H560-B20-001

Airport Saturation, Satellites into the Future, and Emerging Drone Headaches

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Worldwide Airports Lawyers Association

Welcome to WALA XI
Bogotá, Colombia
October 9-11, 2019

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- If questions arise that require a response from MITRE, contact (in English or Spanish): Dr. Bernardo Lisker, International Director: bernard@mitre.org

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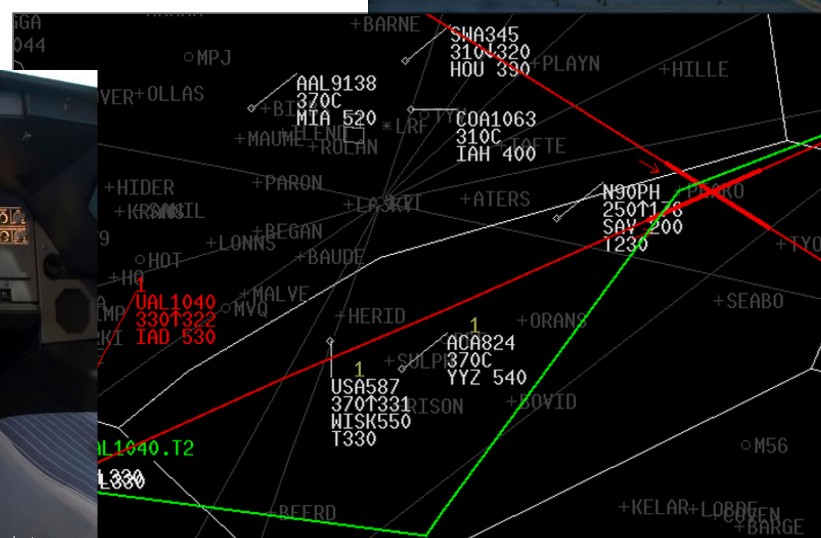
MITRE y su centro de investigación aeroportuario y en control de tráfico aéreo civil

- **Organización de investigación privada, no lucrativa**
  - Orígenes en el Instituto Tecnológico de Massachusetts (MIT)
  - Laboratorio nacional de interés público creado en 1958
  - ~8000 profesionales en ingeniería, matemáticas y otras disciplinas
  - **<u>Misión</u>**: Objetividad e interés público



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Presencia internacional de MITRE

- Gestión de tráfico aéreo y flujos aéreos (ATM)
- Comunicación, navegación y vigilancia (CNS)
- Navegación satelital
- Diseño de trayectorias y espacio aéreo
- Modelado de capacidad, saturación de pista y ruido

Lista representativa:

Albania
Alemania
Arabia Saudita
Argentina
Armenia
Atlas Air
Australia
Bélgica
Brasil
Bulgaria
Canadá
China
COCESNA
Corea
Dubái
Ecuador
Egipto
EgyptAir
Eslovaquia
Eslovenia
España
Estonia
Filipinas
Francia
Grecia
Hungría
IATA
India
Indonesia
Israel
Italia
Japón
Letonia
Lituania
México
Países Bajos
Panamá
Perú
Polonia
Portugal
Reino Unido
República Checa
Rumania
Singapur
Suecia
Suiza
Tailandia
Taiwán
Uruguay
Venezuela

Airport Capacity and Efficiency

Changing Technology and its Impact

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Capacidad aeroportuaria en el "lado aire" y diseño moderno

- **Falta de espacio para construcción cerca de centros de pasaje**
  - Ruido acústico y "visual" vs. distancia y acceso

- **Treinta años: la diferencia entre 1990 y 2020**
  - El modelado y la simulación han sustituido tablas, reglas y manuales
  - La separación entre pistas ha disminuido continuamente
  - La navegación satelital ha cambiado todo tipo de conceptos
  - Los cuellos de botella ahora frecuentemente son en el espacio aéreo

- **El Aeropuerto Chicago O'Hare inició operaciones duales independientes ("simultáneas") en los 1960s**
  - Medio siglo más tarde, solamente una docena de aeropuertos fuera de Estados Unidos utilizan operaciones independientes

- **El Aeropuerto de Denver inició operaciones triples independientes ("simuláneas") en los 1990s**
  - Procedimiento exclusivamente utilizado en Estados Unidos

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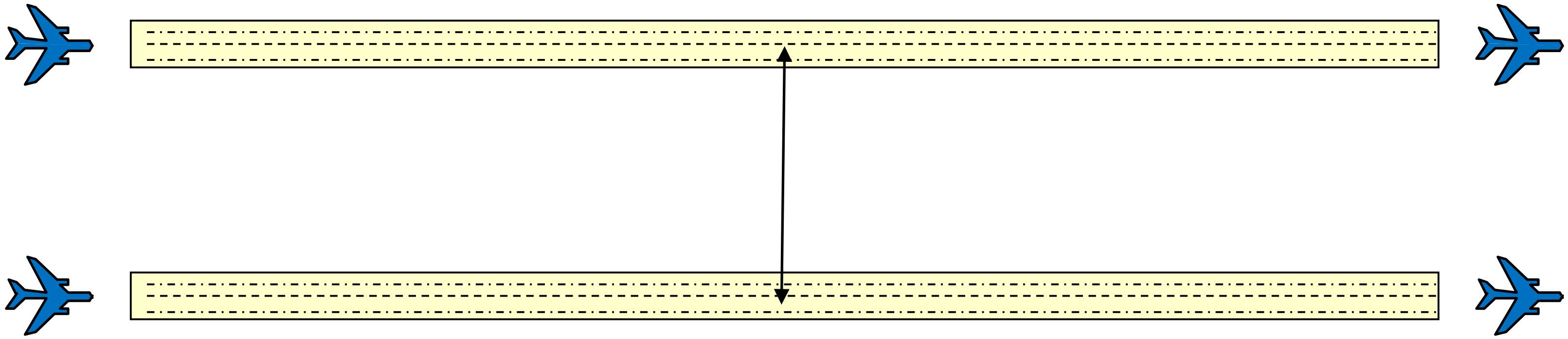
Pistas paralelas duales

Aproximaciones independientes (simultáneas) instrumentales



- **FAA: Separación mínima entre ejes de pista de ~1100 m (para elevaciones bajo ~610 m)**
- **OACI: Separación mínima entre ejes de pista de ~1310 m (es obligatorio un estudio aeronáutico)**

Aproximadamente 30 aeropuertos en EE.UU. y ~12 fuera de EE.UU. operan aproximaciones simultáneas duales

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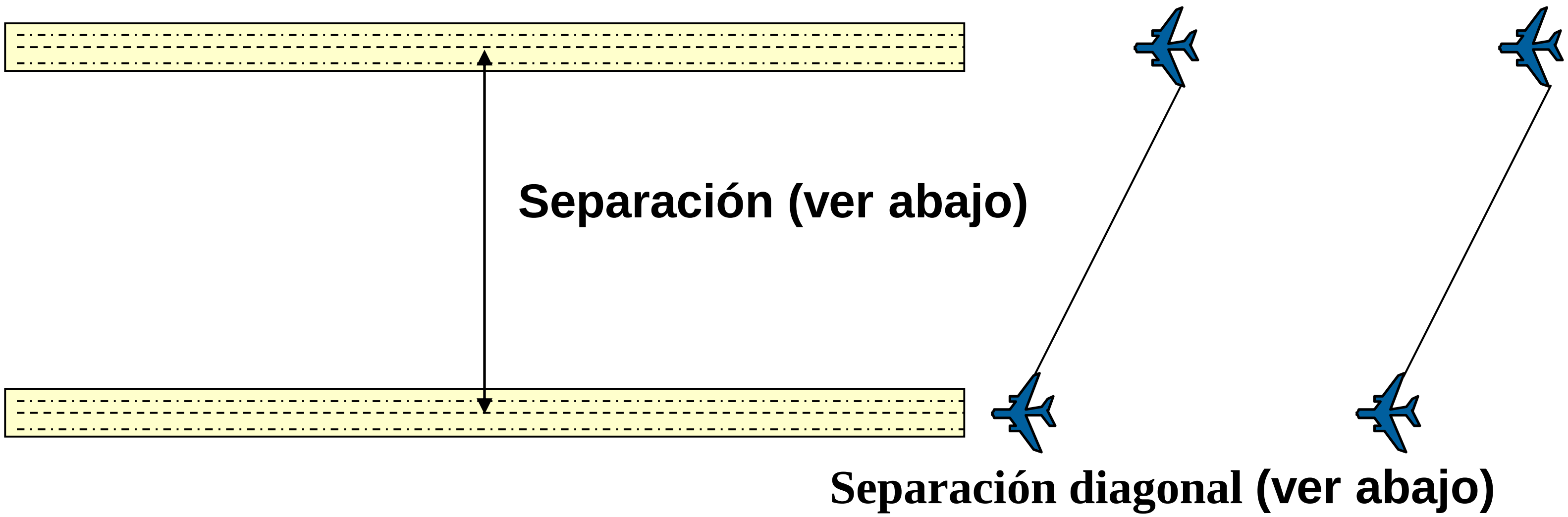
Pistas paralelas duales

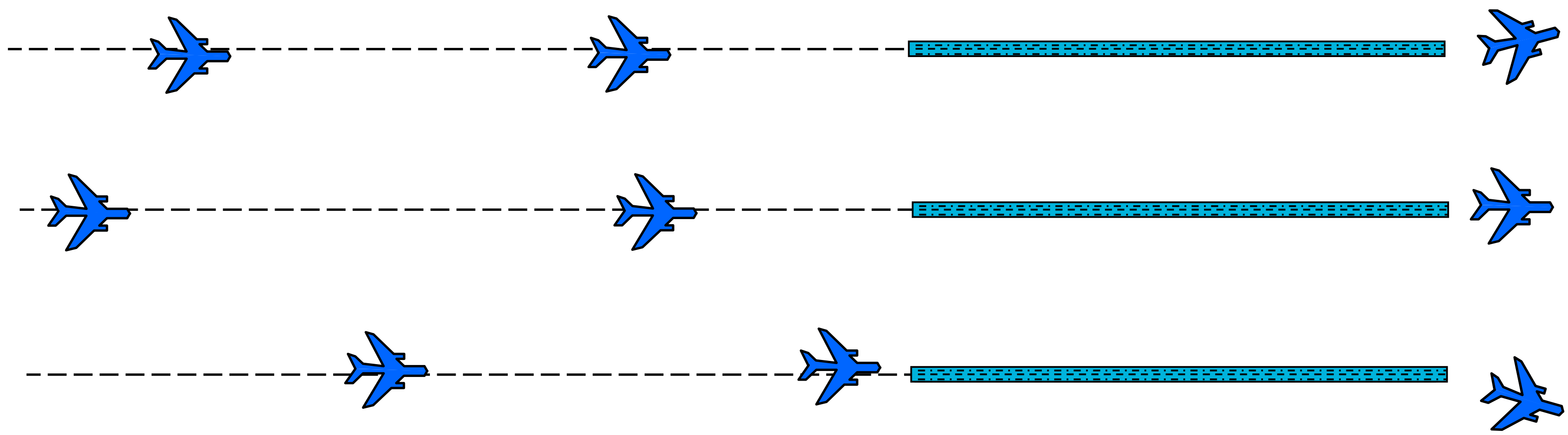
Aproximaciones dependientes instrumentales



- **FAA: Requiere una separación diagonal mínima de 1.0 NM para separación entre ejes de pista iguales o mayores de 760 m (separaciones mayores requieren mayores separaciones diagonales)**
- **OACI: Requiere una separación diagonal mínima de 1.0 NM para separación entre ejes de pista iguales o mayores de 915 m (separaciones mayores requieren mayores separaciones diagonales)**

Pistas paralelas triples*

Aproximaciones simultáneas instrumentales



Se requiere una separación mínima entre ejes de pista de ~1200 m (para elevaciones bajo ~610 m; para mayores elevaciones es requerido un estudio aeronáutico)

Cinco aeropuertos en EE.UU. operan rutinariamente aproximaciones simultáneas triples

