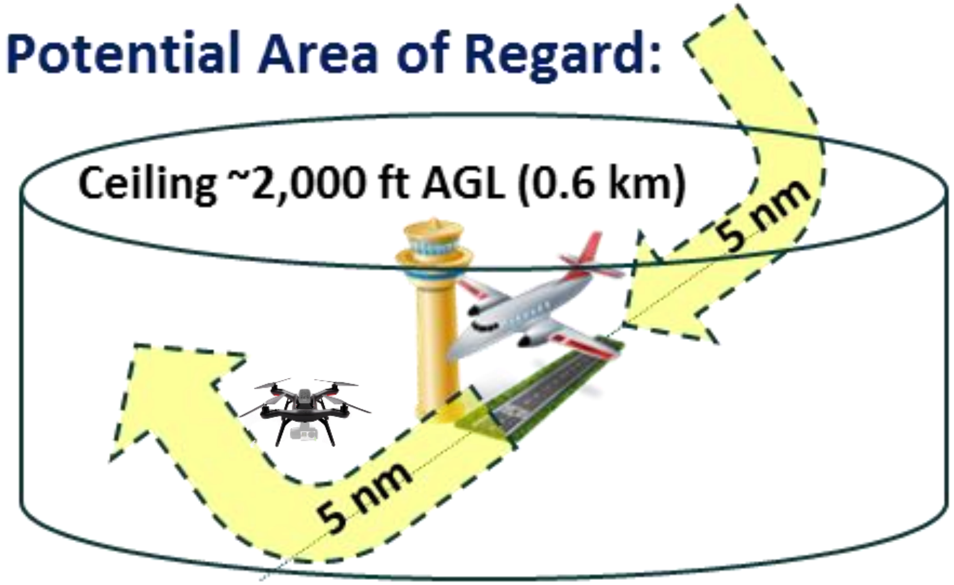
- Takeoffs and landings are the most critical portions of flight due to low speed/altitude
- FY16 CONUS = ~15 million flights = 30 million opportunities to engage an aircraft in the air
- Most aerodromes have standard departure and arrival routes for noise abatement and runway alignment
  - Highly restricted and predictable paths enabling straightforward targeting from bad actors
    - Slight silver lining in detect-to-engage: restricted corridors dictate smaller defended area requirements (in red) and help placement of detection and engagement systems
  - Departure graphic at right shows:
    - Roughly 2-3 km (~45 seconds) from runway center to climb through 1000 ft AGL
    - Roughly 6-8 km (~2 minutes) to 3000 ft AGL



Aerodrome Environment Presents Numerous Cooperative Airborne Targets in Predictable Engagement Windows

http://aspm.faa.gov/opsnet/sys/opsnet-server-x.asp
http://www.airservicesaustralia.com/western-australia-route-review-project-warrp/information-for-the-community/

ZONE OF SUSCEPTIBILITY (DEC 2013 – SEP 2015)

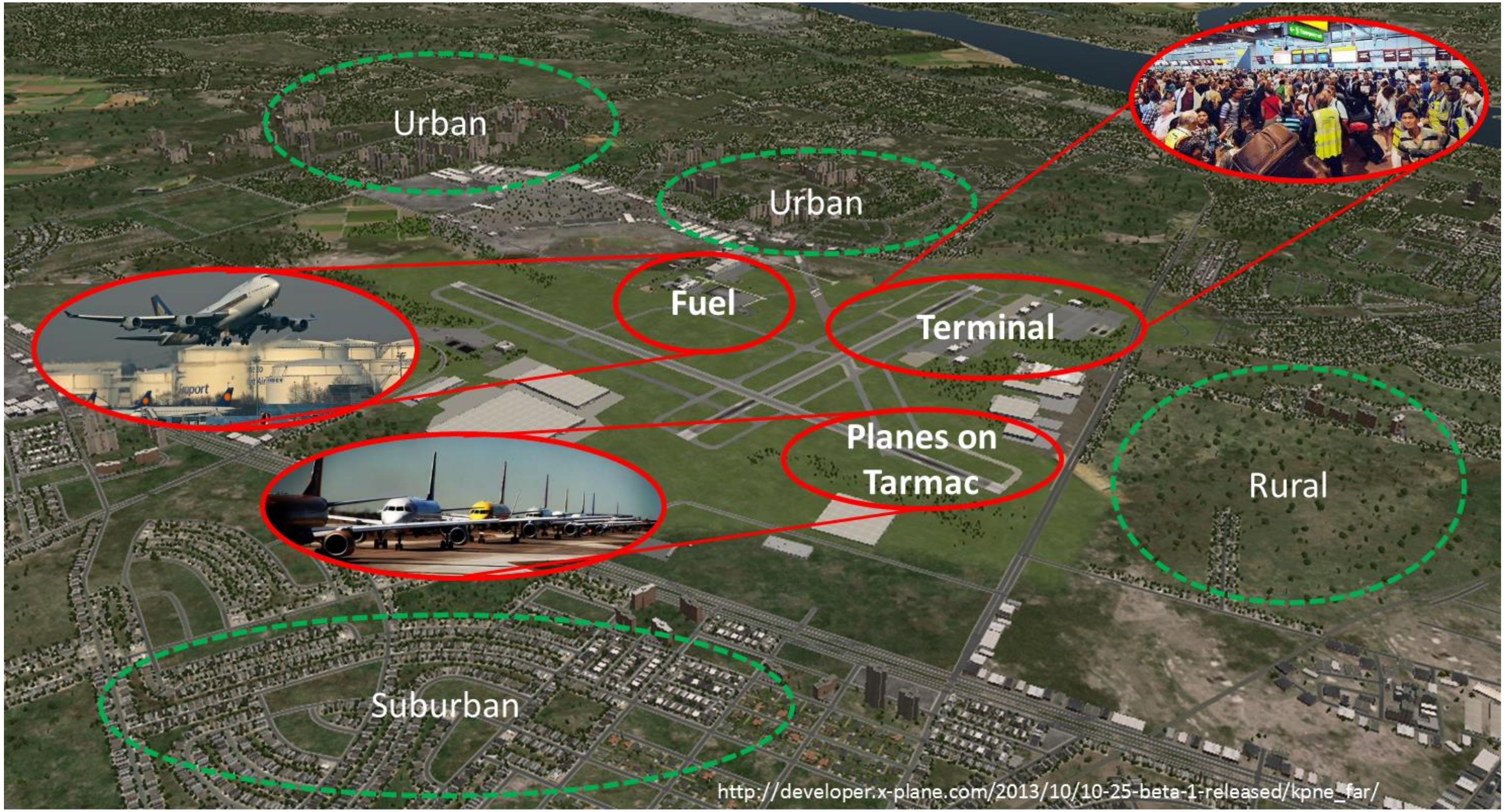


- **921 incidents in U.S. National Airspace System involving drones vs. manned aircraft**
  - **Almost all sUAS detections were pilot observations**
  - **Average altitude within 5 nm of airport: ~ 1,900 ft**
  - **158 incidences with miss distance within 200 ft or less of a manned aircraft; *51 were ≤50 ft.***
  - **116 incidences involved multiengine jet aircraft: 90 of these were commercial flights**
  - **340 drones identified in the reporting: 246 multirotor, and 76 fixed-wing**

The rise in sUAS encounters has drawn repeated calls for action

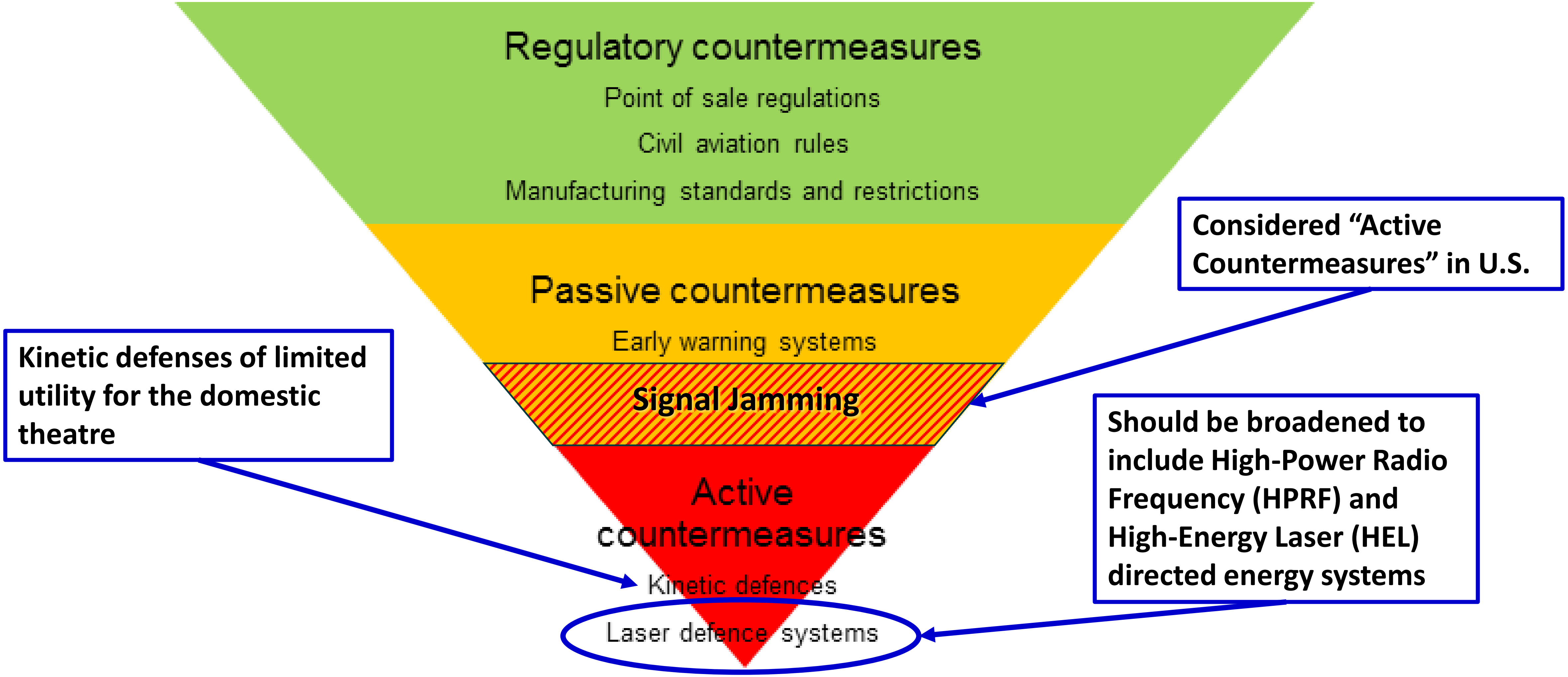
http://dronecenter.bard.edu/files/2015/12/12-11-Drone-Sightings-and-Close-Encounters.pdf

INTERNATIONAL AIRPORTS PRESENT A COMPLEX ENVIRONMENT



Multiple Stationary Targets, in Addition to Aircraft on Approach or Taking Off

sUAS COUNTERMEASURES HIERARCHY[1]



Proposed U.S. Legislation will Ease Barriers between Active and Passive Countermeasures[2]

(1) Hostile Drones: The Hostile Use of Drones By Non-state Actors Against British Targets, Remote Control Project, January 2016 (Oxford Research Group)
(2) May 19, 2017 Government-Wide C-UAS FINAL CLEAN: https://www.nytimes.com/2017/05/23/us/politics/drone-surveillance-policy.html?_r=0

U.S. sUAS LAW AND FAA REGULATORY ACTIVITY

	Fly for Fun	Fly for Work
Pilot Requirements	None	• Remote Pilot Airman Certificate • Pass TSA Vetting
Aircraft Requirements	Must be registered if over 0.55 lbs.	• Less than 55 lbs. • Registered if over 0.55 lbs.
Location Requirements	> 5 miles from airport without notification	Class G airspace
Operating Rules	• Visual line-of-sight only • Yield to manned aircraft • Must be under 55 lbs. • Must notify airport before flying within 5 miles	• Visual line-of-sight only (Day only) • Must fly under 400 feet • Must fly at or below 100 mph • Must yield to manned aircraft • Must NOT fly over people
Example Applications	• Education or • Recreation only	• Flying for commercial use • Flying incidental to a business
Legal or Regulatory Basis	Public Law 112-95, Sec. 336 Rule for Model Aircraft	Title 14 of the Code of Federal Regulation (14 CFR) Part 107

Appeals Court Overturns FAA Registration Rule on Recreational Drones(1) 19 May 2017

- Geofencing: the creation of virtual fences around areas or points of interest to keep drones away
- None of these have anything to do with nefarious actors

Laws/Regulations Prohibit Hazardous Materials (Weapons) from Being Transported by Passengers; Yet We Spend Significant Resources to Enforce Those Regulations

(1) http://www.executivegov.com/2017/05/appeals-court-nullifies-faa-registration-rule-on-recreational-drones/
https://www.faa.gov/news/fact_sheets/news_story.cfm?newsid=20516

WHEN THE REGULATORY APPROACH FAILS

- sUAS operating within airport restricted airspace is a significant growing problem

- There will continue to be illegal acts:
  - Corporations using drones to obtain sensitive information
  - Crime organizations for smuggling
  - Activist campaigns

- And there will be malicious acts:
  - Lone wolves/Homegrown Violent Extremists (HVEs) – between Jan 2013 and Aug 2015 there were 20 suspicious drone related incidents in or around London alone
  - Terrorist and Insurgent using them now

Regulatory Approach is Good for Informing the Honest and Correcting the Unwise; Not for Deterring the Malicious.

https://www.youtube.com/watch?v=zQnOJmesqQ4; https://defensesystems.com/articles/2016/01/26/non-state-threat-small-drones.aspx
Hostile Drones: The Hostile Use of Drones By Non-state Actors Against British Targets, Remote Control Project, January 2016

TERRORIST sUAS DEVELOPMENT TIMELINE

Oct 2014
Initial UAS ISR Capability

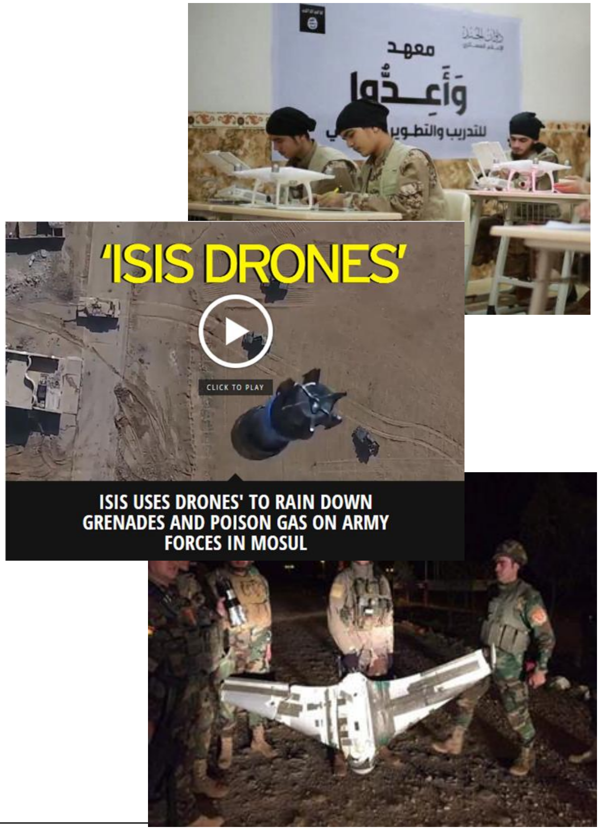
Oct 2016
Booby-trapped UAS Kills 2 Kurdish Troops

