Tools / Tracking

Tracking Solutions Overview

What is drone tracking?

During the Wakanda Beyond program, participants identified the importance of tracking and monitoring drone activity in national airspace to ensure safety and security. Understanding who is operating drones and their locations is crucial for averting collisions, enforcing no-fly zones, and identifying areas with high drone traffic.

Implementing a tracking system will provide Civil Aviation Authorities (CAAs) with valuable data on flight patterns, enabling them to effectively monitor and regulate drone operations across their respective countries. Real-time tracking is particularly valuable for both operators, who require constant awareness of their drone's whereabouts and condition, and CAAs/Air Traffic Control (ATC), who need to prevent potential conflicts with other aircraft.

Key data such as the drone's ID, position, altitude, speed, and heading need to be transmitted in near real-time to ensure effective tracking. Therefore, the development of a dependable flight-tracking system is imperative.

How can live tracking be realized?

Reliable telecommunication is essential to support live drone tracking. Currently, direct telecommunication works only via line-of-sight for wavelengths above a few MHz. Some form of radio telecommunication is needed to enable operations beyond visual line of sight (BVLOS). For longer-distance transmission, intermediate 'relay' systems are necessary, which can be either ground-based or space-based.

Ground-based relay options include standard telecom systems like GSM (Global System for Mobile Communications) where available in populated areas, or a dedicated network of radio relays. However, utilizing GSM poses drawbacks such as unreliable bandwidth for drone operations, lack of prioritization, and potential transmission delays. Moreover, telecom companies are hesitant to invest in installing GSM networks in rural areas due to limited customer potential. Dedicated ground relays can be set up. However, they often require political will and/or a solid business case, offering advantages like independence from commercial entities, enhanced safety and security, and resilience during disasters. Nonetheless, setting up such relays entails significant initial investment, ongoing maintenance costs, and susceptibility to damage from adverse weather or vandalism.

Alternatively, if setting up a dedicated ground network is impractical or costly for the government, satellite transmission presents an attractive solution. This approach ensures nationwide connectivity regardless of ground infrastructure or power failures, leveraging established worldwide satellite networks such as Starlink from SpaceX or Iridium, along with smaller networks with more limited availability.

Starlink®

Starlink® boasts a large constellation of satellites in low orbits, potentially offering high bandwidth for transmission, reaching up to 10 MB/s in optimal conditions. However, there are notable drawbacks. First, telecommunication availability can be unreliable, as it hinges on decisions made by Elon Musk, the founder of SpaceX. For instance, during the early days of the conflict in Ukraine, Musk opted to disable connections over the Crimean region, preventing Ukrainian forces from using marine drones to target the Russian navy. In addition, the endpoint equipment required for Starlink® connectivity, consisting of an antenna dish and receiver, is too bulky for small UAVs, akin to the size of a pizza box and weighing approximately 900g. Finally, the cost of accessing Starlink® services is quite expensive, exceeding $100 USD per month.

Iridium®

The system operates a fleet of low-flying satellites, established in the 1990s, with extensive experience, notably mandated for flight-following for wildfire-fighting aircraft in the US. The equipment, including the data modem, is designed to be small, lightweight, and power-efficient. However, the bandwidth is limited, precluding the transmission of live video streams. Communication costs are calculated based on data usage and can be relatively expensive, exceeding $5 USD per minute.

