UAS Integration in the NAS
Detect and Avoid Subproject

Kitty Hawk – NASA Collaboration Discussion

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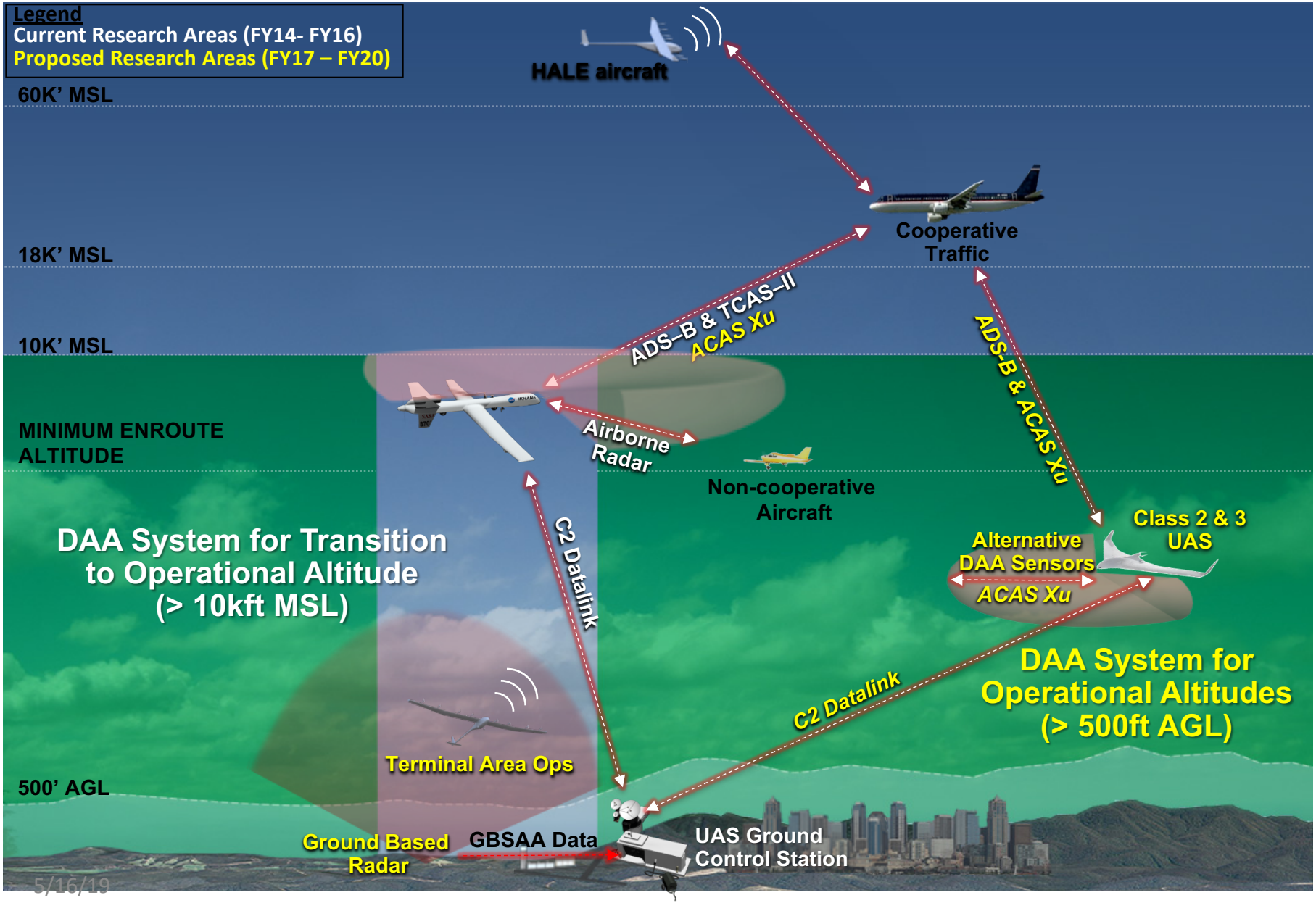
Sub-Project Manager

