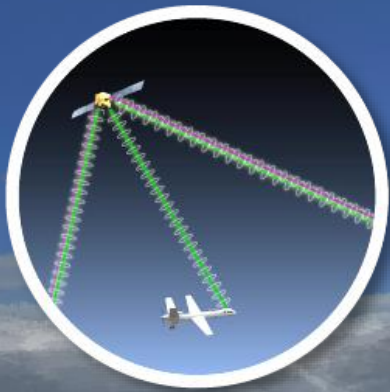




Systems Integration and Operationalization

Kurt Swieringa
SIO Technical Manager
kurt.a.swieringa@nasa.gov
757-864-9789





- 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

Remote piloted
supersonic highly
maneuverable
aircraft technology
research



Remote piloting with a
Piper PA-30 Twin Comanche

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



GL-10 Greased Lightning
Prototype electric
propulsion research



Sierra B Science Sensor Platform

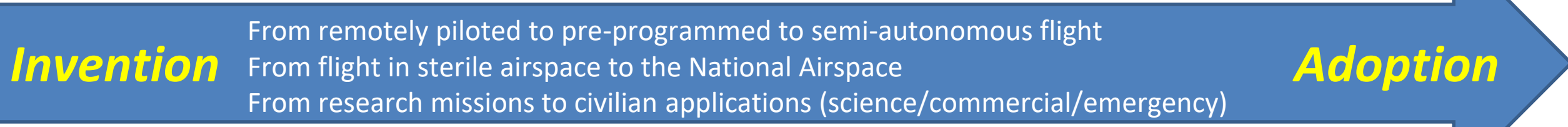


Prandtl tailless
flight research



X-48 Hybrid / Blended
Wing Body Research

X-56
aerodynamics
flight research



1970's



Remote
piloted DAST
aeroelastic
research



F-15A Remotely Piloted
Research Vehicle Project

1980's



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

1990's

X-36 Tailless
Fighter Agility
Research



X-43 hypersonic
propulsion flight
research



X-45A Flight Test
Program



2000's



Aerosonde science platform
for hurricane research

2010's



Ikhana UAS-NAS Research



Global Hawk Science Platform

DROID Automatic
Ground Collision
Avoidance flight
testing



2020's



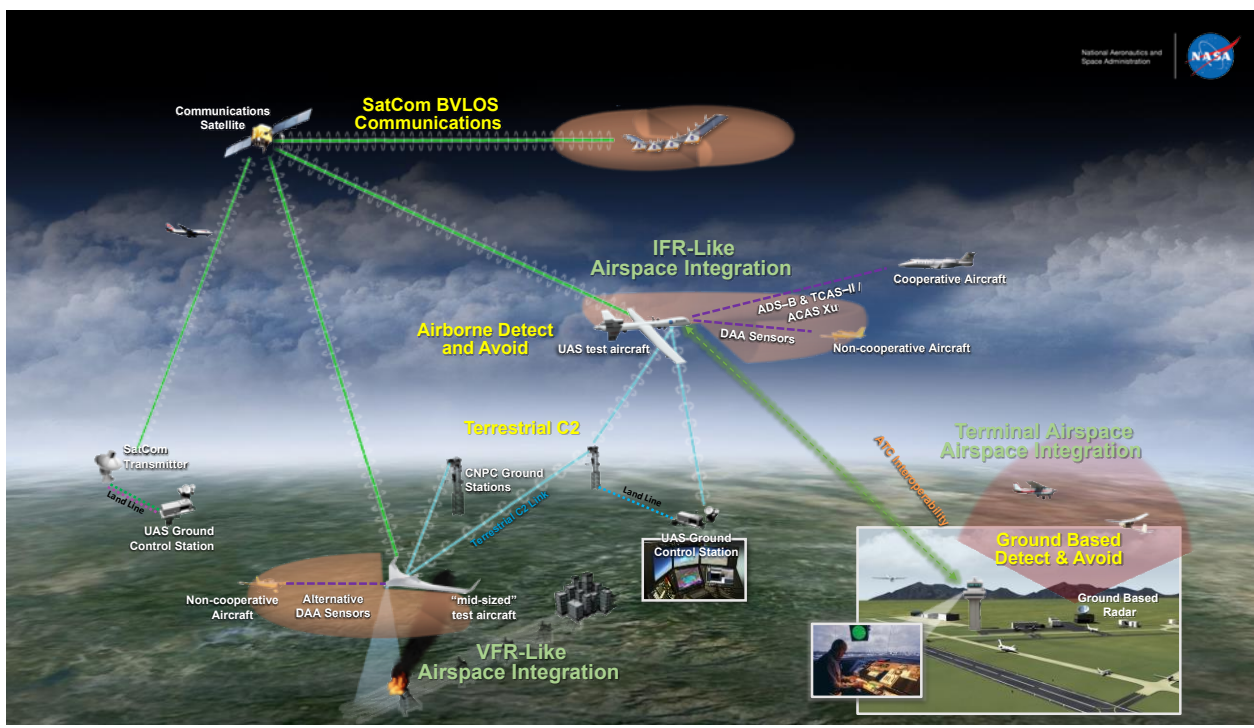
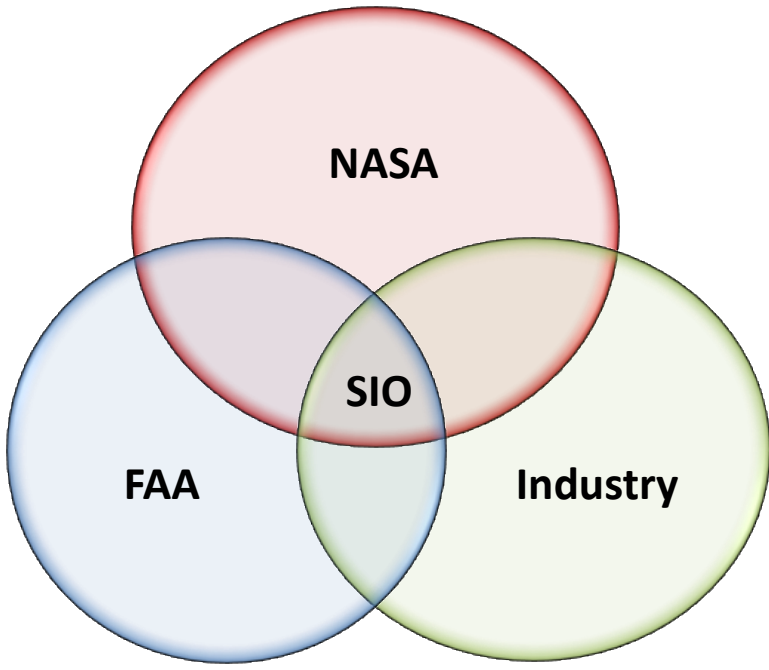
NASC Tigershark
DAA flight testing



SIO Overview

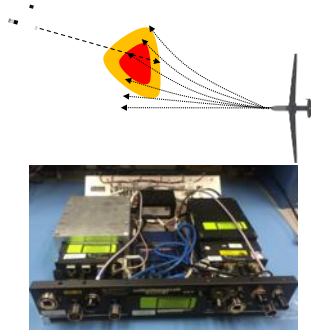
Goal: Work toward routine commercial UAS operations in the National Airspace System (NAS)

