The Science of Drones

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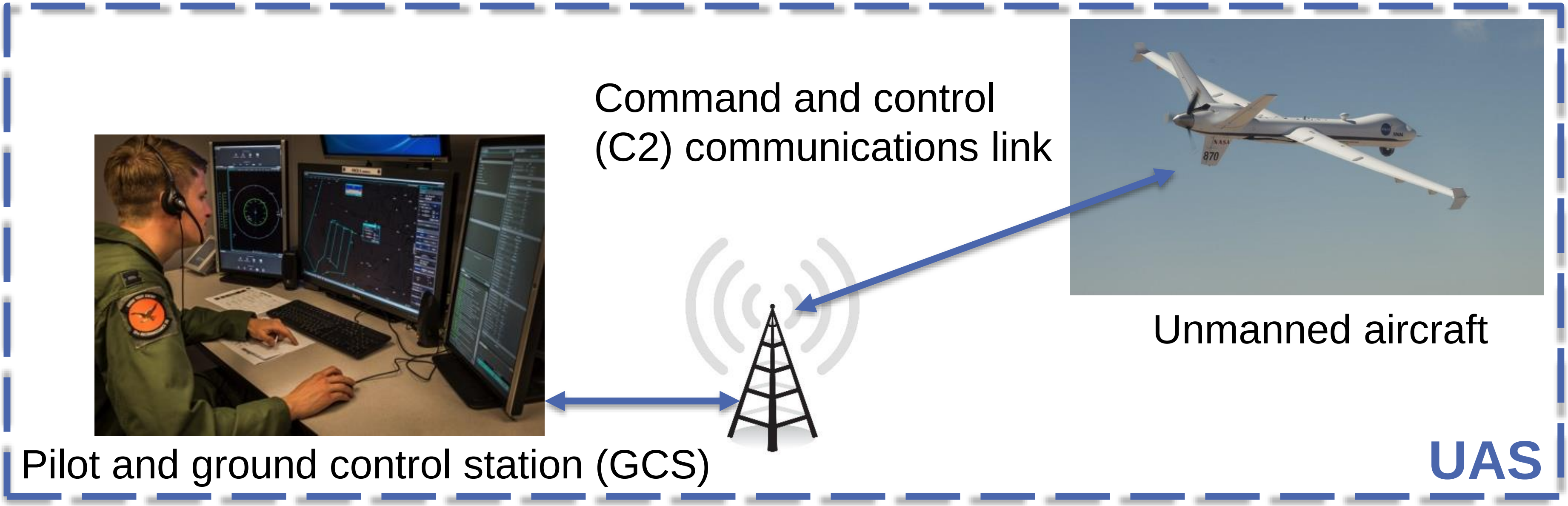
Outline

- Overview
- What is a drone?
- Drone types and systems
- Challenges for wider drone operations

Overview

- Aviate
- Navigate
- Communicate

What is a “Drone”?



- Terminology
  - *Drone*: the public’s term for any flying vehicle that doesn’t have a pilot onboard
  - *Unmanned aircraft system* (UAS): preferred civil term that emphasizes the drone as a “system”
  - *Unmanned aerial vehicle* (UAV): older but common term, especially in academia
  - *Remotely piloted aircraft system* (RPAS): the military’s most common term for a drone, and probably the most accurate

Common Drone Types

DJI Phantom

Yuneec Typhoon

Intel Aero

Small multicopter (hobbyist, commercial)

Raven (RQ-11)

Fire Scout (RQ-8)

Shadow (RQ-7)

Small/medium fixed wing and rotorcraft

X-47

Predator B (MQ-9)

Global Hawk (RQ-4)

Large fixed wing

Drone Classification System

US DEPARTMENT OF DEFENSE (DOD) CLASSIFICATION SYSTEM				
Category	**Size**	**Maximum Gross Takeoff Weight (MGTW) (lbs)**	**Normal Operating Altitude (ft)**	**Airspeed (knots)**
Group 1	Small	0-20	<1,200 AGL*	<100
Group 2	Medium	21-55	<3,500	<250
Group 3	Large	<1320	<18,000 MSL**	<250
Group 4	Larger	>1320	<18,000 MSL	Any airspeed
Group 5	Largest	>1320	>18,000	Any airspeed