Jan 2017
Propaganda video depicts weaponized UAS dropping bombs on Coalition

ISIS sUAS Implementation Timeline

Future: Increased range, payload capacity, accuracy

- Why sUAS?
  - Psychological weapon; highly effective when combined with social media
  - Inexpensive, highly portable, widely available systems that can provide tactical advantages in asymmetric warfare conditions
  - Current range of applications from filming propaganda videos, to ISR (scouting enemy positions), to command and control (guiding indirect fire), to direct attack (ordnance delivery and kamikaze), with anticipated increases in lethality
- How terrorists develop capability:
  - Iterative process to purchase, modify, and/or develop capabilities which run counter to existing target defenses; similar to “Improvised Explosive Devices” campaign that emerged in Iraq and Afghanistan in 2004
- How we characterize and counter the threat:
  - Intelligence and forensics; examine kill chain, harden/improve defensive systems



http://www.icsve.org/brief-reports/the-potential-threats-posed-by-isiss-use-of-weaponized-air-drones-and-how-to-fight-back/

THE THREAT IS REAL

- In July 2011, Rezwan Ferdaus, a homegrown violent extremist (HVE), attempted to use sUAS carrying IEDs to attack the Pentagon and Capitol building
  - Only documented case in the United States of an HVE attempting to use a device similar to a weaponized sUAV in the last 10 years
- ISIS English-language propaganda provides operational "how-to" guides intended to inspire HVEs
  - Most ISIS's weaponization of UAVs in Iraq and Syria involves the use of modified military ordnance (difficult to acquire in the United States)
- On February 1 (2017), ISIS released an image called the "Islamic State Nightmare," featuring fighters preparing to launch a UAV over an image of the Statue of Liberty

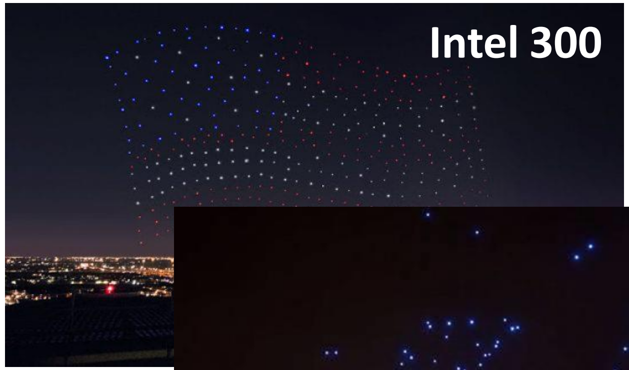
Weaponized UAV with customized IED

Pro-ISIS propaganda depicting UAV weaponization

"We cannot rule out the possibility HVEs will learn how to construct and weaponize UAVs based on future ISIS propaganda."[1]

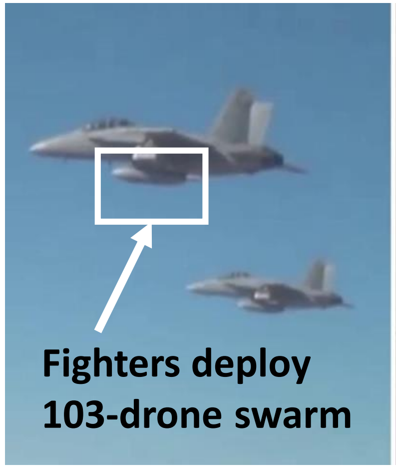
(1) https://www.njhomelandsecurity.gov/analysis/isis-deploying-unmanned-aerial-vehicles-uavs

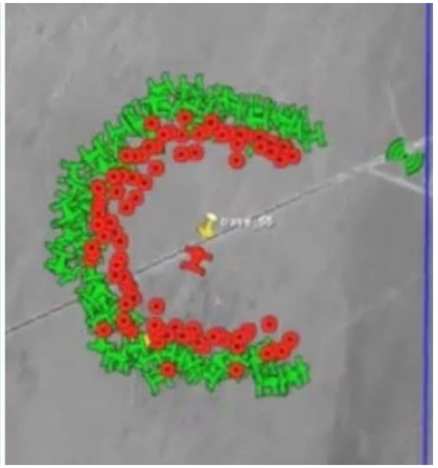
"LIKELY" FUTURE THREAT-sUAS TECHNOLOGY DEVELOPMENTS



- "Drone SWARM" technologies
  - Intel 300 drones used for Super Bowl lightshow 2017
  - Intel able to control a 500-drone lightshow with one laptop
  - Perdix micro-UAV swarm was held at China Lake, Calif. on Oct. 26, 2016. Three F/A-18's were deployed to launch the swarm of tiny drones, according to the Department of Defense
- "… drones will soon have a **hunt-and-destroy capability**. Algorithms exist today to program a drone with **"see-and-avoid"** ability as demonstrated at the MIT with proven autonomous software logic."
  - Lt Col Leslie F. Hauck III, USAF, Dr. John P. Geis II, Colonel, USAF, (Ret), *Air Mines: Countering the Drone Threat to Aircraft*, Air & Space Power Journal, Vol. 31, No. 1, Spring 2017
- Autonomy and Machine Learning, takes away need for direct control
  - Potentially negates a significant EW attack vector

Imagine a World Where Terrorists Tactics Previously Discussed are Combined with these Technology Advancements





http://www.nextbigfuture.com/2017/02/oncoming-drone-swarms.html, http://www.foxnews.com/tech/2017/01/10/video-shows-fighter-jets-launch-swarm-tiny-drones.html
http://www.rightthisminute.com/video/rtmtv-intel-sets-world-record-500-sparkling-drones

sUAS KILL-CHAIN DISCUSSION

“Victory smiles upon those who anticipate the changes in the character of war, not upon those that adapt themselves after the changes occur.”

- Air Marshal Giulio Douhet, *Command of the Air*, 30, 1921

Maj Dillon R. Patterson, USAF, *Defeating the Threat of Small Unmanned Aerial Systems*, Air & Space Power Journal, Vol. 31, No. 1, Spring 2017
NSWCDD Counter-UAS Testing Conducted at San Nicolas Island Navy Test Range, May 2010

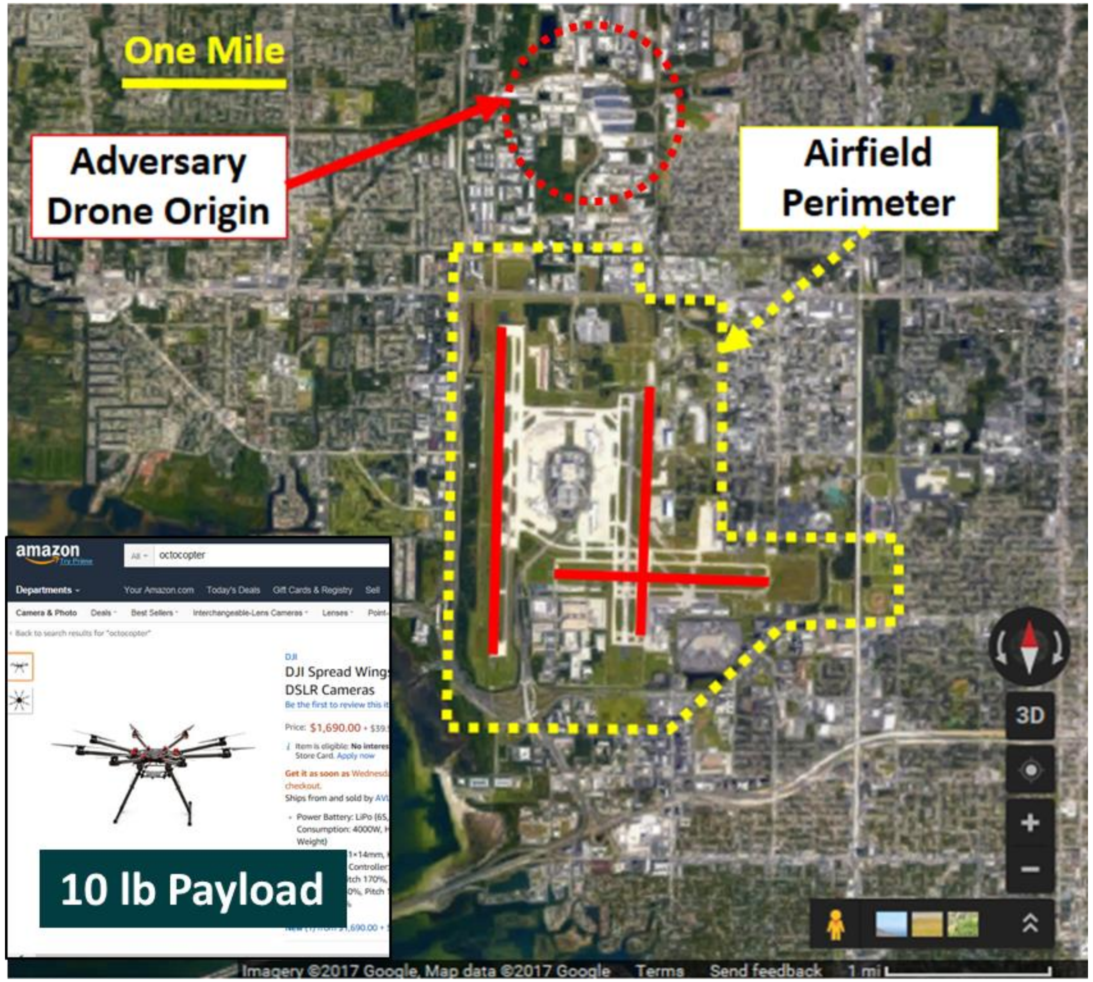
VIGNETTE: sUAS-AIRLINER MIDAIR COLLISION ATTACK

Homegrown violent extremist (HVE)

Threat platform: DJI S1000+ octocopter:
- Takeoff weight – 6-11 kg; empty weight 4.4 kg
- Max speed – 30-45 mph
- Hover time – 15 minutes
- DJI Lightbridge 2.4G HD digital video downlink
- "Multi-rotor, autopilot feature makes it ideal for videography and photography by maintaining stability while flying and hovering"

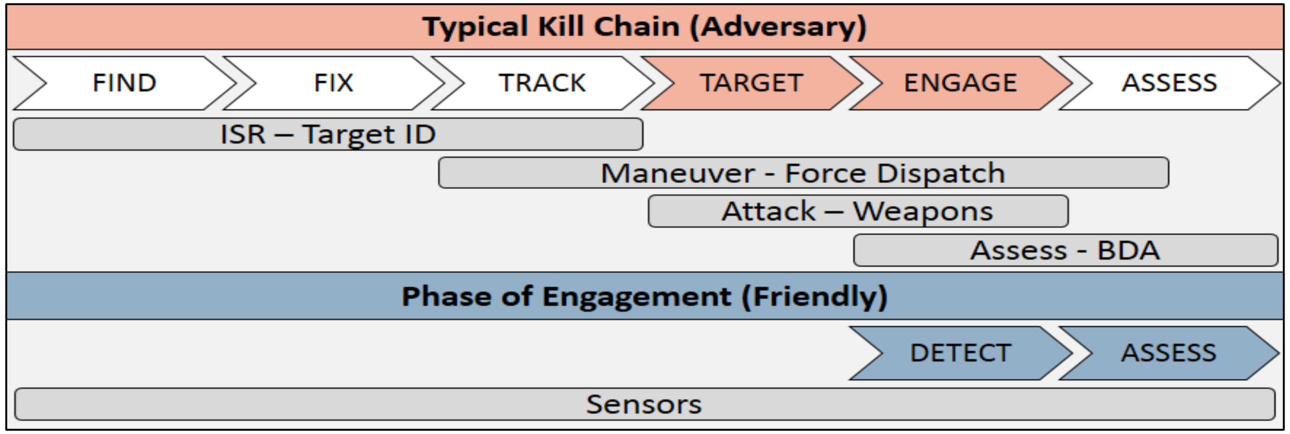
Target: commercial airliner
- Departure speed – ~150 mph

Objective: Midair collision with commercial passenger aircraft during departure from International airport



An Adversary is Determined to Create a "Shock and Awe" Propaganda Event

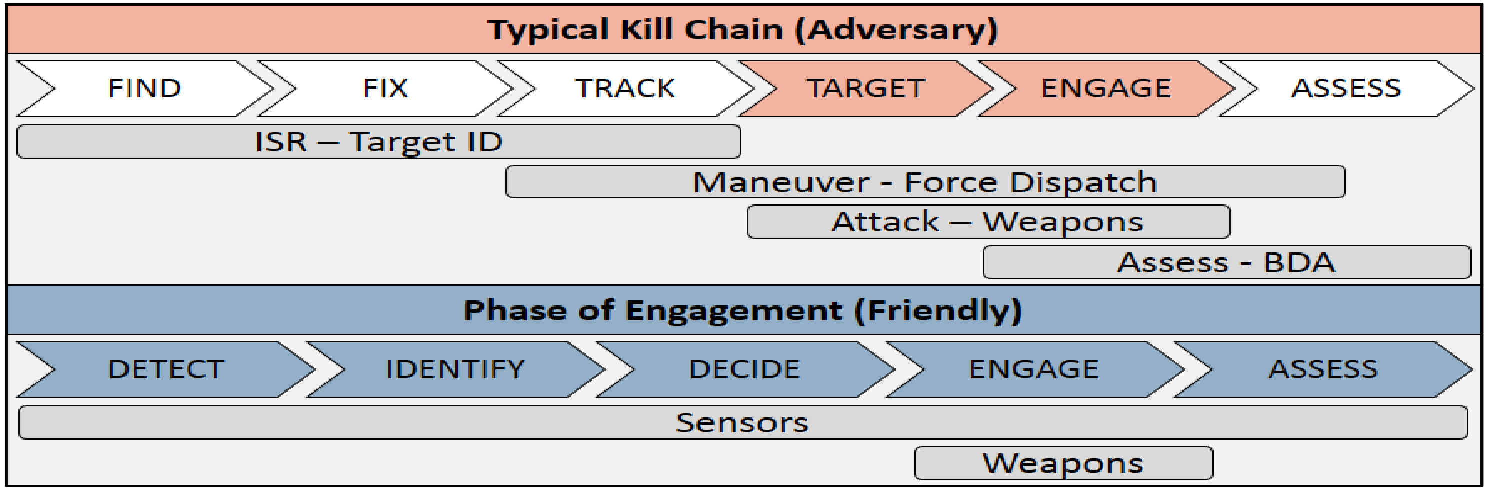
OVERLAPPING MISSION THREADS "TODAY" (F2T2EA)



- Adversary:
  - **Find/Fix/Track** – pre-mission activities which include monitoring "international airport" patterns-of-life; identify vulnerabilities; determine engagement parameters; conduct pre-mission rehearsals
  - **Target/Engage** – pre-position octocopter in such a way that mission engagement timelines are very short and enable multiple engagements on single battery charge
  - **Assess** – utilize onboard and offboard sensors for situational awareness
- Friendly:
  - **Detect** – Anticipate first reports will be "close encounters" or "Mayday" from targeted aircraft
  - **Assess** – Anticipate only confirmation of threat vector during post-event analysis/forensics

The Adversary has Advantages in Selecting Time and Place of Attack; and in Slow 'Friendly' Response Times and Minimal Capabilities

OVERLAPPING MISSION THREADS "TOMORROW"



- Adversary:
  - Activities remain the same as in previous chart
- Friendly:
  - **Detect/Identify/Decide** – Addition of new sensors provides "battlespace awareness", supports determination of intent, enables positive hostile ID and discrimination, and creates time for command authority decision-making
  - **Engage** – Incorporation of "low-collateral" non-kinetic means to engage threats prior to their achieving their goals
  - **Assess** – Utilization of sensors to survey operating area and make determinations on outcome of engagement, and assessment of threat status (i.e., single sUAS, multiple, SWARM, etc.)

