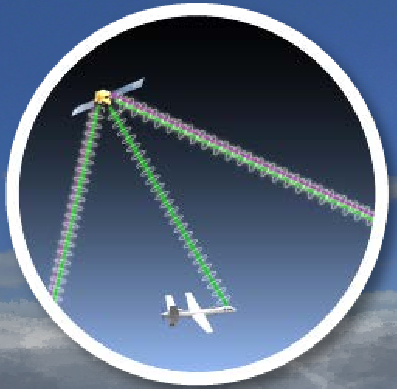

Systems Integration and Operationalization: Supporting Unmanned Aircraft Systems Integration into the National Airspace System

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Outline

- NASA Role in UAS Research and Development
- Overview and Benefits of SIO
- Overview of SIO Partners
- Best practices and lessons learned derived from SIO
- Gaps identified
- Conclusions

Transformation of Aviation

Historical Involvement in UAS Research & Applications

Remote piloting with a Piper PA-30 Twin Comanche

Remote piloted supersonic highly maneuverable aircraft technology research

Environmental Research & Sensor Technology (ERAST) Project on high altitude UAS

X-48 Hybrid / Blended Wing Body Research

GL-10 Greased Lightning Prototype electric propulsion research

Sierra B Science Sensor Platform

Prandtl tailless flight research

X-56 aerodynamics flight research

Invention

From remotely piloted to pre-programmed to semi-autonomous flight
From flight in sterile airspace to the National Airspace
From research missions to civilian applications (science/commercial/emergency)

Adoption

1970's 1980's 1990's 2000's 2010's 2020's

Remote piloted DAST aeroelastic research

F-15A Remotely Piloted Research Vehicle Project

Federal Aviation Administration (FAA) teamed with NASA on Controlled Impact Demonstration (CID) employing a remotely piloted Boeing 720

X-36 Tailless Fighter Agility Research

Aerosonde science platform for hurricane research

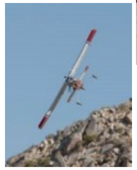
X-43 hypersonic propulsion flight research