- 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



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

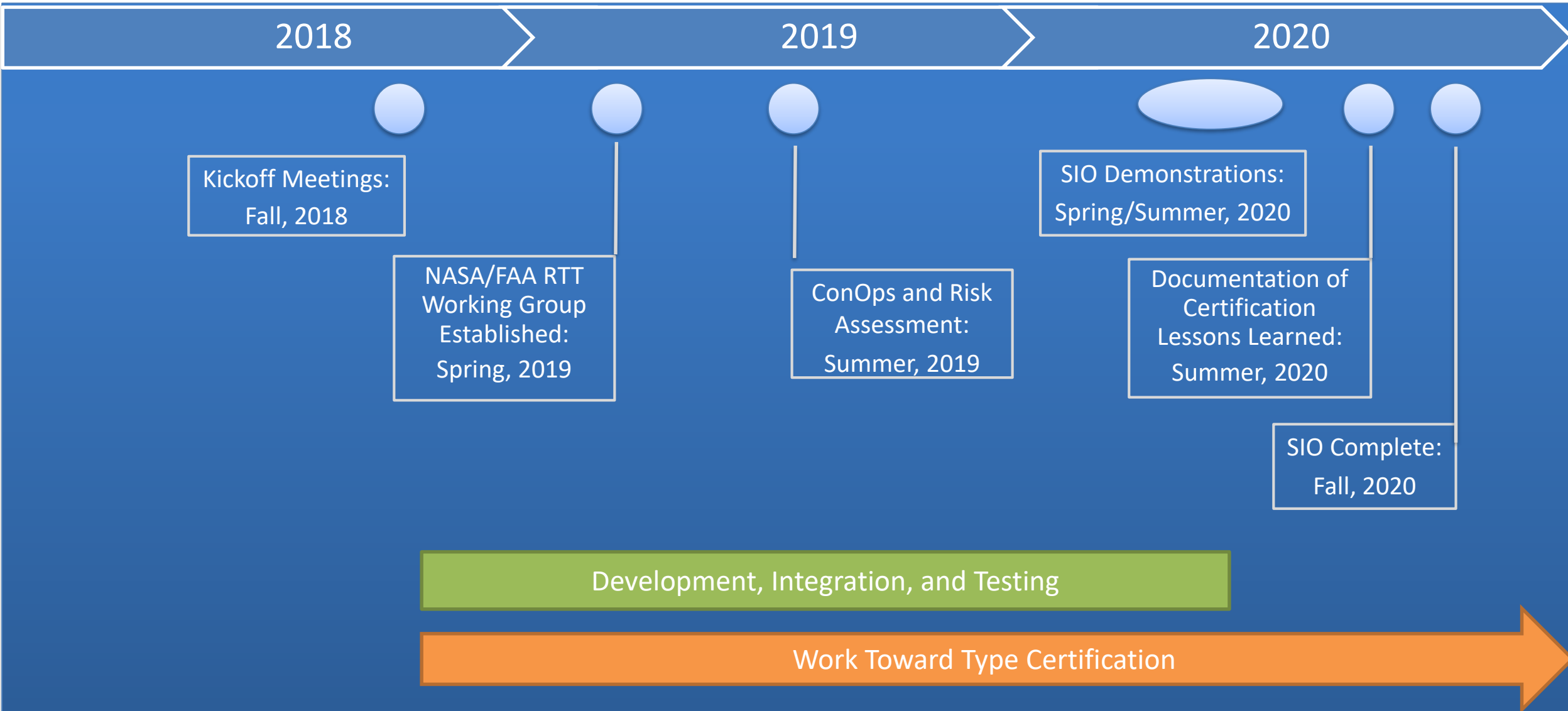


Output/Benefit of SIO

