33RD CONGRESS
OF THE INTERNATIONAL COUNCIL
OF THE AERONAUTICAL SCIENCES
STOCKHOLM, SWEDEN, 4-9 SEPTEMBER, 2022

ICAS 2022 SWEDEN

OVERVIEW OF JAXA AND NASA COLLABORATION ON MANNED AND UNMANNED AIRCRAFT OPERATION INTEGRATION IN DISASTER RESPONSE

Adriana Andreeva-Mori[1], Jeffrey Homola[2], Marcus Johnson[2], Keiji Kobayashi[1], Yoshinori Okuno[1], Parimal Kopardekar[2]

[1]Japan Aerospace Exploration Agency (JAXA), Mitaka, Tokyo, 181-0015, Japan
[2]NASA Ames Research Center, Moffett Field, CA, 94035, United States of America

Abstract

Natural disasters have increased in frequency and intensity. With that increase has come an increased focus on improving disaster response efforts. As part of this focus, the Japan Aerospace Exploration Agency (JAXA) and the National Aeronautics and Space Administration (NASA) have been in collaboration since 2016 to explore improved airspace management for disaster response through the integration of manned aircraft and small Unmanned Aircraft Systems (UAS). The approach to this integration has been through leveraging JAXA's Disaster Relief Aircraft Information Sharing Network (D-NET) system for the coordinated management of manned aircraft assets combined with NASA'S UAS Traffic Management (UTM) system for the management of UAS assets. To drive the innovation in improved response, JAXA and NASA have successfully connected respective systems and conducted a series of live flight tests first as part of a large-scale disaster drill and later in dedicated research flights. In each case, the D-NET and UTM systems were connected and exchanged data in real-time, which supported the planning and tracking of manned and unmanned operations. Through these test events, a number of key findings were derived through data analysis and stakeholder interviews with respect to the improvements offered by the integrated systems as well as key considerations for situation awareness of pilots regarding other operations in the airspace and flight path management.

Keywords: disaster response, UTM, helicopter mission, system integration, information exchange

1. Introduction

The prevalence and severity of natural disasters has greatly increased over recent decades due to global warming and climate change. The increased occurrences of tropical storms, earthquakes, tornadoes, and wildfires have produced devastating global impacts to economies, wildlife and vegetation, infrastructure, and resulted in substantial loss of life. In 2018, the National Oceanic and Atmospheric Administration (NOAA) released the Fourth National Climate Change Assessment report that concluded that there had been at least 44 weather and natural disaster events that cost over a billion dollars each and the United States had incurred costs of over 400 billion dollars between 2015-2018 as a result of the disasters [1]. NOAA also reported an overall increase in the frequency, severity, and costs of natural disasters in the United States over the years [2].
Disaster events are certainly not isolated to the United States, however. With Japan being a very earthquake-prone country, the impact of natural disasters and the need for fast and efficient response have been demonstrated by numerous actual relief operations [3], [4]. The Great East Japan Earthquake in 2011 and Kumamoto Earthquake in 2016 were the most recent large-scale disaster examples which required coordinated aircraft operations in both immediate and longer-term response.

During disasters, damaged infrastructure often prevents ground vehicles from accessing geographic areas. To facilitate an effective response, disaster operations often rely on aircraft for reconnaissance, search and rescue (SAR), and supply delivery missions. Large-scale disasters require the coordination of multiple air assets and ground-based resources for safe and efficient response operations. Until recently, only manned aircraft needed to be coordinated for mission assignments and flight planning. Despite emerging research on the topic [5], this process can prove onerous given that few decision-support systems have been developed and implemented in practice. The existing process of coordinating mission assignments and flight planning limits illustrates a challenge in increasing the number of missions and integrating new types of technologies such as unmanned aircraft systems (UAS). Recent technology advances have led to increasing use of UAS in post-disaster relief operations to support or replace manned operations for: reconnaissance, SAR, and supply deliveries [6]-[9]. Over the years, the use of UAS in support of disaster response efforts has progressively become a more accepted practice. For example, during Hurricane Katrina in 2005, the southern United States experienced severe flooding [10] and deployed small UAS (sUAS) to the areas affected by the storm to support search and rescue operations, reconnaissance, and damage inspection [11]. The use of small UAS has only increased over the years as their utility and benefits have become more widely recognized.