X-45A Flight Test Program

Ikhana UAS-NAS Research

Global Hawk Science Platform

DROID Automatic Ground Collision Avoidance flight testing

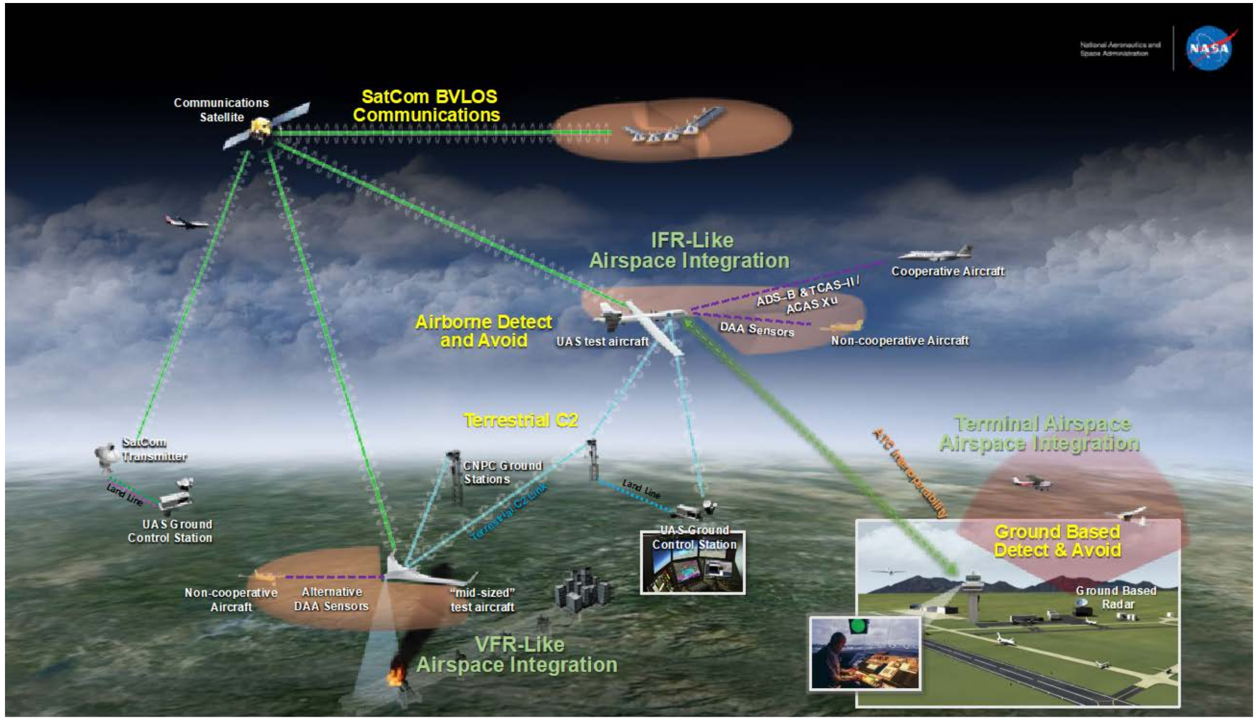


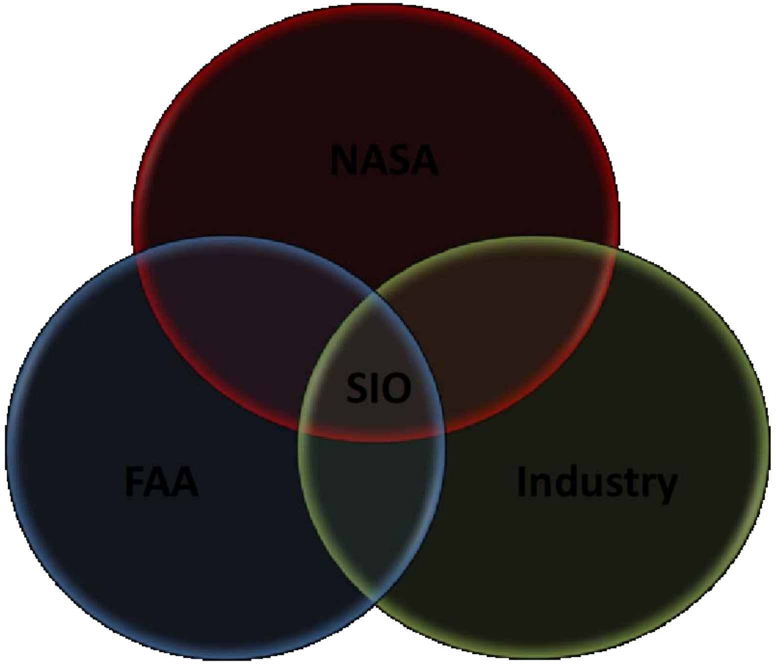
NASC Tigershark DAA flight testing

SIO Overview

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

- Integrate prototype Detect and Avoid (DAA) and Command and Control (C2) technologies
- Conduct flight demonstrations in the NAS
- Work toward UAS type certification
- Share lessons learned with the UAS community

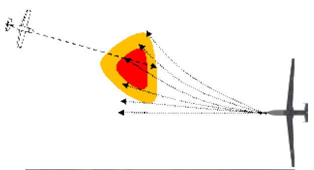




Operational Environments:

- Operations in controlled airspace above 500 feet
- Partners span a range of different operating environments and types of UAS
  - Different operational environments and missions
  - Different UAS weights and characteristics

SIO Overview




Integration of Prototype DAA and C2 systems

- DAA and C2 are key technologies for the integration of UAS into the NAS
- Integrate and evaluate prototype DAA and C2 systems to determine gaps that must be addressed for certified systems

Flight demonstration in 2020

- Emulate commercial concepts of operations
- Obtain approval to fly in the National Airspace System
- Help inform industry if certain concepts of operation are viable in the current NAS, or whether a more limited operation may be needed in the interim as air traffic infrastructure and technology evolve