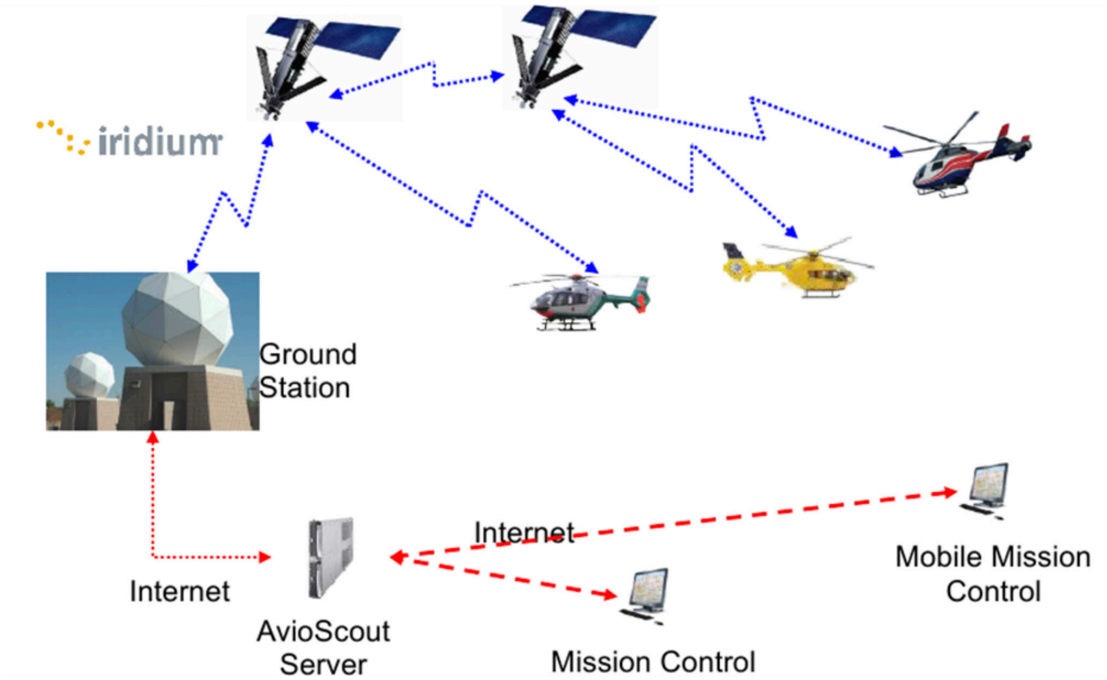
Despite this, transmitting position data using the “Short-Burst-Data” (SBD) method is cost-effective. As an illustration, in Germany, the use of IRIDIUM for Airborne Firefighting (AFF) involves equipping several helicopter fleets, including police and HEMS (Helicopter Emergency Medical Services), with SBD-modems. Each helicopter periodically sends its position via IRIDIUM to a central server, allowing any ground station to monitor the locations of all connected aircraft.

How does Iridium work?

First, the Iridium Modem onboard the aircraft sends a position message to the satellite. The satellite then relays this message to another satellite within its network that has visibility of the Iridium ground station, typically located in Arizona in the United States. From there, the message is transmitted to the ground station. At the ground station, the received information is compiled into an email format and forwarded to a predetermined server, such as the server of the Civil Aviation Authority (CAA) or Air Traffic Control (ATC).

Once stored on the server, the position data can be displayed on a screen, allowing for near real-time analysis, such as assessing the risk of collision or detecting violations of no-fly zones. This information is also accessible to ground stations operated by drone operators, providing both operators and the CAA with a comprehensive overview of ongoing flights.
This system is well-established and has been tested and proven to be reliable.

Live tracking system scheme using IRIDUM satellites



Iridium Costs

The subscription fee is $13 per month, with an additional charge of $0.05 per message sent. For instance, if the air vehicle reports its status in 2-minute intervals, this results in 30 reports per hour, equating to a cost of $1.50 per hour for messaging. Opting for shorter reporting intervals will incur higher costs accordingly.

Iridium Limitations

Iridium has its limitations:

- Costs – can get expensive depending on the length of the flight
- Limited update periods (reliable updates every 30 seconds).
- Time lag - there's a delay of about 15-20 seconds for any message to reach the server.

Other possible technical solutions for live tracking

LoRa ("Low Power Long Range" Radio)

LoRa technology supports transmissions from a sender to a receiving station over distances of up to 15 km in unobstructed areas. With suitable antennas, this range can extend even further, reaching up to 100 km.

