Systems Integration and Operationalization

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• NASA Role in UAS Research and Development

• Overview and Benefits of SIO

• High Level SIO Schedule

• Overview of SIO Partners

• Best practices and lessons learned derived from SIO
NASA Role in Aviation Research and Development

• NASA has a long history of research and development supporting new aviation technologies and concepts
  – Air Traffic Management systems
  – Communications
  – Aerodynamics
  – Propulsion
  – Avionics
  – Sensors
  – Materials

• One of NASA’s goals is to enable and encourage new United States industries
  – Unmanned Aircraft Systems
  – Urban Air Mobility
  – Supersonic Flight (Low Boom Flight Demonstrator)
  – Autonomy

• One challenge is taking technology from a research environment to operational use
Historical Involvement in UAS Research & Applications

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
- Remote piloting with a Piper PA-30 Twin Comanche
- Federal Aviation Administration (FAA) teamed with NASA on Controlled Impact Demonstration (CID) employing a remotely piloted Boeing 720
- X-36 Tailless Fighter Agility Research
- X-45A Remotely Piloted Research Vehicle Project

1980’s
- Remote piloted DAST aeroelastic research
- F-15A Remotely Piloted Research Vehicle Project
- X-48 Hybrid / Blended Wing Body Research
- X-56 aerodynamics flight research

1990’s
- Environmental Research & Sensor Technology (ERAST) Project on high altitude UAS
- X-43 hypersonic propulsion flight research
- Prandtl tailless flight research

2000’s
- Aerosonde science platform for hurricane research
- Ikhana UAS-NAS Research

2010’s
- X-45A Flight Test Program
- Global Hawk Science Platform
- DROID Automatic Ground Collision Avoidance flight testing

2020’s
- GL-10 Greased Lightning Prototype electric propulsion research
- Sierra B Science Sensor Platform
- NASC Tigershark DAA flight testing
Goal: Work toward routine commercial UAS operations in the National Airspace System (NAS)

- Integrate Detect and Avoid (DAA) and Command and Control (C2) technologies
- Obtain approval to operate in the NAS for a flight demonstration in 2020
- Work toward UAS type certification
- Share lessons learned with UAS community

Operational Environments:

- Operations in controlled airspace above 500 feet
- Partners that 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 DAA and C2 systems*
- DAA and C2 are key technologies for the integration of UAS into the NAS
- DAA and C2 systems integrated for SIO are expected to have a path toward commercialization

*Flight demonstration in 2020*
- Emulate commercial concepts of operations
- Cover different operational environments
- Obtain approval to fly in the National Airspace System

*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
- Full certification is not required by 2020, but progress is expected

*Documentation of certification lessons learned*
- Description of concept of operations for SIO missions
- Risk-based safety assessment of SIO missions
- Lessons learned from SIO certification efforts
Output/Benefit of SIO

• Encourage industry to advance the state-of-the-art of UAS used for flights above 500 feet in controlled airspace
  – Develop and demonstrate integrated Detect and Avoid (DAA) and Command and Control (C2) systems
  – Highlight commercially viable UAS use cases

• Encourage progress toward UAS type certification and operational approval
  – Encourage meaningful progress toward certification of UAS that weigh more than 55 lbs and fly above 500 feet
  – SIO deliverables include creation of a Concept of Operations, Operational Risk Assessment, and a Project Specific Certification Plan
  – Provide opportunity for FAA to exercise certification policy has been, and continues to be, developed

• Share lessons learned with the UAS industry (particularly companies that are new to aviation)
  – Share items that should be considered before beginning a type certification effort
  – Share items that industry should consider when developing DAA/C2 systems
  – Point industry to relevant standards and research documentation
High Level SIO Schedule

- **Kickoff Meetings:** Fall, 2018
- **NASA/FAA RTT Working Group Established:** Spring, 2019
- **SIO Demonstrations:** Spring/Summer, 2020
- **ConOps and Risk Assessment:** Summer, 2019
- **Documentation of Certification Lessons Learned:** Summer, 2020
- **SIO Complete:** Fall, 2020

**Development, Integration, and Testing**

**Work Toward Type Certification**
Summary of SIO Partners

**Bell**
- **Mission:** Medical supply transportation in urban areas at altitudes between approximately 500 feet to 1,000 feet AGL
- **Vehicle:** Autonomous Pod Transport - 70 (APT-70) (~300 Pounds)
- **SIO Demonstration Locations:** Urban area in Texas

**General Atomics Aeronautical Systems, Inc.**
- **Mission:** Infrastructure inspection at altitudes above 10,000 feet MSL
- **Vehicle:** SkyGuardian (~12,000 Pounds)
- **SIO Demonstration Location:** Southern California

**PAE ISR**
- **Mission:** Infrastructure inspection at altitudes between approximately 1,000 feet to 3,000 feet AGL
- **Vehicle:** Resolute Eagle (~180 pounds)
- **SIO Demonstration Location:** Rural Oregon
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 hitting people or critical infrastructure.