*** Procedimiento FAA (no OACI)**

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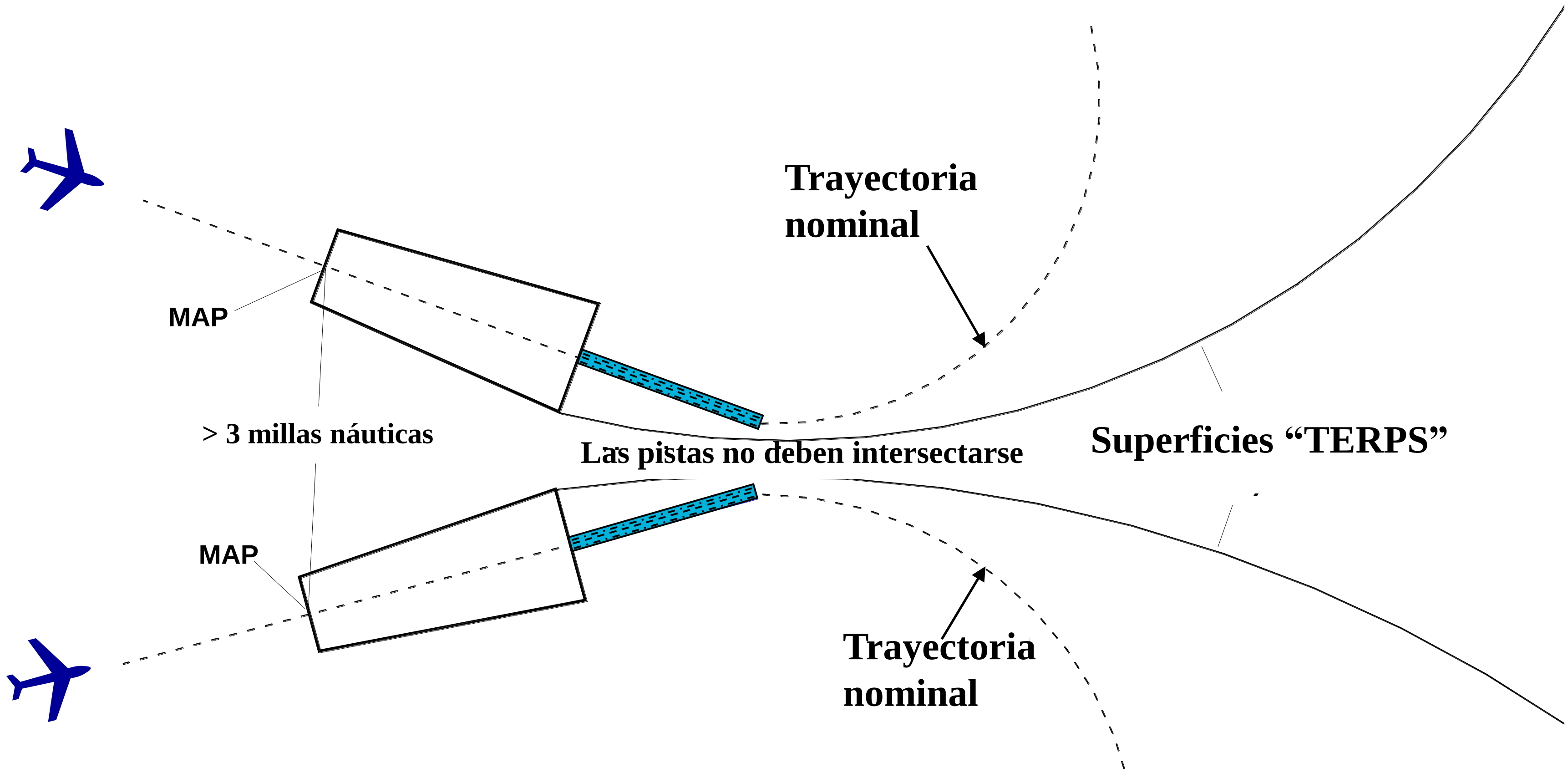
Pistas convergentes: aproximaciones por instrumentos (IMC) independientes*



MAP: missed approach point
(punto de aproximación frustrada o fallida)

* **Procedimiento FAA (no OACI)**

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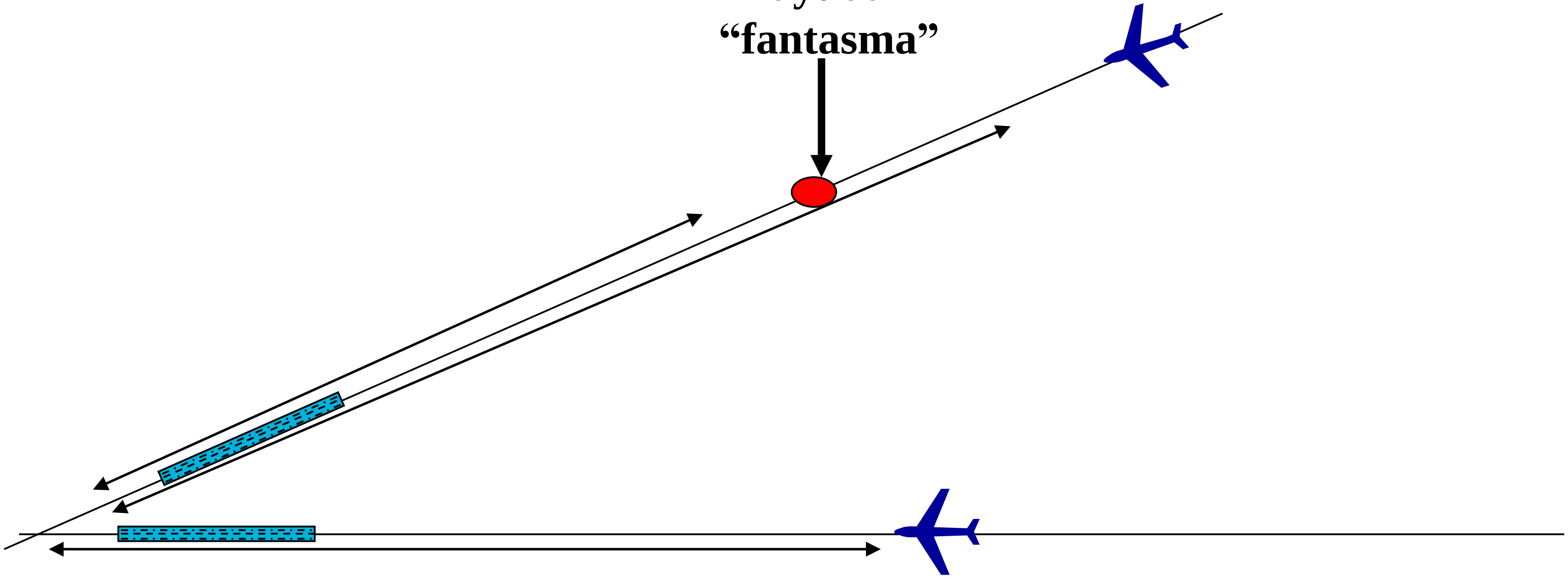
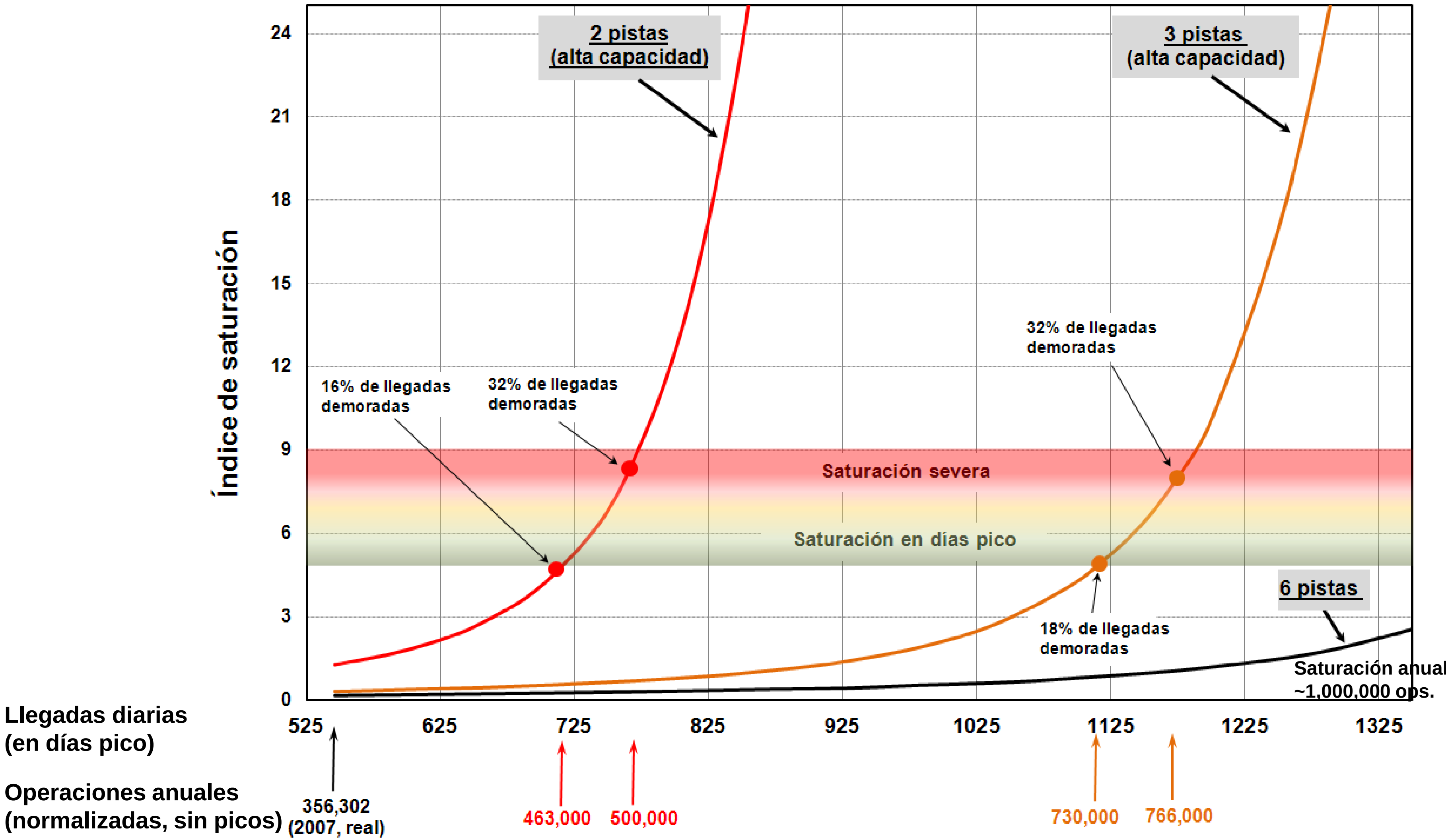
Pistas convergentes: aproximaciones por instrumentos (IMC) dependientes*



*** Procedimiento FAA (no OACI)**

Requerimientos de pista en base a niveles de saturación (*noción gráfica*)