- 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



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)

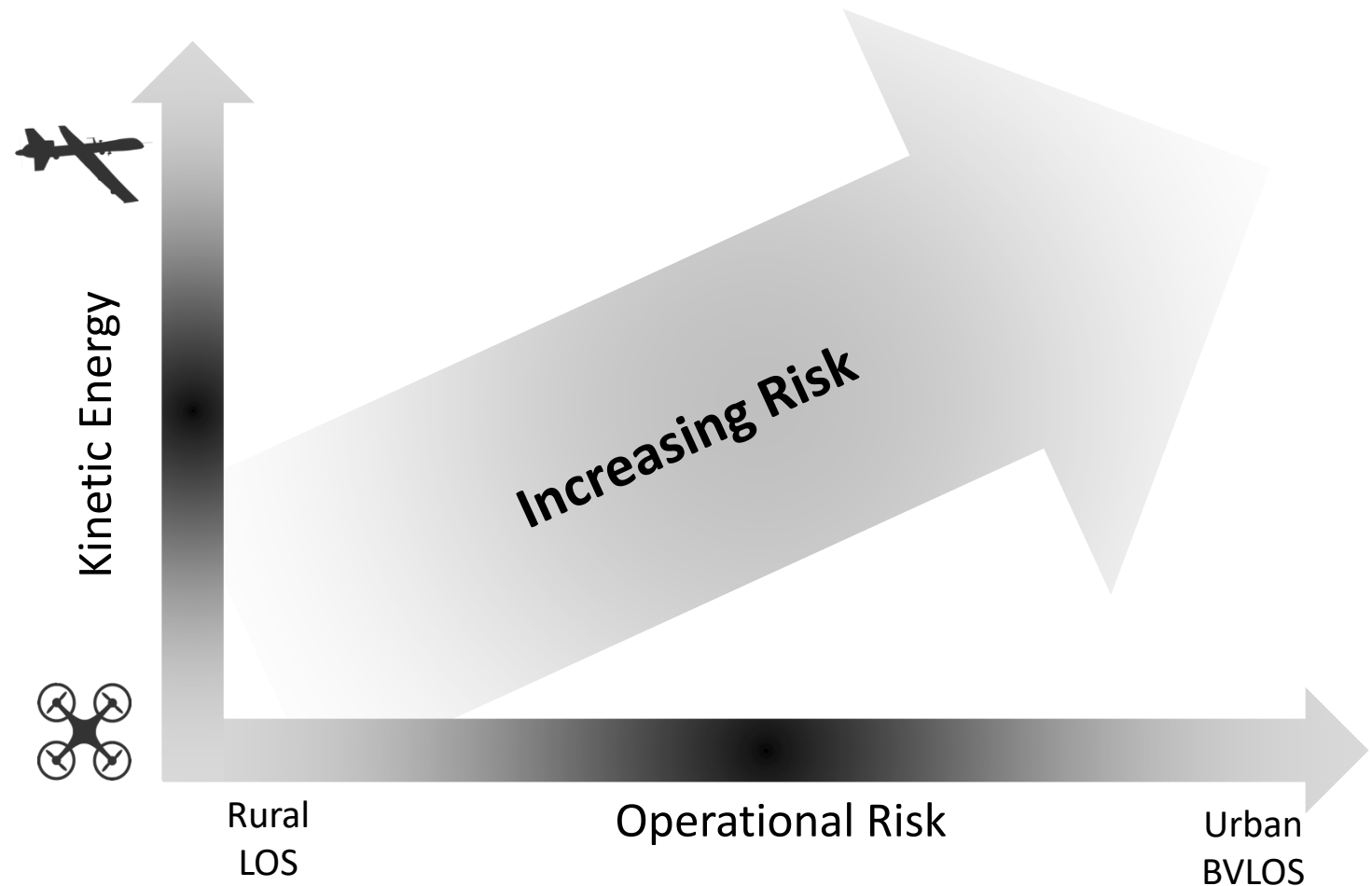
SIO Demonstration Location: Rural Oregon





