Validation of e-Conspicuity and Conflict Detection and Resolution Services in GA-UAS Encounter

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***Abstract*—The increasing integration of Uncrewed Aerial Systems (UAS) into controlled airspace presents significant operational and safety challenges, particularly in conflict detection and resolution (CD&R) for Beyond Visual Line of Sight (BVLOS) operations. Ensuring reliable separation management in U-Space requires robust e-conspicuity solutions that address uncertainties in Communication, Navigation, and Surveillance (CNS) systems. This study evaluates the CERTIFLIGHT UTM Box, an e-conspicuity device designed for General Aviation (GA) and UAS operations, incorporating authenticated GNSS tracking, blockchain-based data integrity, and conflict resolution advisory services. Flight validation tests were conducted using a GA aircraft and a UAS to assess the system's effectiveness in detecting and resolving conflicts under realistic operational conditions. The results indicate that while the UTM Box successfully provided conflict advisories, navigation uncertainties and communication delays exceeding five seconds affected its performance. The study highlights the importance of incorporating CNS system uncertainties into CD&R algorithms to ensure safe separation. Future work will focus on refining conflict resolution strategies, integrating advanced filtering techniques to mitigate sensor noise, and enhancing pilot interface design for improved situational awareness and decision support.**

***Keywords*—e-Conspicuity, Conflict Detection and Resolution, U-Space, UAS, Flight Test, CNS Uncertainty**

I. INTRODUCTION

The commercial use of Uncrewed Aerial Systems (UASs), commonly known as drones, is expected to grow significantly. According to a recent study in 2022, around 400,000 to 800,000 drones will fly in the European airspace by 2030 [1]. Key applications such as medical logistics, parcel delivery, and infrastructure monitoring for emergency response are driving this growth. However, integrating UASs safely into the airspace alongside existing traffic poses major challenges that require dedicated solutions.

In response to these challenges, the CORUS project has introduced a Concept of Operations (CONOPS) for U-Space, designed to facilitate the safe operation of UASs within shared airspace [2]. U-Space aims to provide several essential services, including registration, remote identification, and separation management, to ensure safe and efficient operations. The registration process is mandatory for all airspace users, including both crewed and uncrewed aircraft. Remote identification increases situational awareness by making aircraft electronically conspicuous, a concept referred to as e-conspicuity. Communication, Navigation, and Surveillance (CNS) systems play a critical role in enabling e-conspicuity by providing real-time aircraft data, such as position, speed, and track angle, via radio communication or internet-based platforms. Given the anticipated traffic density, automation is a fundamental component of U-Space, as human operators alone will be insufficient to manage the airspace effectively. Therefore, separation management within U-Space is expected to be fully automated, comprising multiple layers, including strategic (pre-flight) planning to optimize traffic flows, tactical in-flight conflict resolution, and collision avoidance systems to ensure last-resort safety measures [3].

The European Union Aviation Safety Agency (EASA) has contributed to these efforts through the development of a technical specification for Automatic Dependent Surveillance-Light (ADS-L), which is one of the means to achieve e-conspicuity [4]. This service typically relies on Global Navigation Satellite Systems (GNSS) to locate aircraft, supplemented by internal sensors such as inertial measurement units (IMUs) and magnetometers to obtain speed and track data. However, these measurements are subject to various sources of error, including sensor noise and bias. Furthermore, while navigational data is transmitted at regular intervals, the reception of these signals by surrounding entities is not always guaranteed, as data packets may be lost due to interference or signal attenuation. These factors introduce uncertainty into CNS systems, posing challenges for effective tactical conflict resolution.

U-Space operations primarily involve UASs flying Beyond Visual Line of Sight (BVLOS), relying on GNSS positioning for navigation. Unlike Visual Flight Rules (VFR), where pilots visually detect and avoid other aircraft based on right-of-way conventions [5], UASs lack visual assessment capabilities and depend entirely on electronic means for conflict detection and resolution. Despite the presence of e-conspicuity devices, there is no established coordination framework in U-Space yet, making conflict resolution uncertain.