Drone Subsystems

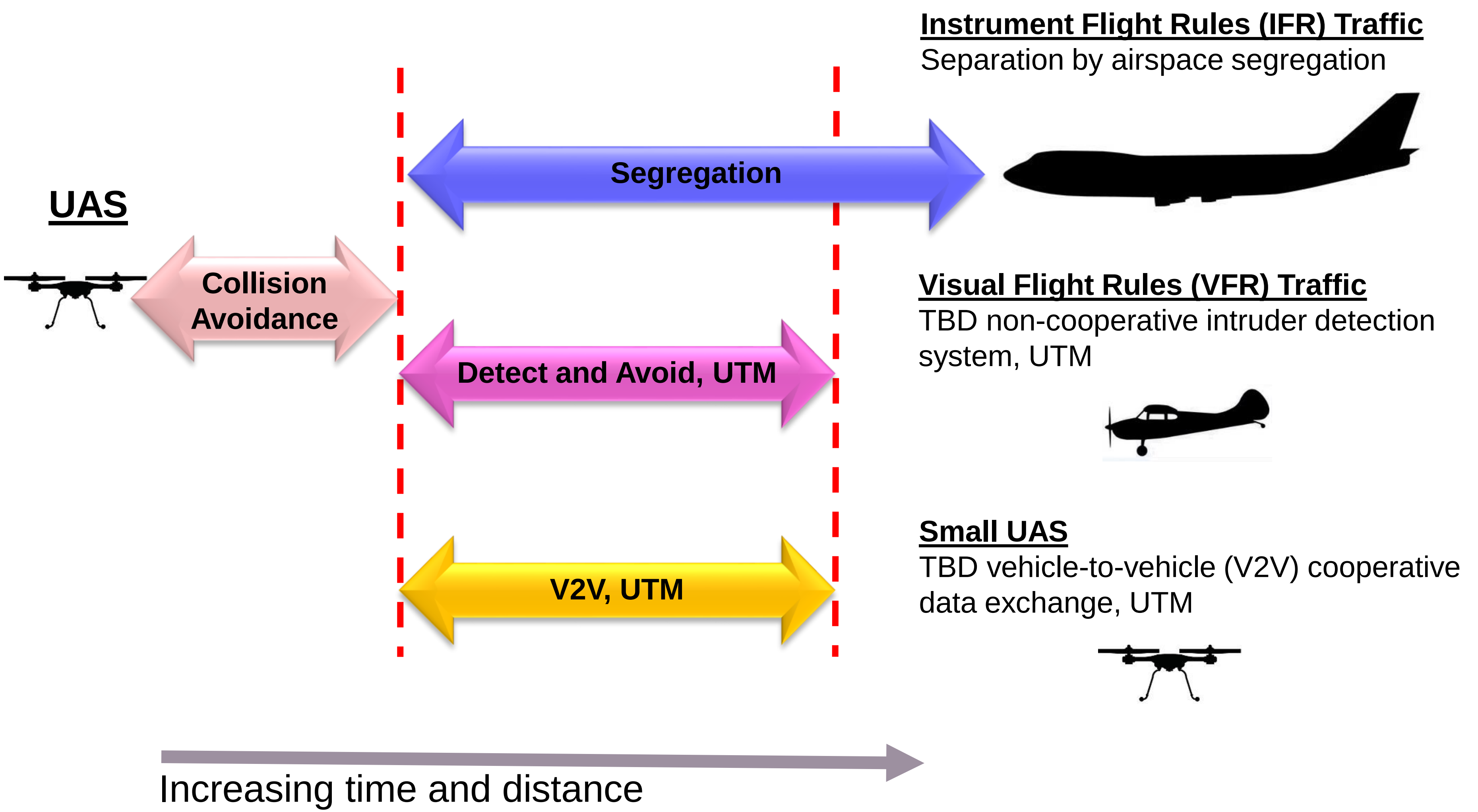
Drone Subsystems

Vehicles and Airspace Operations

Advanced Vehicle	Airspace Operations
Detect and avoid (separation and collision)	Architecture and roles/responsibilities
Tracking	Planning, scheduling, sequencing and separation
Control system	Weather
Geo-fencing conformance	Alerts
Safe Landing	Data exchange protocols
Cyber security	Cyber security
Low-noise	Spectrum
Long endurance	Dynamic and static geo-fence definition
GPS-free/degraded	Contingency management
Autonomous Last/first 50 feet	