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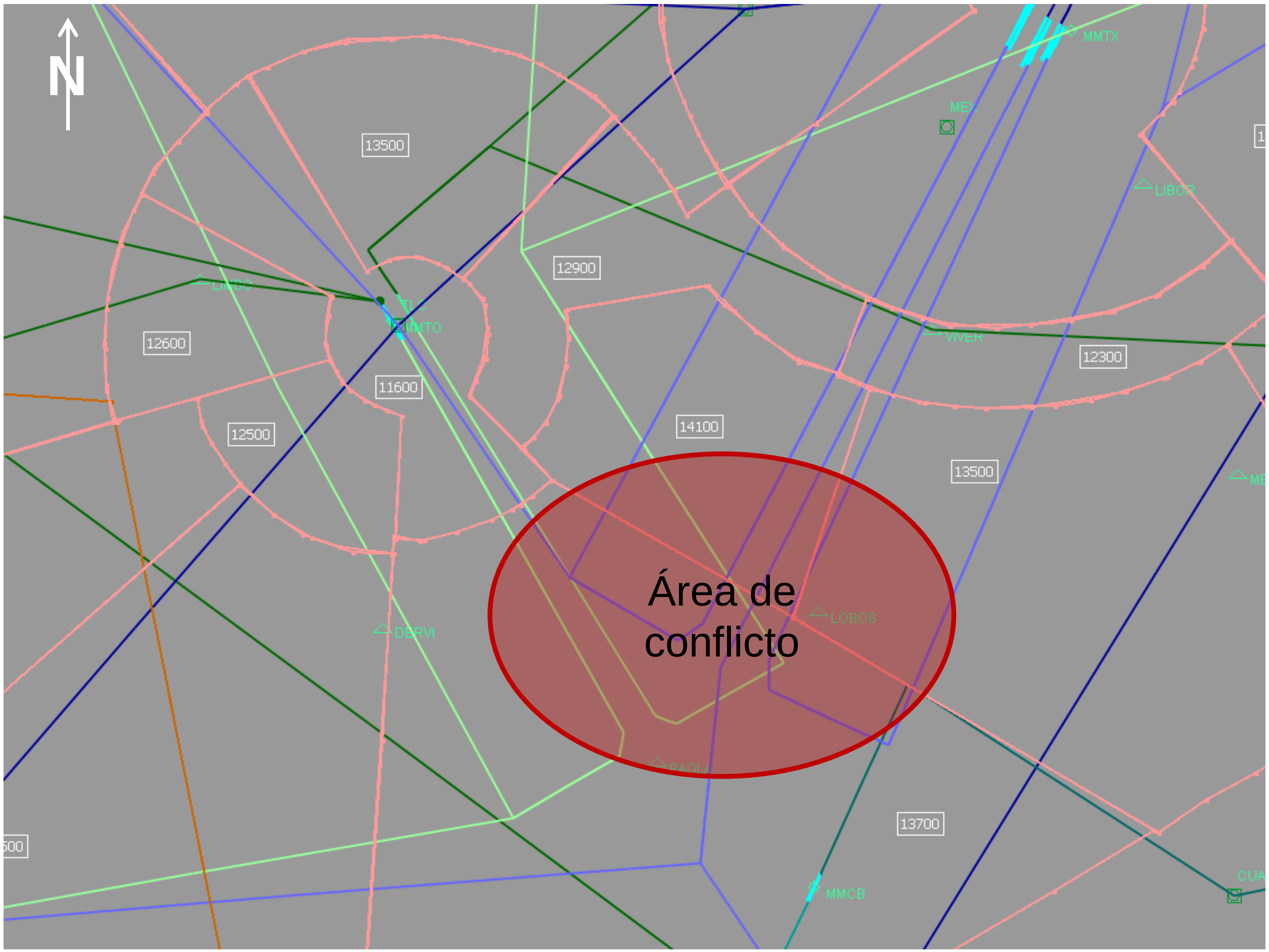
Conflictos entre aeropuertos



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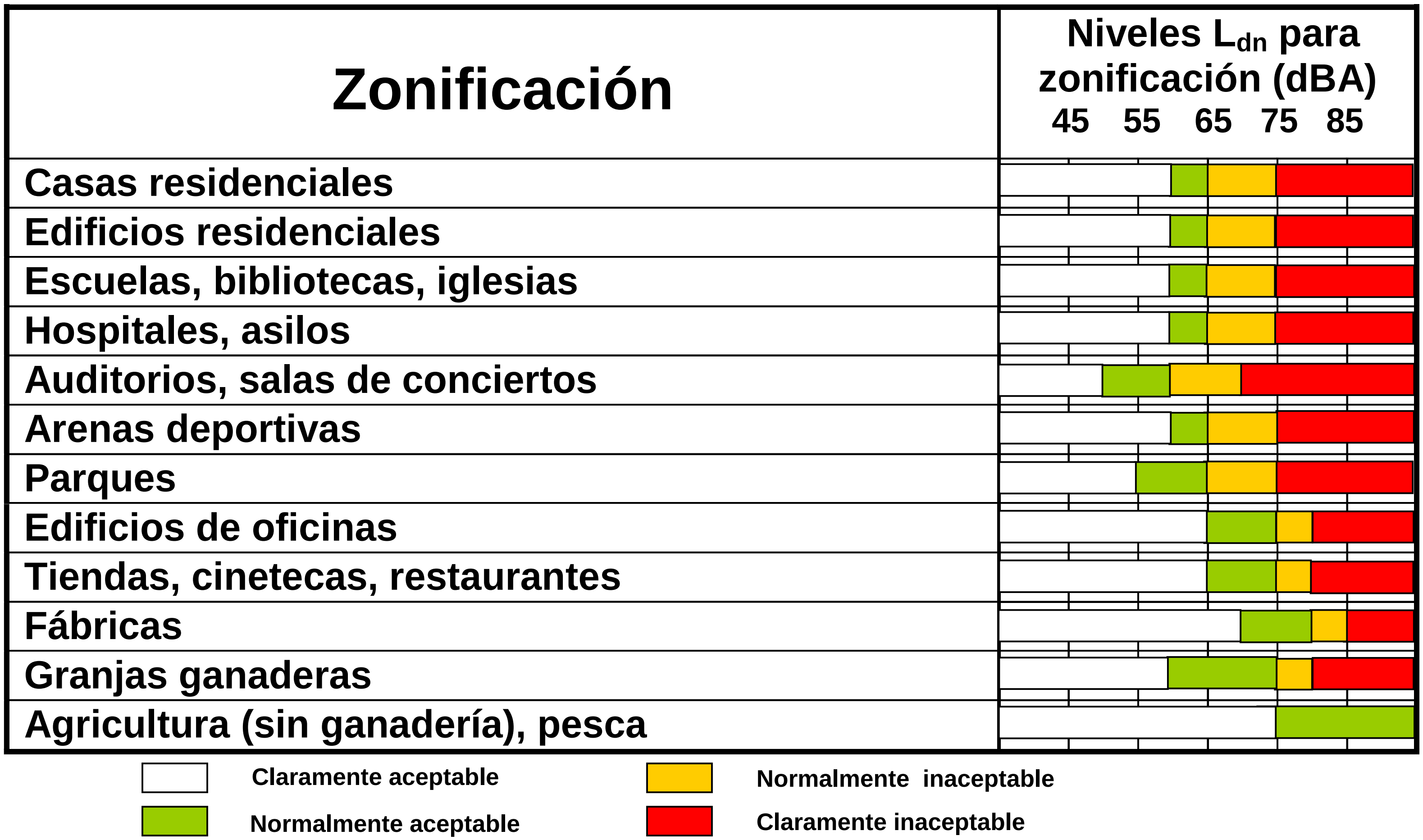
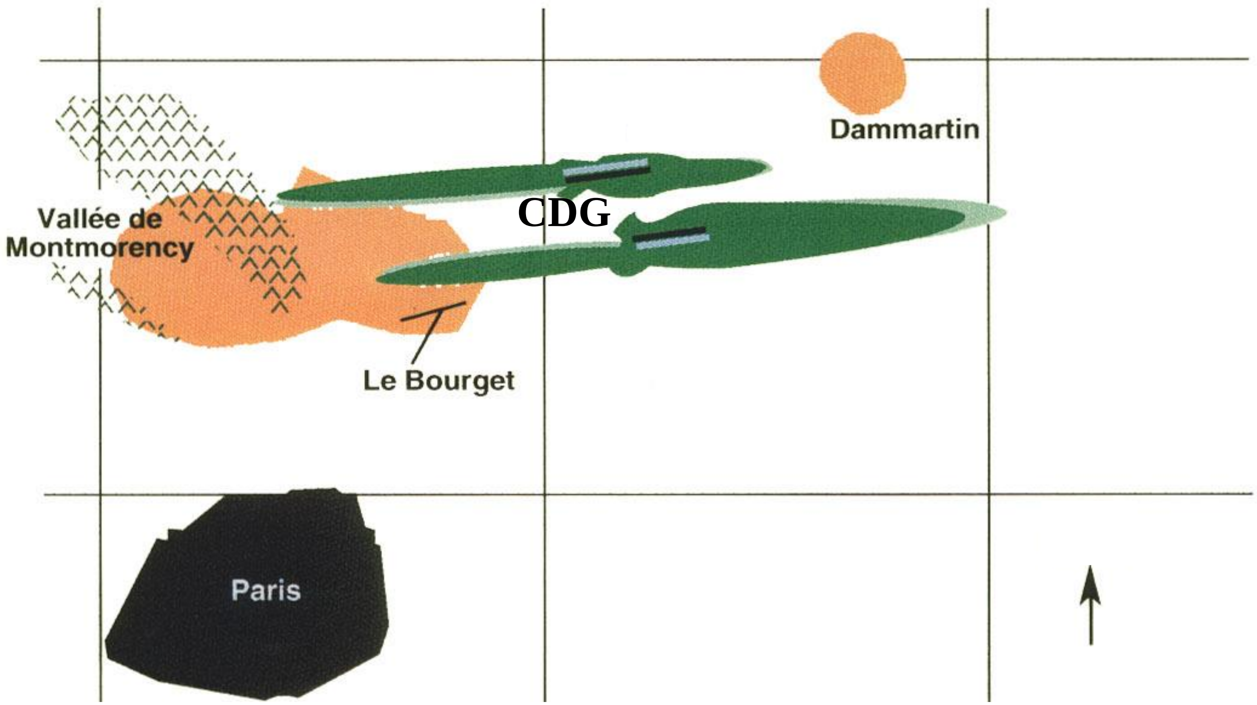
Niveles de ruido recomendados para zonificación



Fuente: U.S. Department of Housing and Urban Development (HUD)

Analyse du dispositif de circulation aérienne de Charles de Gaulle en configuration face à l'Est



60 dBA (vols Concorde exclus)

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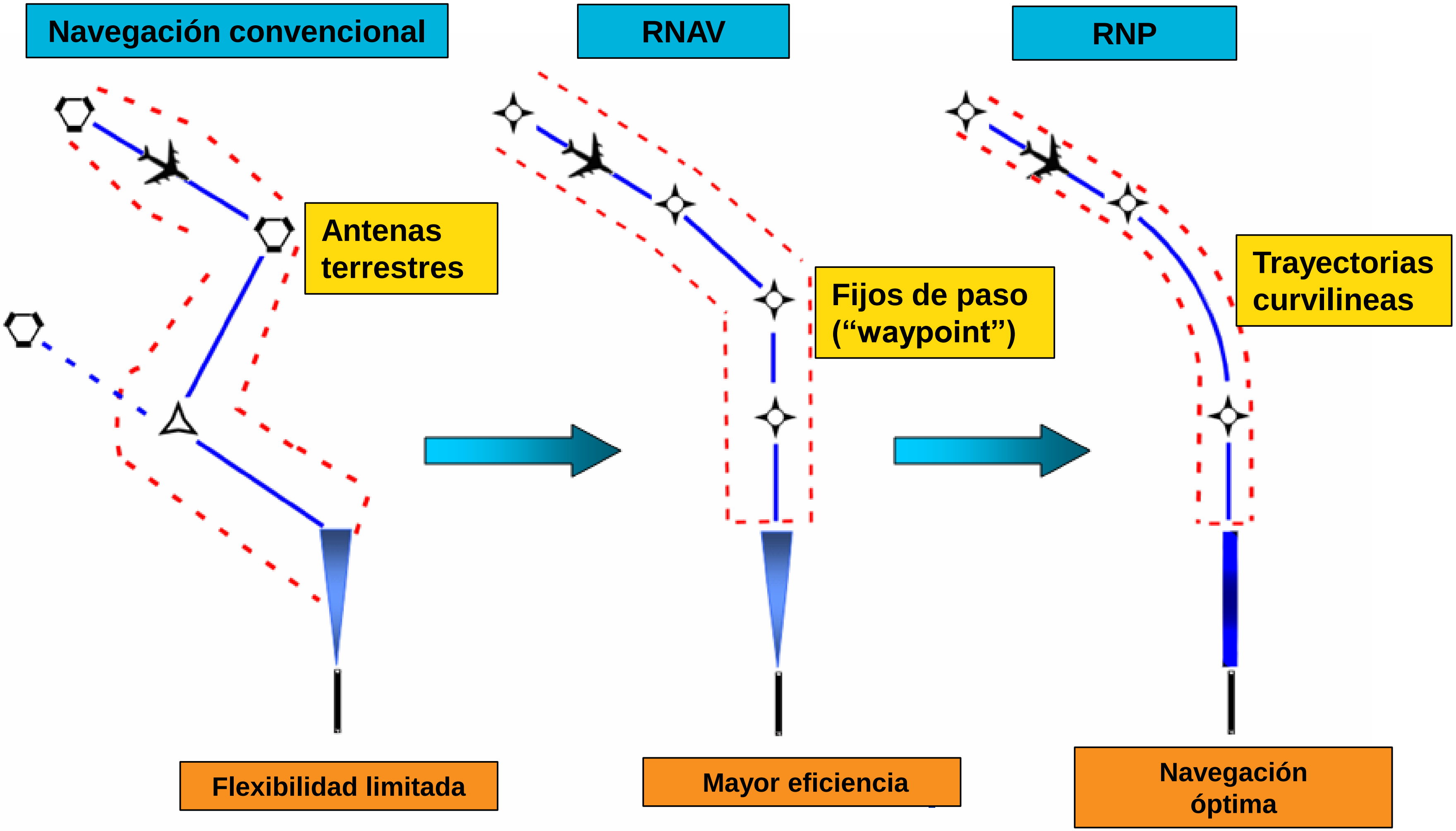
Navegación avanzada