Progress toward UAS certification

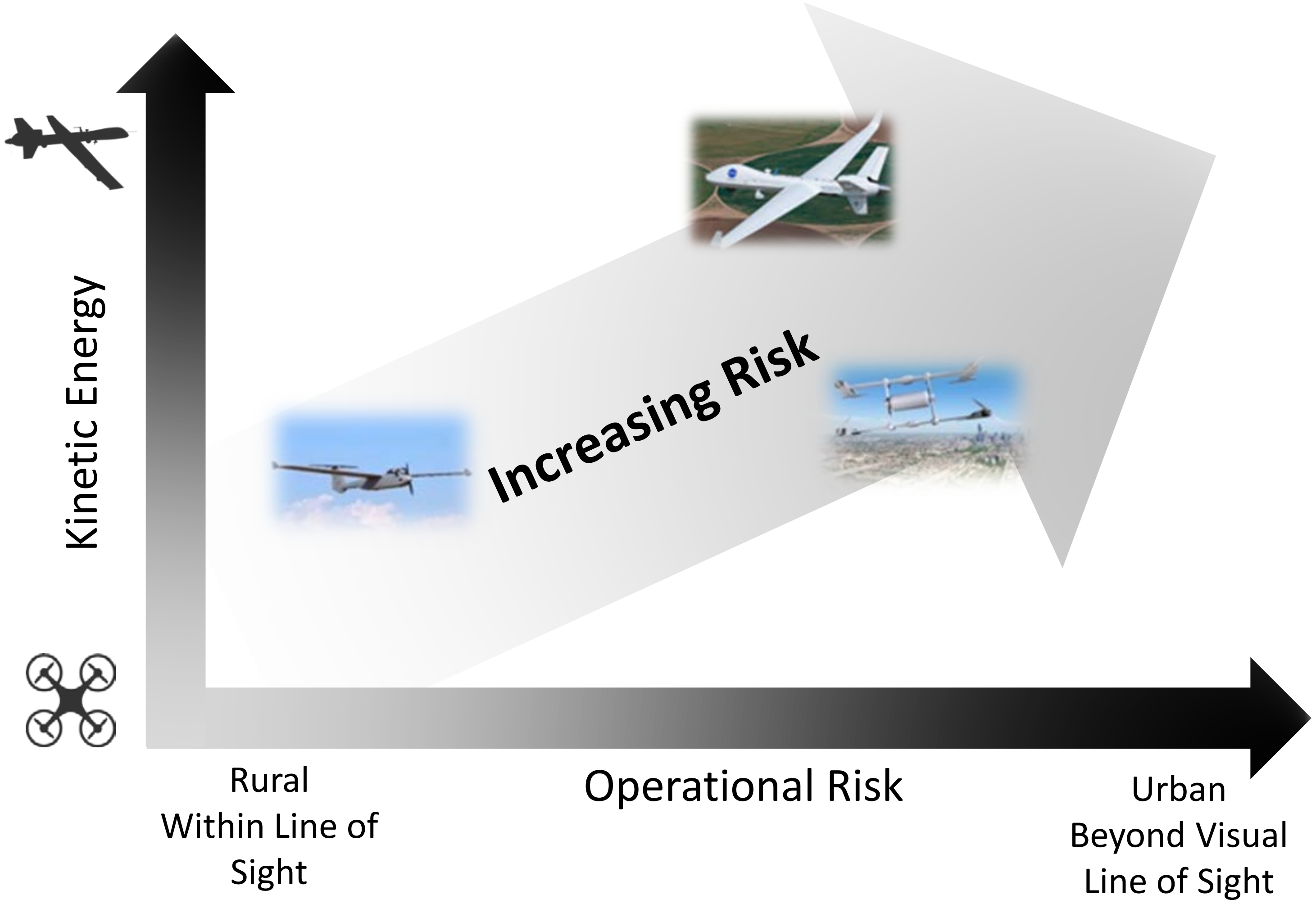
- Certification will be necessary to enable routine commercial UAS operations in the NAS
- The SIO partners are all pursuing or plan to pursue certified UAS
- SIO projects will help inform certification strategies for new technology, based on the lessons learned from the flight demonstrations in 2020

Documentation of best practices and lessons learned

- Description of concept of operations for SIO missions
- Best practices and lessons learned from SIO certification efforts
- Identify gaps in current UAS technology solutions and current barriers

Risk-Based Approach to Certification and Operational Approval

- The FAA plans to use a risk-based approach for UAS certification
- Kinetic energy reflects the severity of harm to people or property on the ground
- The operational environment reflects the likelihood of encountering people, air traffic, or critical infrastructure
- The risk-based approach allows tradeoffs between operational mitigations and system integrity mitigations



Summary of SIO Partners

Bell

Mission: Medical supply transportation in urban areas at altitudes between 500 feet to 1,000 feet AGL

Vehicle: Autonomous Pod Transport - 70 (APT-70) (~300 Pounds)

SIO Demonstration Location: Urban area in Texas

General Atomics Aeronautical Systems, Inc. (GA-ASI)

Mission: Infrastructure inspection at altitudes above 10,000 feet MSL

Vehicle: SkyGuardian (~12,000 Pounds)

SIO Demonstration Location: Southern California and Southern Arizona

American Aerospace Technologies, Inc. (AATI)

Mission: Infrastructure inspection at altitudes between 1,000 feet to 5,000 feet AGL