To ensure that all vehicles involved in a conflict act in a complementary fashion, coordination of manoeuvres is required. This coordination can be performed explicitly and implicitly. Explicit coordination requires direct communication between conflicting parties to share intended flight paths [6]. Despite promising, the current e-conspicuity infrastructure lacks the

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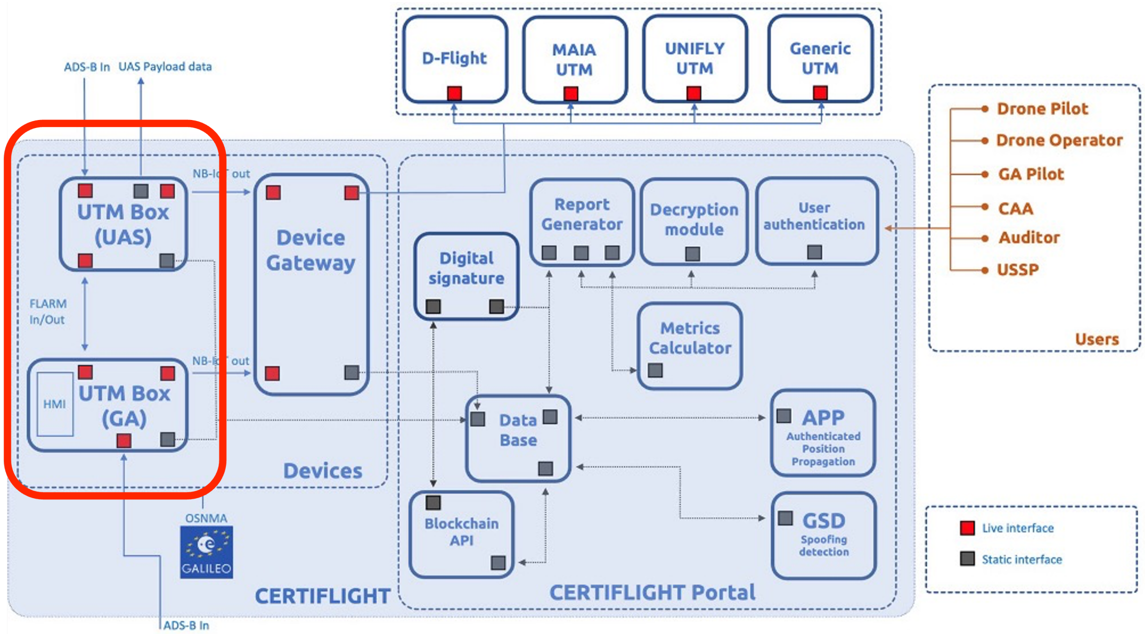

Figure 1: CERTIFLIGHT system architecture for UTM, showing interactions between UTM devices, the CERTIFLIGHT portal, and external UTM providers. The focus of this paper is on the interaction between the UTM Box for UAS and GA as an e-conspicuity device providing a CD&R advisory.

bandwidth to support such exchanges. Implicit coordination, on the other hand, relies on a common conflict detection and resolution algorithm among all agents, where complementary actions by all aircraft follow implicitly from the manoeuvre selection strategy of the algorithm, thus allowing safe operations without explicit communication of intent. Given the constraints of BVLOS operations, developing robust implicit coordination mechanisms is crucial for ensuring the safe integration of UASs into the airspace.

However, even with implicit coordination strategies, the effectiveness of conflict detection and resolution is heavily influenced by the performance of underlying communication, navigation, and surveillance (CNS) systems. Studies have shown that the uncertainties and limitations inherent in CNS systems significantly complicate tactical separation management. Langejan's research highlights how inaccuracies in ADS-B data and reception limitations can degrade conflict detection and resolution capabilities, particularly in high-density traffic scenarios [7]. Similarly, Khan et al. demonstrated that constraints in surveillance range and increased interference reduce the effectiveness of self-separation, leading to delayed conflict detection and less efficient resolution strategies [8]. Further supporting this, Rahman et al. showed that communication delays and navigation inaccuracies diminish the effectiveness of autonomous separation in U-Space, increasing intrusion risks and separation losses [9]. These findings underscore the need to incorporate uncertainty considerations into the design of tactical separation systems to maintain safe separation under varying operational conditions.

To address these challenges, the CERTIFLIGHT project offers an advanced tracking solution for flight operations within U-Space. By leveraging cutting-edge technologies such as Galileo's Open Service Navigation Message Authentication (OSNMA), blockchain, and spoofing detection algorithms, CERTIFLIGHT provides a secure framework for GNSS-based tracking. This paper outlines the CERTIFLIGHT system, focusing on a UTM Box for General Aviation as an e-conspicuity device and on conflict detection and resolution services designed to improve the safety of flights inside U-Space. The remainder of this paper presents the methodology, describing a simple simulation to evaluate the safety of the chosen parameters for the CD&R and the flight tests conducted to validate the usability of the device. Finally, the results and discussion section provides insight into the key milestones achieved in this ongoing project.

