VIEW:

REMOTE PILOT-IN-COMMAND

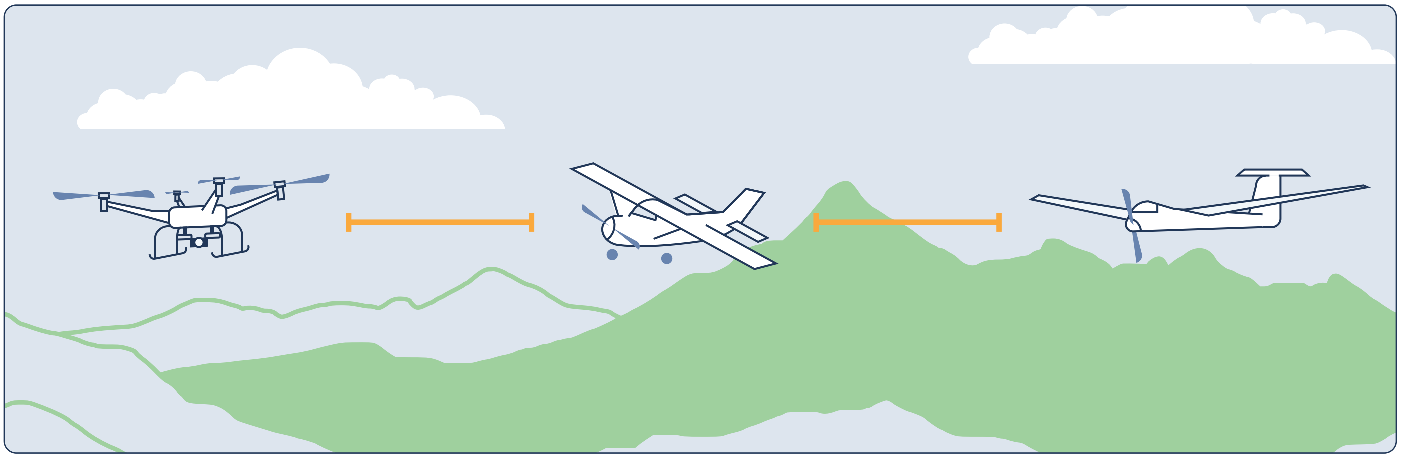
MONITORED BVLOS: A NEW MODEL FOR UAS INTEGRATION IN THE NATIONAL AIRSPACE SYSTEM

June 2023

INTRODUCTION

The current and potential applications of Uncrewed Aircraft Systems (UAS, also known as drones) are transformative for many industries. They can improve efficiency and allow professionals to accomplish tasks they were never capable of before.

However, following more than a decade of investment in UAS technology and years of widespread UAS use within Visual Line of Sight (VLOS) by hobbyists, businesses and the military, aviation still has not seen strong commercial adoption – nor has the United States realized the scale and efficiencies in the market. UAS scalability has been hindered by the lack of terrestrial connectivity in rural and remote areas; however, modern-day satellite communications solutions can turbocharge adoption.



The ability to cost-effectively scale drone use will require adoption of operations to fly Beyond Visual Line of Sight (BVLOS) in the National Airspace System (NAS) and eventually have each Remote Pilot-in-Command (RPIC) monitoring/controlling multiple aircraft operations simultaneously.

This is a complex issue – but it could be addressed in stages to permit technology, operations, and certification to evolve over time and mature the industry.

While regulators and Civil Aviation Authorities (CAA) work to balance agility with safety, innovation and growth associated with BVLOS, the manual waiver and exemption process presently utilized to ensure safe operations has proven to be unscalable.

The challenges to BVLOS operations include:

- Maintaining safe separation
- Detecting and Avoiding (DAA) other aircraft
- Communications with tower and other aircraft (using VHF common frequency)
- Communication links for Command & Control (C2)
- Situational awareness

Even standard operating procedures lack guidance for monitored BVLOS operations in a designated airspace at a designated time with a defined Minimum Equipment List (MEL) to perform the mission safely.

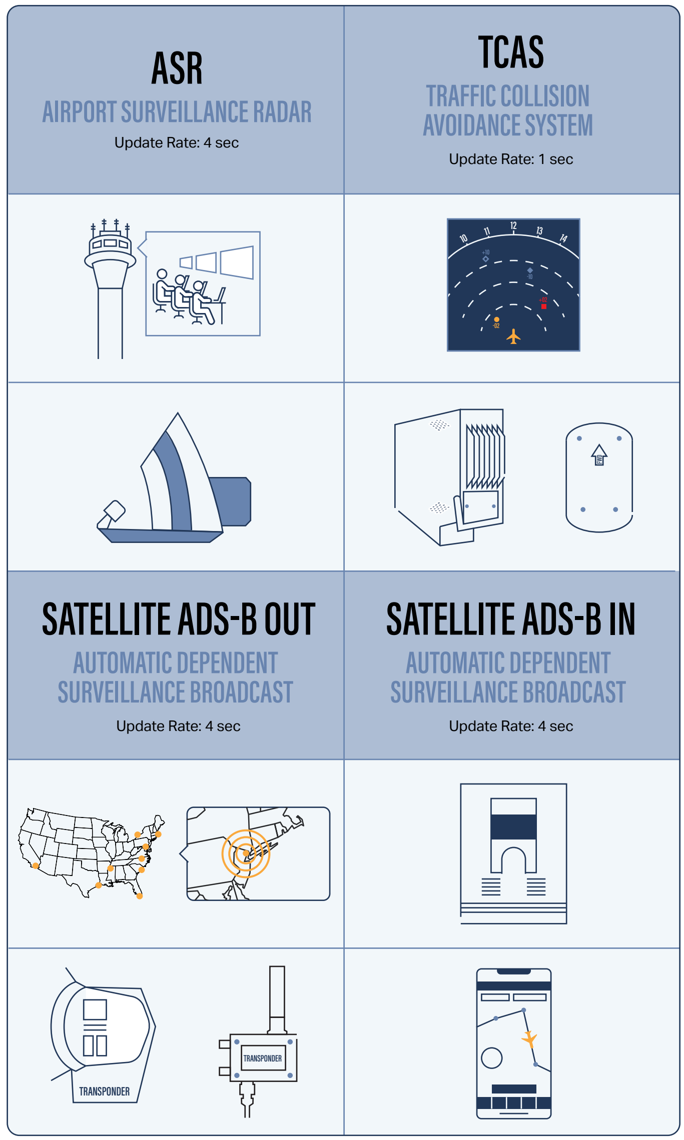
Aviation authorities today are expected to handle both traditional (human pilot on board) and uncrewed (remotely piloted) aircraft with effectively the same resources. This reality presents an aircraft type certification process designed around airframes that carry passengers in controlled airspace that typically last more than 20 years to carry out their mission. With respect to expectations concerning the life cycle of the aircraft, the uncrewed market does not resemble the crewed market other than the fact the aircraft also fly.