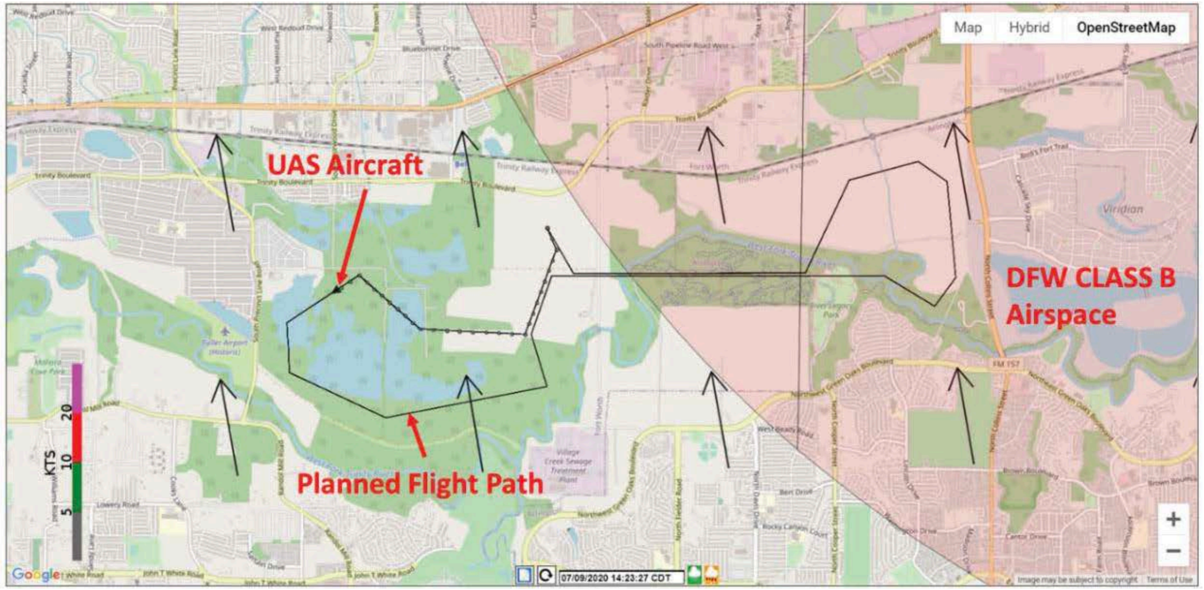
Vehicle: Resolute Eagle (~180 pounds)

SIO Demonstration Location: Central California

Bell: Flight Demonstration

Bell Flight Demonstration

- Emulated emergency medical transportation mission
- Flight between 500 and 1,000 feet AGL to deconflict from sUAS and most conventional aircraft
- 8.2 nautical mile round-trip route that included segments in Class G and Class B airspace
- Use of weather data from CASA CityWarn™ Hazard Notification sensors and software suite



Flight Demonstration Risk Mitigations

- Flight over riverbeds in airspace deconflicted from airline traffic
- Visual observers in a chase aircraft to augment DAA system
- Landing locations for along route for lost link or other emergencies
- Flight test of DAA and C2 systems using helicopter