Area Navigation (RNAV) y Required Navigation Performance (RNP)



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Salidas de Dallas-Fort Worth

Con RNAV

Sin RNAV

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Aproximación simulada RNP AR

Palm Springs, California Airport (PSP)

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Unmanned Aircraft Systems

Issues and Acceptance

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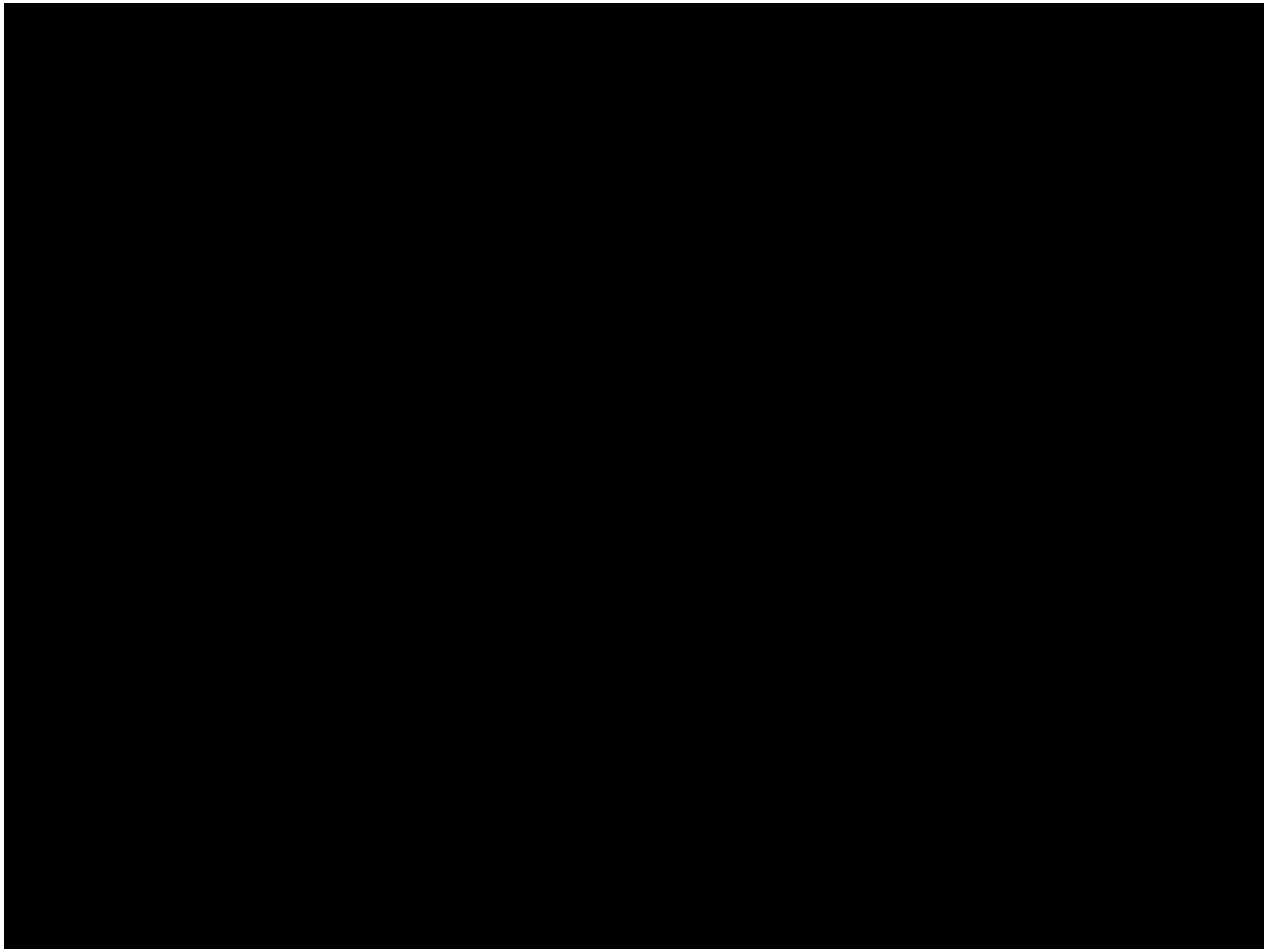
Historical Retrospective

FAA Video



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Dangerous

Military

https://www.youtube.com/watch?v=SLFYdMWgrqI

Unmanned aircraft or drones became popular with the military

https://www.youtube.com/watch?v=LI9SNt3Kv2k

- **Persistent**
- **Keeps soldiers out of harm's way**

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Dangerous, Dirty
Public Safety

Civil and commercial applications soon followed


National Park Service

City of Arlington, TX


Department of Homeland Security

Albemarle, NC

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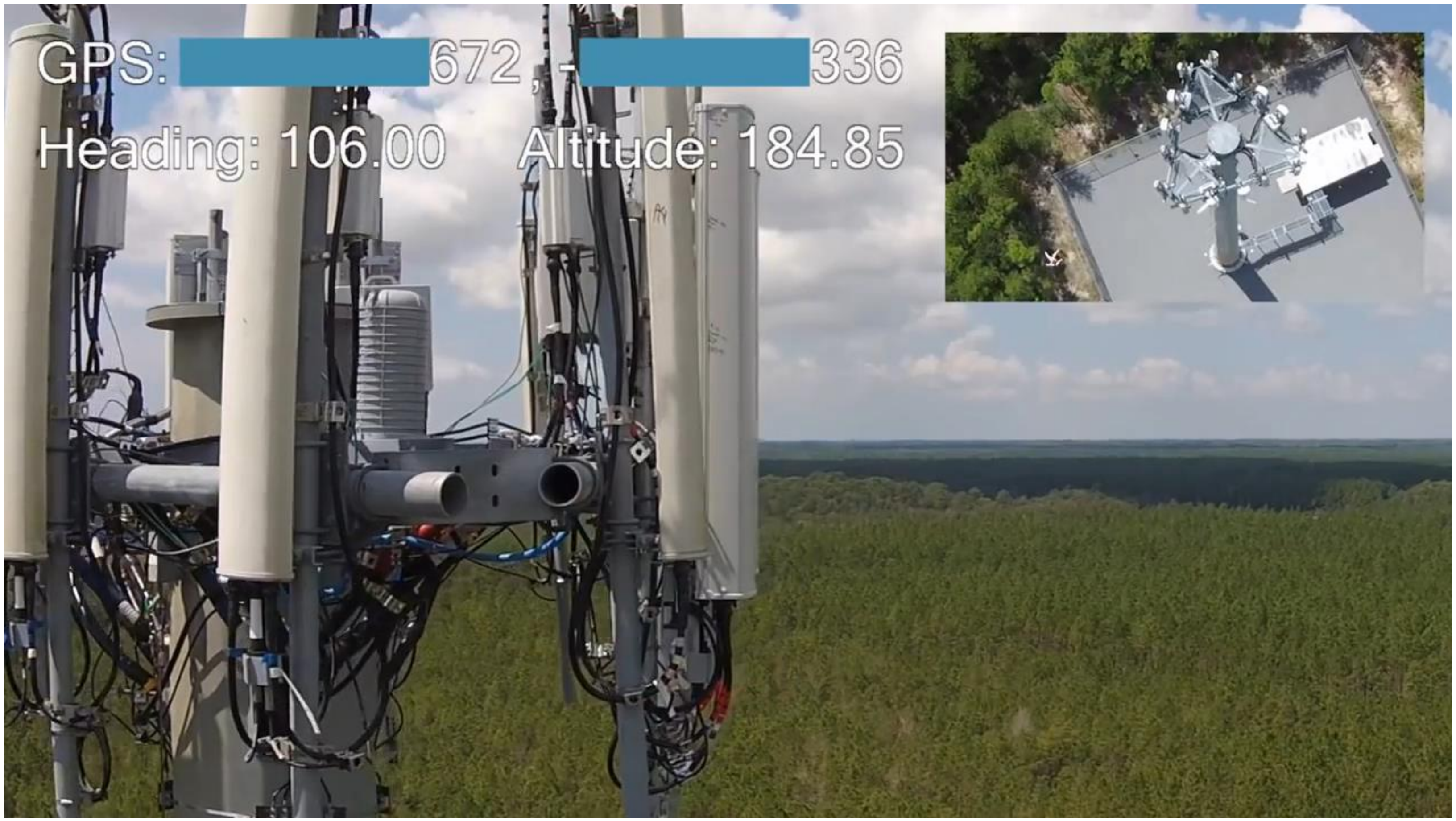
Dangerous, Dirty, + Decreased Costs
Infrastructure Inspection



https://www.youtube.com/watch?v=mo598T1ek-8

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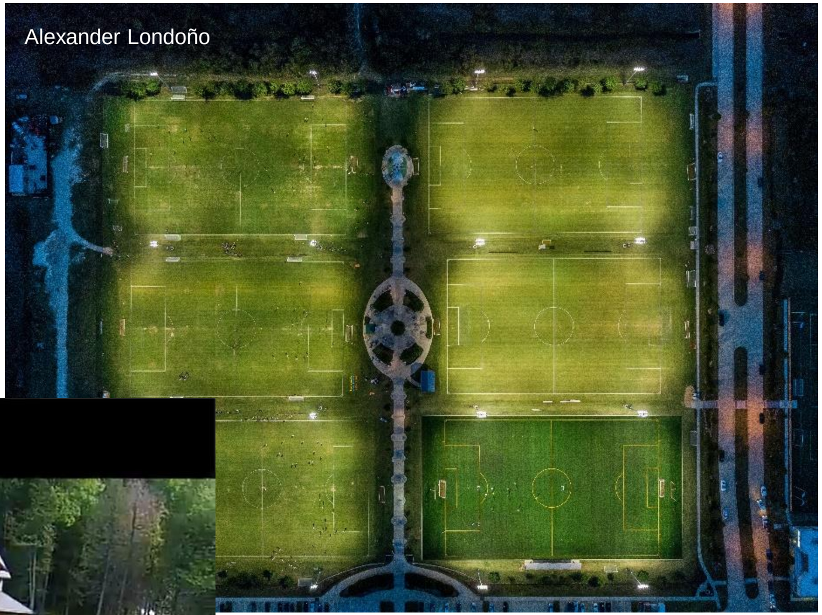
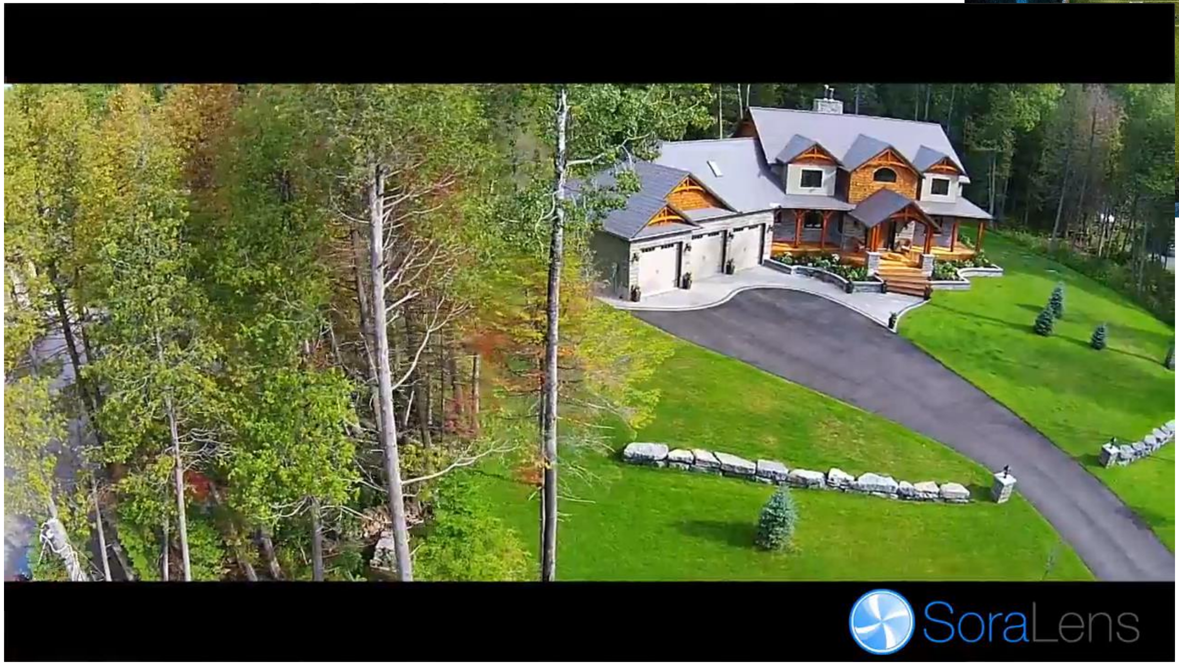
Dangerous, Dirty, + Decreased Costs
Aerial Photography





https://www.youtube.com/watch?v=P0OwbZRq2zk

Dangerous, Dirty, + Decreased Costs
Agriculture

https://www.youtube.com/watch?v=ydfPzqaNkuA

Dangerous, Dirty, + Decreased Costs

Research

NASA

https://www.youtube.com/watch?v=VIbzUs

Zbynek Burival

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Dangerous, Dirty, + Decreased Costs
Communications Platform

X Company – Project Loon

Dangerous, Dirty, + Decreased Costs

Package Delivery

https://www.youtube.com/watch?v=OnDpE8uSb7M

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Dangerous, Dirty, + Decreased Costs …Dramatic

https://www.youtube.com/watch?v=fzBVPKU_qX8

MITRE Uses Small UAS for Airport Safety Assessments – Reducing Costs

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Urban Air Mobility
Example – Cora Aero (Kitty Hawk)

Larry Page's Flying Taxis, Now Exiting Stealth Mode

Andrew Ross Sorkin
DEALBOOK MARCH 12, 2018

The New York Times

Since October, a mysterious flying object has been seen moving through the skies over the South Island of New Zealand. It looks like a cross between a small plane and a drone, with a series of small rotor blades along each wing that allow it to take off like a helicopter and then fly like a plane. To those on the ground, it has always been unclear whether there was a pilot aboard.