II. CERTIFLIGHT Overview

CERTIFLIGHT provides position-based services for UAS and GA operating inside U-Space. These services are designed to meet the position trustworthiness needs of UAS and GA operators by offering secure and authenticated EGNSS-based tracking. By leveraging Galileo's OSNMA and blockchain technologies, it improves the robustness of flight data. Using these technologies allows the CERTIFLIGHT UTM box to produce legally significant flight information, which can be used for compliance, safety, and operational efficiency within the U-space and the broader air traffic management (ATM) environments.

The operational workflow of CERTIFLIGHT services is divided into several phases, starting from the initialization of the UTM Box devices, which are equipped with secure communication capabilities and GNSS receivers. During flight operations, these devices transmit authenticated positioning data to the CERTIFLIGHT platform and associated UTM Service Providers (USPs), ensuring that the data is securely stored and available for post-flight analysis. This data forms the basis for generating both basic and full reports, with the latter including detailed post-processed information to verify the integrity and authenticity of the UAS trajectory. In addition, tactical conflict detection and resolution advisory features are employed during flights to identify and mitigate potential conflicts in real-time, enhancing flight safety and operational coordination.

The UTM Box, developed as part of the CERTIFLIGHT project, is an EGNSS/IoT transponder, that can be installed on UAS and GA/Ultralight aircraft as an Electronic Flight Bag (EFB). It incorporates GNSS positioning authentication to provide UAS operators and pilots with advanced features, such as user authentication, data encryption, raw data download, real-time authenticated tracking, and flight report certification.

Figure 1 illustrates the architecture of the CERTIFLIGHT system, highlighting the integration of UTM devices, the CERTIFLIGHT portal, and external UTM service providers (D-Flight, MAIA UTM, UNIFLY UTM, Generic UTM). The UTM Box (UAS) and UTM Box (GA) are critical hardware components that collect GNSS data and transmit it via NB-IoT to the Device Gateway, which interfaces with the CERTIFLIGHT portal. The Device Gateway ensures secure data transmission, while the OSNMA (Open Service Navigation Message Authentication) from Galileo adds an additional layer of GNSS signal authentication to counteract spoofing threats.

Specialized modules such as APP (Authenticated Position Propagation) and GSD (Spoofing Detection) amplify the reliability of positional data, protecting against GNSS spoofing and ensuring that post-flight analyses are based on accurate, authenticated information. Live interfaces (highlighted in red) facilitate real-time data flow and user interactions, while static interfaces (in gray) handle secure data processing and storage. This architecture enables seamless coordination between drones, GA pilots, U-space service providers (USSPs), and regulatory authorities, ensuring compliance and operational safety within U-Space.

A. UTM Boxes for UAS and GA

The UTM Box, a key innovation of the CERTIFLIGHT project, serves as an e-conspicuity and tracking device tailored for both Unmanned Aerial Systems (UAS) and General Aviation (GA). This device integrates GNSS-based tracking with secure

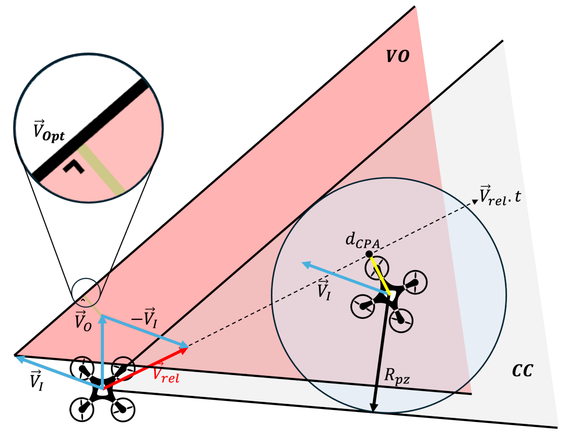

Figure 2: Illustration of Velocity Obstacle algorithm. The red-shaded area is a set of velocity that will lead to a loss of separation. Projecting the current ownship velocity to the nearest edge resolves the conflict with the least velocity change.

data management, ensuring compliance with U-space regulatory requirements and enhancing airspace safety. The device is equipped with a GNSS receiver that supports multiple satellite constellations, including GPS, GLONASS, and Galileo. The integration of OSNMA provides an additional layer of security by authenticating navigation messages at the source, thus mitigating risks associated with GNSS spoofing and ensuring reliable positional information. The GNSS data are further enhanced by an Inertial Measurement Unit (IMU) comprising a gyroscope, accelerometer, magnetometer, and barometer, which collectively improve the accuracy and robustness of the positioning information, especially in environments where GNSS signals may be degraded.

The UTM Box facilitates communication with various UTM Service Providers (USPs) and air traffic management platforms. It utilizes NB-IoT cellular networks for real-time data transmission, ensuring continuous tracking and remote identification capabilities. For the GA version, additional support for ADS-B-in and FLARM-in/out increases surveillance capabilities, allowing for real-time visualization of surrounding air traffic. These data are transmitted once every second via radio-based communication.