DAA Operational Environments



See and Avoid: FAR Sec. 91.113

General. When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

Piloted “see and avoid” = UAS “detect and avoid”

Pilots vision replaced by sensors (on- or off- board or both)

Pilot judgment of well clear = mathematical expression of well clear

Horz Miss Distance = 4000ft; Vert Miss Distance = 450ft;
modTau = 35sec

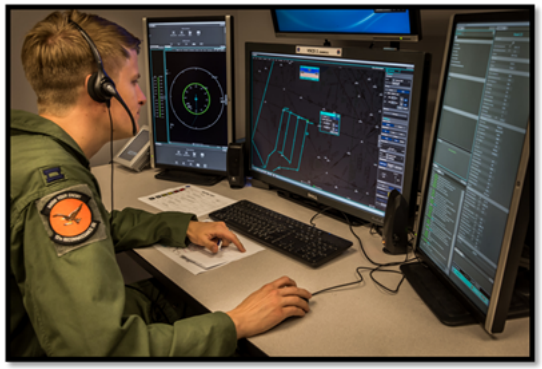
DAA
(grossly over-simplified)

Three Technical Areas:

- Human Systems Integration
  - Displays
  - Guidance
  - Alerting
  - Human in the loop simulations
- Modeling and simulation
  - Fast time simulations (ACES)
  - Well clear definition(s) and analysis
- Guidance and Control
  - Avoidance algorithm (DAIDULUS)
  - Terminal area focus simulations