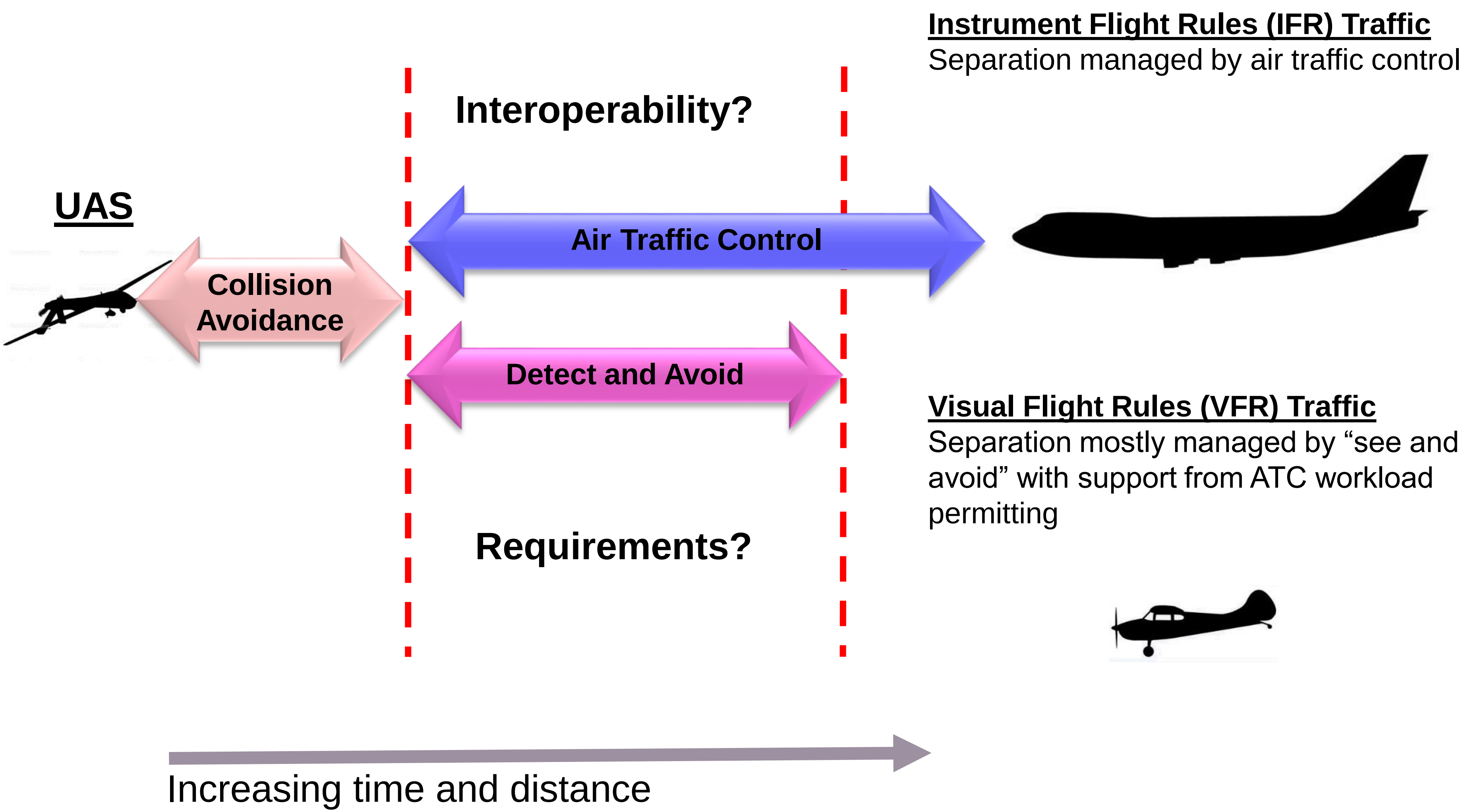
Detect and Avoid (DAA) Overview for Small UAS