Incorporate New Sensors and Weapons to Shift Advantage Away from Determined and Intelligent Adversary

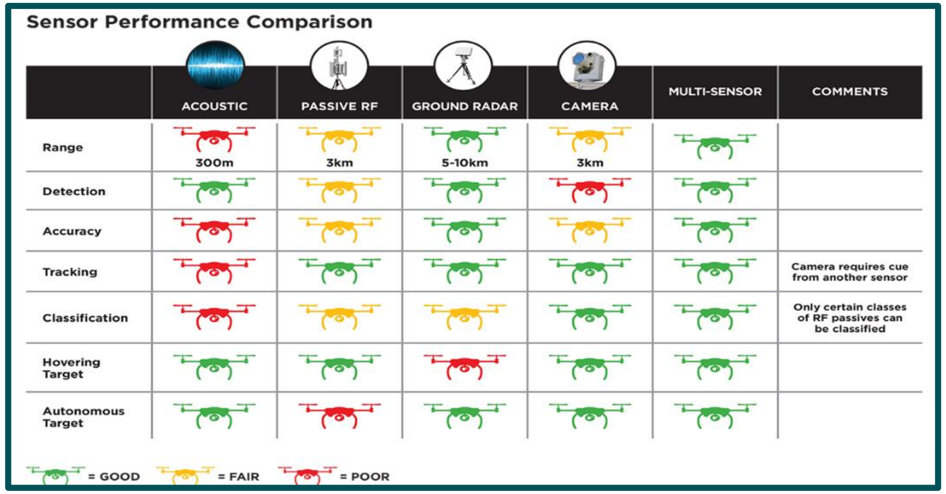
NSWCDD Counter-UAS Testing Conducted at San Nicolas Island Navy Test Range, May 2010

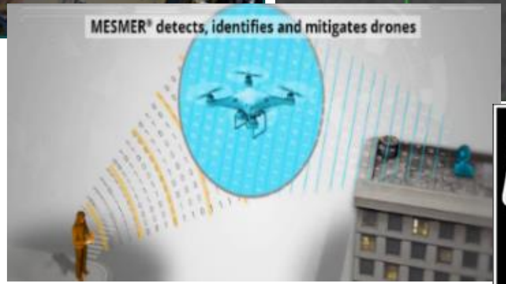
sUAS DETECT, IDENTIFY, DECIDE

http://www.simulyze.com/blog/humanitarian-aid-gets-helping-hand-from-uas-technology

FAA APPROACH TO sUAS DETECTION

- Existing air traffic control system, which relies on few, powerful radars, mostly ineffective for sUAS
  - Small cross section; radar does not work well at low altitudes; significant natural and manmade clutter
- FAA Pathfinder Program, begun in 2015, includes Cooperative Research and Development Agreements to focus on detecting and identifying sUAS flying too close to airports
  - “We selected manufacturers with a variety of UAS detection technology, including radar, radio frequency, and optical.”
  - “Research suggests more than one type of sensing technology may be needed in an airport environment, and each airport has unique user needs and engineering challenges.”





Providing New Detection Capability Where Previously There Was None

https://www.theguardian.com/technology/2015/nov/26/drone-regulations-united-states-testing-air-traffic-control-system-precisionhawk, https://www.faa.gov/uas/programs_partnerships/uas_detection_initiative/, https://www.faa.gov/news/updates/?newsId=83927, https://www.faa.gov/news/updates/?newsId=84810, https://www.faa.gov/news/updates/?newsid=85532, http://gryphonsensors.com/products/, https://issuu.com/auvsi/docs/pages_from_08_unmannedsystems_web, https://www.sensofusion.com/, http://www.liteye.com/uncooled-thermal.html, http://www.unmannedsystemstechnology.com/2015/06/new-anti-uav-defence-system-successfully-detects-tracks-disrupts-uavs/, https://department13.com/mesmer

STRENGTHS AND WEAKNESSES OF sUAS DETECTION APPROACHES

Sensor Performance Comparison

Best Answer → MULTI-SENSOR

	ACOUSTIC	PASSIVE RF	GROUND RADAR	CAMERA	MULTI-SENSOR	COMMENTS
Range	POOR 300m	FAIR 3km	GOOD 5-10km	FAIR 3km	GOOD	
Detection	GOOD	FAIR	GOOD	POOR	GOOD	
Accuracy	POOR	FAIR	GOOD	FAIR	GOOD	
Tracking	POOR	GOOD	GOOD	GOOD	GOOD	Camera requires cue from another sensor
Classification	POOR	FAIR	FAIR	GOOD	GOOD	Only certain classes of RF passives can be classified
Hovering Target	GOOD	GOOD	POOR	GOOD	GOOD	
Autonomous Target	GOOD	POOR	GOOD	GOOD	GOOD	

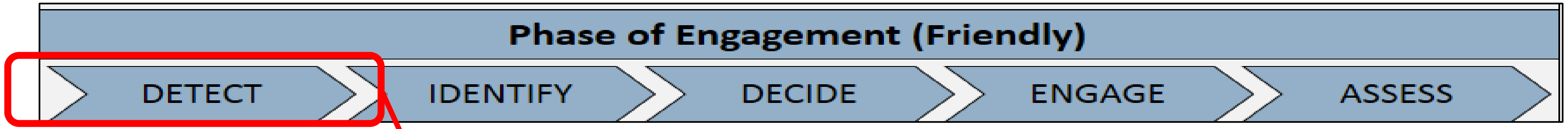
“Green” for HEL Beam Director (pointing to Camera Range and Camera Accuracy)

= GOOD = FAIR = POOR

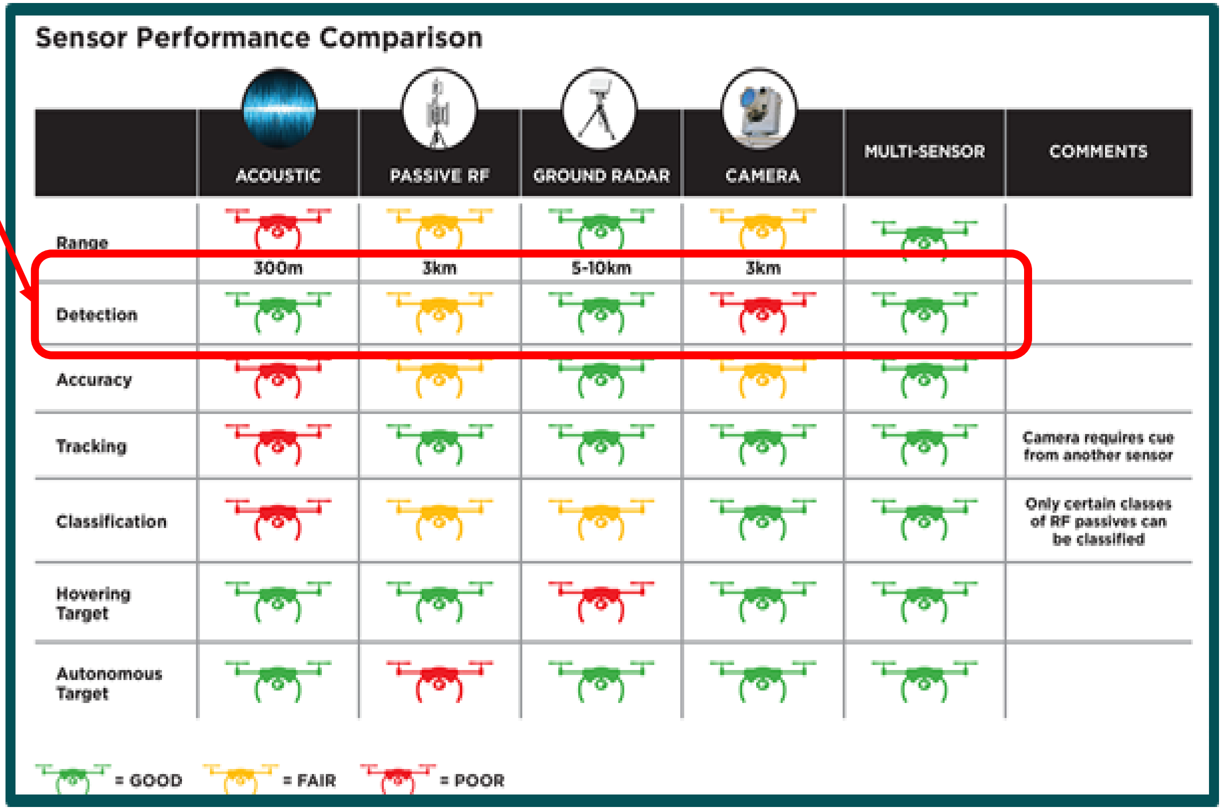
Gryphon Sensors

http://gryphonsensors.com/wp-content/uploads/2016/11/Multi-Sensor-Advantage.pdf

DETECTION FIRST



- Detection:
  - Impacts decision and response timelines
  - Impacted by natural and manmade obstructions
  - Impacted by physics and environmental conditions
- Each sensor has its own needs and challenges
- Note the EO/IR (i.e., Camera) is best at target identification



Initial Detection Establishes Timelines and Options

http://gryphonsensors.com/wp-content/uploads/2016/11/Multi-Sensor-Advantage.pdf

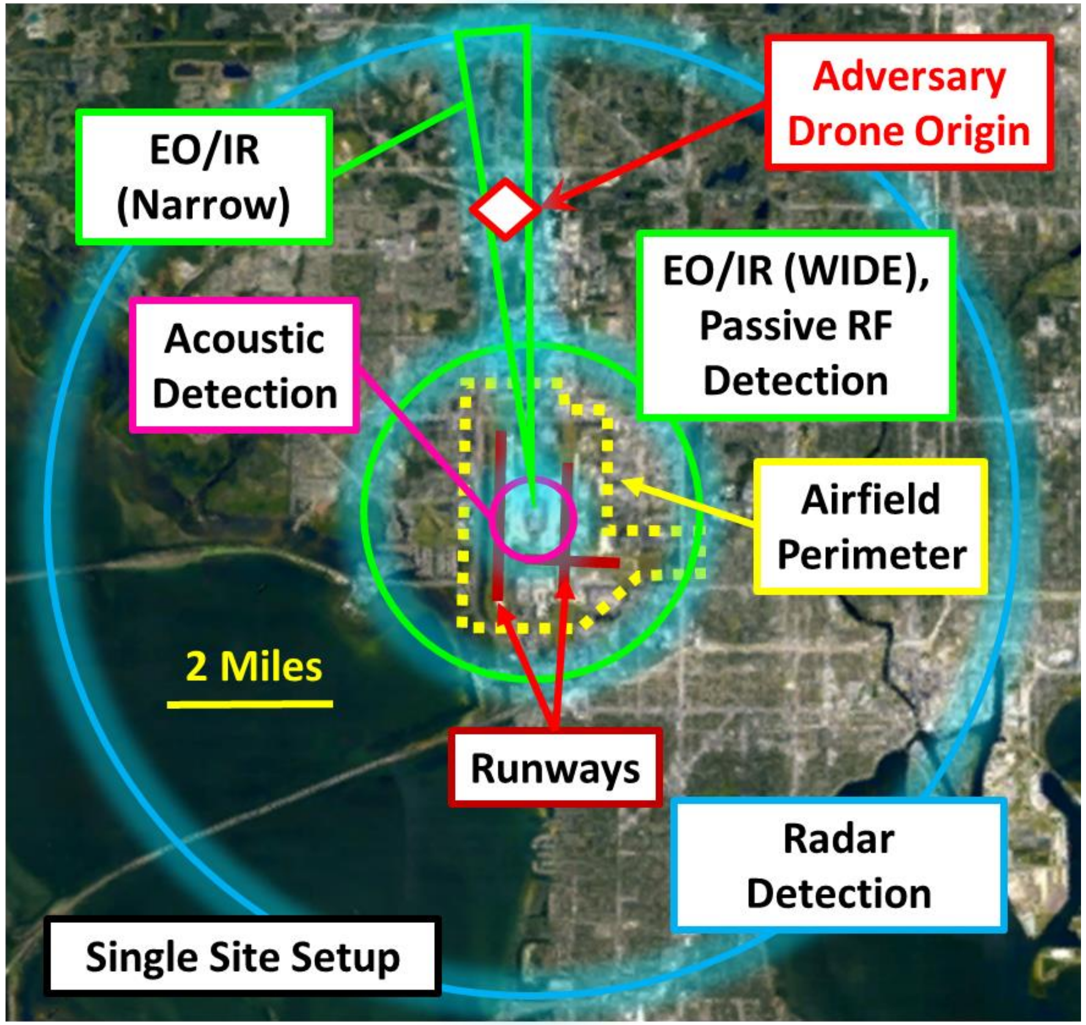
INITIAL sUAS DETECTION "POTENTIAL" NEAR FLIGHT PATH

Sensor Performance Comparison

	ACOUSTIC	PASSIVE RF	GROUND RADAR	CAMERA	MULTI-SENSOR	COMMENTS
Range	POOR 300m	FAIR 3km	GOOD 5-10km	FAIR 3km	GOOD	
Detection	GOOD	FAIR	GOOD	POOR	GOOD	
Accuracy	POOR	FAIR	GOOD	FAIR	GOOD	
Tracking	POOR	GOOD	GOOD	GOOD	GOOD	Camera requires cue from another sensor
Classification	POOR	FAIR	FAIR	GOOD	GOOD	Only certain classes of RF passives can be classified
Hovering Target	GOOD	GOOD	POOR	GOOD	GOOD	
Autonomous Target	GOOD	POOR	GOOD	GOOD	GOOD	

= GOOD = FAIR = POOR

- Single-site-approach graphic to right portrays initial optimistic best case ranges from chart above
  - All sensors co-located
  - Added narrow (cued)/wide FOV for EO/IR
- Need to understand actual detection areas, environmental and manmade impacts