Human in the Loop (HITL) Simulation Facility

Vigilant Spirit Ground Control Station



ATC

Sim Manager

Pesudo Pilot

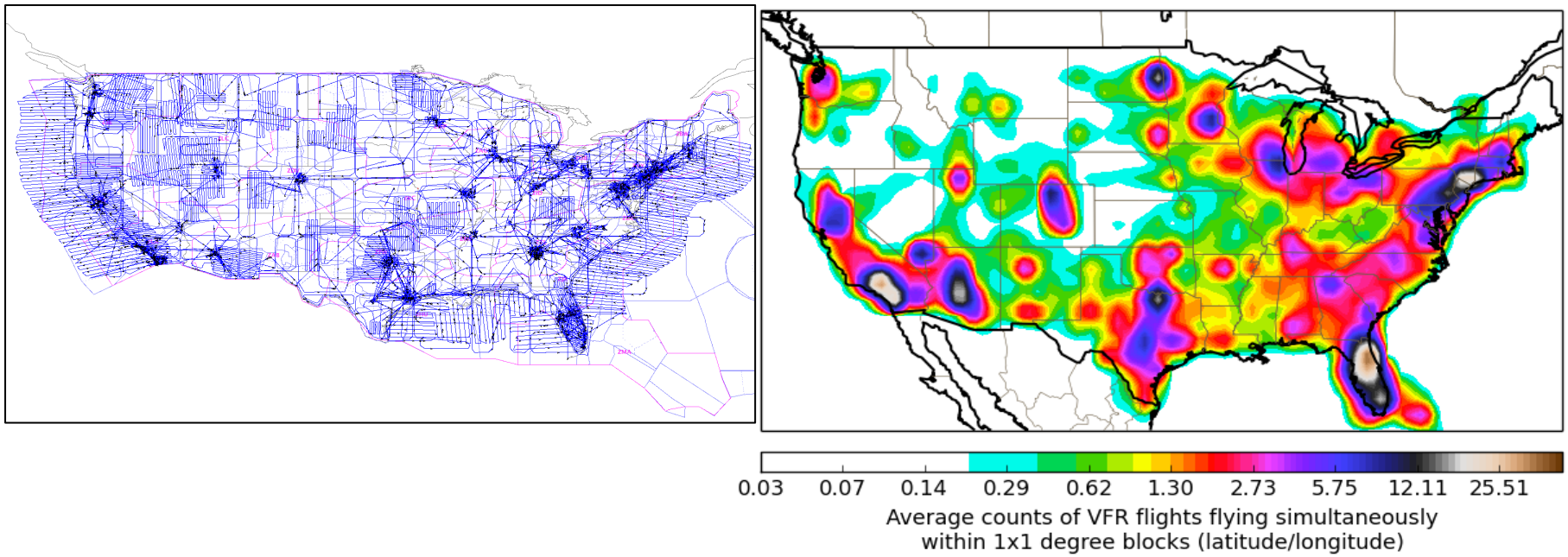
Via
LVC

DAA Alerting Structure

Symbol	Name	Alert Meaning & Expected Pilot Response	Aural Verbiage
	**Resolution Advisory (ACAS Xu/TCAS II systems only)**	***Collision Imminent*** Immediately comply with guidance and then contact ATC	"Climb/Descend" x2 "Turn Left/Right" x2
	**Warning Alert**	***Loss of DAA Well Clear Imminent*** Immediately maneuver to avoid loss of well clear and then contact ATC	"Traffic, Maneuver Now" x2
	**Corrective Alert**	***Loss of DAA Well Clear in ~30-60 seconds*** Coordinate with ATC and then maneuver to avoid loss of well clear	"Traffic, Avoid"
	**Preventive Alert**	***Currently DAA Well Clear but Close in Altitude*** Monitor altitude separation for potential increase in threat level	"Traffic, Monitor"
	**Guidance Traffic**	***Currently DAA Well Clear but Generating Peripheral Guidance*** Monitor for potential increase in threat level	N/A
	**Remaining Traffic**	***Traffic Within Surveillance Range*** No associated guidance	N/A

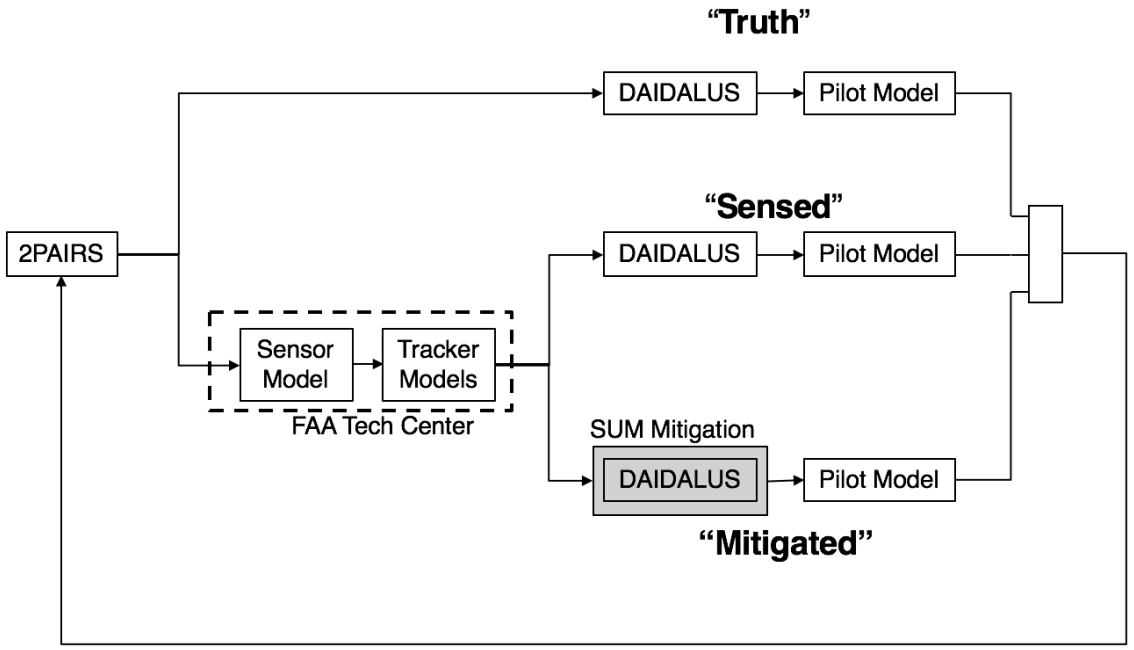
Airspace Concept Evaluation System (ACES)

- 26,500 hours of projected UAS mission trajectories in one day overlaid with each of 21 days' radar recorded visual flight rules (VFR) traffic



DAIDALUS and Unmanned Batch Simulation (UBS)