Well, it turns out that the airb… …le has been part of a series of "st…

https://y2mate.com/youtube/LeFxjRMv5U8

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Applications are Continuously Emerging

Examples

- **Public Safety**
  - Search and rescue
  - Law enforcement tactical operations
  - Crime scene investigation
  - Fire spotting
  - Accident recreation
  - Disaster response
  - Infrastructure protection
  - Security
- **Scientific**
  - Natural hazards research/monitoring
  - Environmental monitoring/mapping
  - In-situ atmospheric monitoring
  - Wildlife observation
  - Technology experimentation
- **Commercial**
  - Surveying/mapping/imaging
  - Aerial photography/surveys
  - Agricultural application
  - Crop monitoring
  - Motion picture
  - High altitude imaging
  - Communications relay
  - Utility/pipeline patrol
  - Traffic monitoring
  - News/media
  - Aerial advertising
  - Fish spotting
  - Parcel/cargo delivery

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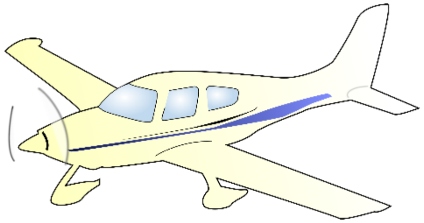
Regulatory Requirements



1. Airworthy aircraft

2. Qualified personnel and organization

3. Operational approval

Source: Creative Commons CC BY-SA

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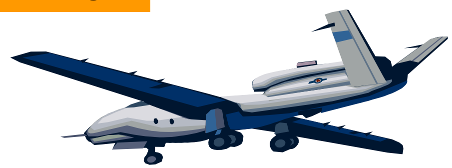
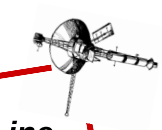
Principal Integration Challenges

Lack of "See and Avoid" Capability

Airworthiness/ Certification



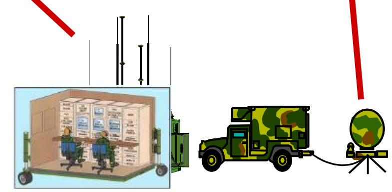


Beyond Line-of-Sight

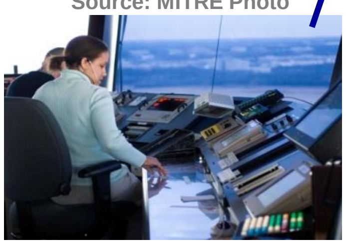
Radio Line-of-Sight

Command and Control (C2) Vulnerabilities

ATM*/Airspace Integration



Source: MITRE Photo



Air Traffic Control (ATC)

Source: http://www.af.mil/photos

Crew

Crew Qualifications and Training

*ATM = Air Traffic Management

Some Specific Challenges for UAS

- **Flight over people**
- **Beyond visual range operation of sUAS**
  - Beyond Visual Line-of-Sight (BVLOS)
  - Low altitude, Class G airspace
  - Start with remote areas, e.g., Arctic, agriculture survey
- **Airport surface operations**
  - Including unmanned airport surface vehicles
- **Automated take off and landing**
- **Incorporation of non-traditional components**
  - Open-source software
  - Commercial-off-the-Shelf (COTS)
- **Autonomous flight**

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Merging of Two Cultures

Information Technology

Innovation
Revolutionary
Speed to market
Entrepreneurial
Open
Minimally regulated

Risk rewarded

Aviation

Safety
Evolutionary
Proven
Conservative
Proprietary
Tightly regulated

Risk avoided

Used with Permission

Unmanned Aircraft

Technology Innovations → ← Safest Mode of Transportation

- Rapidly evolving technology
- Very dissimilar vehicles
- Designed for multiple purposes
- Wide variety of missions (ocean to urban)

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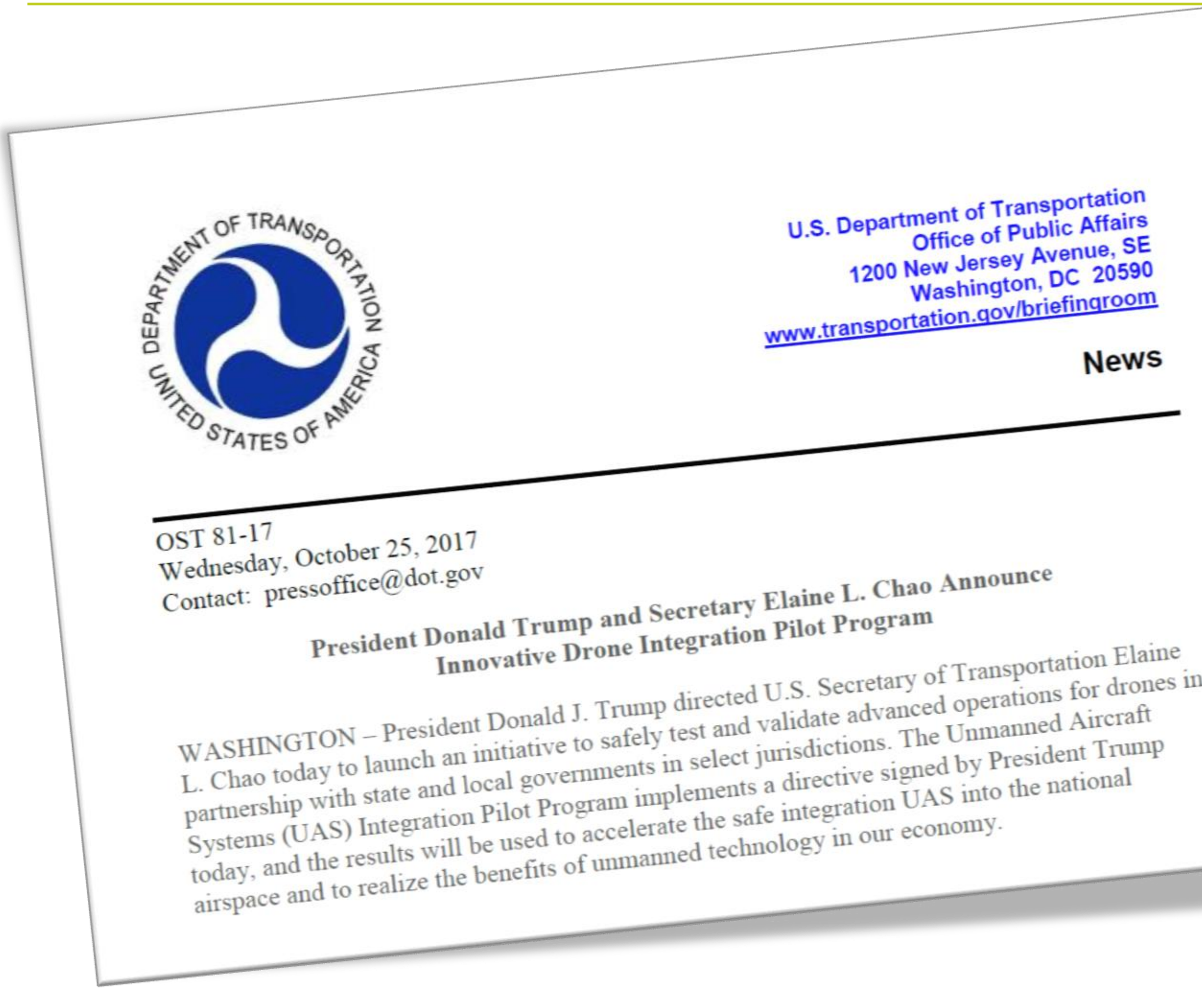
U.S. FAA Integration Pilot Program (IPP)

"Pilot" = Exploratory



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Office of Public Affairs
1200 New Jersey Avenue, SE
Washington, DC 20590
www.transportation.gov/briefingroom

News

OST 81-17
Wednesday, October 25, 2017
Contact: pressoffice@dot.gov

President Donald Trump and Secretary Elaine L. Chao Announce Innovative Drone Integration Pilot Program

WASHINGTON – President Donald J. Trump directed U.S. Secretary of Transportation Elaine L. Chao today to launch an initiative to safely test and validate advanced operations for drones in partnership with state and local governments in select jurisdictions. The Unmanned Aircraft Systems (UAS) Integration Pilot Program implements a directive signed by President Trump today, and the results will be used to accelerate the safe integration UAS into the national airspace and to realize the benefits of unmanned technology in our economy.

- **Presidential Order**
- **White House Oversight**
- **DoT Led Initiative**
- **U.S. FAA Execution**
- **Purpose: Advance Commercial Drone Operations**
- **Key: Partnerships With State and Local Governments**

DoT = Department of Transportation

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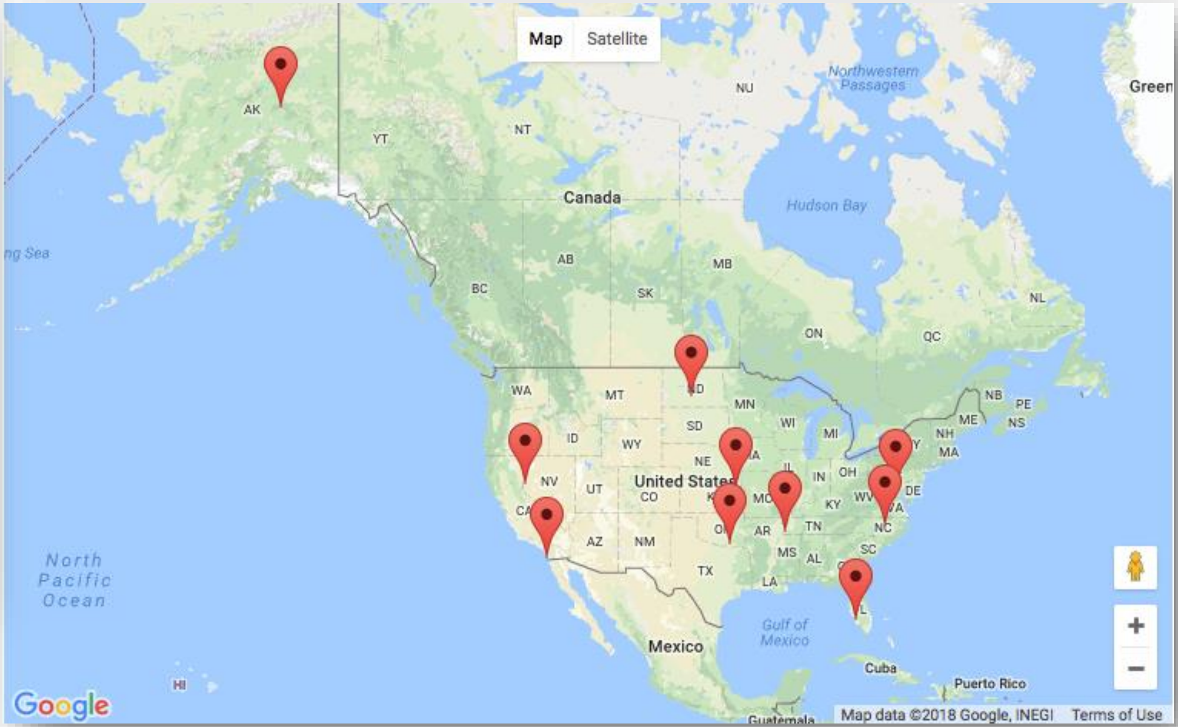
Integration Pilot Program Scope