Detect and avoid for UAS replaces "see and avoid" for pilots

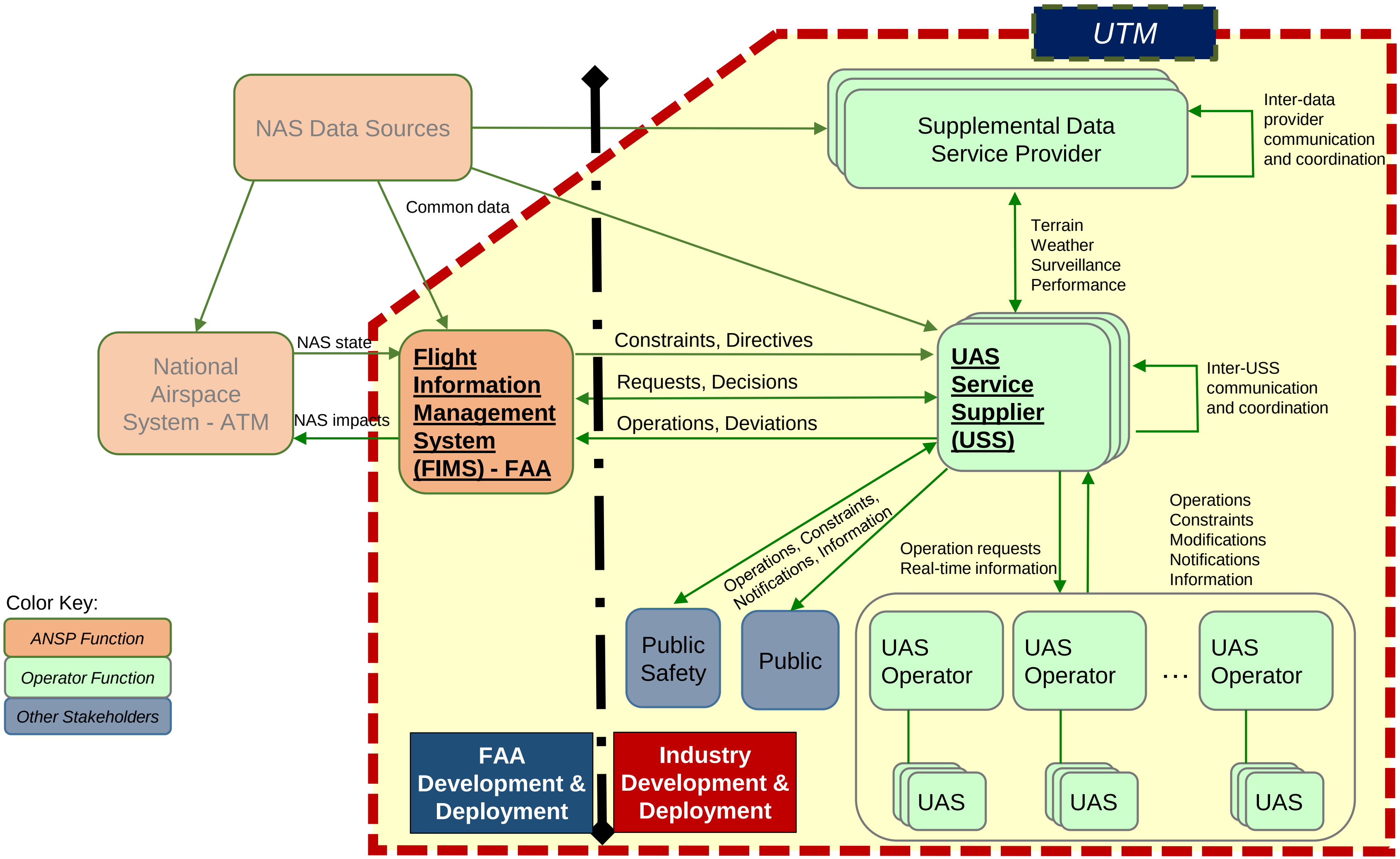


Detect and Avoid (DAA) Overview for Large UAS

Detect and avoid for UAS replaces "see and avoid" for pilots



UTM Architecture



UTM Technical Capability Levels (TCLs)