- Detect and Avoid Alerting Logic for Unmanned Aircraft Systems (DAIDALUS) Algorithm
  - The system can generate or ingest truth vectors or generate vectors involving ADS-B, Mode S, or airborne radar sensor uncertainty
  - With a simple, rules-based pilot model, UBS can test the ability to follow maneuver guidance generated by DAIDALUS to avoid intruders



Characteristics of UAS Missions

Mission Type	Unmanned Aircraft	Cruise Altitude	Cruise Speed (KTAS)	Flight Pattern
Aerial Imaging and Mapping	Aerosonde Mk 4.7	3000 ft. AGL	44 to 51	Radiator-grid pattern
Air Quality Monitoring	Shadow (RQ-7B)/NASA Sierra	4k,5k, and 6k ft. AGL	74 to 89	Radiator-grid pattern
On-Demand Air Taxi at Low Altitude	Cirrus SR22T	6k-11k MSL	153 to 166	Point-to-Point
On-Demand Air Taxi at High Altitude	Cessna Mustang	11k-32k MSL	156 to 340	Point-to-Point
Airborne Pathogen Tracking	Shadow (RQ-7B)/NASA Sierra	3k ft., 5k ft., to 10k ft. AGL	72 to 97	Radiator-grid pattern
Border Patrol	Predator-B (MQ-9)	5k ft., 10k ft., and 15k ft. AGL	129 to 173	Radiator-grid pattern
Cargo Delivery	Cessna 208	7k, 8k, 9k, 10k ft MSL	137 to 172	Point-to-Point
Flood Inund. Mapping	Aerosonde Mk 4.7	4,000 ft. AGL	46 to 51	Grid pattern
Flood Stream Flow	Aerosonde Mk 4.7	4,000 ft. AGL	46 to 51	Grid pattern and/or along stream direction
Law Enforcement	Aerosonde Mk 4.7	3,000 ft. AGL	44 to 51	Three types of pattern: 1) grid pattern, 2) random, 3) outward spiral
Maritime Patrol	Global Hawk (RQ4A)	5,000 ft. to 35,000 ft. AGL	151 to 321	Radiator-grid pattern
News Gathering	Aerosonde Mk 4.7	1,500 ft. and 3,000 ft. AGL	44 to 51	Random-path: e.g., police-chase; Circular orbit:
Point Source Emission	Shadow (RQ-7B)/NASA Sierra	3,000 ft. AGL	72 to 80	Round-the-clock
Spill Monitoring	Shadow (RQ-7B)/NASA Sierra	3,000 ft. to 10,000 ft. AGL	72 to 93	Radiator-grid pattern
Strategic Wildfire Monitoring	Predator-B (MQ-9)	31,000 MSL	209	Grid pattern
Tactical Fire Monitoring	Shadow (RQ-7B)/NASA Sierra	3,000 ft. AGL	72 to 75	Circular flight path following the perimeter of a wildfire
Traffic Monitoring	Shadow (RQ-7B)/NASA Sierra	1,500 ft. AGL	58 to 84	Geo-spatial monitoring flight path
Weather Data Collection	Global Hawk	5,000 ft. to 35,000 ft. AGL	151 to 321	Radiator-grid pattern
Wildlife Monitoring	Aerosonde Mk 4.7	3,000 ft. AGL	44 to 51	Radiator-grid pattern

Phase 1

- Ikhana with large General Atomics RADAR
- TSO-C211 (DAA) and TSO-C212 (ATAR)
- No Chase COA

Phase 2

FOCI

- Low Space, Weight and Power (SWaP) Sensors
- Smaller UAS (class 2 & 3)
- Terminal Area Operations