For practical reason during the development, the conflict detection and resolution uses the FLARM system for navigation and communication, enabling real-time awareness of nearby air traffic and potential collision risks. By exchanging position, speed, and track information between aircraft equipped with FLARM, the system facilitates the timely detection of potential conflicts and supports automated or pilot-initiated avoidance maneuvers.

B. Conflict Detection and Resolution Advisory

As part of its features for GA, CERTIFLIGHT provides a conflict detection and resolution advisory system, allowing users to navigate through an airspace without interfering with the surrounding flight routes. The conflict detection and resolution used in the service is implemented as a decentralised system with implicit coordination, in which each agent can locally solve the conflict with a common algorithm among them.

CERTIFLIGHT uses state-based algorithms for the tactical CD&R methods, a tactical separation that resolves conflict locally [10]. The conflict detection algorithm projects the current state of the aircraft such as position, track angle, and speed, within a defined lookahead time. In case the projected states show that the distance at the closest point of approach lies within the radius of protected zone of other aircraft, and the time to this point is less than the lookahead time, then it is considered a conflict.

The conflict resolution algorithm used in CERTIFLIGHT's system is based on the Velocity Obstacle algorithm [11]. This algorithm is constructed by drawing tangent lines between the current position of an ownship aircraft to the protected zone of an intruding aircraft. The area between the lines is then called a Collision Cone, and when translated along the velocity vector of the intruder, a Velocity Obstacle is obtained, as shown in Figure 2. The conflict resolution then can be calculated by changing the ownship velocity such that it lies outside the VO. The smallest velocity vector change can be obtained by projecting the ownship velocity to the nearest edge of the VO and choosing the new velocity from the projected line. If this resolution strategy is followed by both actors in a conflict, implicit coordination is ensured.

When applying this algorithm in a real-life situation, the performance of the communication, navigation, and surveillance systems must be considered. For instance, the radius of the protected zone must be selected such that it allows the aircraft to maneuver around the drone even in the presence of uncertainty in the CNS systems.

III. Methodology

To test the CERTIFLIGHT UTM box, a validation flight was conducted at an airstrip in Manduria, Province of Taranto, Italy, using a General Aviation (GA) aircraft, the Tecnam P92, and an unmanned aerial system (UAS), the DJI Matrice M350 RTK. Before the flight, the pilot was briefed about the usability of the GA Box, the conflict detection, and the resolution advisory. The pilot was then asked to follow the advisory given by the box and perform another trial such that the conflict detection would be triggered several times.

During the test, the UAS was maintained in a fixed hover position, with the objective of recording the reported position, speed, and track angle of the UTM Box. Meanwhile, a general aviation (GA) aircraft maneuvered around the UAS at a ground speed of 70 to 80 knots. This setup was designed to trigger the in-flight conflict detection and resolution (CD&R) algorithms, providing valuable insights into the system's performance under realistic operational conditions.

For tactical separation, a state-based conflict detection algorithm combined with the Velocity Obstacle (VO) method was selected as the conflict resolution strategy. This choice was motivated by the simplicity and computational efficiency of the VO method. The look-ahead time for conflict detection was set to 50 seconds, ensuring that the algorithm would be triggered when the aircraft was approximately 2 kilometers away from the UAS. The radius of the protected zone was set to 200 meters, allowing for a 5-degree deviation from the UAS position to trigger a conflict. This value was chosen to provide a higher probability of detection while remaining slightly larger than the Near Mid-Air Collision (NMAC) and Well Clear (WC) boundaries, defined as 500 feet and 2000 feet, respectively, in the ASTM F3442/F3442M standard [12].

Before conducting the flight test, we validated the selected conflict resolution strategy through simulations in BlueSky [13], an open-source air traffic simulator. The simulations were performed using the same scenarios as described earlier, with a condition when the conflict was no longer detected the aircraft will resume its original speed and heading. This encounter is repeated 6000 times incorporating an assumed position uncertainty of 10 meters and 30 meters. Additionally, a 1 m/s velocity uncertainty and 90% probability of successfully receiving a 1Hz message broadcast were considered.

The chosen position uncertainty values align with the second and third accuracy levels, while the velocity uncertainty follows the highest accuracy level specified in EASA's technical standards for ADS-L. However, due to the lack of prior research on communication system performance, the 90% message reception probability was selected as a reasonable approximation, close to an ideal scenario while still accounting for potential losses. This approach ensures that the simulation accurately represents the conflict resolution strategy under expected operational conditions, providing a realistic assessment of its effectiveness in managing airspace conflicts.