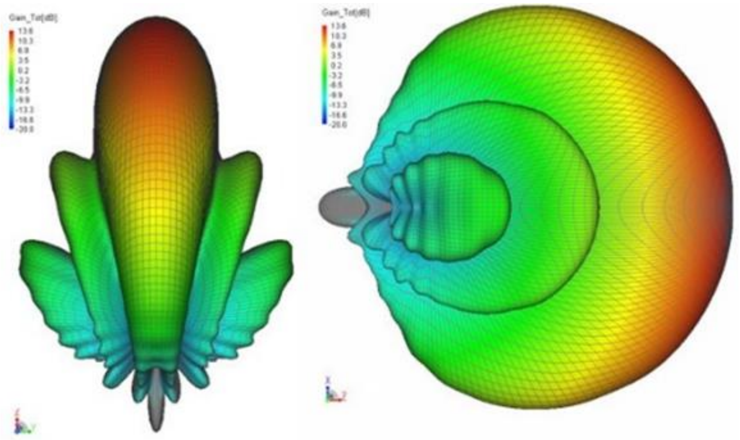


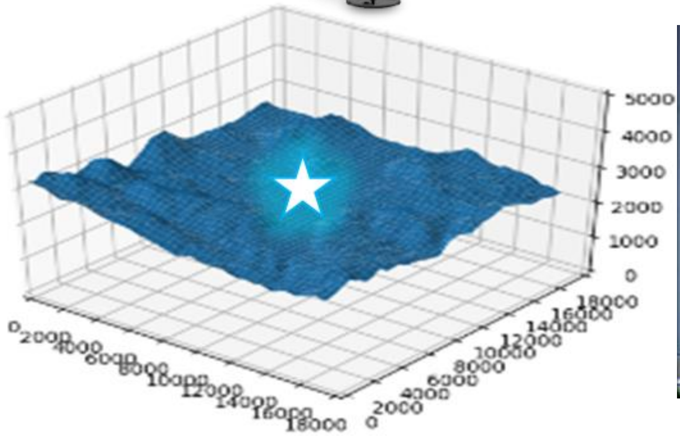
Radar Detection Area Has Greatest Potential Coverage for Initial Detection

http://gryphonsensors.com/wp-content/uploads/2016/11/Multi-Sensor-Advantage.pdf, https://www.google.com/maps/

DETERMINING sUAS DETECTION: FIRST STEPS

- Airfields will likely consider non-technical factors during radar down-selection such as cost and availability
  - Installation location decisions include security, elevation, obstacles
- After deciding radar type and installation location, next steps in determining “actual” radar detection area are:
  - Characterize technical parameters for candidate system(s)
  - Import/develop terrain data
  - Generate antenna patterns in situ (tower, rooftop, mast, etc.)



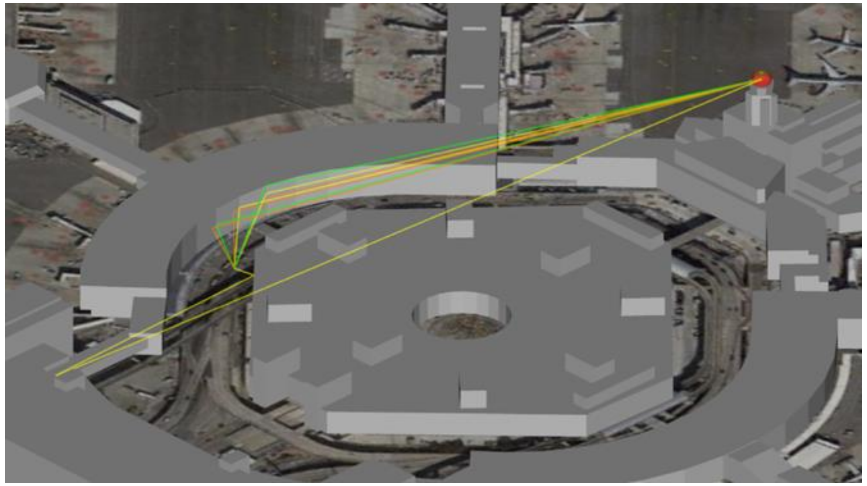


Initial Steps to Understanding Operational Radar Detection Ranges

http://gryphonsensors.com/wp-content/uploads/2016/11/Multi-Sensor-Advantage.pdf, http://cache3.asset-cache.net/xd/756-25.jpg?v=1&c=IWSAsset&k=2&d=F13A1F9190F009361CC679039555E0F9FE9531BE62E93F72C3184A351847B13E49AAE4E13EDE9114

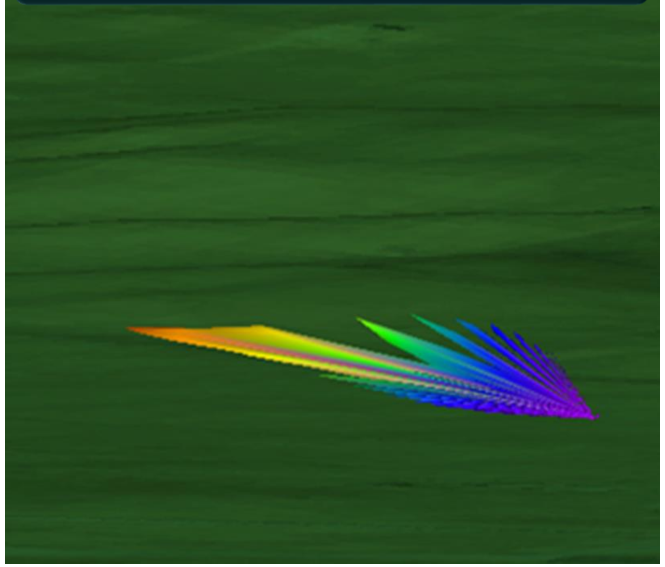
DETERMINING RADAR EFFECTIVENESS FOR sUAS DETECTION: RF CLUTTER

- We use M&S to determine the RF clutter environment
  - Generate time-delayed returns through Shooting-Bouncing Ray (SBR) Geometrical Theory of Diffraction (GTD)
  - Generate terrain clutter map by steering co-located transmit and receive antennas across azimuth and elevation
  - Calculate reflected and diffracted rays; post-processing to determine time-gated returns and relative strengths
- Clutter Map = Return mapped to each steering angle

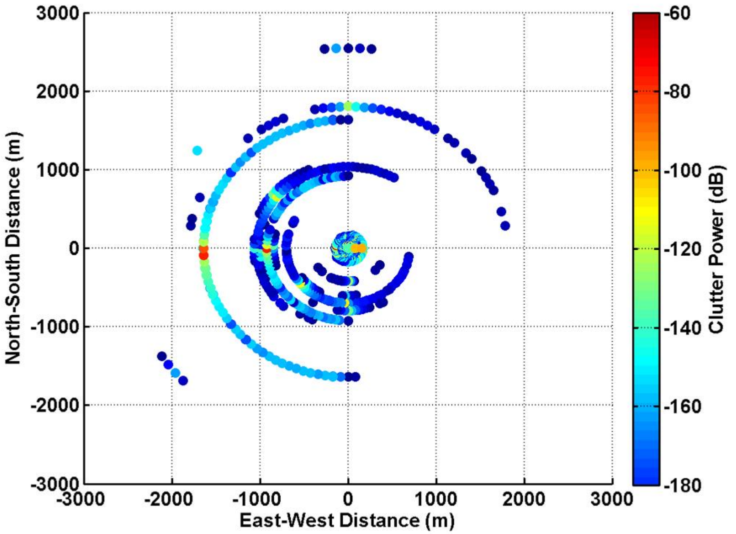


Detection Ranges Are Impacted by RF Clutter and Target Radar Cross Section

Terrain With Overlaid Antenna Pattern

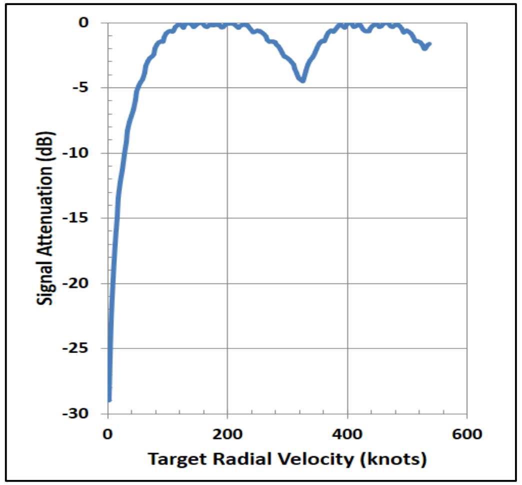


Clutter map for beam at 0° elevation

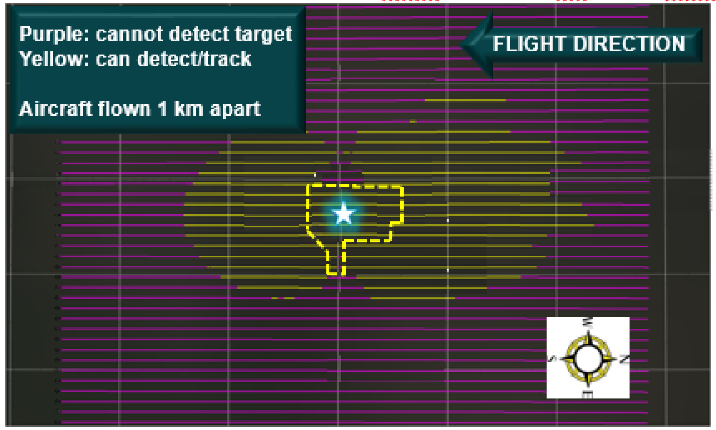


DETERMINING RADAR EFFECTIVENESS FOR sUAS DETECTION: ANALYSIS

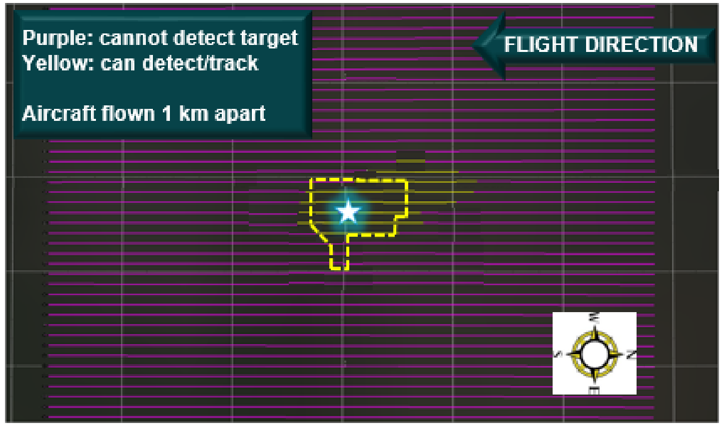
- Incorporate anticipated radar signal processing:
  - Digital signal processing to mitigate clutter
  - Placement of radar in terrain (ground level in examples with sUAS at 200 & 1000 ft AGL)
- Fly grid of UAVs past radar:
  - UAVs fly at constant altitude, constant speed
  - Look at detection history to identify regions where radar cannot track UAVs
  - For a particular UAV cross-section, ability to detect depends on altitude, velocity, heading, and clutter
  - Slow-moving targets are generally harder to detect
    - increasing sensitivity increases clutter (i.e., birds, trees moving, etc.)

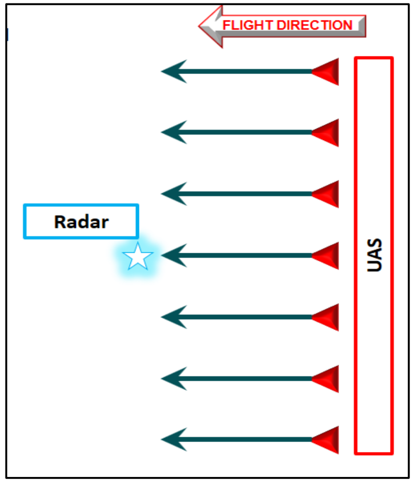


ANALYSIS RESULTS CLASS I UAS @ 1000 FT & 30 KTS



ANALYSIS RESULTS CLASS I UAS @ 200 FT & 30 KTS

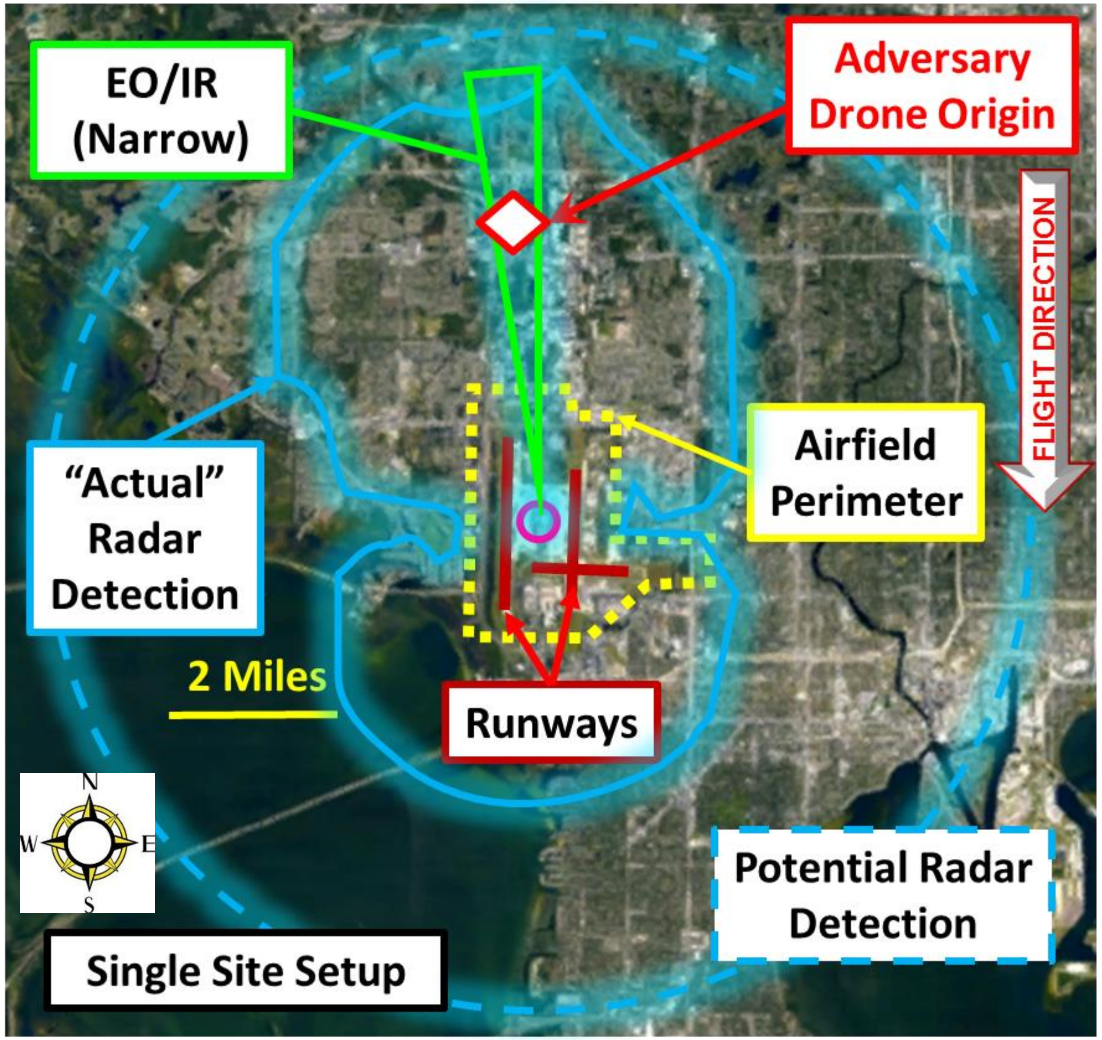




Detection Ranges Are Significantly Impacted by Radar Placement AGL and Target Speed/Altitude