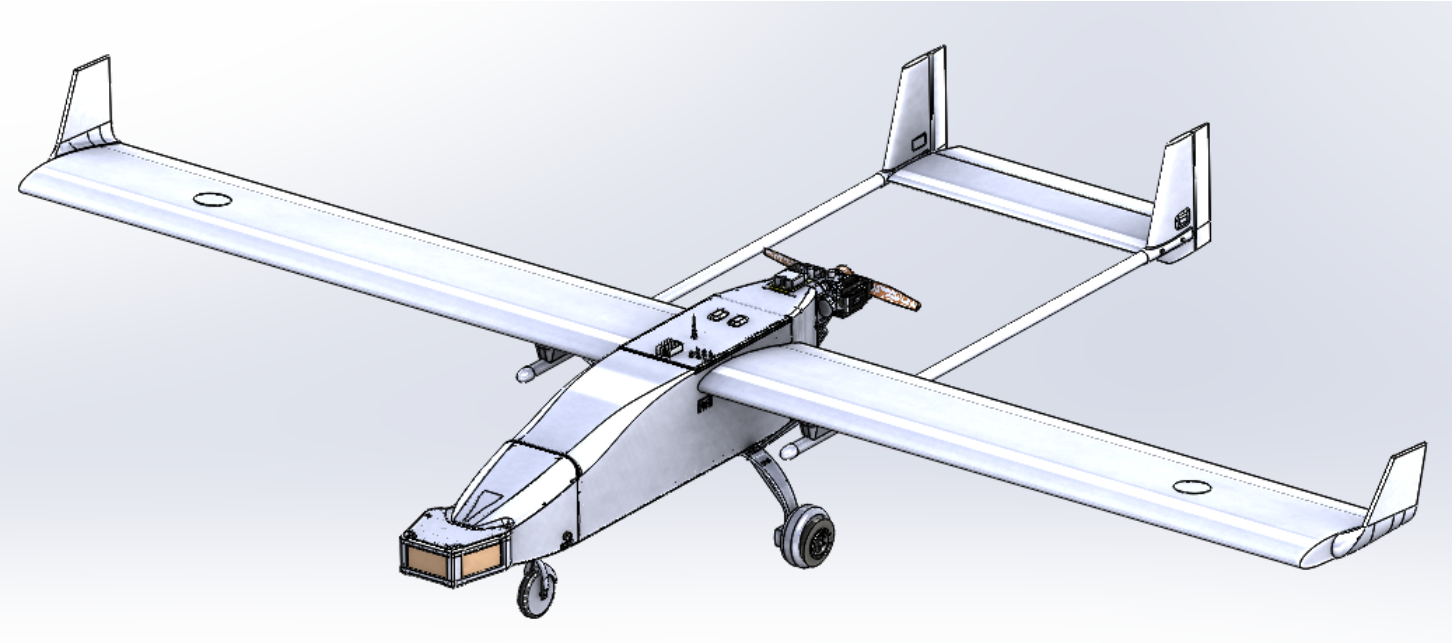
Tiger Shark with Honeywell RADAR Panels

Flight Test 6

- Characterize RADAR: 64 Encounters
  - Priority: 17 high, 20 medium, 27 low
  - Procedure:
    - UAS and intruder fly planned course
- DAA Encounters: 72 Encounters
  - RADAR Range Requirement: ~2 nmi
  - Priority: 17 high, 22 medium, 33 low
  - Procedure:
    - UAS and intruder begin at specified entry criteria
    - UAS pilot detects DAA alerting and guidance
    - UAS pilot holds for prescribed interval of time
    - UAS pilot initiates horizontal maneuver to within 15 degrees of edge of heading band