Capability 1: Demonstrated how to enable multiple Operations Under Constraints

- Notification of area of operation
- Over unpopulated land or water
- Minimal general aviation traffic in area
- Contingencies handled by UAS pilot

Product: Overall con ops, architecture, and roles

Capability 3: Focuses on how to Enable Multiple Heterogeneous Operations

- Beyond visual line of sight/expanded
- Over moderately populated land
- Some interaction with manned aircraft
- Tracking, V2V, V2UTM and internet connected

Product: Requirements for heterogeneous operations

Capability 2: Demonstrated How to Enable Expanded Multiple Operations

- Beyond visual line-of-sight
- Tracking and low density operations
- Sparsely populated areas
- Procedures and “rules-of-the road”
- Longer range applications

Product: Requirements for multiple BVLOS operations including off-nominal dynamic changes

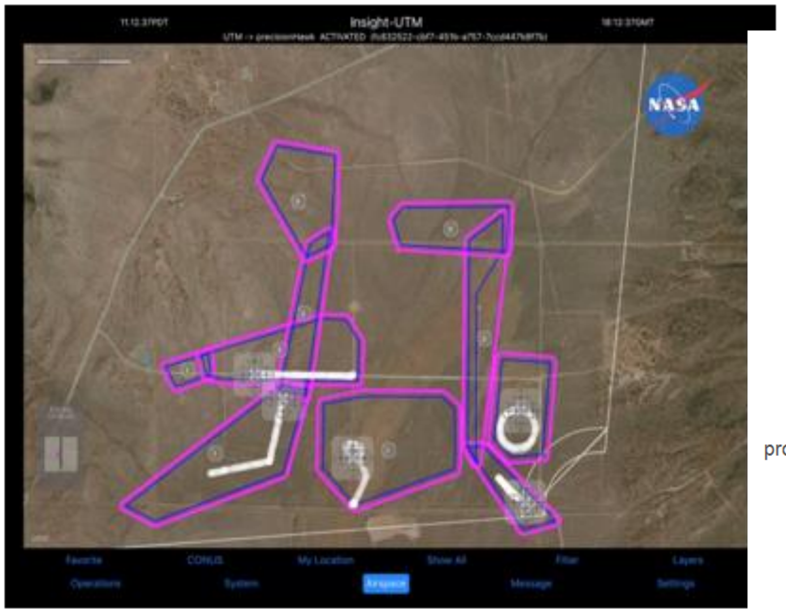
Capability 4: Focuses on Enabling Multiple Heterogeneous High Density Urban Operations

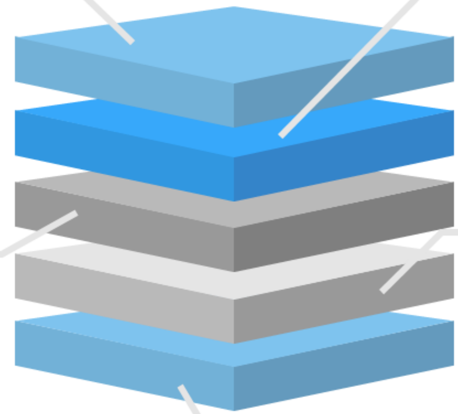
- Beyond visual line of sight
- Urban environments, higher density
- Autonomous V2V, internet connected
- Large-scale contingencies mitigation
- Urban use cases

Product: Requirements to manage contingencies in high density, heterogeneous, and constrained operations

Risk-based approach: depends on application and geography

UTM TCL2: Scheduling and Executing Multiple BVLOS Operations





Conflict Alerts

Alert triggered by proximity to other aircraft

Intruder Alerts

Alert triggered from radar submitted warning regions to UTM research prototype

Contingency Alerts

Simulated in-flight emergency reported to the UTM research prototype and relayed to impacted operations

Flight Conformance Alerts

Alert triggered from departing from operational area and relayed to impacted operations

Priority Operations

Users with special privileges are given priority of the airspace and impacted operations are informed of any conflicts

Scheduling and tracking operations and contingency management

NASA FAA RTT Comm&Nav Working Group

Comm&Nav (C&N) Working Group (WG) is one among 4 NASA-FAA RTT working groups, the others being Data Architecture, Concept and Operations, Sense and Avoid.