Meanwhile, the pace of innovation that would drive progress is constrained by regulatory framework. While the Federal Aviation Administration (FAA) and others have made tremendous strides, the framework is not agile nor adapting the certification processes at the necessary pace. For example, a typical aircraft certification takes approximately 36 months. The battery technology for an electric propulsion UAS will undergo multiple improvements in efficiency and reliability in those 36 months, which will require the operator to start the supplemental certification process immediately after certification, thereby further straining resources. This results in an expensive product and technology that is several generations behind at the time of aircraft certification.

While this type certification process is underway, operators can request a BVLOS waiver; however, the process is manual and has many challenges including:

- **Risk assessment**: The acceptable level of risk over a remote region dramatically differs from a densely populated community.
- **Aircraft performance**: The performance of a 55-pound quad copter dramatically differs from a high glide ratio, fixed-wing aircraft.
- **Minimum equipment list**: There is no direction for an MEL on an aircraft fitted with electronics systems needed for BVLOS, despite it dramatically differing from traditional LOS.
- **Separation**: Separation rules for aircraft should be defined for BVLOS operations, and other aircraft that choose to fly without 1090 MHz (ADS-B) transponders should be constrained to Visual Flight Rules (VFR) and bear the responsibility for right of way, as recommended by the FAA BVLOS Advanced Rulemaking Committee in 2022.[1]

TODAY'S TECHNOLOGY FOR SITUATIONAL AWARENESS IN THE NATIONAL AIRSPACE SYSTEM



Avionics technology and infrastructure to enhance situational awareness in BVLOS operations exist today and can be applied safely under the guidance of BVLOS operations – just as it is for Instrument Flight Rules (IFR). Operators can integrate Commercial Off-the-Shelf (COTS) avionics and communication technology into their drones. This MEL could enable an RPIC to safely monitor a mission, communicate with air traffic control, and ensure safe IFR separation from other aircraft.

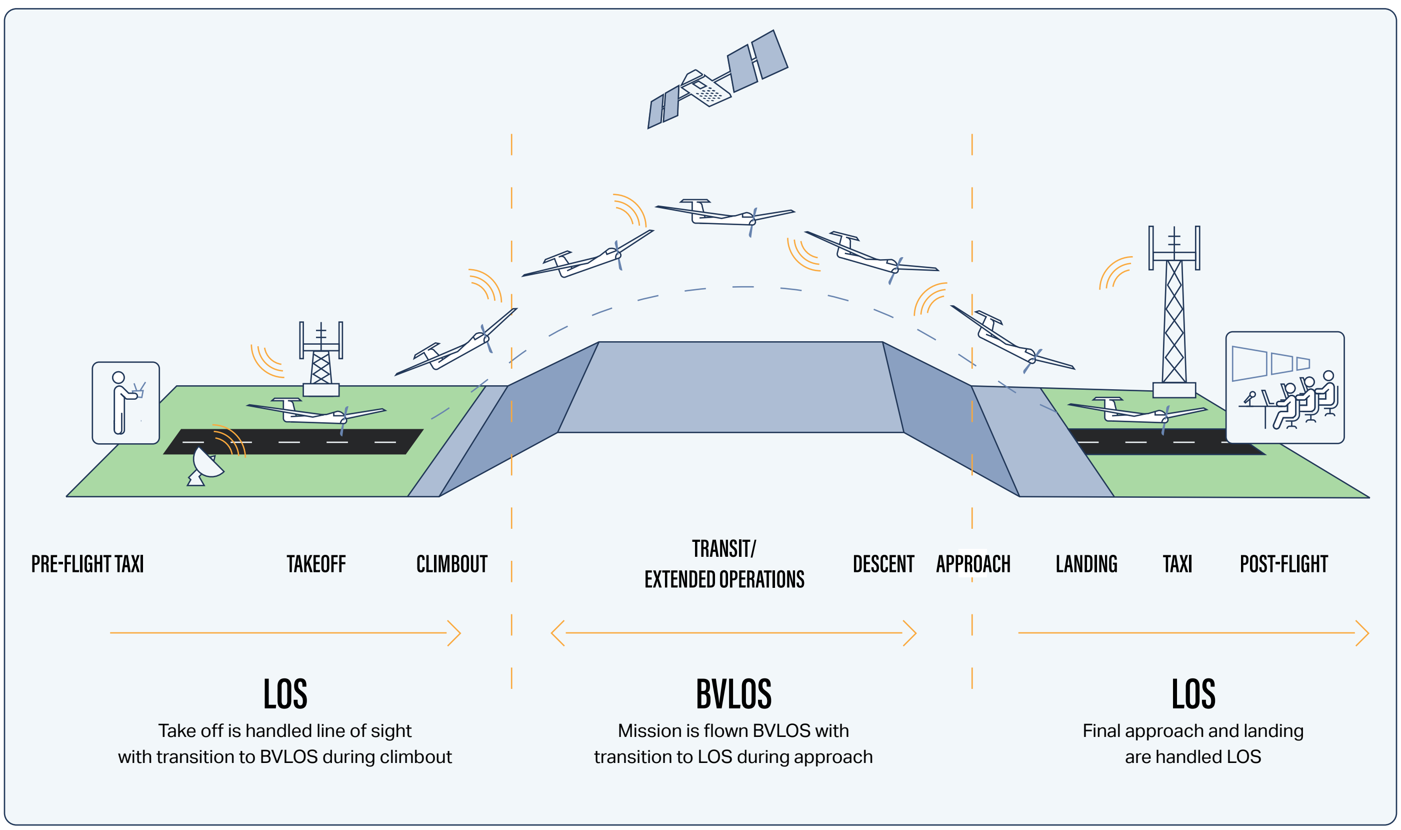
APPLICATION OF TODAY'S TECHNOLOGY FOR SITUATIONAL AWARENESS IN THE NAS

This whitepaper will demonstrate integrated COTS technology and provide data analysis from a flight test designed to illustrate that many of the challenges to BVLOS operations can be overcome:

- **Risk assessment**: Operations in Class E and G airspace have little congestion when operated over rural and remote regions.
- **Aircraft performance**: When COTS technology is integrated into fixed-wing aircraft with glide ratios of 10 to 20x, the altitude flown dramatically increases the ability to find a safe landing location in rural or remote regions in the event of an emergency.
- **Minimum Equipment List**: The use of an MEL to optimize the communication and surveillance capabilities of the aircraft increases the ability of the RPIC to perform maneuvers that maintain safe separation. An MEL will go further to improve and streamline the submissions of waivers to perform operations knowing the equipment integrated has already been assessed.
- **Safe separation**: When an MEL is used, the data will be consistent to operations and the ability of an RPIC to operate at safe separation minimums throughout the mission.

ABOUT THE MISSION

On December 7, 2022, a consortium of partners including Iridium, American Aerospace and others coordinated the test flight of a 220-pound fixed-wing aircraft over agricultural land near Bakersfield, California.



The mobile command trailer in Bakersfield, California, from which the aircraft was flown.

Flight tracking, Command and Control (C2), and telemetry data over L-band satellite communications. The top monitor displays the tail camera streaming over LTE.

The American Aerospace RPIC operating center in Sterling, Virginia, monitors the flight trial.

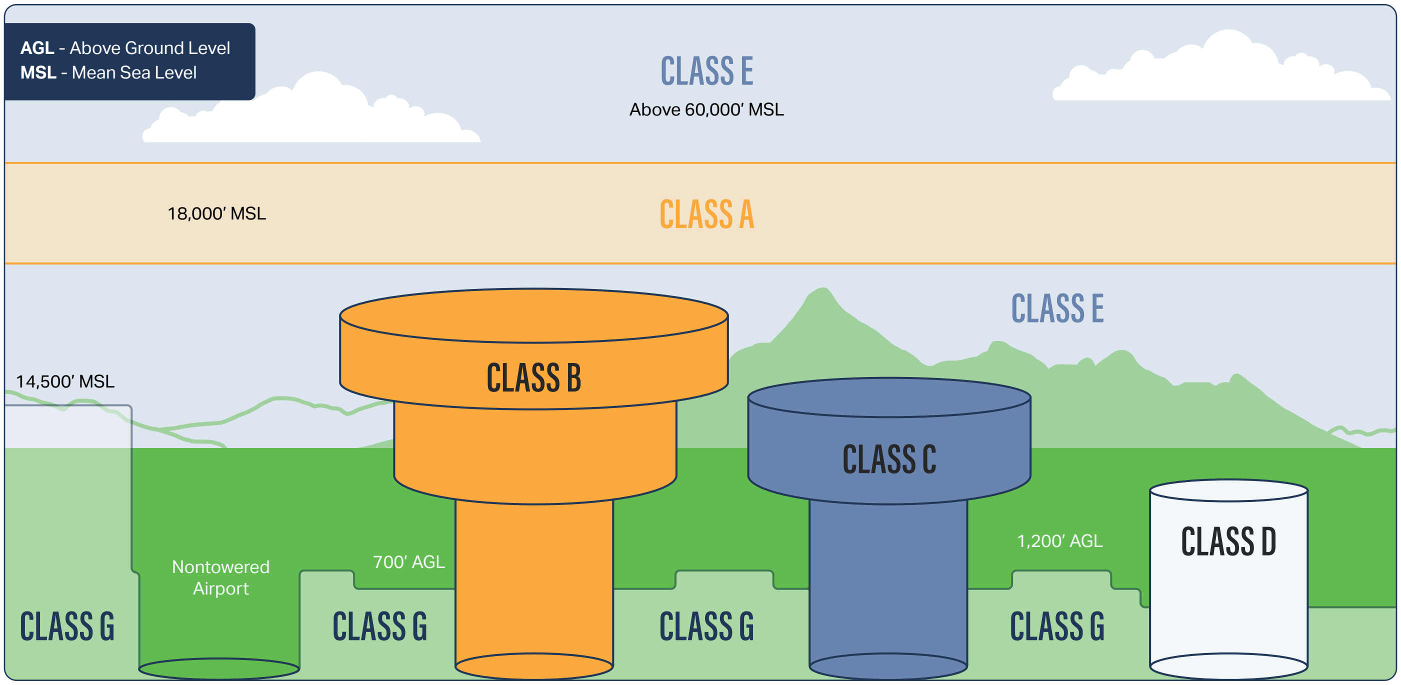
Although takeoff and landing were handled LOS, the aircraft was flown BVLOS by an American Aerospace RPIC in their mobile operations center at the launch/landing site. American Aerospace received permission from the FAA through the existing BVLOS waiver and flight plan submission process.

ABOUT THE TEST AIRCRAFT: AMERICAN AEROSPACE AiRANGER™

The medium-altitude, fixed-wing AiRanger is ideal for linear infrastructure inspection. Not only can it fly for 15 hours on a full tank of fuel, its 20:1 glide ratio helps to ensure a safe landing in case of communication loss or another emergency.

WINGSPAN: 18.2′
PROPULSION: GASOLINE
PAYLOAD: 75 LBS

ENDURANCE: 15 HOURS WITH PAYLOAD
RANGE: 750 MILES
MODE S: 52065156
HEX #: A86A6E



We propose that BVLOS operations are ideal for Class E and G airspace, as both present a greatly reduced risk of "crossing paths" (encounter) with other VFR aircraft being piloted by a human onboard.

Equipped with the proper transponder – in this mission, ADS-B – a UAS increases an RPIC's ability to safely monitor and fly the mission relative to all other properly equipped (or "participating") aircraft within the airspace. Per recommendation from the FAA BVLOS Advanced Rulemaking Committee, aircraft flying VFR without a proper transponder would need to be alert and prepared to yield to other traffic.