The receiving stations are low-power consumers, with senders typically consuming between 0.1 W to 10 W, and receivers consuming 2-4 W. Additionally, they are cost-effective, starting at around $600 USD. Furthermore, they are compact and inconspicuous, making them difficult to detect and relatively easy to protect against vandalism.

LoRa operates within license-free sub-gigahertz radio frequency bands, including EU868 (863–870/873 MHz) in Europe, AU915/AS923-1 (915–928 MHz) in South America, US915 (902–928 MHz) in North America, IN865 (865–867 MHz) in India, AS923 (915–928 MHz) in Asia, and 2.4 GHz worldwide.

Key Properties of LoRa technology:

- Long-range transmissions with low power consumption.
- Data rates ranging between 0.3 kbit/s and 27 kbit/s, depending on the spreading factor.
- Geolocation capabilities allow for the trilateration of device positions using timestamps from gateways.

For further information, visit *https://lora-alliance.org/*

Advantages and Disadvantages of LoRa

Advantage	Disadvantage
• Can be set up for little money • long range (up to 100km) • low energy consumption • independant power supply	• Bandwidth not wide • Topography must be suitable

Issues with LoRa

Challenges with LoRa include the need to establish an adequate number of ground stations to ensure sufficient coverage, particularly in mountainous regions. It's also important to know how to effectively network these ground stations. Furthermore, if a single LoRa receiving station fails within a cell, the transmitted information is lost. One solution to mitigate this risk is to install LoRa systems at a distance where each sender can "see" at least two stations. In the event of a receiving station failure, the redundant system can seamlessly take over, ensuring uninterrupted data transmission.

ADS-B (Automatic Dependent Surveillance–Broadcast)

The ADS-B system, widely by in crewed airplanes, operates by the aircraft determining its position through satellite navigation or other sensors and then periodically broadcasting this information for tracking purposes. This data can be received by ground stations of air traffic control, serving as an alternative to secondary surveillance radar, as it doesn't require any interrogation signal from the ground.

ADS-B out system

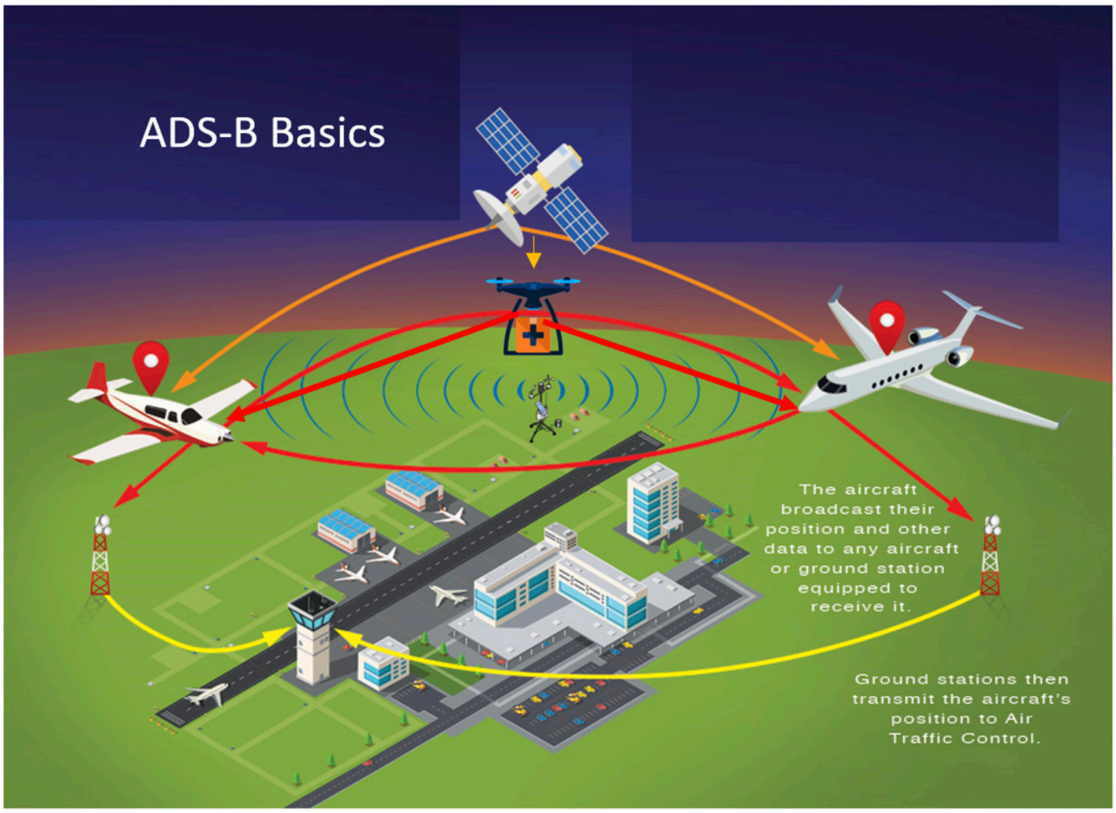
The transmitting device sends out the aircraft's position along with other pertinent information such as identification, current position, altitude, and velocity.