The flight test produced valuable insights, including the aircraft's trajectory during conflict resolution, the navigation accuracy of the UTM Box, and its communication performance. Additionally, we gathered pilot feedback on potential improvements for the user interface, ensuring that the system not only functions effectively but is also intuitive and practical for real-world operations

Although CERTIFLIGHT's UTM Box does not broadcast navigation accuracy information, it is essential to quantify this uncertainty to ensure safe separation, as it directly influences the parameters used in the CD&R algorithm. Variations in reported position and velocity can significantly affect the ability of the system to predict and mitigate potential conflicts. Understanding these uncertainties is therefore critical for refining separation standards and improving the reliability of CD&R mechanisms in BVLOS operations.

Navigation accuracy was evaluated using position, speed, and track data from the hovering UAS. To comply with EASA's ADS-L technical specifications [4], and to support future navigation accuracy modeling, the position data were converted into local coordinates. The median was used as the reference point, and the standard deviation was calculated to quantify positional uncertainty. Similarly, the speed and track angle uncertainties were computed following the ADS-L technical specification guidelines.

Communication performance was evaluated by measuring the time intervals between consecutive messages sent by the UTM Box on the UAS and received by the GA aircraft. This analysis provided information on the reliability and latency of the communication system, which is essential for real-time conflict resolution. The data obtained from this test flight served as an initial assessment, contributing to the refinement of separation algorithm parameters and overall system performance.

IV. Results and Discussion

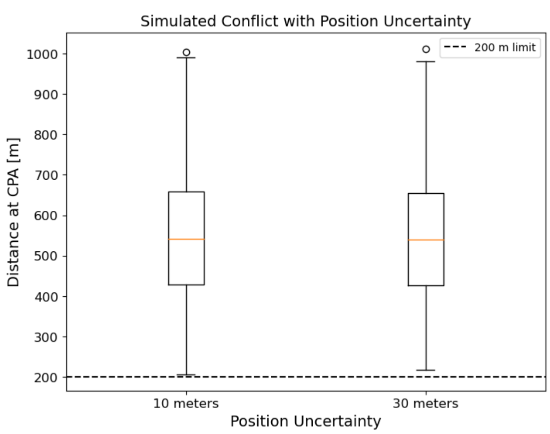

Figure 3

Figure 3 illustrates the closest point of approach (CPA) distances obtained from the simulation. Across 6,000 encounters for each position uncertainty level, no loss of separation was detected. However, the separation distances remained large due to the scenario setup, which included uncertainties and the assumption that the aircraft returns to its initial condition after conflict resolution. The uncertainties can result in a a false positive situation, and the aircraft performs additional avoidance maneuver when there's no longer conflict. The simulation results indicate that with position uncertainties of 10 meters and 30 meters, an additional 1 m/s velocity uncertainty, and a 90% message reception probability, selecting 200 meters as the separation standard and a 50-second look-ahead time ensures a safe operational margin for conflict resolution.

Figure 4 illustrates the conflict detection and resolution advisory process. Initially, a warning sign, as shown in the left subfigure, is displayed for 3 seconds to capture the pilot's attention. Following this, the middle figure presents the GA Box displaying a resolution advisory, including recommended adjustments to speed and heading, indicated by an arrow showing the direction. The GA's current heading is 354 degrees, with a suggested adjustment of 6 degrees to the left. Finally, after the pilot executes the maneuver and successfully avoids the intruder, a tick mark accompanied by a "collision avoided" notification is shown. The subfigure on the right depicts this success notification, with the GA's heading adjusted to 346 degrees, slightly exceeding the recommended change.

From the user's perspective, the pilot noted that the interface could be improved. First, the warning sign should be larger than its current size to ensure better visibility. Second, during the resolution advisory phase, the display presented too much information, making it difficult to process quickly. Instead of showing both an advised heading and speed change, the pilot preferred a simplified directional arrow for guidance. This preference is mainly due to the limited time available for decision-making, requiring the information to be concise, intuitive, and easy to interpret at a glance.

Subsequently, we reconstruct the flight paths by plotting the trajectories of the aircraft and the positions of the UAS. A total of four trials were conducted over two flight sessions. Figure 5 illustrates these trials. The blue line represents the GA's trajectory, with the heading indicating its direction. The UAS positions are marked with "x," and the circles denote the 200m radius of the protected zone. Red dots highlight the moments when conflict resolution advisories were issued to the pilot. In all four trials, the pilot successfully followed the advisories to avoid the UAS.