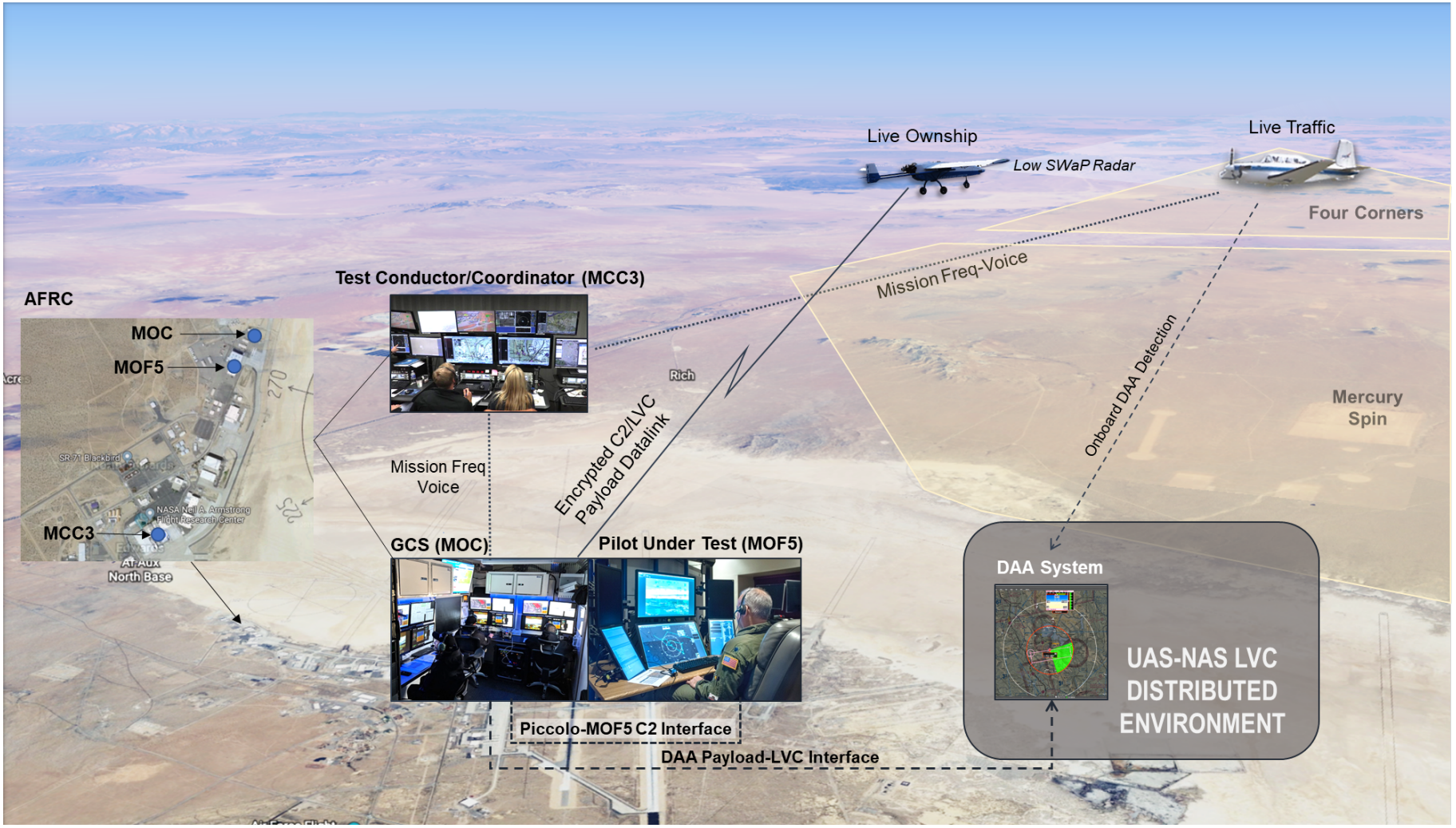
- Large Twin: KingAir 200
- Small Single: T-34C Mentor
- Small: TG-14 M