Ten partnerships established

- Variety of partners - cities, universities, states, tribal nations
- Different types of UAS applications
- Geographic diversity of locations



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Integration Pilot Program Applications

- **Critical infrastructure inspection**
- **Law enforcement support**
- **Border protection**
- **Search and rescue**
- **Media reporting**
- **Agriculture support**
  - Wildlife management
  - Crop monitoring and precision application
- **Package delivery**
  - Medical
  - Food and commerce
- **Insurance claims support**
- **Pest control**
- **Aircraft inspection**
- **Airport perimeter surveillance**

Source: http://insideunmannedsystems.com/reaching-for-the-horizon-ipp-alaska/

Source: https://www.thedrive.com/tech/22944/the-choctaw-nation-in-oklahoma-is-using-drones-to-trap-feral-pigs

Source: https://www.govtech.com/fs/automation/Wake-County-NC-First-to-See-Meds-By-Drone-Delivery-in-US.html

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Industry Participants

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AIRMAP
Google
Dominion Energy®
UPS
MATTERNET
FedEx®
BELL™
GE
State Farm®
L3
Rockwell Collins
Uber
zipline
HARRIS
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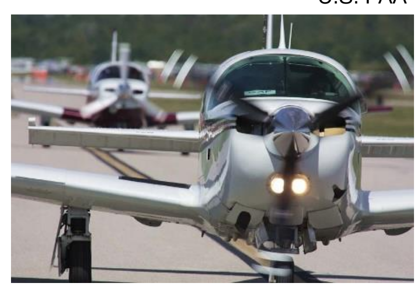
Shift in Thinking about Airworthiness

Protecting the occupants to an acceptable level of risk → **Protecting the people on the ground or in other aircraft**

UnSplash: Gerrie van der Walt

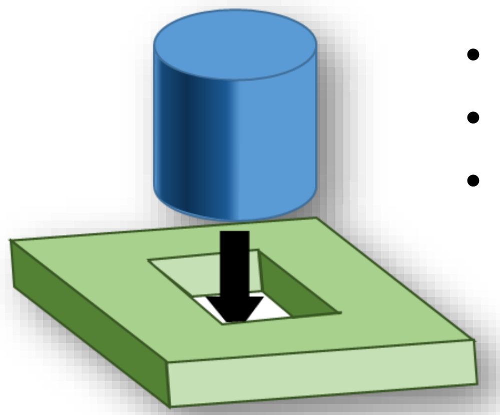
UnSplash: Nick Herasimenka

U.S. FAA



UnSplash: Meriç Dağlı

The Problem



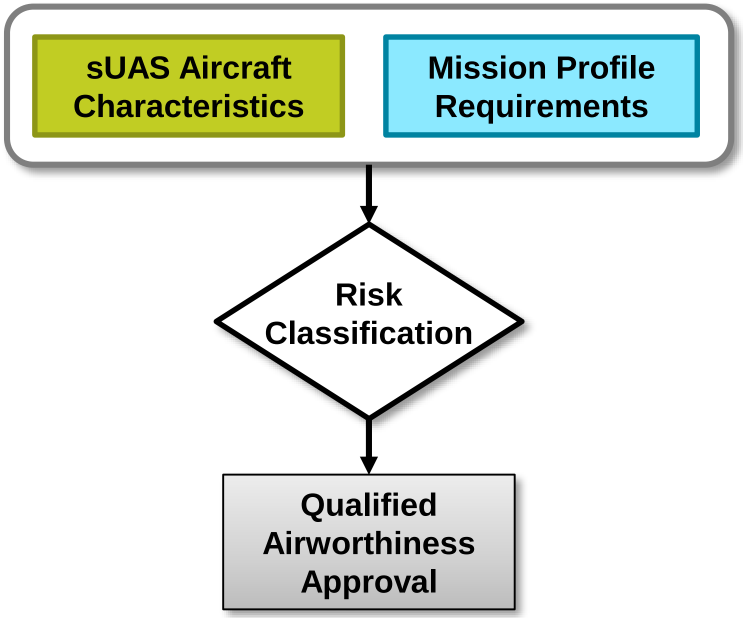
Manned aircraft airworthiness design standards do not scale down to the sUAS environment

- **Very limited design standards for the sUAS industry**
- **Wide variety of aircraft, missions, and users**
- **Rapidly evolving technology**
- **Current rules are very restrictive for sUAS**
- **Waiver process is labor intensive, time consuming, and costly**

Current approach costs too much, takes too long, and lacks defined UAS standards

A Risk-Based Approach

Can a risk-based approach for sUAS airworthiness approval be developed that combines the *aircraft* and *mission* characteristics to ensure an acceptable level of safety?



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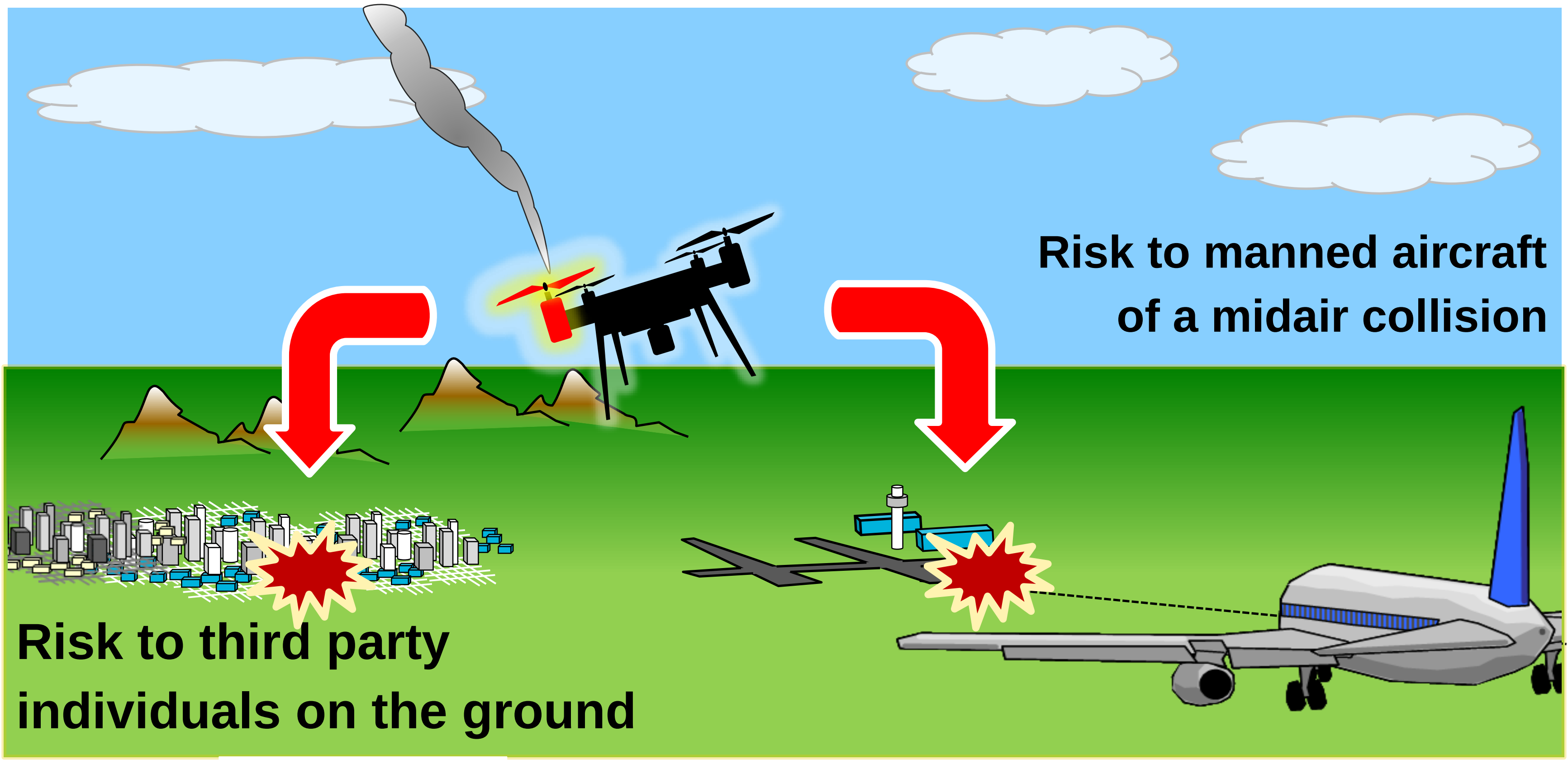
Two Aspects of sUAS Risk



Source: MITRE

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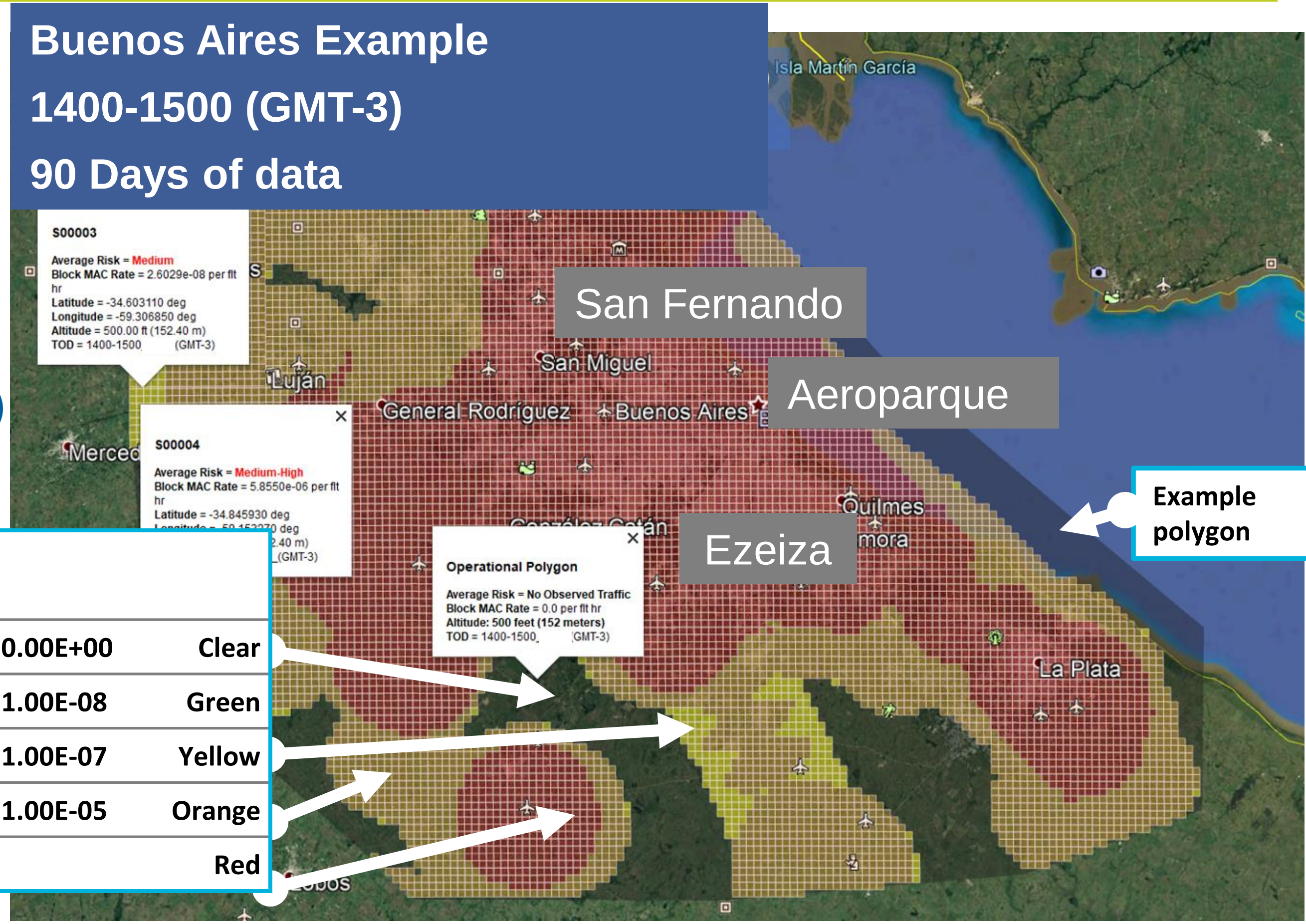
Example Outputs: Manned Aircraft Traffic around Buenos Aires