While UAS have been gaining popularity in their application to disaster management, the further integration of UAS into operations is limited by several factors: (1) Regulatory restrictions preventing access to airspace, (2) ensuring safety and privacy, and (3) challenges optimizing data capture and translating aerial data into decision making [12]. Furthermore, in disaster and emergency response situations, the use of manned aircraft assets is often a key component of an effective response strategy. However, the inclusion of UAS at low altitude in emergency response operations where current high-density visual flight rules (VFR) disaster aircraft operations exist, pose considerable challenges for pilots and response coordinators. For example, pilots in these environments currently rely on visuals and voice communication to support deconfliction from other aircraft. However, UAS are not easily acquired visually from a flight deck and therefore would cause considerable increase in the risk of midair collisions and a loss of situation awareness during response operations due to increased uncertainty.

Since 2016, the Japan Aerospace Exploration Agency (JAXA) and National Aeronautics and Space Administration (NASA) have partnered to investigate and address the challenges related to the safe and efficient integration of UAS in disaster relief operations. JAXA has been developing “Disaster Relief Aircraft Information Sharing Network (D-NET) ", a solution for safe and efficient integrated aircraft operations. Due to the advancement in UAS technologies, public safety organizations have started incorporating small UAS as an asset in their disaster response activities. In the United States, the National Aeronautics and Space Administration (NASA), under the UAS Traffic Management (UTM) Project, has been engaged in research to enable large-scale commercial applications of sUAS operating in low altitude airspace. The collaborative inter-agency work has focused on the integration of the D-NET and UTM systems through simulation and testing with results and lessons learned that highlight an example solution with benefits to disaster response and more broadly to civil operations as well.

2. Background

The following presents an overview of the mission focus areas as they relate to the technical collaboration between JAXA and NASA with highlights of the key findings and future directions for further UAS integration into disaster response operations.

2.1 Manned and Unmanned Disaster Response Operations

Disaster response often involves a wide variety of aircraft assets from different organizations such as the military, firefighting agencies, medical agencies, and the media. During disaster response operations in the United States and Japan, most aircraft operate under visual flight rules (VFR), which requires the pilot to see and avoid other aircraft and operate under visual meteorological conditions (VMC) to avoid collisions with terrain and ground obstacles. The need for VFR operations, as opposed to operating under instrument flight rules (IFR), is because a large portion of disaster response aircraft assets are helicopters that are not properly equipped for IFR operations and disaster response involves uncertainties during the mission that require the pilot to make on-the-fly assessments and course corrections. To this end, operations under VFR have a higher degree of flexibility to adapt to the needs of the response mission and can more easily deviate from a flight plan than operations under IFR. In addition, operations under VFR benefit from the pilots’ ability to see and avoid other aircraft, which can support more aircraft operating in a target area. However, see and avoid can be problematic to the coordination between manned aircraft and UAS. The risk of collision is increased when manned operations fly in low altitude airspace where the integration of UAS is most prevalent.

In this research, three mission types were considered in the evaluation of coordination between manned and unmanned systems: 1) Point-to-point movement (transfer), 2) Reconnaissance, and 3) Search and rescue (SAR).

1) *Point-to-point movement*: Point-to-point flight segments can be controlled either manually or by the helicopter's autopilot. Manual control is preferred when the target point is near and is visible (up to 2.5 nm ahead on a clear day). Pilots often use major landmarks such as mountain peaks (e.g., Mt. Fuji, Mt.Tsukuba, etc.) when the target is relatively far and switch to smaller landmarks (e.g., towers, factory chimneys, etc.) as they get closer. The pilot may use the flight director to aid in navigation as well. Control by an autopilot requires a pre-programmed set of waypoints and is therefore often used in the initial and final segments of the flight. Few deviations from the route are expected during point-to-point operations, so the lateral allowance of the operation volume often is relatively small.
2) *Reconnaissance*: Reconnaissance missions are essential for fast and efficient disaster response. Right after the disaster, no information on the damage and rescue needs is available. In particular, information on ground infrastructure (e.g., road and railroad conditions, bridges, etc.) and the extent of flooding and landslides are crucial for efficient and timely resource and personnel allocation. Flights performing reconnaissance missions have more uncertainty regarding the intended flight path and, therefore, are not as static as point-to-point movement operations. During flight, detailed observation by the pilot might require route deviations and longer time to examine the damage and confirm the number of evacuees. Unlike point-to-point movement, the flight control is manual only. According to pre-flight interviews with disaster responders, the pilot often navigates by tracking landmarks such as rivers, bullet train lines, and highways. Flying along a landmark offers a high level of stable positional awareness. Therefore, for reconnaissance missions, operation volumes were defined to follow geographic landmarks.
3) *Search and rescue*: The third disaster relief mission modeled is the search and rescue (SAR) of victims. The search is usually initiated after information on the victim's approximate location is received at the disaster operation center. Therefore, a typical flight pattern consists of circling around the expected victim's location gradually expanding the radius until the victim is visually identified. The rescue depends on the terrain and helicopter equipage- the helicopter can either land to pick up the victim or send rescue personnel to hoist the victim if landing is not safe. During hoist, the helicopter hovers over the victim's location. Once the victim is on board, they are transported to a safe location; often to a nearby evacuation point or field.