Navmar Applied Science Corp (NASC) TigerShark

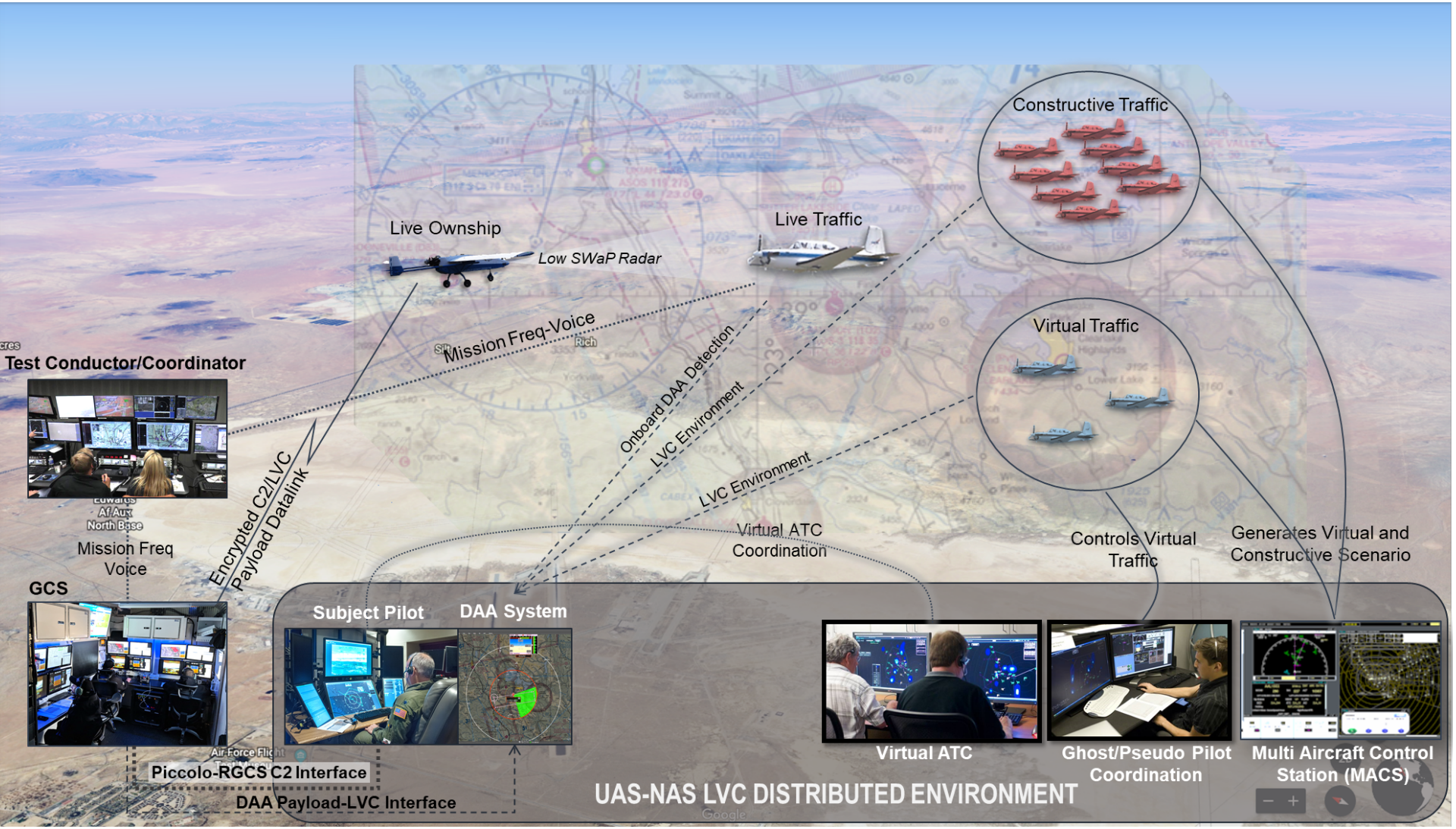


Wingspan	22'
Length	15'
Maximum Take Off Weight	500 lbs
Payload Capacity	100 lbs
Maximum Operating Altitude	>14K ft
Maximum Endurance	8-12 hrs*
Maximum Speed	80 kts*