Risk Levels of a mid-air collision with manned air traffic below 1000 feet (ft) Above Ground Level (AGL)



Unmitigated Collision Risk (UCR) (Collisions/Flight Hour)				
No Traffic		UCR =	0.00E+00	Clear
Low	0.00E+00	< UCR ≤	1.00E-08	Green
Medium	1.00E-08	< UCR ≤	1.00E-07	Yellow
Medium-High	1.00E-07	< UCR ≤	1.00E-05	Orange
High	1.00E-05	< UCR		Red

GMT = Greenwich Mean Time

MAC = Mid Air Collision

deg = degrees

TOD = Time of Day

Based on Flight Radar 24 and MITRE Global Flight Infomatics (MGFI) data

Principal Enabling Technologies for UAS Flight Beyond Line of Sight

- **Detect and Avoid (DAA)**
- **Command and Control (C2) and communications**
- **Navigation**
- **Identification (ID)**
- **UAS Traffic Management (UTM)**

Methods of Traffic Detection

	Cooperative Requires intruder aircraft to be appropriately equipped	**Non-Cooperative** Does not require intruder aircraft to be appropriately equipped
Passive	**Broadcast Position (ADS-B)**	**Camera** / **Microphone**
Active	**Two-way communication systems**	**Radar**

Passive – Cooperative: Broadcast Position (ADS-B)

FreeFlight Systems RANGR

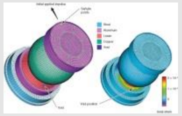
Garmin GDL-90

Passive – Non-Cooperative

Camera

Photo: US Army Research Lab Web-site

Microphone

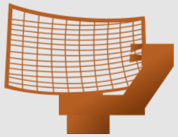


Drawing: Lawrence Livermore National Lab Web-site

Active – Cooperative: Two-way communication systems

Photo: US Navy Web-site

Active – Non-Cooperative: Radar



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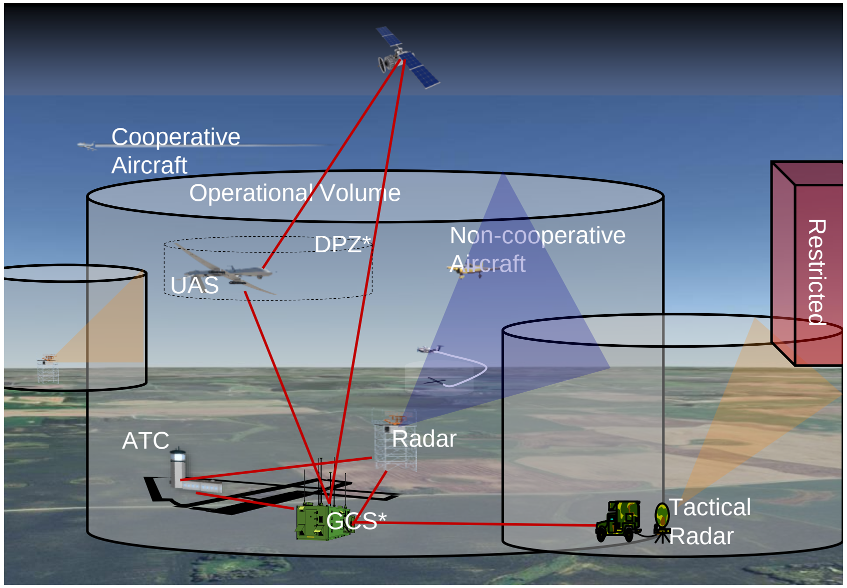
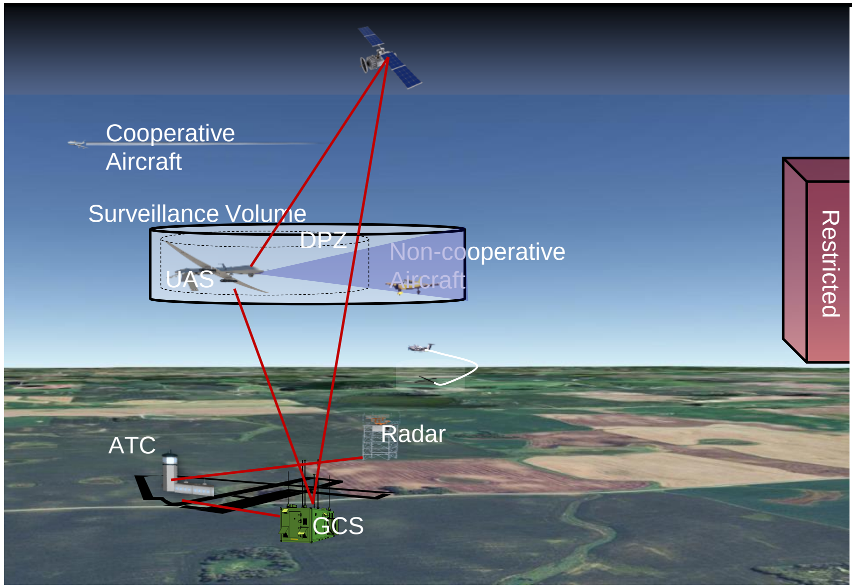
Location of Traffic Detection Sensor

Ground Based DAA



- Near-term capability, part of long-term solution
- Operations constrained to radar surveillance volume

Airborne DAA



- Long-term development
- Size, Weight, and Power (SWAP) requirement limits applicability to sUAS

*GCS = Ground Control Station

DPZ = Dynamic Protection Zone

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UAS C2 and Communications Data

Unmanned Aircraft (UA)

Source: Don McCullough (Creative Commons)

Command and Control (C2) Link

COMMANDS →

← TELEMETRY

← OTHER DATA →

Control Station

Source: Tomwsulcer (Creative Commons)

- UAS identification
- Mission data
- ADS-B validation
- Traffic management information
- Aeronautical information

Unmanned Aircraft System (UAS)

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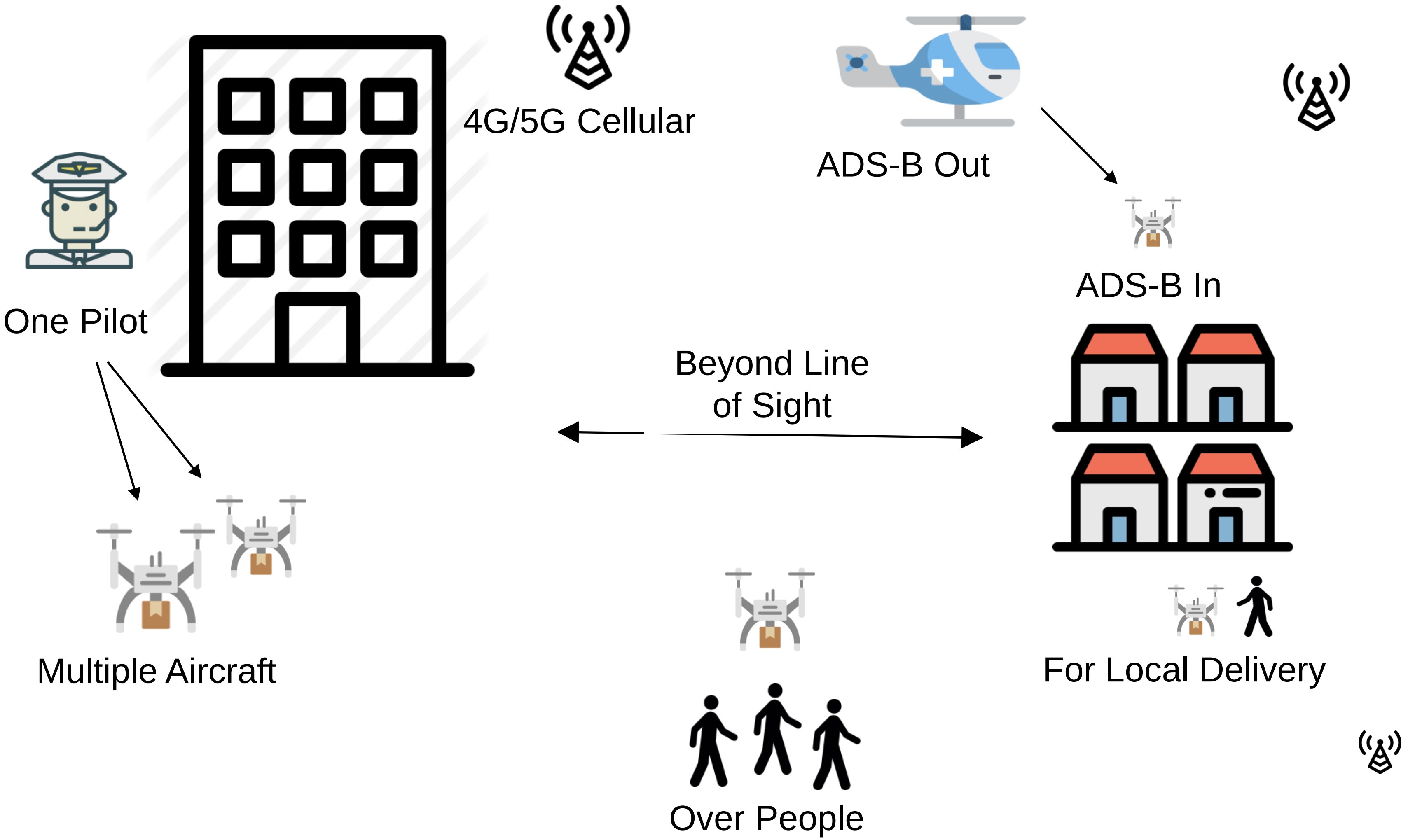
Industry Thinking



Icons: www.flaticon.com

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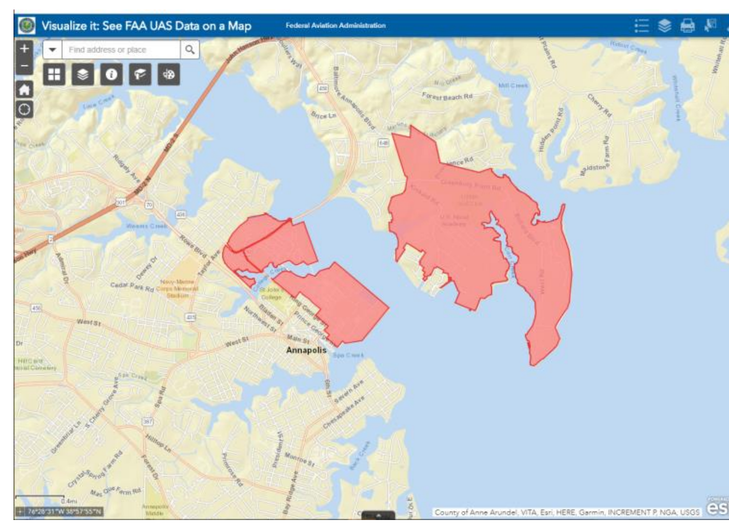
Geofencing

- **Virtual 3 Dimensional boundary based upon position**
  - Exclusion or containment zone
- **Implemented <u>within</u> the UAS software**
- **New kind of navigation specification**
  - Area versus route
  - No recognized standards exist
- **Recognized mitigation**



https://www.faa.gov/uas/commercial_operators/uas_facility_maps/

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UAS Identification

- **UAS are tools that can be used with bad intentions**
- **In the 1950s the aircraft transponder was created to separate friend from foe**
- **The current sUAS rule does not require UAS to have electronic identification**
  - Security agencies became very concerned about unauthorized use
  - The inability to connect the unmanned aircraft to its pilot creates new challenges for law enforcement
  - Before expanding sUAS access, addressing the lack of electronic identification became a priority for rulemaking

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UAS Identification Goals

- **Law enforcement worldwide must be able to determine owner/operator information of flying drone**
  - **Cost** is a major driver as, for example, there are over 18,000 federal, state, and local law enforcement agencies in the U.S.