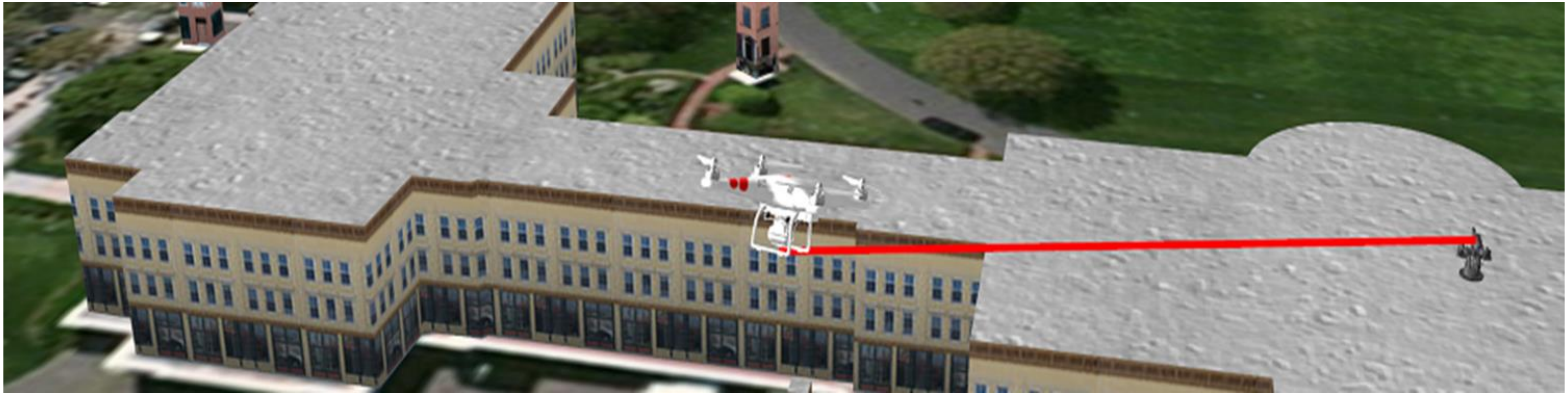
sUAS DETECTION "ACTUAL"(1)

- Assuming all factors are accounted for, the graphic to right portrays initial "actual" detection range of radar vs. "potential" detection range
  - Graph shown for sUAS @ 1000 ft and 30 kts
  - Primary impacts to radar caused by scattering and clutter
  - Manmade obstacles can have a significant impact as well
- Next steps will address
  - sUAS ENGAGEMENT
  - Mission planning and visualization
  - Operator training



Actual Detection Ranges Are a Complex Function of Detection System, Target, and Environment

(1) All "actual" detection ranges are notional.



sUAS ENGAGEMENT

EW APPROACHES TO COUNTER-sUAS ENGAGEMENT

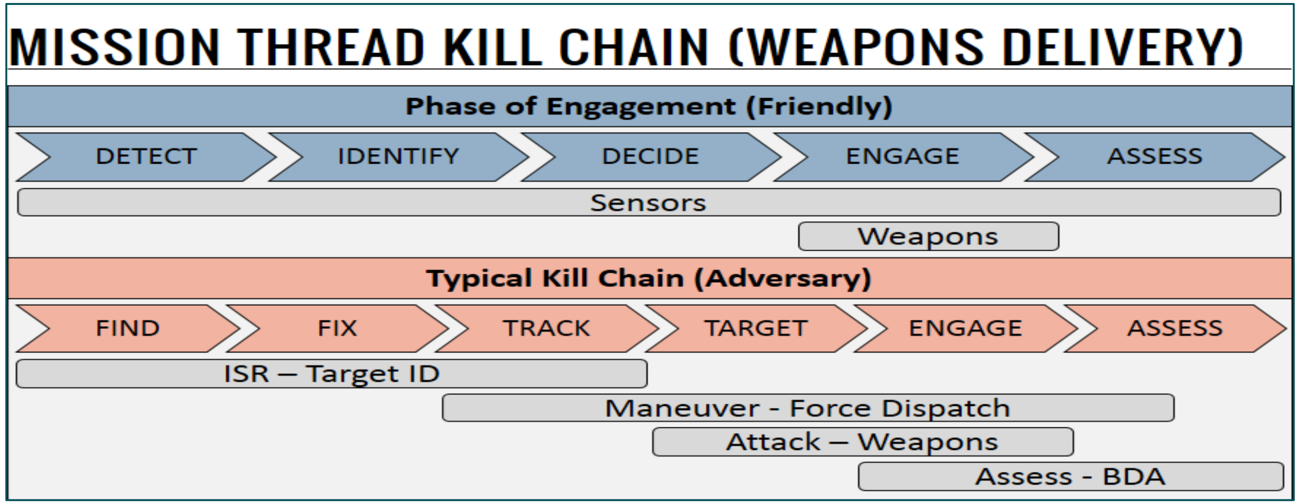
- Electronic Warfare approach to C-UAS:
  - Asymmetric target set – will likely mirror counter-IED lifecycles and dependencies
    - Adversary – advanced technology access (buy/build); system reprogramming; TTP
    - Friendly – intelligence (human intelligence/forensics); system reprogramming; TTP
    - General – “zero event” mentality becomes potentially very costly
  - Current EW approaches deny, degrade, or deceive communication channels
  - Broadband versus narrowband jamming:
    - Broadband – potentially reduced effectiveness due to power-sharing; potential for interference in friendly spectrum; potential for increased effectiveness in multi-threat scenario (swarming UAS or multi channel C2)
    - Narrowband – highly dependent on predictable adversary or up-to-date intelligence; potential to miss target entirely; potential reduced effectiveness in multi-threat scenario
  - Potential collateral damage:
    - An intelligent adversary will piggy-back communications on critical “local” networks (emergency response, GPS), or incorporate autonomy/BLOS capabilities
- Future developments in autonomy, artificial intelligence (AI), machine learning etc. will be problematic for EW

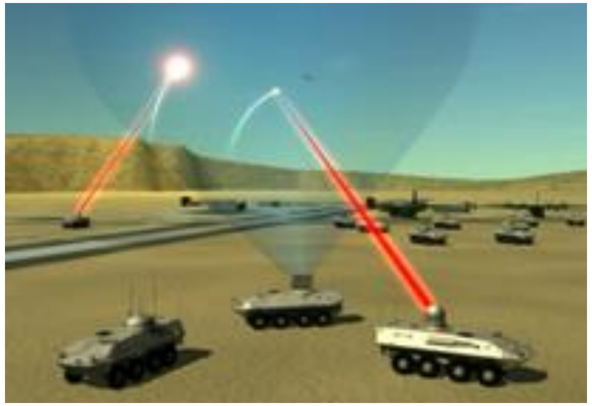
Primary Goal of EW is to Prevent the Successful Reception or Transmission of Data

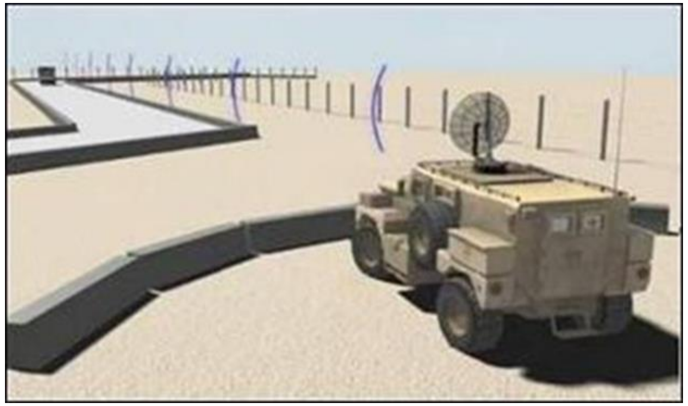
Sandia National Laboratories, “UAS Detection, Classification, and Neutralization: Market Survey 2015; http://www.blighter.com/products/auds-anti-uav-defence-system.html, https://www.droneshield.com/dronegun

DIRECTED ENERGY FOR COUNTER-sUAS

- **Definition:** Technology and weapon systems based on **the application of force on target with electromagnetic energy vice kinetic energy** (no projectile)
- Advantages
  - Engagement opportunities across adversary Kill Chain
  - Speed-of-light delivery (HEL needs dwell)
  - Precise engagement
  - Graduated effects
  - Depth of magazine
  - Low collateral damage
- Energy Classes
  - **High Energy Laser (HEL)**
    - Impacted by weather
    - Concerns over sensor safety
  - **High Power Microwave/RF (HPM/HPRF)**
    - Impacted by range
    - Concerns over interference







Directed Energy Weapons Provide Scalable Effects Against a Broad Range of Targets

CONVERGENCE

- Advancing state of the art in DE technology, along with the immergence of threats addressable by those technologies, present a unique opportunity to get DE capabilities operationally used
- Evolving threats addressable by Directed Energy Weapons (DEW):
  - Guided/Unguided: Rockets, Artillery, Mortars and Missiles (RAM&M)
  - Proliferating unmanned areal systems (UAS) for both ISR and strike
  - Asymmetric "Swarm" capabilities (UAS, FIAC, etc.)
  - Complex improvised explosive devices (IEDs)

- For military applications, low cost per engagement, and a deep magazine, allows the use of DE capabilities to move us to the *right side* of the cost curve by negating lower-end threats, thereby preserving expensive high-end KE capabilities for higher-end threats
- U.S. DE-related policy and legal issues are generally supportive of DE capability development and deployment
- When an HEL weapon is deployed, ISR capabilities are significantly enhanced throughout the life of the DE system

Has Resulted in Significant Increase in DoD Warfighter and Acquisition Community Interest

http://www.dronedefinition.com/boeings-new-laser-cannon-shoots-down-drones/

EXAMPLE DIRECTED ENERGY sUAS COUNTERMEASURES

- **High-Energy Laser (HEL):**
  - Boeing’s Compact Laser Weapon System (CLWS)
    - 2 kW man portable (600 lbs)/5 kW Stryker

- **SMDC HEL_TVA (Tactical Vehicle Demonstrator)**
  - 100 kW-class HEL
  - ≥30 cm aperture
  - target illuminator
  - adaptive optics,
  - low jitter precision pointing and tracking system

- **High Power Radio Frequency (HPRF):**
  - Raytheon’s Phasor
    - Very high power, short pulse
    - Potential for >100’s of meter range

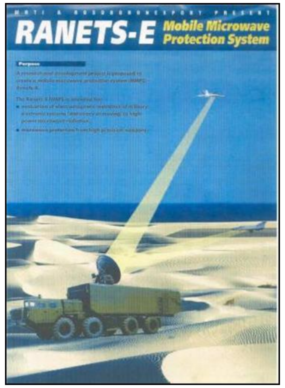
- **USMC GBAD HEL**
  - 10’s kW HEL
  - C-UAS capability
  - 30 cm aperture
  - Target illuminator
  - On-the-move cap.

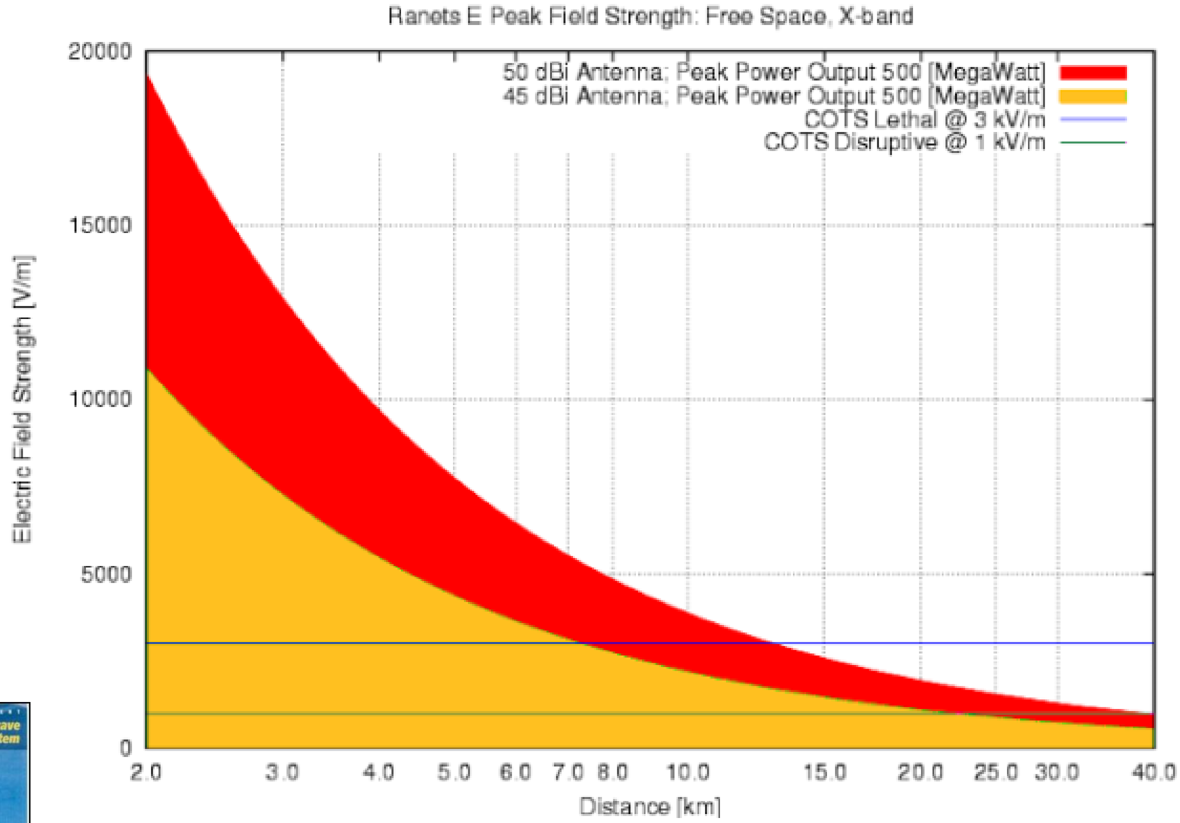
http://www.thedrive.com/the-war-zone/9345/the-u-s-armys-laser-armed-stryker-has-blasted-dozens-of-drones, http://www.raytheon.com/news/feature/laser_tech.html
http://www.popularmechanics.com/military/weapons/a23881/the-army-is-testing-a-real-life-phaser-weapon/, https://www.smdc.army.mil/FactSheets/HEL_TVD.pdf

RUSSIAN *RANETS-E* – HPRF DIRECTED ENERGY WEAPON

- First disclosed by Rosoboronexport in 2001 (concept), now reported openly in Russian press
- X-band pulsed 500 Megawatts HPRF source, generating 10 - 20 ns pulses at a 500 Hz PRF, P_{ave} of 2.5 to 5 kilowatts
- Antenna gain 45 to 50 dB X-band
- Russian sources credit it with a lethal range of 20 miles against the electronic guidance systems of PGMs and aircraft avionic systems.