GA-ASI: Flight Demonstration

GA-ASI Flight Demonstration

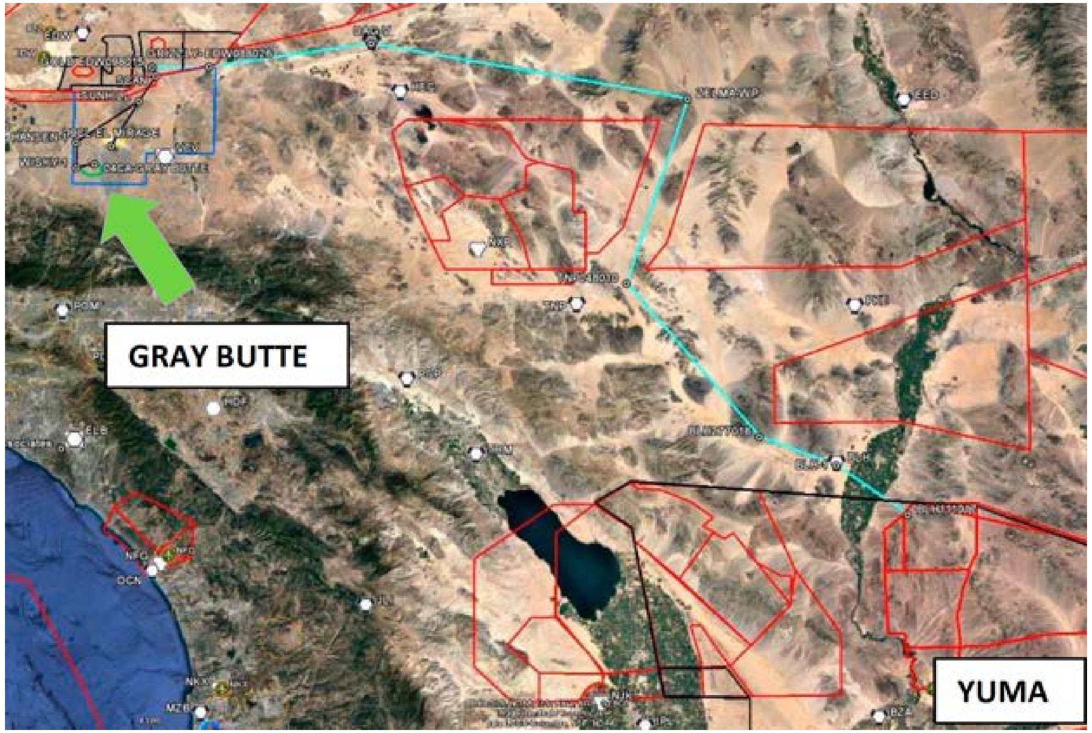
- BVLOS Multi-phase infrastructure survey using existing COA
- Altitudes above 10,000 feet in Class E and A airspace
- Long-endurance mission that took place over an approximately nine-hour period

Flight Demonstration Risk Mitigations

- Chase aircraft in Class E airspace
- Visual observers for taxi and takeoff and landing
- Flight path deconflicted from major airways

GA-ASI BVLOS COA

- After the flight demonstration a COA for operations in Class E airspace without visual observes was obtained
- Proceed expediently to above 10,000 feet
- Visual observers required for takeoff and landing



AATI: Flight Demonstration

AATI Flight Demonstration

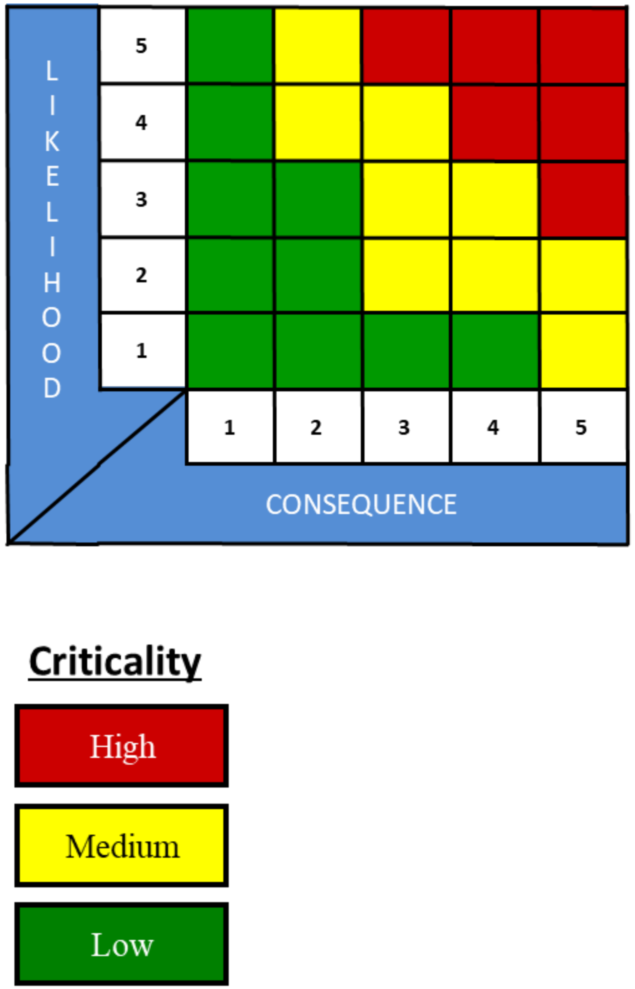
- Inspected ~40 nautical miles of pipeline in the San Joaquin Valley (SJV) in California
- Flight at altitudes altitudes between ~1,000 and 3,000 feet AGL
- Use of AATI proprietary pipeline threat detection system payload
- Tested C-Band CNPC radio aligned with RTCA DO-362 standards