Testing currently available COTS technology was necessary to gain a greater understanding of:

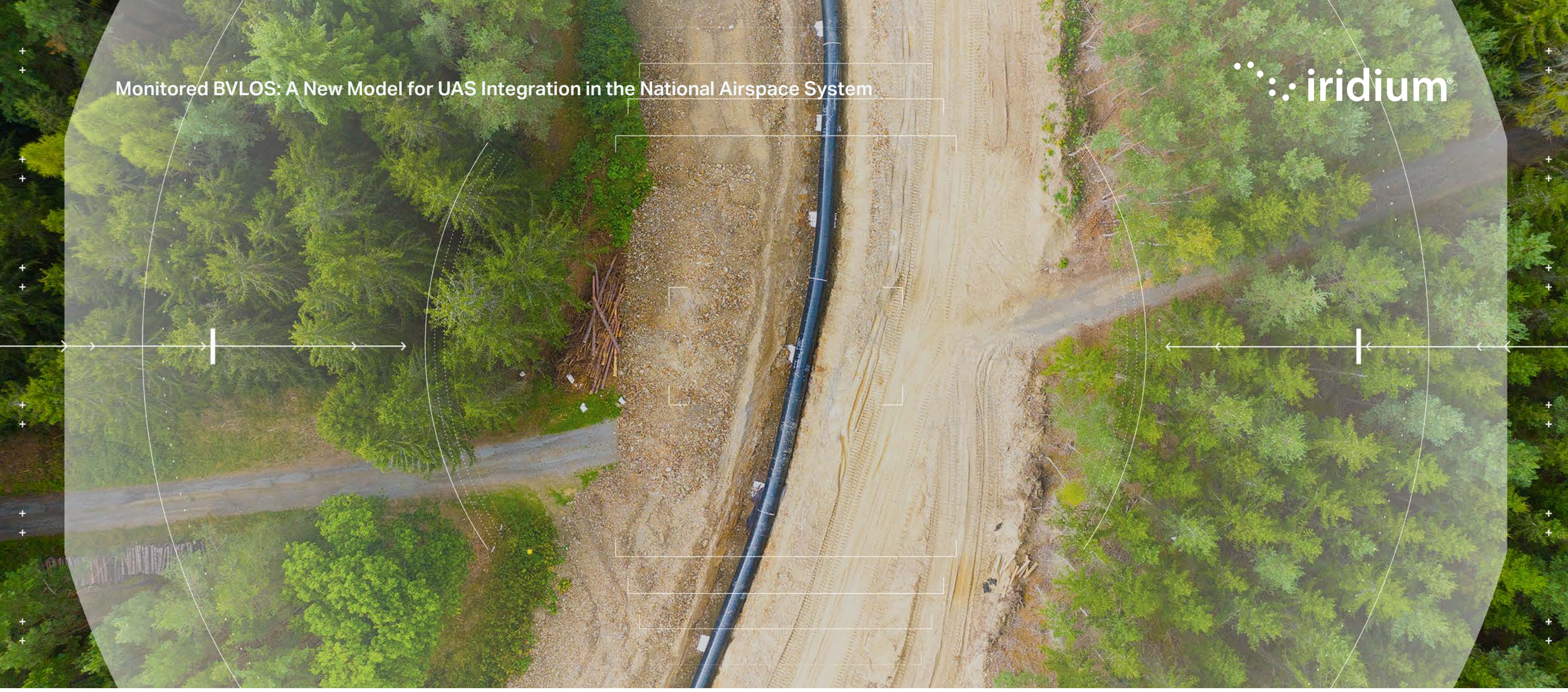
- How RPIC operations and procedures inform decision-making
- How long maneuvers actually take to communicate – and then complete – over BVLOS communication links
- Safe spacing in Class E and G airspace

As the drone was flown in a rectangular pattern, an operations procedure was established to practice an evasive maneuver around an aircraft that entered the airspace on an intersecting flight path – giving us a baseline of how long it takes to recognize the problem and maneuver accordingly.

This procedure was flown over the course of several hours to maximize test results and better understand the response of the drone's components.

LIKE ALL MEANS OF AUTONOMOUS SYSTEMS COMMUNICATION, THE UAS BVLOS ECOSYSTEM HAS MANY COMPONENTS AND DEPENDENCIES.

THE FOLLOWING SECTIONS WILL FOCUS ON THOSE ASPECTS, AND HOW THEY WORK IN HARMONY TO ENSURE SAFE FLIGHT.



MINIMUM EQUIPMENT LIST (MEL)

Aviation has made use of an MEL for safe operations in oceanic and IFR conditions to ensure clear communication and safe aircraft spacing. We believe the drone industry and the BVLOS waiver process could take advantage of the proven MEL process. Applying a BVLOS MEL in Class E and G airspace when flying in low-density population or rural or remote areas would be a great step toward dramatically increasing innovation and operational efficiency while the type certification process matures.

Below are the items and conditions for our flight that will serve as a start to an industry-recommended minimum equipment list.

TECHNOLOGY	PRODUCT	PURPOSE	
Iridium Satellite L-band	Iridium Connected® Blue Sky Network SkyLink 7100	Tracking and Command/Control	
LTE Air to Ground	Iridium Connected® Blue Sky Network SkyLink 7100	Tail camera video	
VHF	AirPlus KRT2	Listen to ATC	
RoIP	SyTech Radius	Convey the VHF traffic over satellite for RPIC	
Transponder	SAGEM Mode S	Situational awareness of the drone broadcasting to all other traffic	
Satellite Surveillance	Aireon	Situational awareness of the drone with all other traffic and at all altitudes	
Traffic Awareness	PASSUR ARiVA	Browser-based software tool that provides situational awareness of traffic with a 4-second update rate	
900 MHz Radio		LOS Command/Control	
Control	Piccolo	Command/Control	

AN EXAMPLE OF WHAT A SIMPLIFIED WAIVER FOR BVLOS OPERATIONS COULD LOOK LIKE:

Date: ☐ **Takeoff Location:** ☐ **RPIC:** ☐

AIRCRAFT TYPE

☐ Fixed Wing ☐ Rotor Wing ☐ Other

(Explain)