Based on the log files, the aircraft was flying between 63 to 83 kts, or about 33 to 43 m/s. Multiplying the speed and the 50 seconds lookahead time, the distance when the warning sign was first broadcast should be between 1.65 to 2.15 kilometers. However, the recorded warning sign was first given to the pilot when the distance was between 1.45 to 1.60 kilometers. This delay can happen due to a missed message reception during the flight.

The next important measure is the distance at closest point of approach. Of the four trials, the closest distance was 467 meters and the farthest was 838 meters. Although the separation distance was set to 200 meters, the recorded distance at closest point of approach was well above the standard. One key factor is that the device does not provide guidance on when to stop or adjust maneuvers after conflict resolution. Once a conflict is

Figure 4: GA Box showing a warning sign (left), suggested speed while avoiding (middle), and successfully avoiding conflict (right). The polar plot on the left of the screen shows the relative position of the intruder.

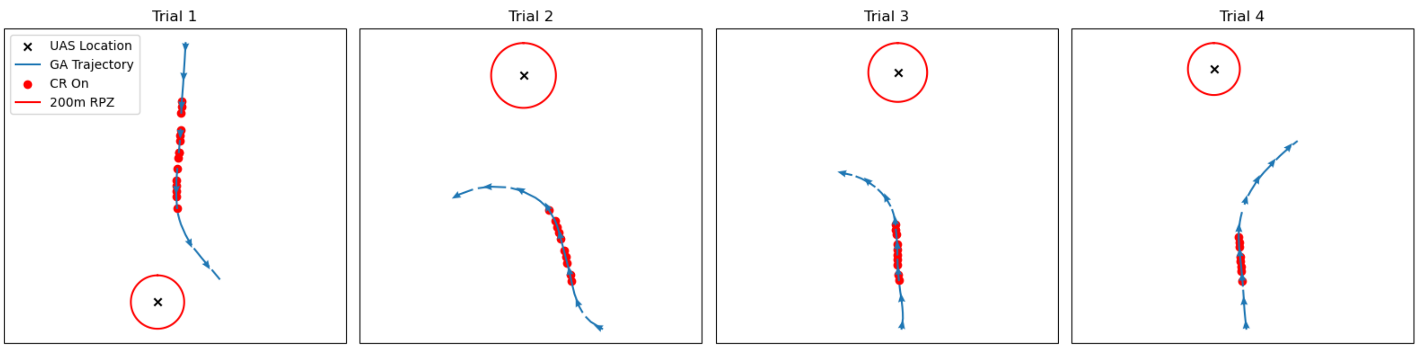

Figure 5: GA aircraft trajectories (blue lines with arrows) and UAS positions (black crosses) during four conflict resolution trials. Red dots indicate advisory issuance, and red circles mark the 200m protected zones. All advisories were successfully followed, ensuring safe separation between the GA and the UAS.

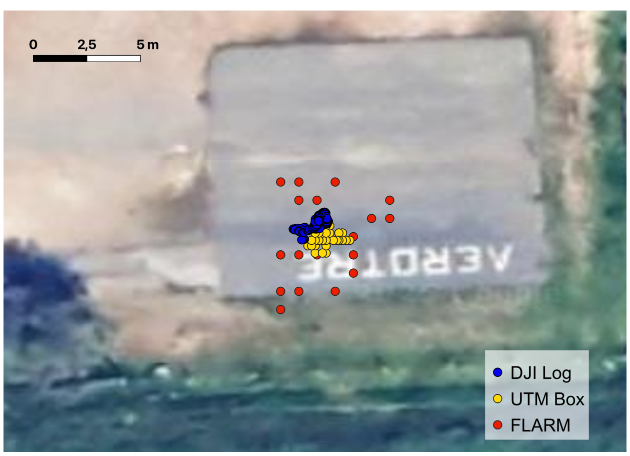

Figure 6: Recorded position from the DJI flight log, the UTM Box, and FLARM as received by the GA device. The values of these observations are close to each other, with offset of 1.2 meters and 2.0 for the UTM Box and FLARM respectively. Base map: Google Satellite. Copyright: © 2025 Google. [Accessed February 2025]

detected, the system prompts an avoidance response, but after the conflict is no longer a threat, the system does not actively guide the aircraft to return to an optimal trajectory that will minimize the distance between the conflicting aircraft but keeping them separated. This leads to these extended avoidance maneuvers, resulting in a larger CPA than required.