<u>C&N WG Objectives</u>

Develop C&N guidance to industry for ensuring that

- Unmanned Aircraft (UA) are under operational control of the pilot
- UA remain within a defined area

NASA Guidance to Industry (Comm)

CG01. UAS operator should have a means to detect loss of Command and Control (C2) radio link

CG02. UAS operator should make the means to detect loss of C2 known to public

CG03. UAS operator should define steps to mitigate loss of C2 link

CG04. UAS operator should make loss of C2 link contingency mitigation steps known to public

CG05. When loss of C2 link occurs, UAS operator should gather contextual and digital data that can describe this event for further review

CG06. UAS operator should have a means verify Unmanned Aircraft (UA) execution of a maneuver command from the operator

CG07. UAS operator should make the means to verify Unmanned Aircraft (UA) execution of a maneuver command from the operator known to public

CG08. UAS operator should define steps to mitigate a condition where UA does not execute a maneuver command from the operator

CG09. UAS operator should make steps to mitigate a condition where UA does not execute a maneuver command from the operator known to public

CG10. When UA does not execute a maneuver command from the operator, UAS operator should gather contextual and digital data that can describe this event for further review

NASA Guidance to Industry (Nav)

NG01. UAS operator should know position error of their UAS system

NG02. UAS operator should know velocity error of their UAS system

NG03. UAS operator should have a means to detect loss of navigation

NG04. UAS operator should make the means to detect loss of navigation known to public

NG05. UAS operator should define steps to mitigate loss of navigation

NG06. UAS operator should make loss of navigation contingency mitigation steps known to public

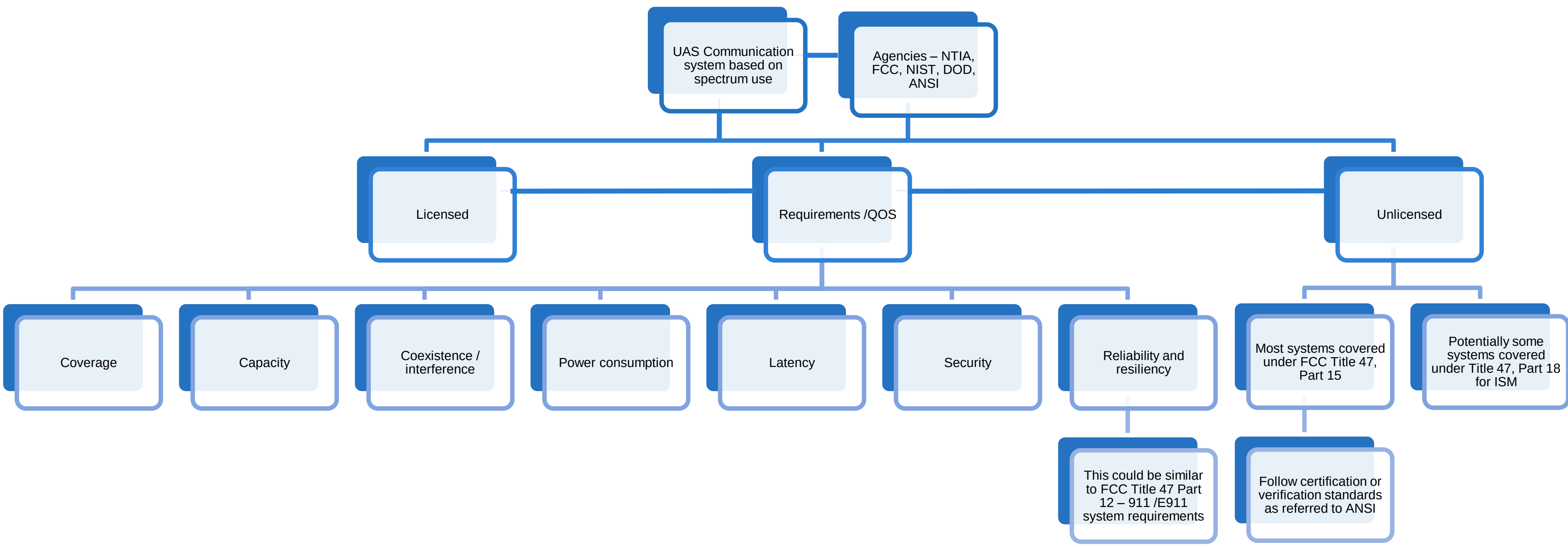
NG07. When loss of navigation occurs, UAS operator should gather contextual and digital data that can describe this event for further review