MISSION TYPE

☐ Surveillance ☐ Delivery ☐ Inspection

☐ Other (Explain)

DESCRIPTION OF MISSION ROUTE

☐ Rural ☐ Suburban

☐ Remote ☐ Infrastructure

☐ Urban

(Explain)

BEYOND VISUAL LINE OF SIGHT MINIMUM EQUIPMENT LIST (MEL)

Surveillance ADS-B (Out):

☐ 1090 MHz Transponder ☐ Other Transponder

(Equipment Detail)

Surveillance Operations Feed ADS-B (In):

☐ Ground ☐ Satellite ☐ Other

(Explain)

Communication (Must have a minimum of 2 available through all phases of flight):

☐ 4G/LTE/5G ☐ L-band ☐ 900 MHz ☐ C-band ☐ VHF ☐ Other

Equipment Type and Part Number

Equipment Type and Part Number

Equipment Type and Part Number

Equipment Type and Part Number

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Equipment Type and Part Number

VHF ROIP Description

Communication Prioritization (Must have a minimum of 2 available through all phases of flight):

Primary Equipment/Coverage

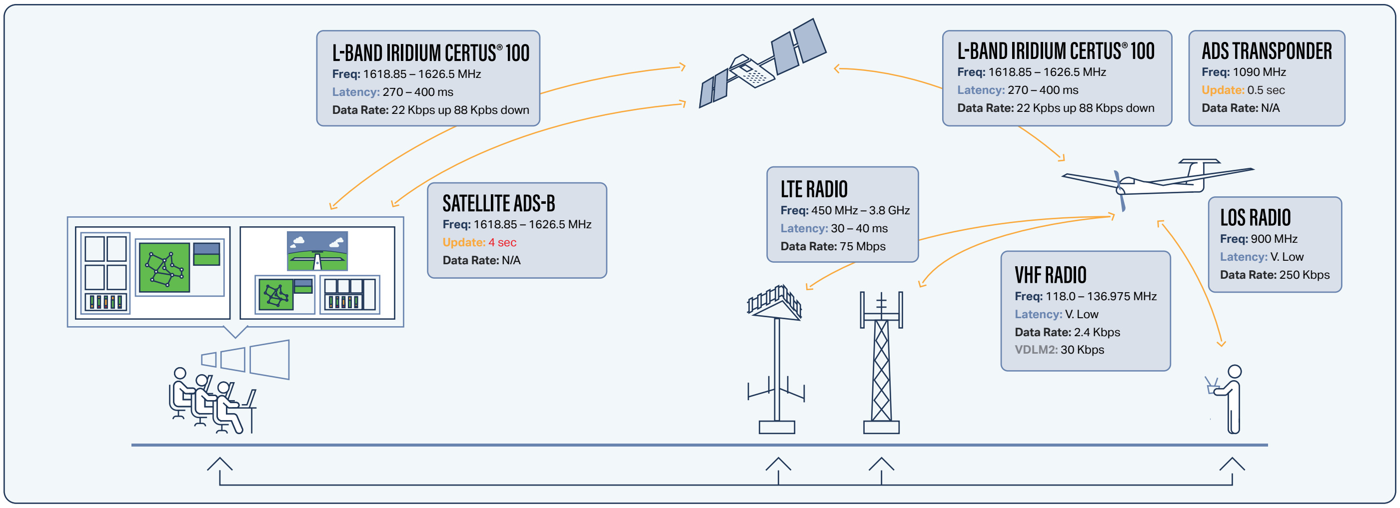
Alternate Equipment/Coverage

Contingent Equipment/Coverage

Emergency Equipment/Coverage

WAIVER GRANTED | WAIVER DENIED

LATENCY



A thorough understanding of latency is critical before any credible case can be made that would assure operators that safe separation from other aircraft can be maintained.

Understanding the longest latency communication and surveillance links is important to ensuring communication between the aircraft and its operator is never broken. As such, the aircraft communication system must have technology that can prioritize and rapidly switch communication paths based on availability. The need to avoid compounding latency is vital when making a decision to deviate in order to maintain spacing from other aircraft or obstacles.

Our current understanding of latency with existing technology can be applied to a handful of technologies commonly used today in controlled airspace either around congested airports or in Class A airspace. The common technologies used on crewed aircraft to maintain safe separation are Airport Surveillance Radar (ASR) S-band and the Airborne Collision Avoidance System II (ACAS II). The ASR has an approximately 4-second update rate, while an ACAS system has an approximately 1-second update rate.

The necessary tools should be in the hands of RPICs monitoring BVLOS operations. Providing an update rate of aircraft position in the 1- to 4-second range can ensure the operator has at least the same reaction time as IFR pilots responding to air traffic controllers today.

Aircraft equipped with a 1090 MHz transponder and an L-band satellite link provided update rates of position within the 1- to 4-second range. The operator had a data feed from satellite ADS-B in with a 4-second update rate as well as a ground feed for their aircraft and any surrounding traffic. Meanwhile, the L-band satellite communication system provided a position update every second.

These two COTS technologies enabled an RPIC to have the same visibility and latency as air traffic control or a pilot flying in the airspace with an ACAS system. This aircraft was also equipped with a second L-band satellite system as backup. The response to a command from the RPIC via satellite link is less than 700 milliseconds, or less than seven-tenths (Command Response <0.7s) of a second.

THE RPIC PREFERRED THE AIRCRAFT COMMAND RESPONSES OVER SATELLITE COMMUNICATION VERSUS THE 900 MHZ LOS RADIO.

For this specific operation – an altitude of 1,500 feet above ground level – the reliability of the satellite communication was superior to the LTE link, which was easily observed as the tail camera video fell out and returned as the aircraft flew through the planned route.