Figure 6 illustrates a comparison between the recorded positions from the DJI log, the UTM Box, and FLARM. The figure shows that the recorded position between the three different observations are very close to each other. To assess the performance of those positioning systems, we calculated the standard deviations of their recorded positions. The DJI log demonstrated standard deviations of 0.40 meters along the local x-axis and 0.39 meters along the local y-axis. Then, the UTM Box exhibited slightly larger standard deviations of 0.52 meters (x-axis) and 0.38 meters (y-axis). Lastly, FLARM has the worst, but still reliable measurement with standard deviations of 1.65 meters and 2.65 meters in x and y axis respectively. According to EASA's ADS-L standard reporting, the DJI and UTM Box system achieves horizontal position accuracy within 3 meters, whereas the FLARM accuracy is within 10 meters. Additionally, the offset between the median position of DJI Log and UTM Box is 1.2 meters, while for DJI Log and FLARM is around 2.0 meters.

Figure 7 presents the ground speed and track angle measurements over time. Both parameters remain zero for most of the time, as expected, since the UAS was in hover. However, the presence of sharp, irregular spikes in both plots indicates

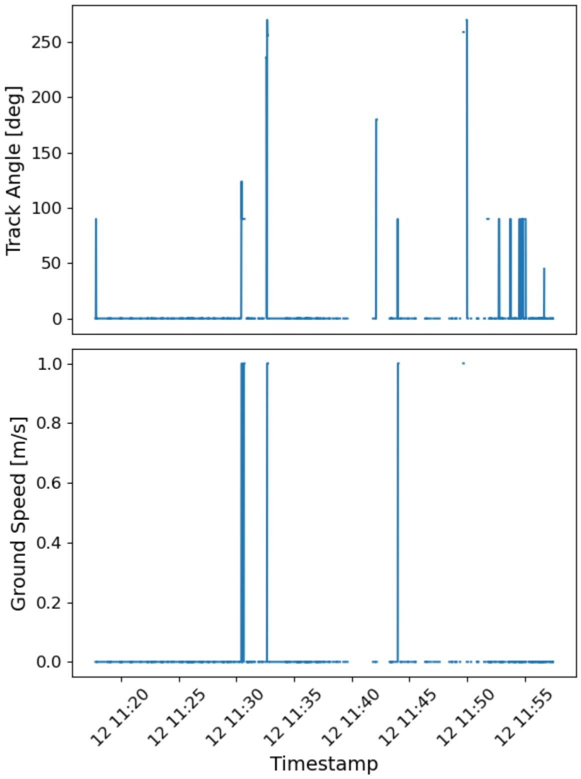

Figure 7: The track and speed recorded from the UTM Box as received by the GA Box

significant noise in the measurement. This noise introduces variability that can affect the effectiveness of the conflict detection and resolution algorithm. To improve the reliability of these measurements, filtering techniques such as Kalman filters can be applied to mitigate the noise and provide smoother, more accurate estimates. The velocity accuracy of this measurement is reported to be < 1 m/s, following EASA's ADS-L standard reporting.

The last reporting of the CNS systems performance is the message reception interval. Figure 8 shows the histogram of message reception interval from the FLARM communication systems. According to the result, 83% of the message is received within 1 second. Then, 12% and 1% of the message is received within 2 and 3 seconds consecutively. However, 4% of the messages are received after 5 seconds, indicating possible blind moments during the operation of the device.

In comparison, Figure 9 illustrates the message reception intervals for internet-based communication. Although this method is not used for conflict detection and resolution in this validation activity, the data provides valuable insights for future applications. For this communication system, 60% of messages are received within 1 second, while 37% arrive within 1–2 seconds. Only about 1.05% of messages are received after 5 seconds. Given the high percentage of messages received within 2 seconds, this suggests that the internet could be a viable option for future communication in conflict detection and resolution.

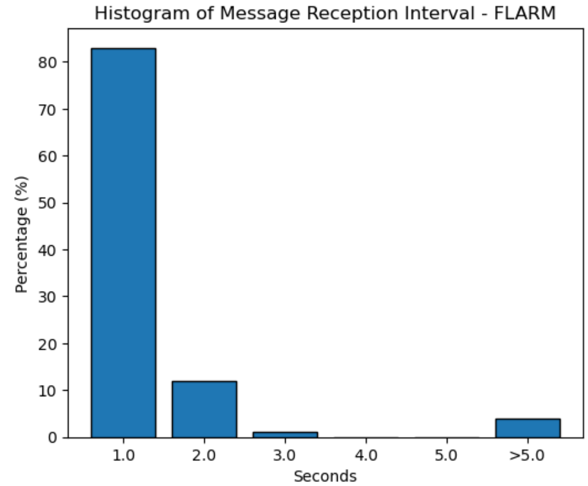

Figure 8: Histogram of message reception interval using FLARM. Around 83% of the transmitted data were received every 1 second. 12% and 1% of the received messages were received after 2 and 3 seconds. Lastly, around 4% of the data were received after more than 5 seconds.