NG08. UAS operator should define boundary of operational airspace where UA will stay within

NG09. UAS operator should make operational airspace boundary known to public

NG10. UAS operator should make UA's operation time in its operation airspace known to public

Flowchart for Current Spectrum Use

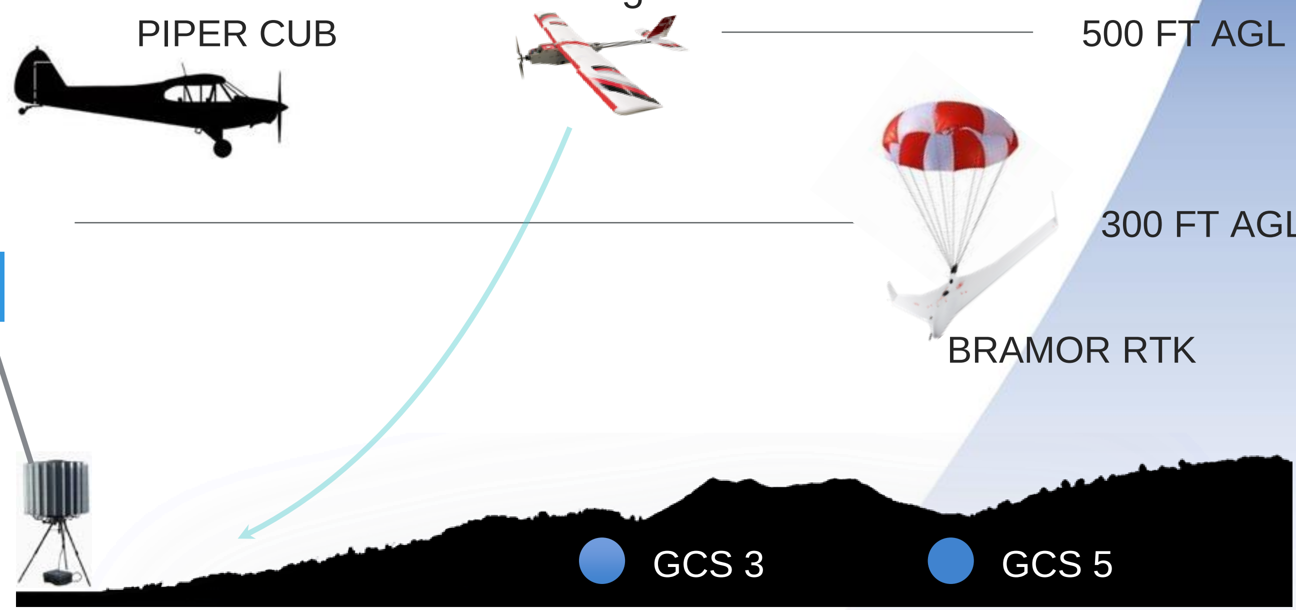


Lessons Learned from Flight Tests

- Altitude standard
- Density altitude
- Up drafts
- High/low temperature grade equipment
- Manned-unmanned vehicle interaction

Manned and unmanned vehicle interaction

Manned Aircraft



National UAS Standardized Testing and Rating (NuSTAR)

- Current State of the Art
  - Many performance measures are considered for UAS
  - Capability to assess and certify performance benchmarking is a huge gap
- Proposed Solution
  - Responsible, credible, collaborative tests and data
  - Parallel: Underwriter’s Laboratory, Consumer Reports, JD Powers
- Approach
  - Drop tests
  - Urban, rural, atmospheric conditions (e.g., fog, smog, rain)
  - Sense and avoid, Simulated obstructions, GPS denied conditions, etc.
- Data oriented rating, acceptance, and assurance
- Every UAS vehicle model goes through
- Support UAS manufacturers, consumers, FAA, insurance companies, and public at large through objective assessments

Summary

- Vehicles will get more capable over time
- Airspace operations capabilities will remain important for scalability
- NUSTAR will help pave the way for assessment of vehicle performance

Thank you!

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