✓ **HPRF effects generated on sUAS in << 1 sec**





Represents a Very "High-End" Approach That While Very Effective, May be Cost Prohibitive

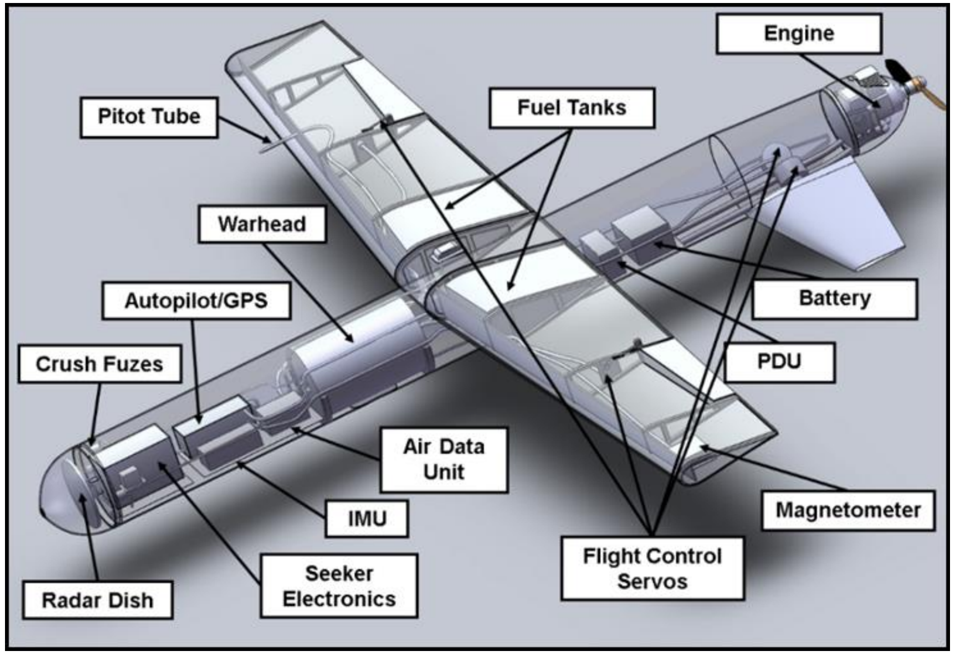
https://thaimilitaryandasianregion.wordpress.com/2016/01/19/ranets-e-high-power-microwave-directed-energy-weapon/

OPERATIONAL CONSIDERATIONS FOR HPRF AND HEL DEPLOYMENT

- **Weather impact/understanding (fog, rain, snow, sandstorm, etc.)**
  - Ability to determine on the "tactical" level (more significant for HEL) (weather major sUAS operational Impact)
- **Atmospheric impact/understanding (turbulence, extinction, utility of adaptive optics, thermal blooming etc.)**
  - Ability to determine on the "tactical" level (real-time or forecast?) (mitigated by short-range sUAS engagement)
- **Target lethality understanding**
  - Fidelity to determine Pk (need to determine HEL "time to effect," or HPRF "duration of effect," with high confidence) (straight forward for sUAS)
  - Ability to perform "aimpoint selection and maintenance" (primarily HEL, easy for sUAS)
- **Weapon effectiveness understanding**
  - Ability to "tactically" perform a kill assessment (straight forward for sUAS)
- **Collateral damage estimation ability**
  - Need to address satellite predictive avoidance and airspace deconfliction
  - Need to understand collateral effects on personnel
- **Consideration of adversary employment of Countermeasures to DE**

HEL: TARGET VULNERABILITY CHARACTERIZATION

- Larger UAS targets necessitate acquiring the target and analyzing its functions and sub systems
- Perform a Failure Modes Effects Analysis (FMEA) results in a target vulnerability characterization
  - Target geometry model
  - Component properties and damage criteria
  - Failure Analysis Logic Tree (FALT)



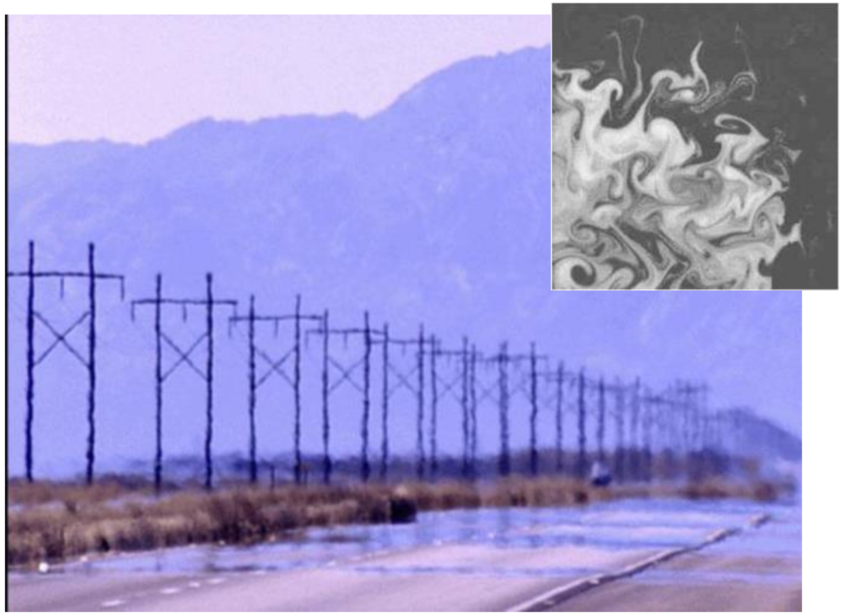
- sUAS Present a much more simplified target approach
- Targets are readily available for acquisition and testing
- FMEA characterization
  - Component properties and damage criteria easily determined
  - Failure Analysis Logic Tree (FALT) normally yields "center of mass" targeting

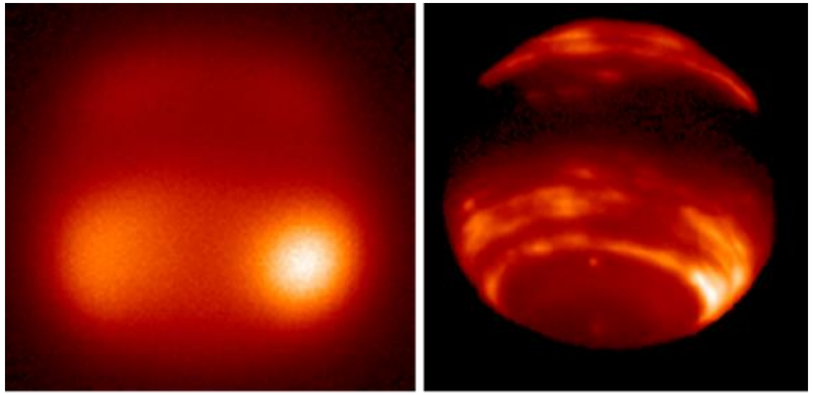
Results in a Series of HEL Aimpoints, Each With a Required Fluence for a Particular Damage Criteria

Graphic used with permission from Dr. Christopher Lloyd and Mr. Bryan Knott, NSWC Dahlgren, HEL Lethality Group
https://www.army.mil/article/167447/HEL_MTT_fires_away_during_MFIX_2016

WEATHER AND PROPAGATION (HEL SPECIFIC)

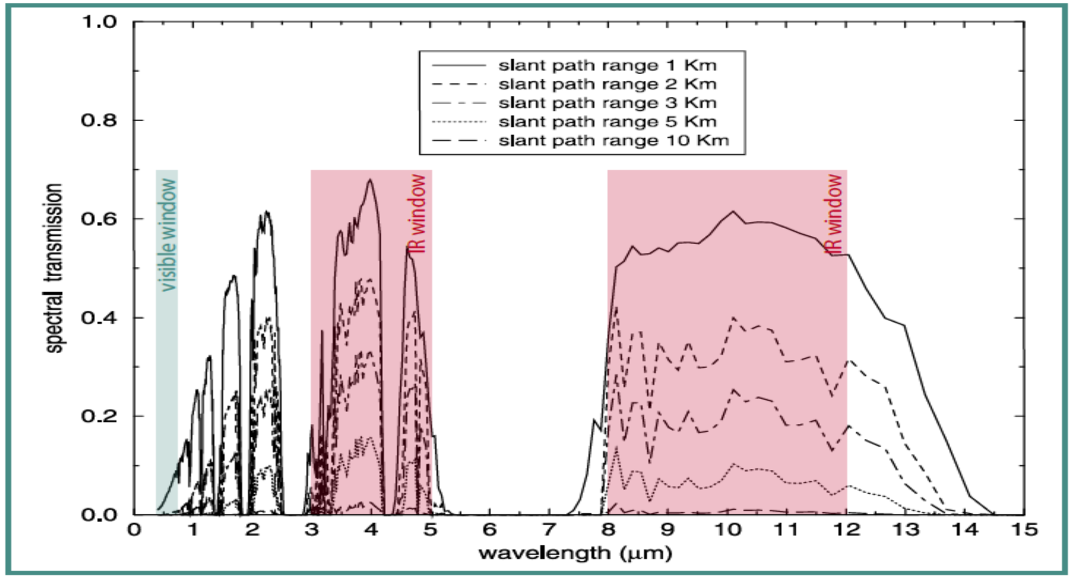
- Propagation describes how the laser beam travels to target
- **Turbulence** "Turbulence" is caused by air / sea / ground temperature differences that create a movement of bubbles of hot air, affecting the propagation
  - Turbulence impacts the ability to focus to a tight spot
  - Can often be improved with Adaptive Optics (AO)
- **Extinction is the scattering and absorption of a laser energy**
  - Elements and particles in air reflect, deflect, and absorb energy out of the HEL beam and lower the irradiance at range
  - Water vapor and particles (clouds, fog, rain, smoke) will reduce the range of an HEL weapon
- **A high-power HEL beam can heat its propagation path**
  - Called "thermal blooming", it can impact an HEL weapon's ability to focus to a small spot (creates a negative lens effect)



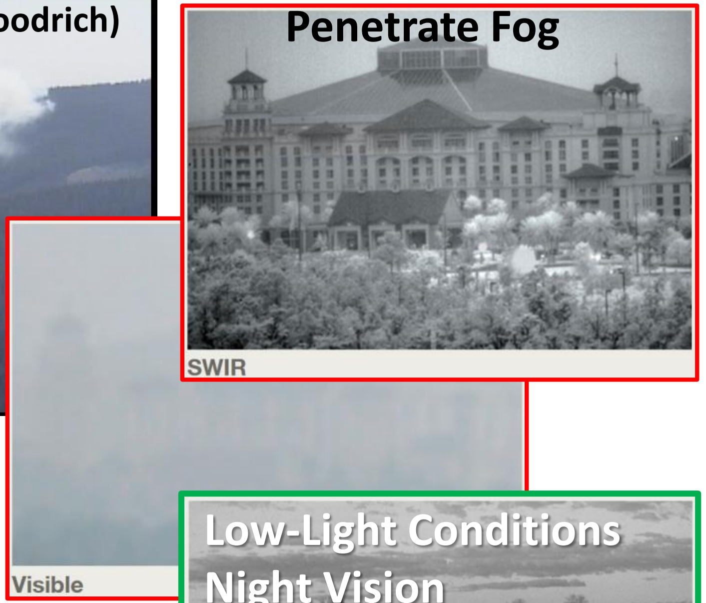


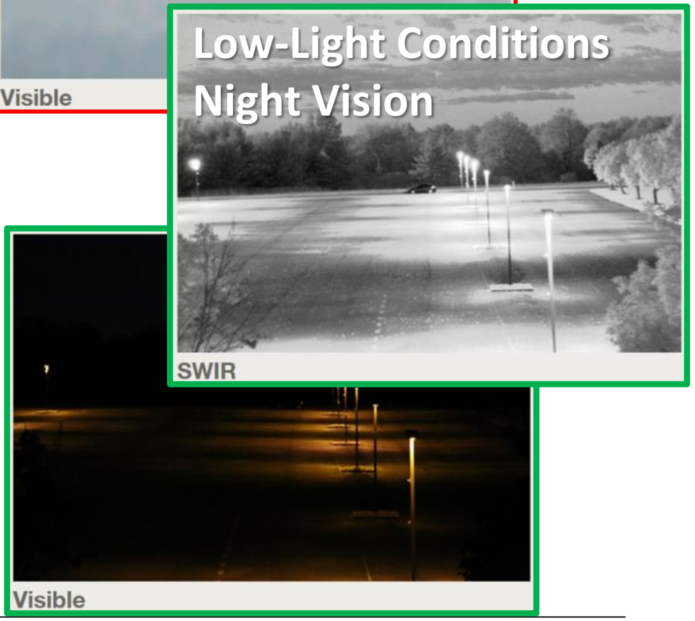
Neptune without and with AO

ADVANTAGES OF LONGER WAVELENGTH



©Deutsches Zentrum für Luft- und Raumfahrt (DLR)

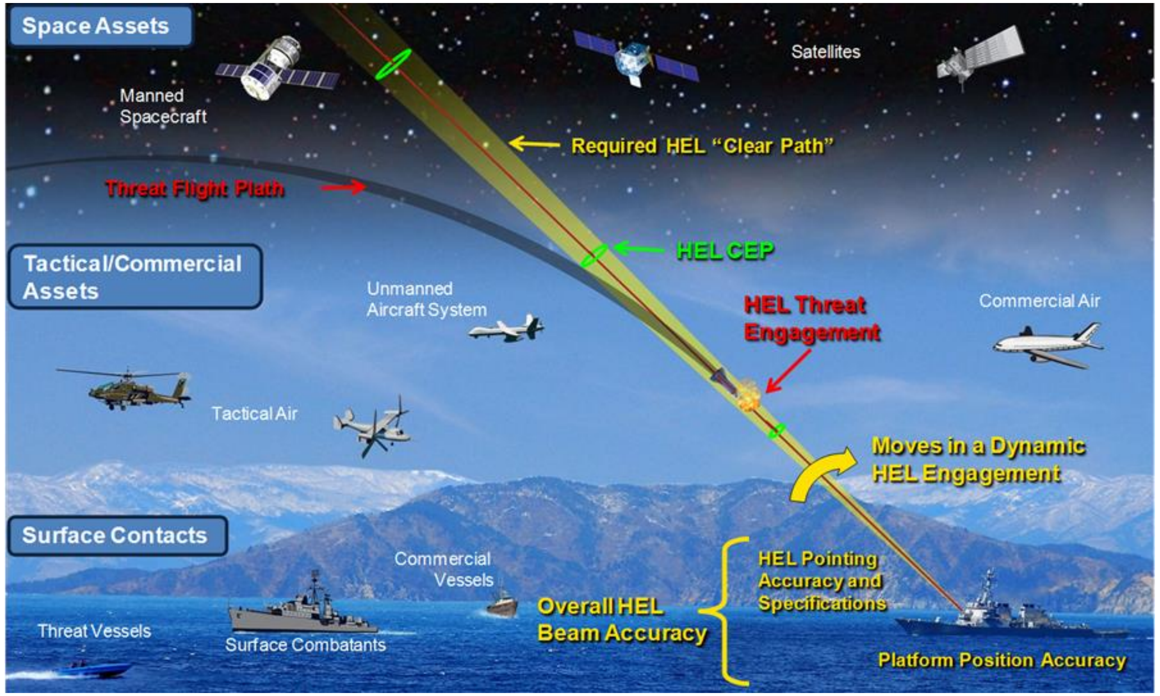




- HEL Beam Director (telescope), when fitted with a SWIR camera, greatly enhances situational awareness out to >10 km
- Mie scattering is important where diameter-to-wavelength ratios of the order of unity (i.e. ≈ 1 μm) or larger
- Beam director excellent for enhancing Situational Awareness for life of the system

http://www.sensorsinc.com/gallery/images/

AIRSPACE DECONFLICTION (AD) AND PREDICTIVE AVOIDANCE (PA)



- Airspace Deconfliction
  - Requires inputs from all sensors for common operating picture
- Predictive Avoidance (New U.S. Policy)
  - Assesses the "risk" of negative impact to space systems
- Joint Laser Deconfliction Safety System (JLDSS) for Military Platforms
  - Integrated with platform sensors for operational picture
  - Addresses AD and PA
  - Sponsored by HEL-Joint Technology Office

[DoD Policy Update]

DOD INSTRUCTION 3100.11

MANAGEMENT OF LASER ILLUMINATION OF OBJECTS IN SPACE

Originating Component:	Office of the Under Secretary of Defense for Policy
Effective:	October 24, 2016
Releasability:	Cleared for public release. Available on the DoD Issuances Website at http://www.dtic.mil/whs/directives.
Reissues and Cancels:	DoD Instruction 3100.11, "Illumination of Objects in Space by Lasers" March 31, 2000

- Supersedes the unclassified information in the May 15, 2014, Commander Joint Functional Component Command for Space (JFCC SPACE) Memorandum; and the 2011-01 Director, National Reconnaissance Office (NRO) Memorandum.