The risk-based approach allows tradeoffs between operational mitigations and system integrity mitigations.
General Best Practices

• Safety first
  – The FAA’s main focus is safety
  – Applicants should collect data, procedures, and design details to provide a convincing argument that their system is safe

• Crawl, walk, run
  – Demonstrate capability in a low risk environment before moving to higher risk environments
  – Test data collected during operations in low risk environments can help obtain authorization to operate in higher risk environments

• Rely on conventional engineering practices
  – Conventional practices such as hazard analysis, code reviews, configuration control can help provide confidence in the unmanned aircraft’s design

• Frequent and early communication with the FAA is beneficial
  – Pre-coordination is often beneficial
  – Utilize experts who can act as guides though the process
There is a trade-off between operational mitigations and system integrity mitigations that should be considered during the design phase of the UAS.

- If operational mitigations are used, make sure that future use cases of the vehicle are considered.

Identify all hazards and sufficient mitigations to those hazards.

- Assess the UAS, procedures, and operating environment in order to identify hazards.
- Use a standard hazard assessment methodology.

Collect data to show that hazards have been mitigated.

- The data collection needs to show sufficient mitigation have not been defined.
- This is an opportunity!
The ability of low Size Weight and Power (SWaP) DAA sensor technology to meet safety goals is still being investigated.

Turnkey MOPS compliant DAA solutions do not appear to exist yet.

When developing contingency procedures for lost link, UAS operators should consider how air traffic will be detected and avoided:
- Land before potential air traffic can cause a hazard
- Coordinate a known lost-link procedure with ATC

Standards
- **RTCA DO-365**: Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems
  - **Phase 1**: Published May 31, 2017, focused on large UAS transiting to/from Class A airspace
  - **Phase 2**: Expected to be published in 2020, adds Terminal operations and Low SWaP UAS operations

- **ASTM F38.01**: Detect and Avoid Performance Requirements
  - Scope includes unmanned aircraft with wingspans below 25 feet flying below 1,200 feet
  - Expected to be published in 2020

Technical Standard Orders (TSO)
- **TSO-C211**: Detect and Avoid (DAA) Systems
Spectrum is valuable
– A DO-362 compliant C2 system will have a limited data rate in order to support as many unmanned aircraft as possible on protected spectrum

Items to consider if implementing a DO-362 compliant system (using protected spectrum)
– Carefully consider which information is safety critical
– Data efficiency techniques must be employed
– Only certain data types supported (See DO-362 for details)
– A separate communications link will be needed for any payload data

Standards
– RTCA DO-362 — Phase 1: Command and Control (C2) Data Link Minimum Operational Performance Standards (MOPS)
  • Published September 22, 2016

– RTCA DO-362 — Phase 2: Command and Control (C2) Data Link Minimum Operational Performance Standards (MOPS)
  • Expected to be published in 2020

Technical Standard Orders (TSO)
– TSO-C213: Unmanned Aircraft Systems Control and Non-Payload Communications Terrestrial Link System Radios
Experimental spectrum licenses from the FCC are intended for development of radio equipment, not for experimental UAS operations
  – UAS manufacturers should work with radio manufacturers to develop and test C2 system with a path toward certification

Unlicensed bands are unreliable for the transmission of safety critical information
  – No regulatory protection against interference from other users in the band

The required performance of the C2 link may depend on the level of autonomy of the unmanned aircraft and other mitigations to loss of the C2 link
  – A UAS controlled manually via stick and rudder will require a reliable low latency link, whereas a UAS controlled via the transmission of waypoints may be more robust to communication latency and dropped packets
  – If voice communications with ATC are routed though the UAS, communication latency should also be considered to avoid stepping on other voice communications
Summary

• Systems Integration and Operationalization (SIO) activity is a NASA partnership with industry to work toward commercial UAS operations in the National Airspace System

• SIO is focused on UAS larger than 55 pounds operating above 500 feet, which differentiates it from other ongoing UAS projects

• The three SIO Partners cover a range of UAS capabilities and operating environments

• Best practices and lessons learned are being collected throughout the SIO activity to share with UAS Industry
  – This presentation contained a high level snapshot of some of the lessons learned to date
  – A comprehensive document will be available at the conclusion of the SIO activity