In contrast to the missions and characteristics of manned aircraft such as helicopters, small UAS will typically operate below 400 ft AGL, typically will have flight durations that span between 5 – 30 minutes and will have frequent take-offs and landings. While UAS also support point-to-point movement, reconnaissance, and SAR missions, they often operate using prescribed waypoint navigation and are less likely to have frequent deviations from their prescribed route. Given the challenge of visual acquisition of UAS by manned aircraft [13] and the predictable nature of UAS operations, this research explores the coordination between manned and unmanned systems by the sharing of operational intent through the UAS Traffic Management (UTM) system.

2.2 UAS Traffic Management (UTM)

The objectives of UTM are to enable a safe and scalable approach to support the use of small UAS operations at low altitude, providing flexibility in use of the airspace where possible and structure where necessary. An architecture was developed to support UTM operations (see Figure 1), and, along with the concept, the integration of public safety entities and their operations into the UTM ecosystem has been a focus of research throughout NASA's UTM Project and beyond. The UTM technology development and assessments focused on a common situation awareness display, airspace deconfliction, operation prioritization, and coordination of dynamic changes to operation intent. These capabilities support the extension of the UTM concept and technologies to disaster response efforts and provide the necessary coordination and situational awareness to facilitate a more efficient response.

One extension of UTM useful in addressing is the ability to optimize–at scale–planned trajectories and operational areas with real-time input to the operator/manager regarding the current and planned state of the airspace. This extension not only benefits airspace management in disaster response, but it also potentially provides a framework that would benefit other related areas such as Advanced Air Mobility (AAM).

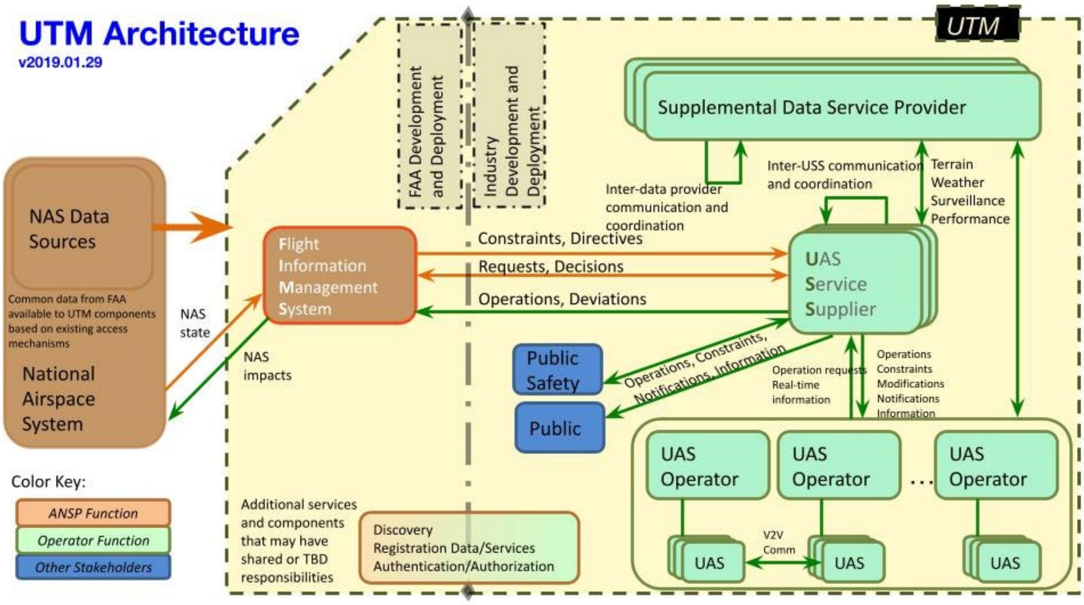

Figure 1 - UTM Architecture (note the Public Safety component in blue)