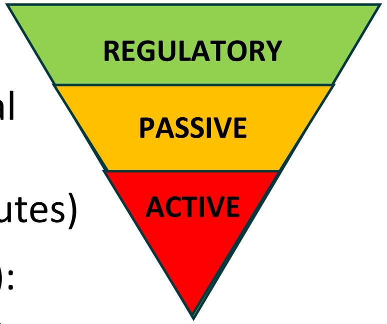
- New DODI 3100.11
- Signed out October 24, 2016
- Establishes requirement for quantitative Probabilistic Risk Assessments (PRA)
- Establishes an exempt category
- Provides guidance for lasers that transitioned to the warfighters

INTEGRATING COUNTER-sUAS CAPABILITIES

http://www.cumberlandtrialjournal.com/drones-an-aerial-view-of-the-future-of-unmanned-aircraft-systems/

PULLING IT ALL TOGETHER

- Operational vignette:
  - Threat platform - DJI S1000+
  - Objective - midair collision with commercial passenger aircraft at International airport
  - Potentially very short engagements (< minutes)

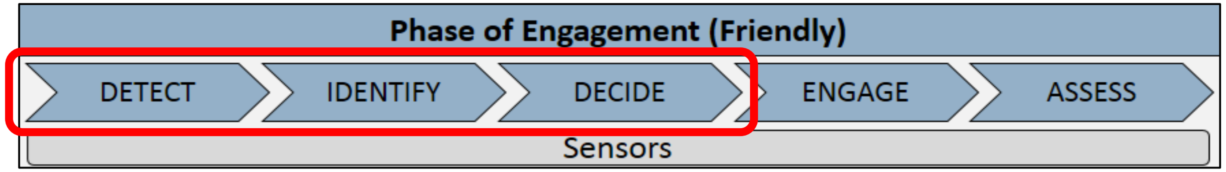


- Passive (EW) countermeasures (Active in U.S.):
  - May deny/degrade communications - force drone to land or “return home”; impact sensor information
  - May deceive communications - assume control of drone/sensors
  - Pros - Cues directly from RF sensors; immediate effects once decision made
  - Cons - Programming dependent (ECCM or swarm impacted); electronic fratricide
- Active DE countermeasures:
  - May degrade/destroy platform, sensors, or payload
  - Pros - Cues directly from radar sensors; rapid effect (<< minute) once decision made
  - Cons - Obstacles impact effectiveness; collateral damage (falling debris); airspace deconfliction

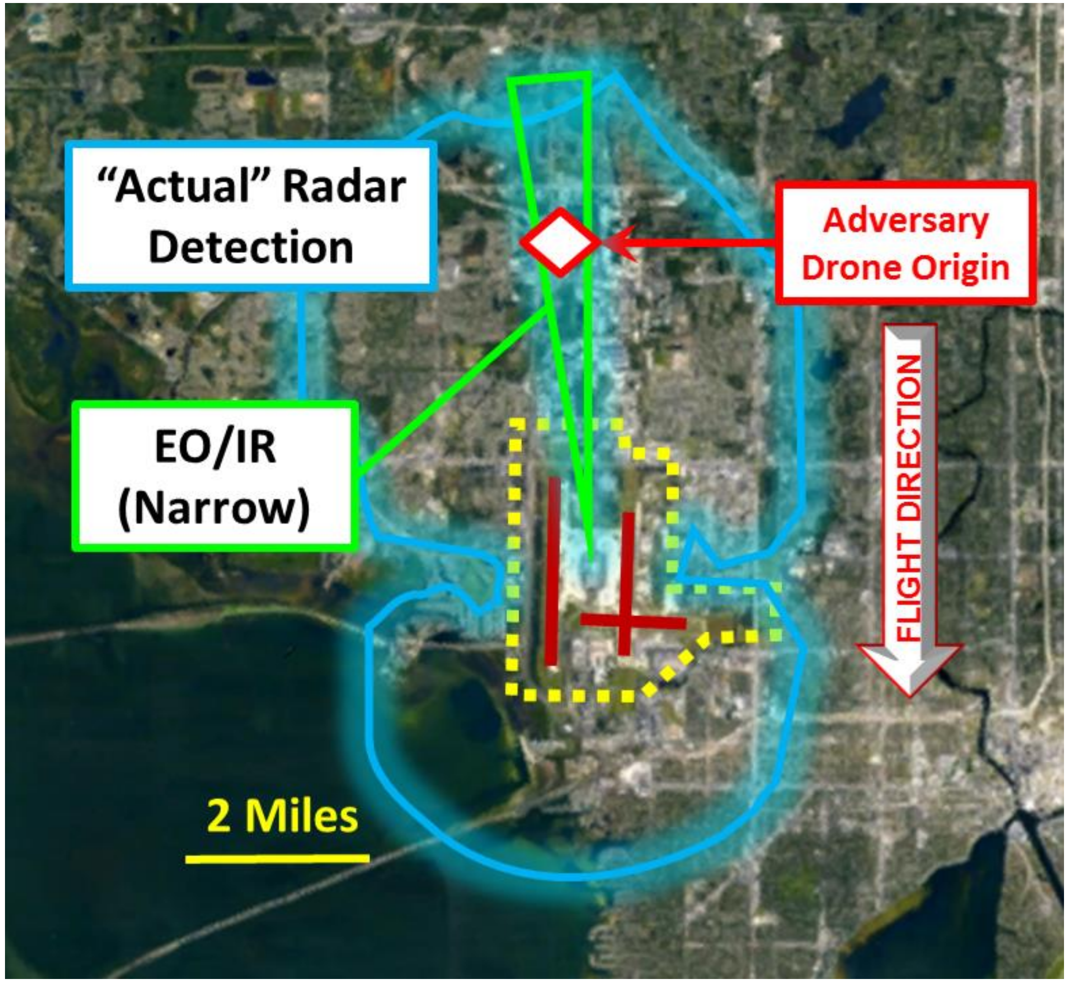
The Counter-sUAS System Should Provide a Range of Engagement Options

https://www.google.com/maps/,

sUAS DETECT, IDENTIFY, DECIDE

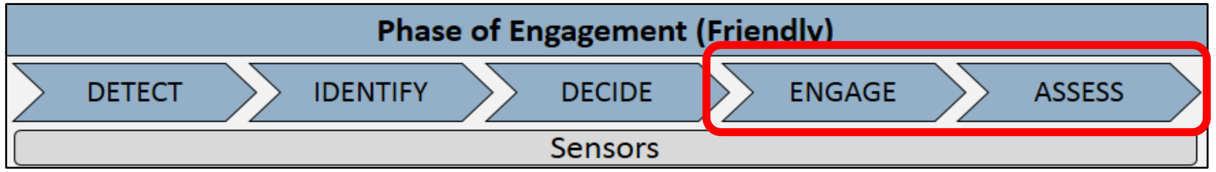


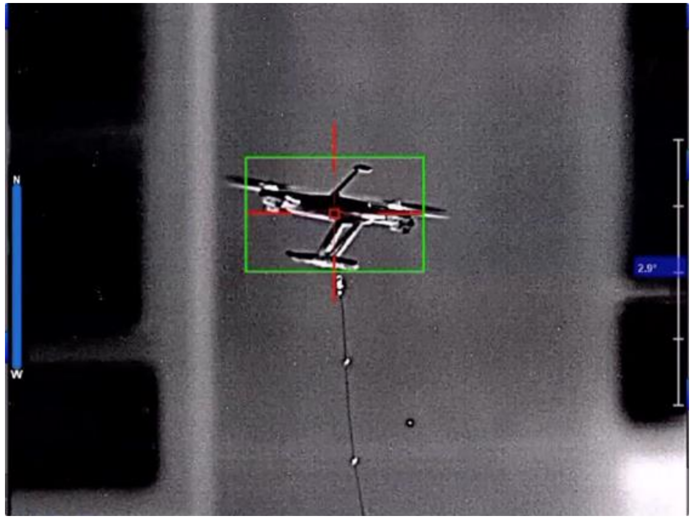
- Number, placement, and complement of sensors will establish range and number of targets that can be detected and tracked
- Detect-through-Decide establishes engagement options
  - Integration and automation enables rapid engagement of multiple threats on multiple axes
  - Phase transitions (handoffs) need to be timely and accurate
- Threat location or sensors (radar, EO/IR) determine intent
  - Proximity to flight corridors or no-fly zones
  - Positive, Hostile Identification (PHID)
- Authorities to decide "engage" need to reside on site
  - Conditions/authorities need to be established in advance
  - Conditions/authorities need to be clearly understood and practiced



Detect-through-Decide Procedures Make Up >90% of the Engagement Timeline

sUAS ENGAGEMENT AND ASSESSMENT





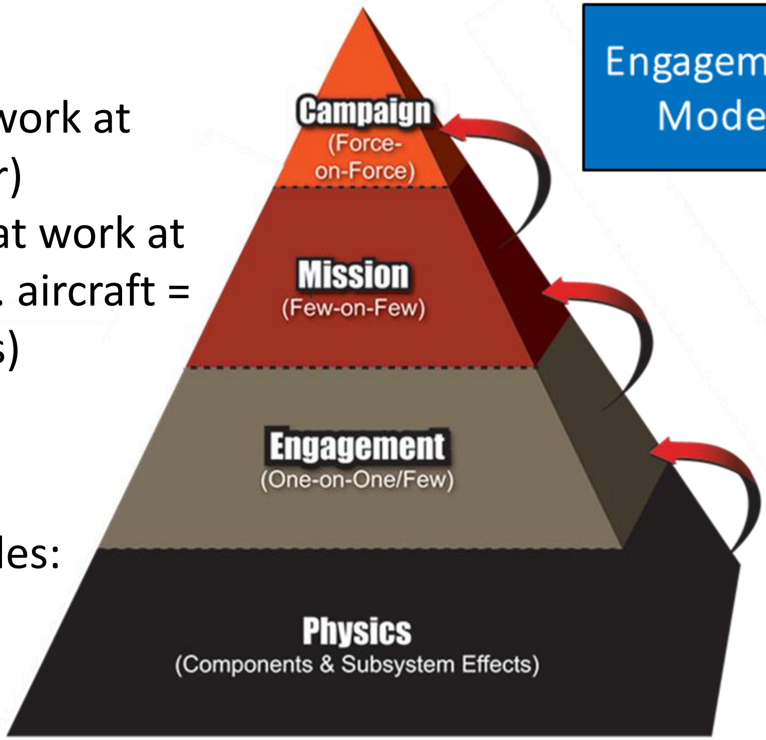
- Number, placement, and complement of weapons will establish maximum targets that can be engaged
  - Defense-in-depth = Fields of fire, obstacles, effective ranges
- Engage and Assess phases establish engagement duration
  - Measures of performance (MOP) informs delivery of fires
    - Aimpoint accuracy and maintenance, effective range
    - Power, EW technique effectiveness, HEL power on target
  - Number and placement of sensors will determine ability to measure performance and effect
  - Measures of effect (MOE) inform effectiveness assessment and ability to engage follow-on targets
    - Changes in sUAS flightpath
    - Changes in adversary EMS usage
    - Pilot reporting

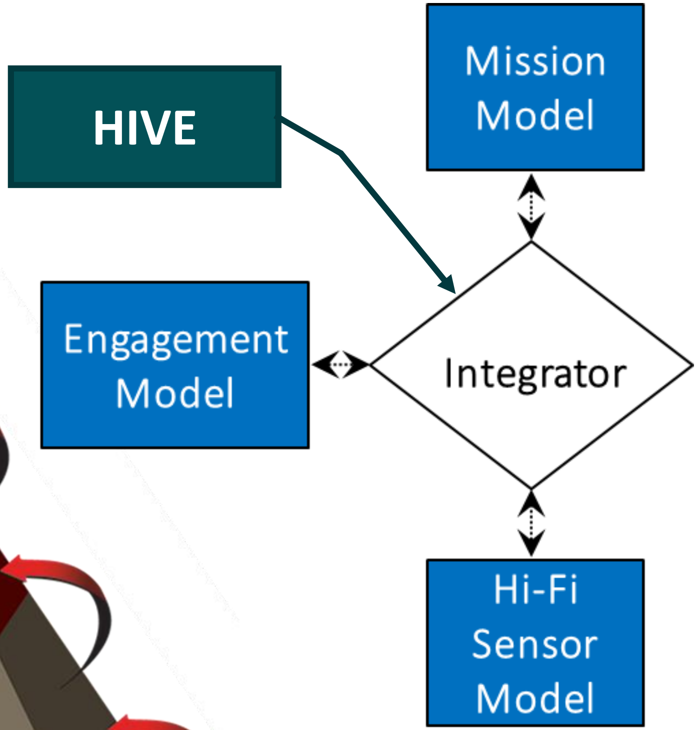
MOP and MOE Determine Engagement Timelines

http://www.dailymail.co.uk/sciencetech/article-4427956/US-Army-tests-high-energy-LASER-drones.html
https://www.wired.com/wp-content/uploads/2015/08/Drone-FEATURE-ART.jpg