ADS-B Out delivers real-time position data to air traffic controllers, typically offering greater accuracy compared to existing radar-based systems.

ADS-B in system

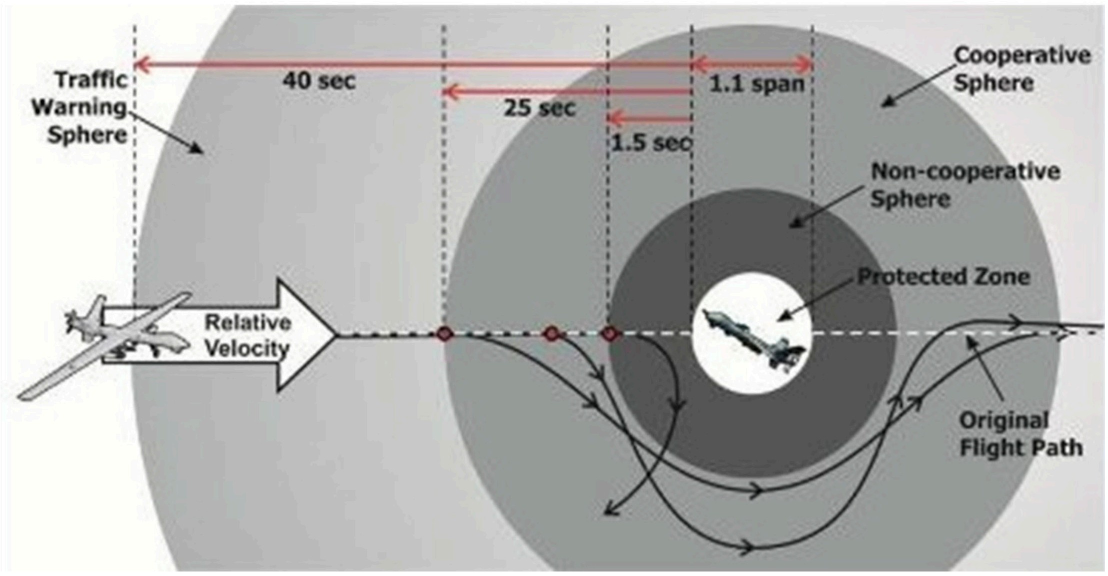
"In" refers to the reception of FIS-B and TIS-B data by aircraft, along with other ADS-B data, including direct communication from nearby aircraft.

Scheme of ASD-B



ADS-B can also be transmitted and received directly between aircraft to enhance situational awareness and enable self-separation. The term “automatic” refers to its operation without pilot or external input, while “dependent” signifies its reliance on data from the aircraft’s navigation system.