Flight Demonstration Risk Mitigations

- Rural environment with low population density
- Visual observers in a chase aircraft to augment DAA system
- Paint colors chosen to enhance aircraft visibility

Design Assurance and Certification Observations

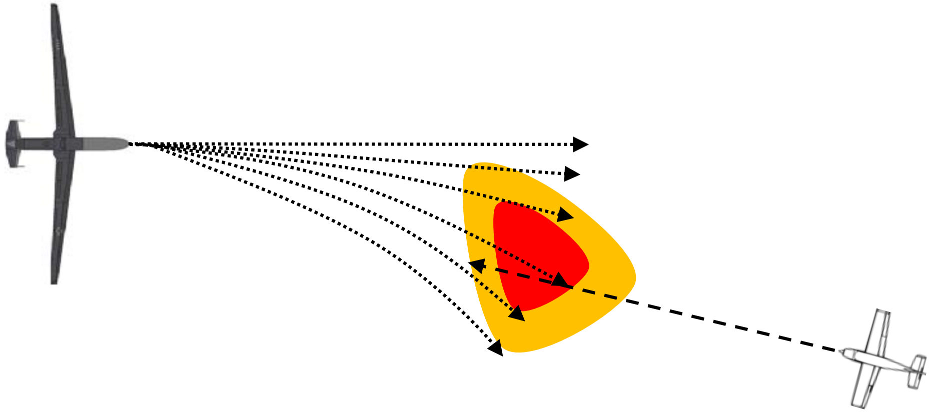
- Overall transition to performance-based regulations worked
  - SIO partners were able to leverage most of the regulations in the new performance-based 14 CFR Part 23 regulations
  - Some tailoring was needed, particularly for the smaller unmanned aircraft demonstrated in SIO
- Performance-based regulations shift the detailed methods of compliance to industry standards and applicants
- Gaps in industry standards are an impediment to progressing through the type certification process
  - E.g., Certification of smaller aircraft that may be in a lower risk category than is assumed for current Part 23 means of compliance
  - E.g., Surface operations, automatic takeoff and landing, etc.
- The quality of standards are important
  - Tradeoff between flexibility and specificity of standards
  - Important for regulator to be able to validate standards against safety targets



DAA and C2 Observations

Detect and Avoid (DAA)

- Ground clutter from air-to-air radars during low altitude flight may reduce the effectiveness of DAA systems
- Gap between performance required by current standards and commercially available low size, weight, and power radars
- Questions about ability of other pilots to see and avoid smaller unmanned aircraft



Command and Control (C2)

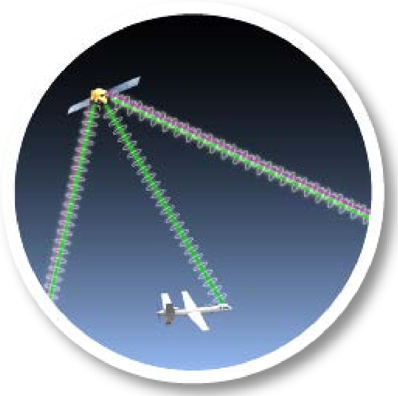
- Importance of using licensed spectrum was emphasized
- Standards are needed for use of commercial networks for C2
- Latency requirmentns for relay of ATC voice communications are an impediment to using commercial networks for C2
- There are tradeoffs between the criticality of the C2 link and mitigations to lost link such as vehicle automation/autonomy

Lost Link and Contingency Planning

- There is a need for standardized lost link procedures that are predictable to ATC

- Other data may be lost along with the C2 link, requiring sufficient mitigation to ensure safety and minimize disruptions
  - Voice communications with ATC
  - DAA functionality (e.g., if pilot is required to initiate maneuver)
  - Ground Base Surveillance System data, particularly when integrating with IFR and VFR aircraft in the traffic pattern
  - Information from airspace services, such as UTM or PSU services

- Future standardized lost link procedures should be compatible with ATC actions
  - Vectors, altitude changes, and speed changes
  - Reroutes around weather
  - Changes to destination airport's flow direction after lost link occurs



Summary

- The Systems Integration and Operationalization (SIO) activity is a NASA partnership with industry, with close FAA coordination, to work toward commercial UAS operations in the National Airspace System

- SIO is focused on UAS larger than 55 pounds operating above 400 feet

- The three industry partners are integrating DAA and C2 systems into unmanned aircraft system and conducting flight demonstrations in the National Airspace System

- Best practices and lessons learned were collected throughout the SIO activity to share with UAS industry and research community

Questions?

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