MODELING & SIMULATION INTEGRATION

- **Hybrid Integrated Visualization Engine (HIVE):** software program we have utilized for enterprise Modeling and Simulation (M&S):
  - High performance simulation integration
  - Rapid simulation development
  - Analytical support and visualization
- Multi-Level model integration:
  - Vertical integration connects many models that work at different fidelities (e.g. campaign down to sensor)
  - Horizontal integration connects many models that work at same fidelity but have different applications (e.g. aircraft = platform aeronautical + sensor + weapon models)
- Hardware integration capabilities:
  - Simulators/virtual reality/research hardware
- Incorporates data integration from sensors and tables:
  - Test range data
  - Flight systems and performance
  - Technical parameters





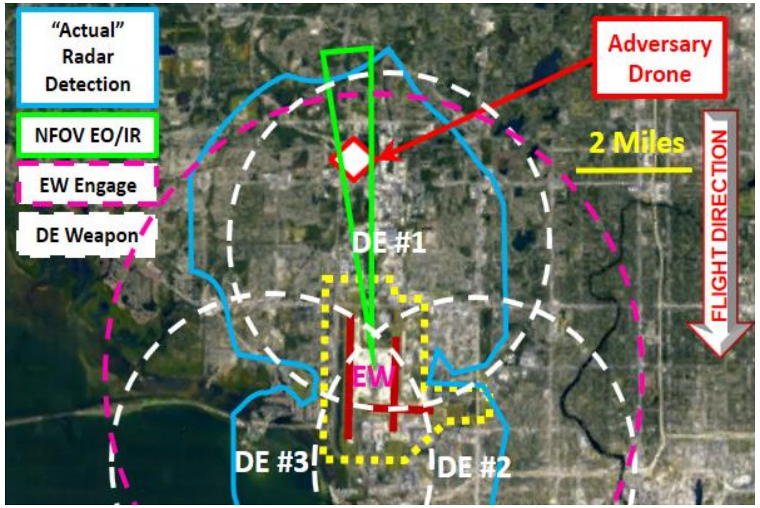
Enterprise M&S Integration can Provide System-level Assessment for Proposed Solutions

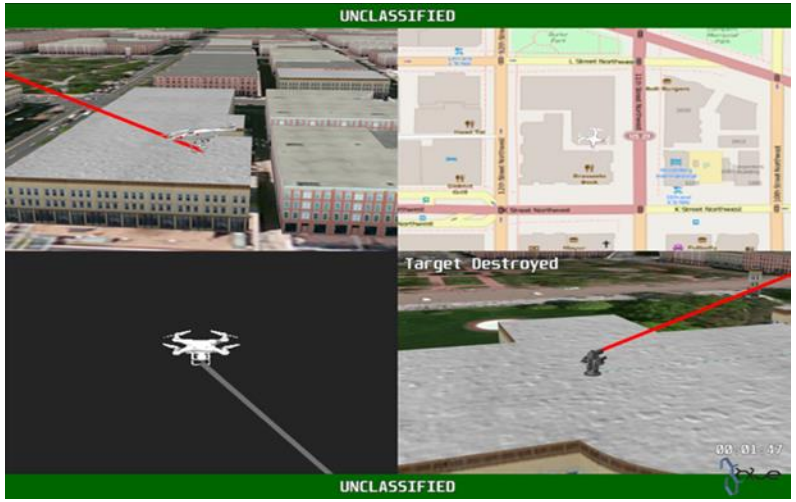
https://www.dsiac.org/resources/journals/dsiac/fall-2015-volume-2-number-4/hive-integrating-environment-simulation-and

VISUALIZATION: MISSION REHEARSAL AND TRAINING

"The commander must decide how he will fight the battle before it begins."

— Field Marshal Bernard Law Montgomery, 1st Viscount Montgomery of Alamein



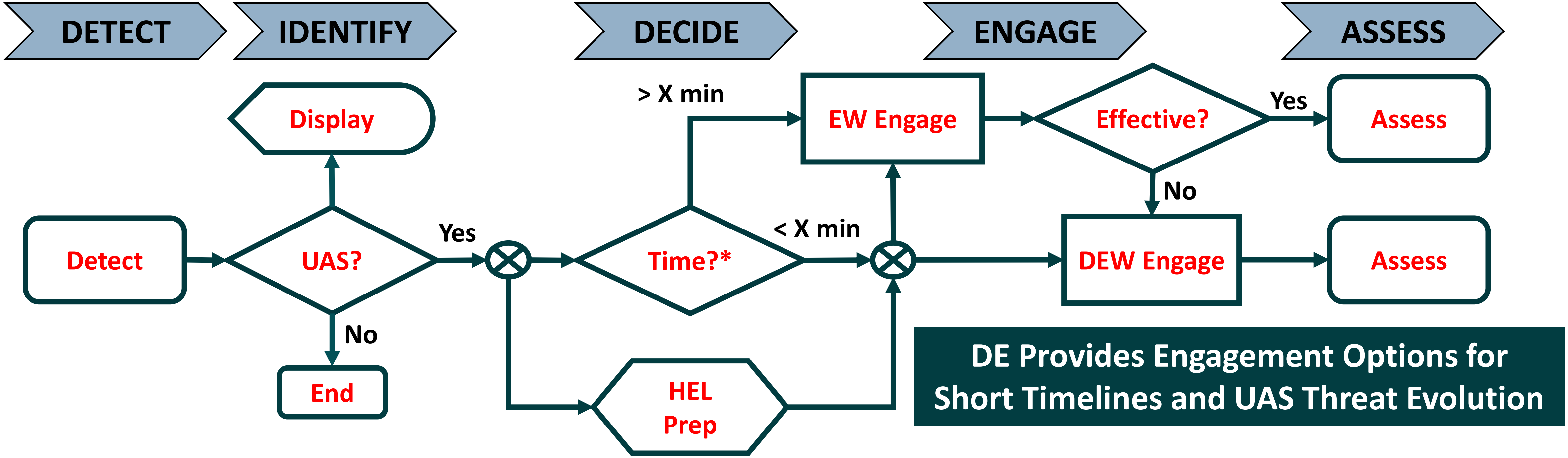


- Real-time and non real-time scenario play supports:
  - Capabilities and limitations of sensors and weapons at component-/system-level engagements
  - Impacts of TTP and obstacles/terrain on weapon and sensor effectiveness
  - Identification of key decision points
- High quality 2D/3D visualization tools enhance analysis, inform decision makers, and create training opportunities
  - Key tools for operators and analysts
  - Support system deployment and integration requirements
  - Support knowledge-sharing across stakeholders

A Well Integrated Environment Leads to Deeply Insightful Visualization of Data and Information

https://www.leadershipnow.com/preparationquotes.html

VIGNETTE: EXERCISING THE sUAS-HEL KILL CHAIN



DETECT

- Radar Cue
- ECM Cue
- Acoustic Cue
- Visual Cue

IDENTIFY

- Discriminate from bird(s) or other
- ECM Identify
- EO/IR Identify
- Ready HEL system

DECIDE

- Determine if Hostile
- Determine timeline (i.e. midair target)
- Decide to Engage via EW or DEW
- Collateral damage?

ENGAGE

- Engage w/EW (if time allows)
- Determine EW effectiveness
- Set point for DEW engagement?
- Airspace Deconfliction/PA?
- Engage with DEW capability

ASSESS

- Determine if UAS neutralized
- Re-Attack (Swarm)?
- Recover/Evaluate
- Notify authorities
- Resume operations

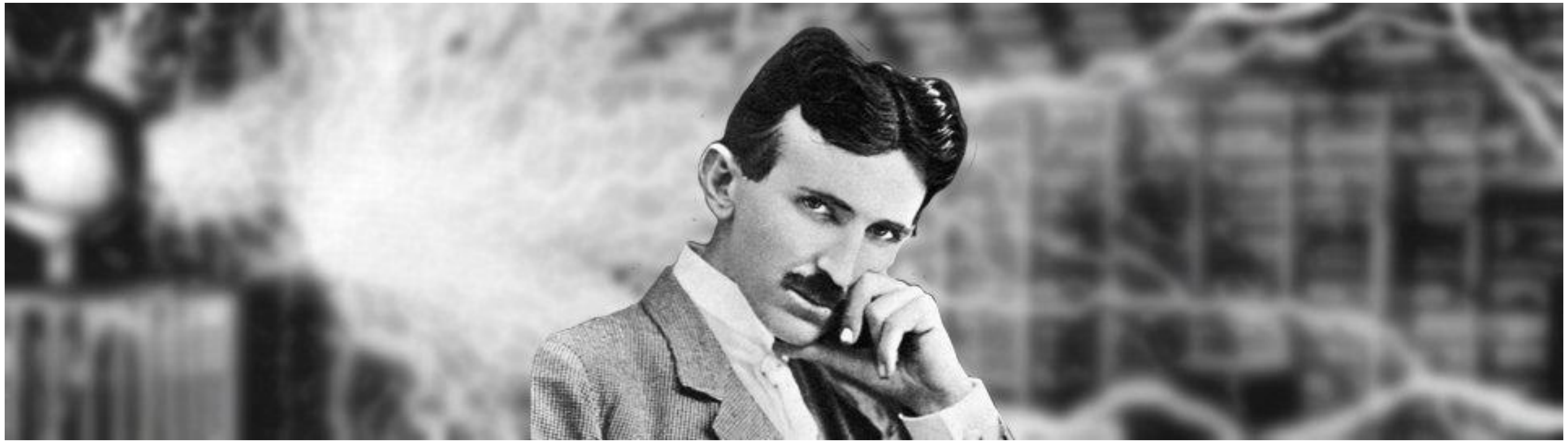
* Overall systems analysis and engagement timelines will dictate required timing of events.

Conclusion

- Small UAS are a Rapidly Evolving and Highly Proliferating Threat
- Enterprise M&S Integration (i.e. HIVE) can Provide a Counter-sUAS System-Level Assessment
  - Well Integrated Environment Leads to Deeply Insightful Visualization of Data and Information
  - Supports Establishing and Practicing the Counter-sUAS Kill Chain
- Directed Energy Provides Engagement Options for <u>Short Timelines</u> and <u>UAS Threat Evolution</u>

http://mediacentre.britishairways.com/contents/archives/216/86/sites__cms/CI_BAHIS8453_58f77f776c732.jpg
https://timeentertainment.files.wordpress.com/2014/02/beatles-jfk.jpg?w=360&h=240&crop=1

QUESTIONS?



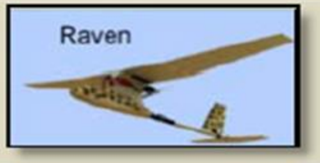
“Telautomata will be ultimately produced, capable of acting as if possest of their own intelligence, and their advent will create a revolution.”

–**Nikola Tesla**, <u>My Inventions</u>, first published in 1919 in the *Electrical Experimenter magazine*.

The *Revolution* is Upon Us

BACKUP SLIDES

[DOD] UAS GROUP DESCRIPTIONS

UAS Groups	Maximum Weight (lbs) (MGTOW)	Normal Operating Altitude (ft)	Speed (kts)	Representative UAS	
Group 1	0 – 20	<1200 AGL	100	Raven (RQ-11), WASP	
Group 2	21 – 55	<3500 AGL	< 250	ScanEagle	
Group 3	< 1320	< FL 180		Shadow (RQ-7B), Tier II / STUAS	
Group 4	>1320		Any Airspeed	Fire Scout (MQ-8B, RQ-8B), Predator (MQ-1A/B), Sky Warrior ERMP (MQ-1C)	
Group 5		> FL 180		Reaper (MQ-9A), Global Hawk (RQ-4), BAMS (RQ-4N)	

Increasing concern over proliferation of commercial Group 1 (including Quadcopters) and Group 2 UAS

Source: DoD Unmanned Aircraft System Airspace Integration Plan, Version 2.0, March 2011

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ISIS: Deploying Unmanned Aerial Vehicles (UAVs)

Timeline of ISIS UAV Development

October 24, 2014
ISIS demonstrates UAV capability.

November 28, 2014
ISIS features UAV image in its English-language magazine, *Dabiq*, depicting an aerial view of the battle in Kobani, Syria.

October 2, 2016
ISIS kills two Kurdish soldiers and wounds two French soldiers with a booby-trapped UAV.

January 24, 2017
ISIS releases propaganda video, "Knights of the Dawawin," depicting a weaponized UAV dropping bombs on US-led coalition forces.

March 1, 2017
ISIS distributes infographic via the social media platform Telegram highlighting its UAV weaponization efforts.

UAVs Used in Iraq and Syria

Make: DJI
Platform: Phantom 3
Endurance: 36 min.
Payload Capacity: 2.5 lbs
Price: $1,199

Make: Guilin Feiyu Electronic
Platform: X-8
Endurance: 1-2 hrs
Payload Capacity: 6 lbs
Price: $111

ISIS: Weaponizing UAVs

ISIS will likely continue refining its UAV capabilities and touting successes as proofs of concept for future operations. Since February, ISIS claims it has conducted approximately 80 UAV attacks in Iraq and Syria, killing approximately 40 and injuring 100. The UAVs are primarily quadcopters, which can be easily purchased online and customized to drop small explosive munitions.

- ISIS has conducted surveillance with commercial drones since 2014, according to West Point's Combating Terrorism Center, and the group has advanced its UAV program by experimenting with weaponization in 2015-16 and industrializing the drone production this year.
- On January 24, ISIS released the video "Knights of the Dawawin," showing militants using a Chinese Skywalker X8 drone and dropping explosives on US-led coalition forces and armored vehicles.

ISIS members receiving drone training in the group's self-proclaimed "Academy for Media Training & Development"

Pro-ISIS propaganda depicting UAV weaponization

Recent ISIS English-language propaganda provides operational "how-to" guides intended to inspire homegrown violent extremists (HVEs) in the United States—an avenue the group will likely expand to weaponized drones. In November 2016, ISIS released a guide outlining effective methods for carrying out vehicular assaults, which resulted in HVE Mohammed Naji plotting to use a truck to target the Macy's Thanksgiving Parade in New York City.

- On February 1, ISIS released an image called the "Islamic State Nightmare," featuring fighters preparing to launch a UAV over an image of the Statue of Liberty.

An NJOHSP review of terrorist attacks and plots in the United States since 2015 reveals HVEs have primarily used simple weapons such as firearms, vehicles, and knives, although we cannot rule out the possibility HVEs will learn how to construct and weaponize UAVs based on future ISIS propaganda.

- In July 2011, Rezwan Ferdaus attempted to use remote-controlled planes carrying improvised explosive devices (IEDs) to attack the Pentagon and the Capitol building. Ferdaus is the only documented case in the United States of an HVE attempting to use a device similar to a weaponized UAV in the last 10 years.
- ISIS's weaponization of UAVs in Iraq and Syria involves the use of modified military ordnance, which is difficult to acquire in the United States. Building similar explosives requires specific bomb-making and engineering skills.

Weaponized UAV with customized IED

To Report Suspicious Activity:
Call: 1-866-4-SAFE-NJ | Email: tips@njohsp.gov | Additional Resources: www.njohsp.gov/tripwires

Information cutoff: March 1, 2017

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