Scheme of the ASD-B detect and avoid system



The system relies on two avionics components installed on each aircraft: a high-integrity satellite navigation source (such as GPS or other certified GNSS receiver) and a datalink unit known as the ADS-B unit. There are various types of certified ADS-B data links, with the most common operating at either 1090 MHz (a modified Mode S transponder) or at 978 MHz.

The FAA aims to encourage aircraft operating exclusively below 18,000 feet (5,500 m) to utilize the 978 MHz link, as this will help alleviate congestion on the 1090 MHz frequency.

Issues with ADS-B:

- Aircraft without transponders or lacking transponder capabilities will not be displayed.
- Pilots who become complacent or overconfident in the system pose a safety risk, especially for aircraft without ADS-B transponders.
- The number of ADS-B transponders per area is limited, and there is no prioritization. This means that the ADS-B signal from a large commercial aircraft has the same priority as that from a small drone using ADS-B. Consequently, if many drones use ADS-B, there's a risk that crewed aircraft might not be detected by air traffic control (CAA), which is unacceptable since crewed aircraft rely on communication with the CAA.
- A security researcher claimed in 2012 that ADS-B lacks defense against interference from spoofed ADS-B messages because they are neither encrypted nor authenticated.
- The absence of authentication within the standard necessitates the validation of received data using primary radar.
- Since the content of ADS-B messages is not encrypted, it can be intercepted by anyone.
- Advantages and disadvantages of ASD-B

Advantages and Disadvantages of LoRa

Advantage	Disadvantage
• Makes air vehicles visible • Readable by everyone • Peer to peer communication • Detect and avoid possabilities • Generally used by manned aircraft	• Only limited number of vehicles per cell • Drones can disturb manned air vehicles • No encryption • Can be easily spoofed or interfered • Expensive

ASD-B for drones can be used for a very limited number of drones for a special task (e.g. inspecting runways at airports) but it is not a general solution.

Flarm

FLARM is a widely utilized system in Central Europe among glider pilots and parachutists. One of its key advantages is its ability to directly communicate with nearby air vehicles equipped with the same system, eliminating the need for a central computer for collision avoidance.

General properties

- FLARM is a proprietary electronic system designed to alert pilots to potential collisions between aircraft.
- It determines its position and altitude using an internal GPS and a barometric sensor, broadcasting this information along with forecast data about the aircraft's future 3D flight path.
- Additionally, FLARM's receiver listens for other FLARM devices within range and processes the received information.
- Advanced motion prediction algorithms anticipate potential conflicts with up to 50 other aircraft, alerting the pilot through visual and auditory warnings.
- FLARM incorporates an integrated obstacle collision warning system with a database containing various obstacles, including point and segmented obstacles like power lines and cableways.
- The system has low power consumption and is relatively inexpensive to purchase and install.

FLARM is more effective in preventing light aircraft collisions, as light aircraft can be close to each other without danger of collision. FLARM selectively issues warnings about collision risks rather than continuously alerting all nearby aircraft.

Advantages and Disadvantages of FLARM

Advantage	Disadvantage
• Inexpensive • Detect and avoid • Low energy consumption • Peer to peer connection • Widely used by gliders and paragliders • Encrypted	• Properitary • Danger of a monopoly

Despite its advantages, FLARM is a proprietary commercial system, making it a non-ideal recommendation as a universal solution. However, FLARM Technology offers the technology to third parties with the implementation of an OEM circuit board in compatible devices. While the FLARM serial data protocol is public, its prediction engine is patented by Onera (France) and is proprietary. Additionally, FLARM signals are encrypted, which has sparked debate regarding processing time and aviation safety in a closed market.

ASD-L

In 2023, a new standard called ASD-L was introduced. It has the potential to become widely adopted, as it appears to address the shortcomings of its predecessor. This suggests that ASD-L might be a viable option for drones in the future. However, due to limited experience with ASD-L thus far, it's premature to make a definitive recommendation. Nonetheless, for future live tracking applications, it is worth exploring ASD-L as a potential solution.