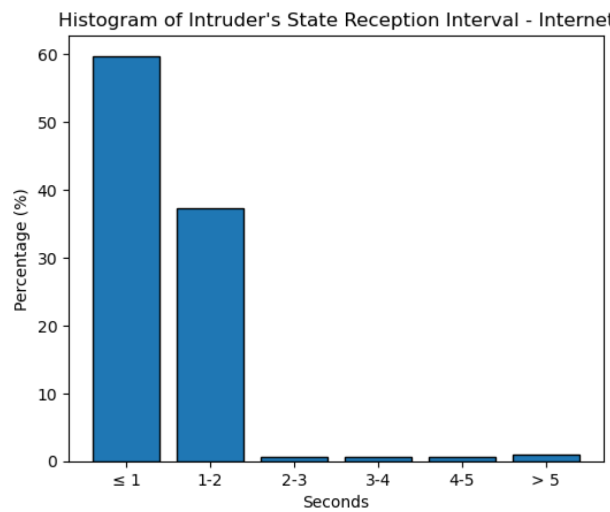

Figure 9: Histogram of message reception interval using Internet. 97% of the messages were received within 2 seconds, with only around 1.05% of the messages were received after 5 seconds.

Although internet-based communication achieves a high percentage of message reception within two seconds, it relies on ground infrastructure for connectivity, which may not always be available or reliable in remote areas. In contrast, radio-based communication operates independently of external networks, enabling direct device-to-device connections that are more resilient in infrastructure-limited environments. However, bandwidth availability also plays a crucial role in both methods. As traffic density increases, radio communication may experience greater interference due to frequency congestion, while internet-based communication may suffer from network delays or packet loss. These factors highlight the trade-offs between the two approaches, furhter highlighting the importance to consider operational constraints when selecting a communication method for CNS applications.

V. Conclusion and Future Works

This study evaluated the performance of the CERTIFLIGHT UTM Box in enhancing e-conspicuity and conflict detection and resolution (CD&R) for General Aviation (GA) and Uncrewed Aerial Systems (UAS) encounters. The flight validation tests demonstrated the system's capability to provide real-time conflict advisories, improving situational awareness and assisting pilots in maintaining safe separation. However, several operational challenges were identified, including navigation uncertainties in reported position and velocity, along with communication delays exceeding five seconds, which could impact the reliability of separation management. Despite these limitations, the CERTIFLIGHT UTM Box showed potential for improving airspace safety by integrating GNSS-based tracking and CD&R advisories within U-Space operations.

The findings highlighted the importance of accounting for Communication, Navigation, and Surveillance (CNS) uncertainties in conflict detection and resolution algorithms. The implementation of state-based CD&R strategies using the Velocity Obstacle method proved effective in ensuring safe separation, but extended avoidance maneuvers were observed due to a lack of system guidance on post-resolution trajectory adjustments. Additionally, pilot feedback suggested that the user interface could be optimized for more intuitive and rapid decision-making. These insights provide valuable input for refining e-conspicuity solutions and conflict resolution frameworks for future U-Space operations.

Future work will focus on several key areas to improve the reliability and usability of the CERTIFLIGHT UTM Box. First, improvements to the user interface will be prioritized, including larger warning displays and simplified resolution advisories to facilitate rapid pilot response. Additionally, the integration of advanced filtering techniques, such as Kalman filters, will be explored to mitigate measurement noise and improve the accuracy of position, velocity, and track data. On top of that, streamlining the information to rely on a single GNSS system and sharing data via internet-based communication could improve overall performance by reducing message delays and improving data reliability. Given the findings on message reception intervals, internet-based communication could serve as an alternative or complementary approach to FLARM, particularly in areas with sufficient network coverage, to ensure more reliable conflict resolution messaging. Further studies will evaluate the feasibility of this approach and its impact on U-Space operations.

Another area of development will involve refining CD&R algorithms to incorporate CNS uncertainties more effectively. This includes optimizing the lookahead time and protected zone radius to account for real-world variations in navigation and communication performance. Lastly, further flight tests will be conducted in more complex airspace environments to assess system performance under high-traffic conditions. These evaluations will examine the scalability of the CERTIFLIGHT UTM Box and its ability to function reliably in denser operational scenarios. Additionally, the feasibility of using internet-based communication as an alternative for conflict resolution messaging will be investigated, given its demonstrated potential in message reception reliability. Through these advancements, the CERTIFLIGHT system aims to provide a robust, scalable solution for safe and efficient U-Space integration of GA and UAS operations.

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