- **Nice to have: a capability for any citizen observing a drone operating in an undesirable fashion to get an identification code**

- **“Smart phones” are emerging as a potential receiver**

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UTM: A Range of Management Concepts

Tightly Controlled

Trajectory/Area De-conflictions

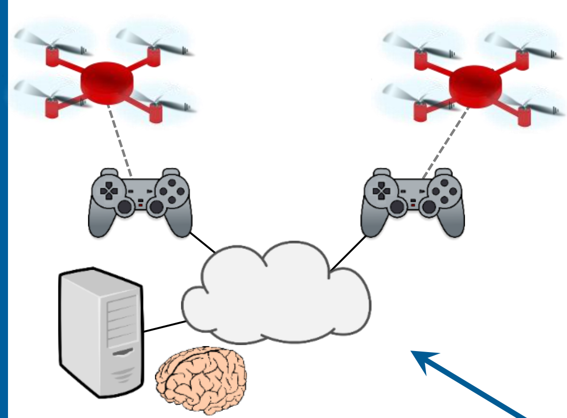
Loosely Controlled

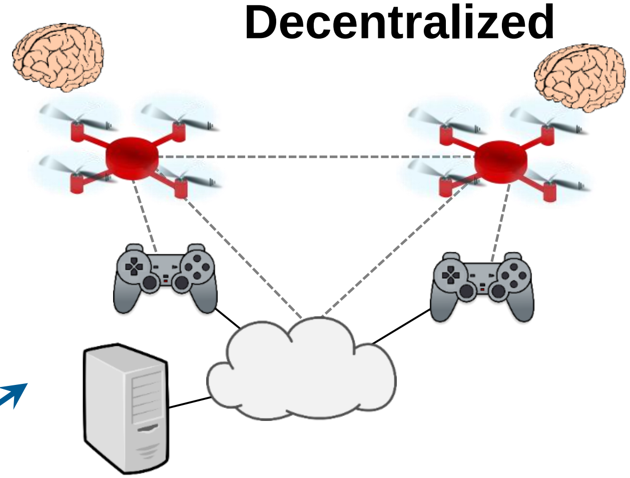
Clear Rules of the Road

Common Operational Picture

Peer Communications

Centralized ⟷ **Decentralized**





Low Altitude

"UAS Traffic Management"

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An Example – Not an Endorsement

https://www.youtube.com/watch?v=uF-WXHwzURs

What is Happening Here?

The system can determine its own flight path, avoid obstacles, and return to a safe landing place

- **Operator can select targets to track, items to film, or predefined panning paths**

- **The systems can choose the flight path**
- **A number of features:**
  - Obstacle avoidance
  - Visual navigation
  - 3 Dimensional (3D) mapping
  - Return-to-home

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Auto-GCAS: Automatic Safety Net *(Ground Collision Avoidance System)*

CFIT* and GLOC* accidents

Six systems on the F-16 → CFIT rate unchanged

LOCKHEED MARTIN

- **Introduced in 2014 – Block 40/50**
- **Maneuver – Roll-to-upright and 5G* pull**

Auto-GCAS Keys to success

- **Design started with the pilot requirements**
  - Nuisance budget
  - Maximum acceptable maneuver
  - Interface

*CFIT = Controlled Flight Into Terrain
GLOC = G-force Induced Loss of Consciousness
5G = Five times the force of gravity

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Counter UAS (C-UAS)

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MITRE Spectrum of sUAS Threat Characteristics

*GPS-Global Positioning System

Characteristic	From	Spectrum	To
Operator's Intent	**Inadvertent**	Uninformed – Disregard Rules – Criminal – Intend harm	**Malicious**
Technical Complexity	**Toys**	Consumer Grade – Commercial Grade – Military Grade	**Highly Sophisticated**
Standardization	**Off-the-shelf**	Out-of-the-box – Modifiable/Configurable – Kits – Components	**Homegrown**
Flight Control	**Remotely Piloted**	Remote Control – Automatic Return-to-Launch – GPS* Waypoint to Waypoint – Visual Navigation – Simultaneous Location and Mapping – Adaptive Missions	**Autonomous**
Number of UASs	**Single**	Single Independent – Multiple Independent – Multiple Cooperative – Multiple Automatic (Swarms: Multiple Cooperative, Multiple Automatic)	**Multiple**
Command and Control Links	**Simple**	Point-to-Point – Spread Spectrum – Cellular – Mesh – Layered	**Complex**

*GPS – Global Positioning System

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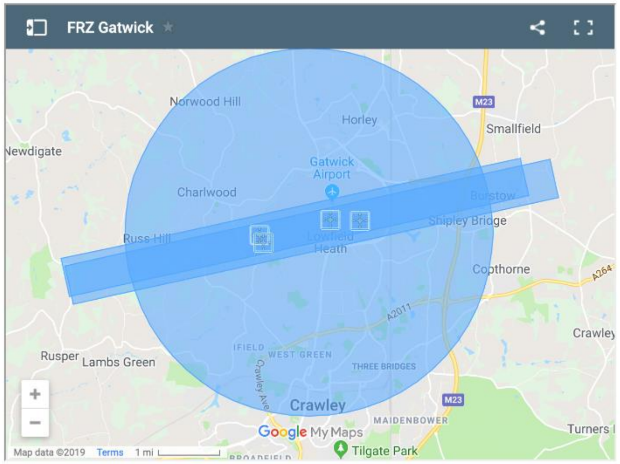
Gatwick Airport Drone Incident

December 19-21, 2018

- **Caused major disruption, affecting approximately 140,000 passengers and 1,000 flights, At least two drones involved, required resources from seven police forces.**
- **Police believe attackers had 'detailed knowledge' of airport and have "identified, researched and ruled out 96 people of interest".**
- **"I think what's clear from the last 24 hours is that drones are a UK aviation issue, or even an international aviation issue." Stewart Wingate, Chief Executive of Gatwick Airport**

Map of no-fly zone around Gatwick



Images: GatwickAirport.com

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Abqaiq–Khurais Attack in Saudi Arabia
September 14, 2019

- **Drones used to attack Saudi Aramco oil processing facilities**


The New York Times

Two Major Saudi Oil Installations Hit by Drone Strike, and U.S. Blames Iran

ABQAIQ, SAUDI ARABIA SEPT. 14 REUTERS
Saudi Oil Facility Ablaze After Strikes
By Reuters

Image: U.S. Government Source, public domain

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Multi-modal Counter UAS Approaches are Better

Modality	Legality*	Effectiveness	Pros	Cons
DETECT & DETERMINE				
Cameras			Target Identification, Computer vision is improving.	Operationally limited by line of sight and visibility. Technology limited by sensor resolution and performance of visual algorithms
C2 Signal Detection			Can sometime detect systems and extract information even before launch.	Automated flights do not require RF signature. Poor geolocation capabilities.
C2 Link Interception			Can give precise identity and location of sUAS.	Requires up to date library of sUAS and their vulnerabilities. Encryption improving. Legality without a warrant is unclear.
Radar			Detects sUAS at about 2km. Can distinguish sUAS from birds and ground vehicles.	Possible interference hazard. Difficult to detect multiple systems in tight formations or close to clutter (urban environments)
Microphones			Under ideal conditions, can distinguish sUAS from jets, vehicles, cars.	Very short range. Environment may have many other noise sources

**MITRE is not claiming legal expertise. Rough estimates only. Will vary by jurisdiction and circumstances.*

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Multi-modal Counter UAS Approaches are Better

Modality	Legality*	Effectiveness	Pros	Cons
INTERDICT				
Projectile Net			Effective against automated and non-automated threats.	Limited range. Limited effectiveness against swarm.
RF Jamming			Effectiveness dependent on sUAS configuration.	Can interfere with local infrastructure. Easy to overcome through user-interface setting.
RF Cyber			Effectiveness dependent on sUAS configuration & model.	Susceptible to constantly changing protocols and to encryption.
GPS Denial+			Effective against most current threats.	Not effective against threats that do not rely on GPS (and instead use SLAM or object recognition)
Kinetic / LASER+			Effective against automated and non-automated threats.	Requires time on target and approvals. Debris poses safety risks.
Interceptor sUAS+			Cost effective. Scales with automated sUAS.	Very difficult with manual piloting, and automated sUAS are low TRL.

+ These technologies have not been field tested by MITRE

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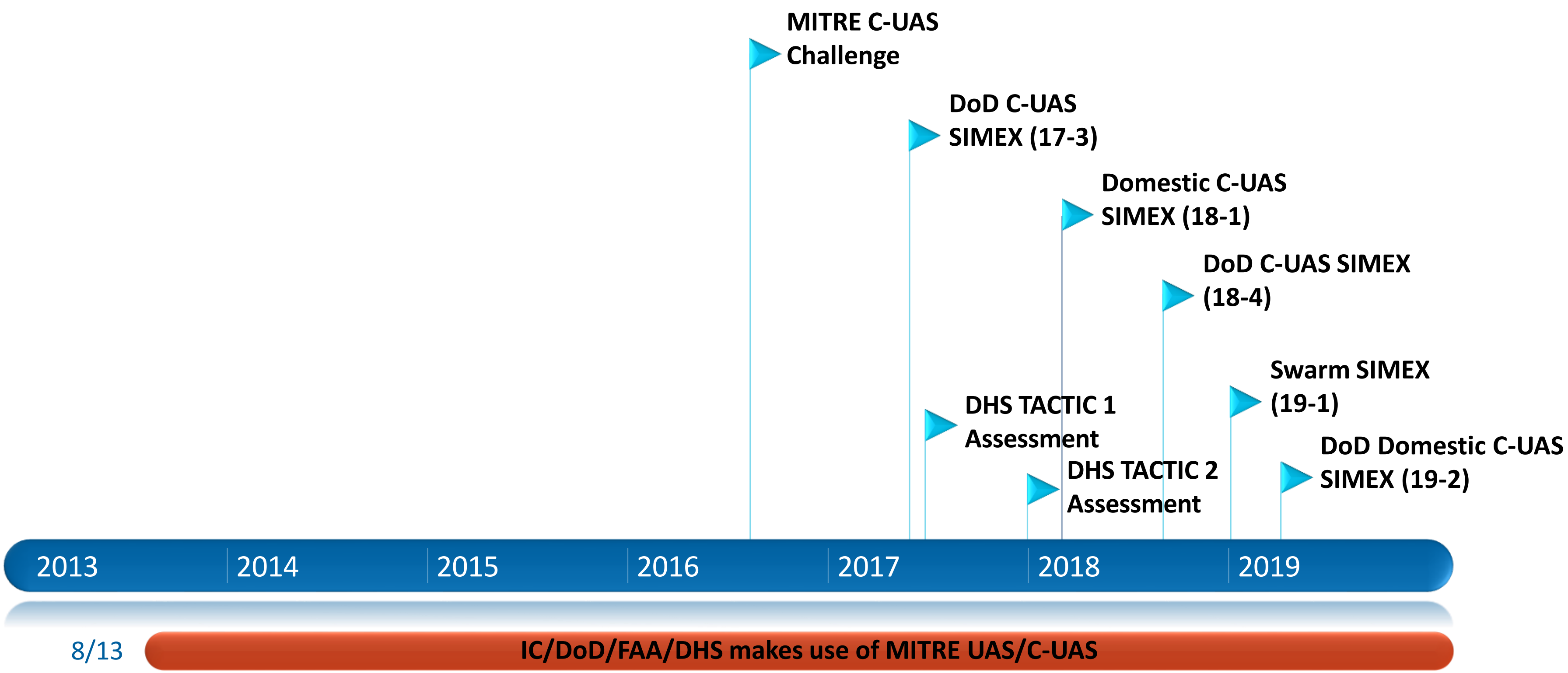
Examples of MITRE Counter UAS Activities



SIMEX: Simulation experiments
TACTIC: Technical Assessment of C-UAS Technologies in Cities

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Summary

- **UAS is a very complex topic that affects all aspects of aviation**
- **Commercial sUAS are here today and ready to provide value, improving our standard of living**
- **Flight Beyond Visual Line-Of-Sight (BVLOS) of the pilot is today's major challenge**
  - Risk Assessment: DAA, C2, UTM, Over-people, etc.
- **MITRE has been working these issues for more than twenty years and is recognized as a world expert**
  - We are here to help make the future a reality, safely and securely

Source: Creative Commons

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MITRE's mission-driven teams are dedicated to solving problems for a safer world. Through our federally funded R&D centers and public-private partnerships, we work across government to tackle challenges to the safety, stability, and well-being of our nation.

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