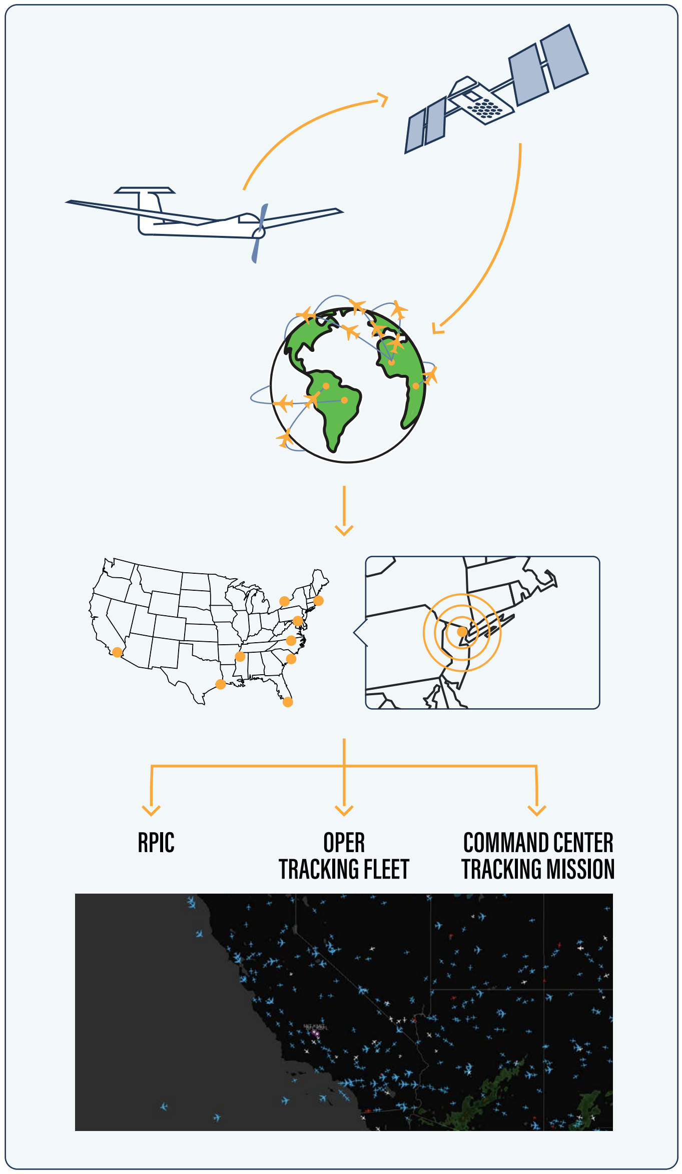
THE ROLE OF ADS-B DISTRIBUTION

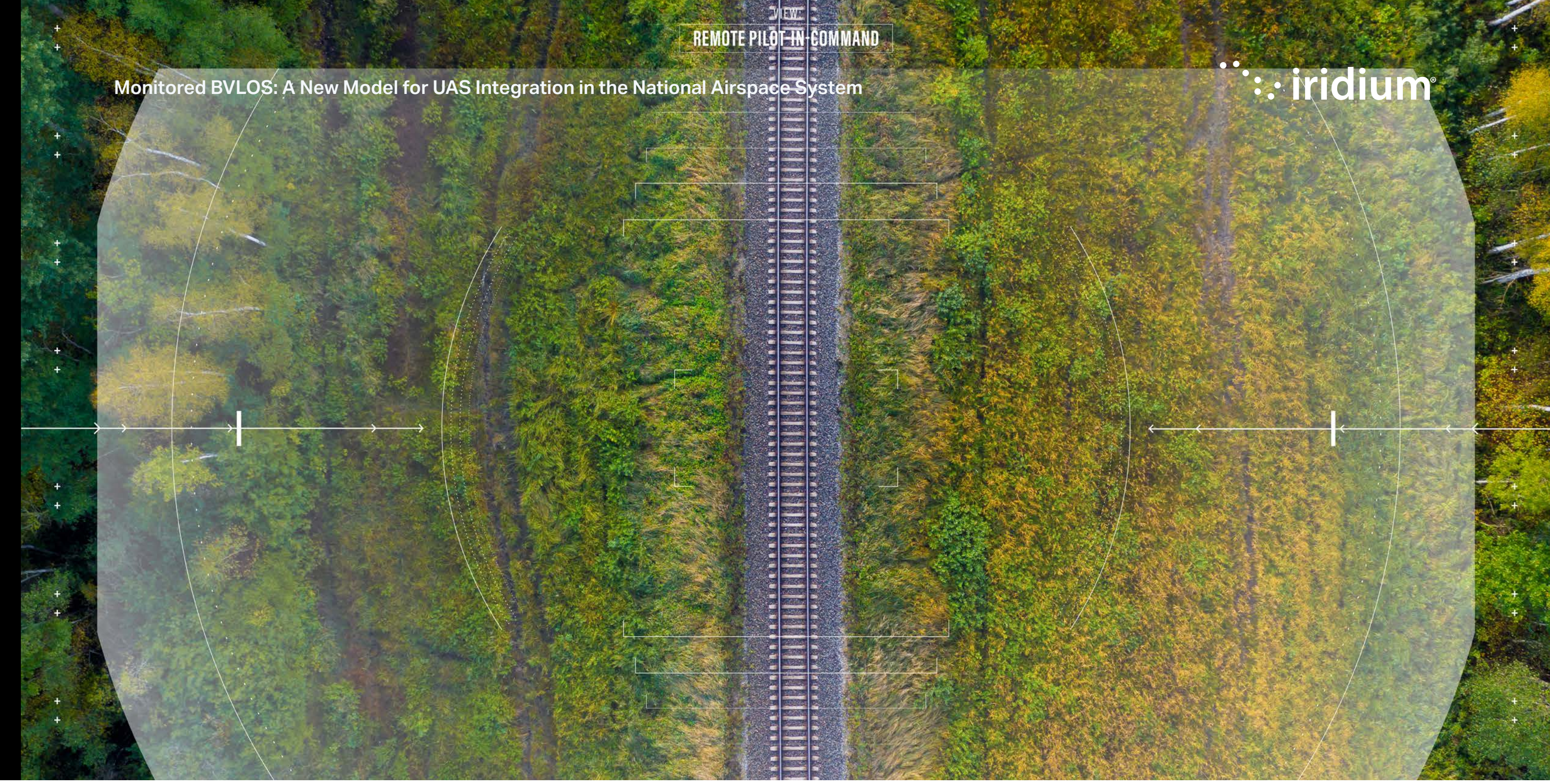
Surveillance is a key element to safe operations, as knowing the behavior of air traffic around a drone provides the situational awareness an RPIC needs to anticipate intersecting paths and plan for maneuvers to ensure safe separation.