Scripted Encounters CONOPS



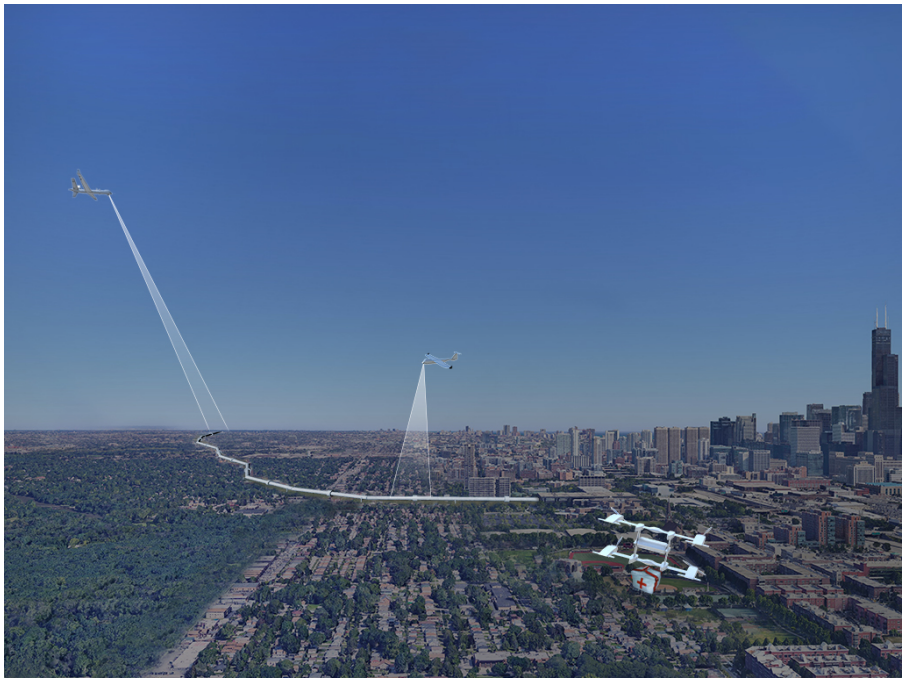
Full Mission CONOPS

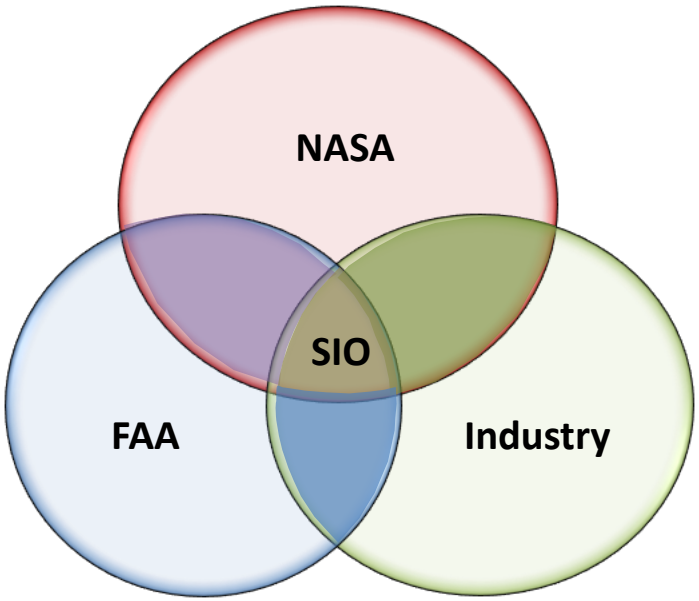


Systems Integration Operationalization (SIO) Overview

Goal: Accelerate routine commercial UAS operations in the National Airspace System (NAS)

- Work toward FAA Type Certification
- Obtain approval to operate in the NAS for a FY2020 demonstration
- Demonstrate integrated Detect and Avoid (DAA) and Command and Control (C2) technologies





Method: Partnership with industry

- Industry provides UAS development, integration, testing, operations, and begin certification process
- NASA provides subject matter expertise in DAA, C2, airworthiness, and certification
- NASA will keep the FAA informed of Type Certification efforts via the Research Transition Team (RTT)

Selected SIO Partners

Bell

Mission: Medical supply transportation in urban areas

Vehicle: Autonomous Pod Transport - 70 (APT-70)

SIO Demonstration Locations: Remote field urban area in Texas

General Atomics

Mission: Infrastructure inspection in IFR-Like airspace

Vehicle: SkyGuardian

SIO Demonstration Location: Southern California and Arizona

PAE ISR

Mission: Infrastructure inspection in VFR-Like airspace

Vehicle: Resolute Eagle

SIO Demonstration Location: Pendleton UAS Range

Future

- Close out
  - FT 6 & All Data Collection - Dec 2019
  - SIO Flights – Summer 2020
  - Final Phase 2 MOPS (RTCA SC-228) Oct 2020
  - ICAO Human Factors Chapter (RPAS Panel)
- Apply concepts to UAM (manned and unmanned and transition)
- Scale to multiple UAS control
- Integrate with Human Autonomy Teaming