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 hitting people or critical infrastructure
- The risk based approach allows tradeoffs between operational mitigations and system integrity mitigations





General Best Practices

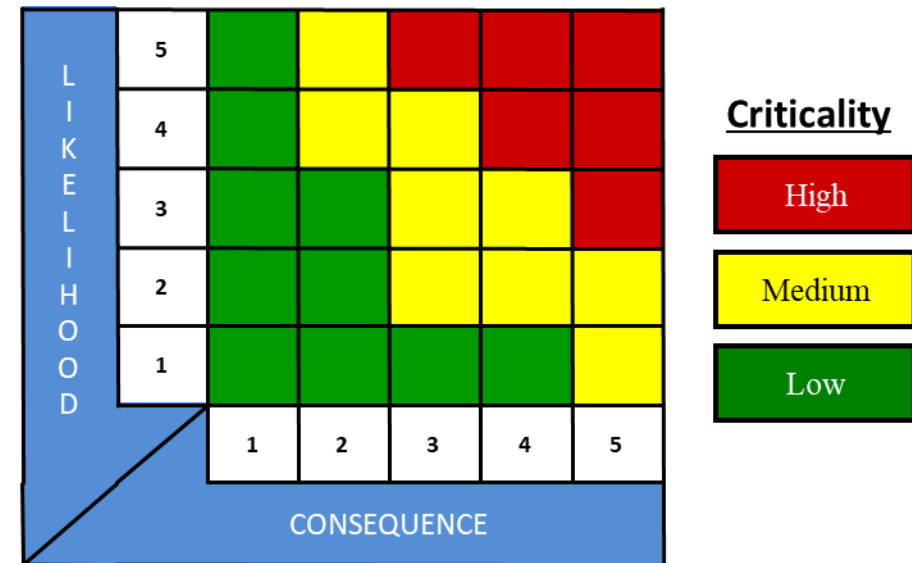
- Safety first
 - The FAA's main focus is safety
 - Applicants should collect data, procedures, and design details to provide a convincing argument that their system is safe
- Crawl, walk, run
 - Demonstrate capability in a low risk environment before moving to higher risk environments
 - Test data collected 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 through the process





Safety and Hazard Assessment

- 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!





Detect and Avoid (DAA) system

- 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



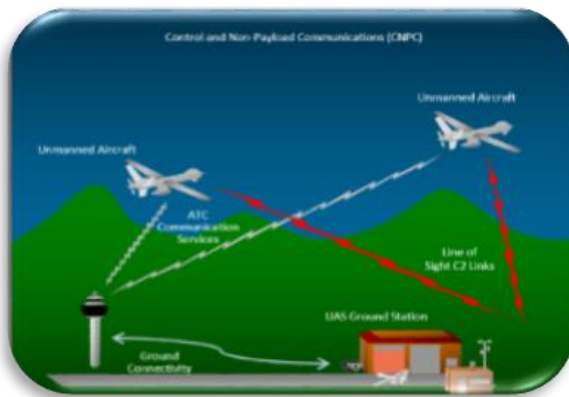
Standards

- **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



Spectrum for Command and Non-Payload Control Data

- 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 through 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