Both prolific and effective, the 1090 MHz ADS-B technology integrates the drone into the airspace and is visible to all other participating aircraft as well as Air Navigation Service Providers (ANSPs) globally. More importantly, its size, weight, power and cost have decreased dramatically in recent years to fit the needs of numerous large fixed-wing uncrewed aircraft platforms.

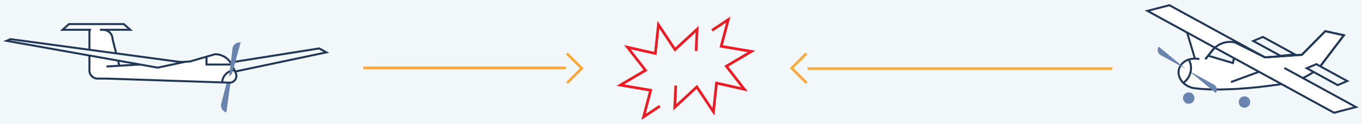
Many existing software applications use both ground and satellite-based receivers to ensure all targets at various altitudes can be observed. These technologies are both affordable and can be integrated into the flight control tools used by the RPIC in remote regions. This could further enhance safety and enable maneuvers that ensure safe spacing is maintained without obstructing other aircraft. Standardization of this technology into BVLOS operations would dramatically improve the integration of these solutions with drone flight control systems, thereby increasing safety and situational awareness.

The total latency (or update interval) from the aircraft to the RPIC through the PASSUR ARiVA software package Iridium used with Aireon® satellite surveillance was approximately 4 seconds – an adequate rate for the mission and lack of nearby air traffic. However, if needed, 1-second update rates are possible.





DETERMINING SAFE SEPARATION



CLOSURE SPEED (KIAS)	SPEED (MPH)	DISTANCE (MILES)	TIME (SECONDS)
500	575	1.0	6
250	288	1.0	13
200	230	1.0	16
150	173	1.0	21
100	115	1.0	31
50	58	1.0	63

Safe separation and reaction time are easiest to calculate based on closing speeds of converging aircraft. The worst-case scenario for converging aircraft includes a head-on approach at a maximum speed below 18,000 feet above ground level – 250 knots-indicated air speed (KIAS). The closure time at such speeds is a minimum of 6 seconds per mile.

If procedures were set to perform evasive maneuvers at a distance of 5 miles, the RPIC would have to carry out those maneuvers in less than 30 seconds to successfully avoid the oncoming aircraft.

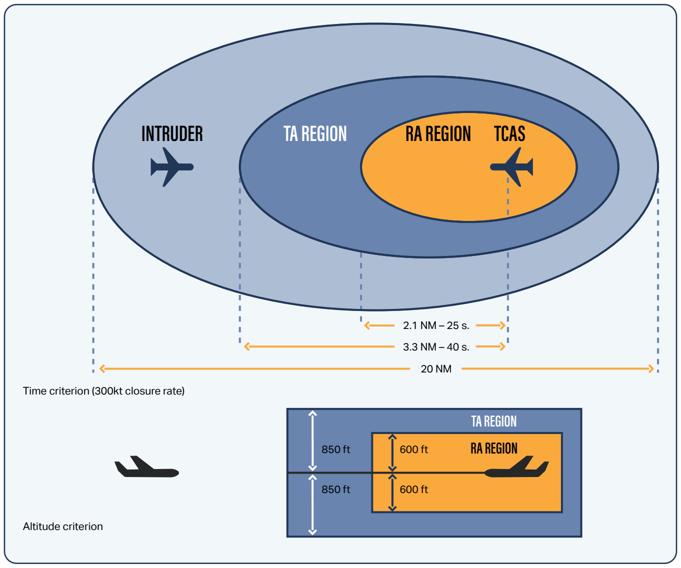
To that end, it is important to test the responsiveness of the system and the time to maneuver an aircraft over the highest availability connection: L-band Low-Earth Orbit (LEO) satellite communications.

RESULTS OF EVASIVE MANEUVER TESTING

The use case to successfully maneuver around a potential intersecting aircraft and maintain 2 Nautical Miles (NM) of separation was performed with encouraging results given the use of COTS equipment and nonidealized operations.

The RPIC used the position report from the aircraft to maintain a reference of the aircraft performing the mission. They went through a process of identifying an issue, ringing the aircraft, developing a response, issuing a flight command, and acknowledging that the aircraft responded and was clear of the issue.

The table below illustrates that this maneuver can consistently be performed in less than 18 seconds. The operator saw significant opportunity for improvement with time and greater integration of surveillance with control software.

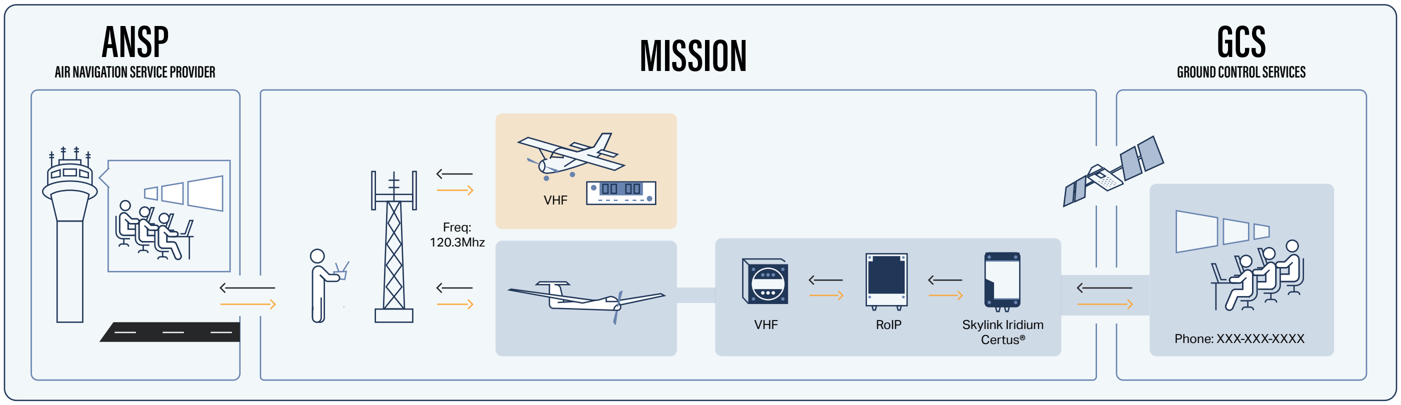


WHEN AN ISSUE IS IDENTIFIED AT 5 NM OF SEPARATION, THE DRONE CAN BE CLEAR OF THE ISSUE WITH GREATER THAN 2 NM OF SEPARATION – THUS MAINTAINING SAFE SEPARATION IN THE AIRSPACE.

		TARGET (SEC)	TEST 1 (SEC)	TEST 2 (SEC)	TEST 3 (SEC)
T0	Identify Issue	0	0	0	0
T1	Ring Aircraft	4	2.05	3.35	2.82
T2	Develop a Response	4	3.40	2.48	1.61
T3	Issue Flight Command	4	2.22	1.28	2.38
T5	Acknowledge Command	4	7.11	6.31	5.69
T4	Aircraft Responds and Clear	4	6.32	3.98	5.29
	Total Time	**20**	**21.1**	**17.4**	**17.79**

OPPORTUNITY: VHF, ROIP AND IRIDIUM® VOICE

Voice communication with air traffic control and nearby aircraft is one of the biggest challenges to BVLOS operations – however, radio over IP technology could be a solution to permit RPIC to listen to VHF communications throughout a mission.



The ability to listen to VHF communications using VoIP while monitoring BVLOS operations would provide an even greater situational awareness of the airspace around the mission and permit the RPIC to communicate with air traffic control in the event of an emergency. Again, this technology is off the shelf – and when integrated in a drone with L-band satellite, it would comply with the standard procedures in the NAS to communicate with the drone either through voice or Controller-Pilot Data Link Communications (CPDLC).

Establishing a mobile-operated satellite communication link takes 2 seconds; once linked, voice over satellite communication is handled in less than 700 milliseconds (0.7 seconds). The radio can be further tuned over the satellite link to additional frequencies on long missions that pass through multiple VHF regions.

This link also permits the RPIC to monitor radio traffic in the area, thereby enhancing their situational awareness.

POTENTIAL APPLICATIONS FOR BVLOS DRONE USE

A scalable BVLOS waiver process including an MEL would align with the recommendations made to the FAA in the January 2023 U.S. Government Accountability Office (GAO) report, "Drones: FAA Should Improve Its Approach to Integrating Drones into the National Airspace System."[2] The report also notes:

- The range of potential applications, including "… inspecting infrastructure, aiding in disaster and wildfire response, and delivering medical supplies."
- How, according to the 2022 FAA Aerospace Forecast for Fiscal Years 2022-2042, "the commercial drone industry in particular is expected to expand rapidly as commercial drones become operationally more efficient and safe, battery life expands, and drone regulations evolve to support more complex drone operations."

Others on Capitol Hill believe in the demand for a simpler, streamlined process – and are actively working to support it. On February 8, 2023, U.S. Senators Mark R. Warner and John Thune introduced the Increasing Competitiveness for American Drones Act of 2023, which would allow BVLOS operations under certain circumstances.

According to Sen. Warner, "Revamping the process for approving commercial drone flight will catapult the United States into the 21st century, allowing us to finally start competing at the global level as technological advancements make drone usage ever more common."[3]

CONCLUSION

The December 7, 2022 test flight concluded that commercial off-the-shelf aviation products:

- Can be integrated into a fixed-wing drone and flown in rural and remote regions while being monitored beyond visual line of sight by a remote pilot-in-command;
- Successfully maneuver the aircraft to maintain safe separation over an L-band satellite communication link.

While the results of the test are encouraging, they do not guarantee that a single solution will work for all aircraft or missions, nor do we intend to imply that the equipment used is a further guarantee of approval of a waiver for a specific mission. We believe this test encourages a collective focus from our aviation industry using best practices in IFR operations to establish industry-driven standardization and minimize risks associated with BVLOS/IFR operations.

As a community of operators, suppliers and pilots collaborating on BVLOS drone waivers near term, the opportunity exists to accelerate approvals with a scalable waiver process for real-world operations such as linear inspections with fixed-wing aircraft in rural and remote regions, bringing faster innovation in technology and realized efficiency to the respective industries they serve.

Expansion of this flight test using a broader range of equipment and scenarios that further enhance an MEL – as well as a more efficient waiver submission process – will present certification agencies and operators with a scalable path forward for monitored BVLOS operations.

ABBREVIATIONS

ACAS: Airborne Collision Avoidance System
ADS-B: Automatic Dependent Surveillance-Broadcast
ANSP: Air Navigation Service Provider
ASR: Airport Surveillance Radar
ATC: Air Traffic Control
BVLOS: Beyond Visual Line of Sight
CAA: Civil Aviation Authorities
C2: Command & Control
COTS: Commercial Off-the-Shelf
CPDLC: Controller-Pilot Data Link Communications
DAA: Detect And Avoid
FAA: Federal Aviation Administration
IFR: Instrument Flight Rules
KIAS: Knots-Indicated Air Speed
L-band: Long-Wavelength Band
LEO: Low-Earth Orbit
NAS: National Airspace System
MEL: Minimum Equipment List
RoIP: Radio over Internet Protocol
RPIC: Remote Pilot-in-Command
TCAS: Traffic Collision Avoidance System
TSI-B: Traffic Information Service – Broadcast
UAS: Uncrewed Aircraft Systems
VFR: Visual Flight Rules
VHF: Very High Frequency
VLOS: Visual Line of Sight

1 Final Report, Unmanned Aircraft Systems Beyond Visual Line of Sight Aviation Rulemaking Committee, March 10, 2022.
2 "FAA Should Improve its Approach to Integrating Drones into the National Airspace System," U.S. Government Accountability Office, January 2023.
3 "Warner, Thune Introduce Legislation to Support Integration of Drones into Airspace," Press Release from the office of Sen. Mark R. Warner, Feb. 8, 2023.

NOTES

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