2.3 Disaster Relief Aircraft Information Sharing Network (D-NET)

As a means to increase aircraft safety and mission efficiency during disaster response, the Japan Aerospace Exploration Agency (JAXA) has developed the Disaster Relief Aircraft Information Sharing Network (D-NET). First, to speed up data acquisition and reduce the errors during voice transmissions when assigning missions, JAXA developed a system for real-time data transmission. The system enables a real-time connection between the pilot of a disaster relief aircraft and a ground server (more details can be found in [14]). Based on that foundation, integrated operation technologies have been developed. The technology objectives are to acquire data efficiently from available sources (e.g., satellites, helicopters, and unmanned aircraft systems), analyze these data in order to provide optimal resource allocation and flight trajectory plans for response vehicles, which can in turn be integrated and applied in actual rescue operations. The system overview is shown in Figure 2. The system has three main blocks: 1) data/information acquisition block, 2) optimal planning block and 3) operation execution block. D-NET optimizes the performance of each vehicle by assigning missions according to the vehicle's equipage, state and location. In terms of UAS applications, D-NET plans and assigns data acquisition missions to UAS to spare resources from the manned aircraft fleet so that more helicopters can be assigned to rescue missions.

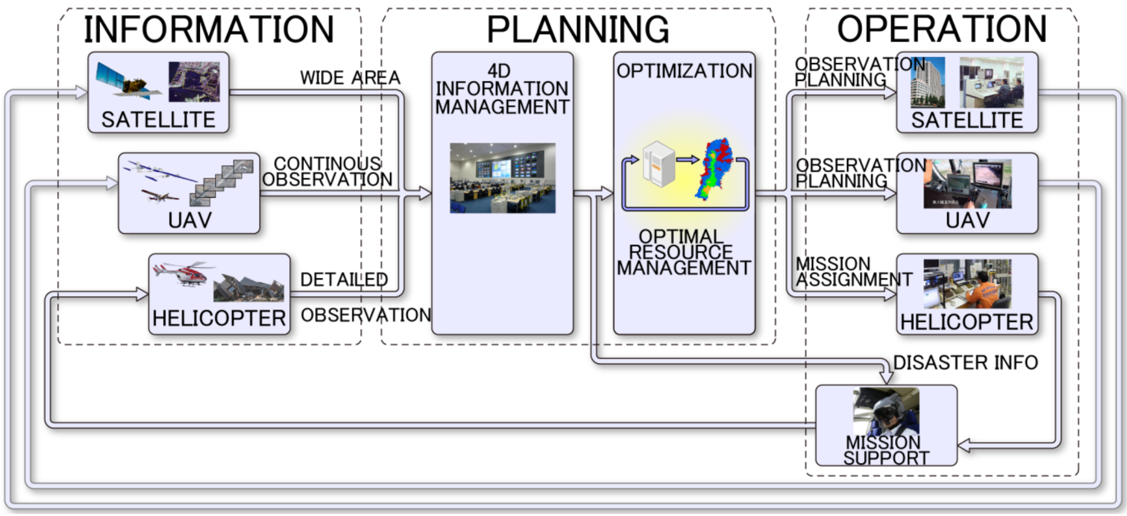

Figure 2 – D-NET System Blocks

3. D-NET and UTM Integration

The integrated system between JAXA's D-NET and NASA's UTM has been focused on the safe and efficient use of UAS in immediate post-disaster relief operations by leveraging the complementary capabilities of the respective systems. The integrated manned and unmanned operations that serve as the focus of this research consist of pre-flight and in-flight interactions that address technical challenge associated with strategic deconfliction and tactical situation awareness. In the configuration of integrated D-NET and UTM systems, mission assignments and planning are performed in D-NET. Thus, all mission trajectories are generated within D-NET as well. Each UAS flight plan is essentially a trajectory, made of multiple line segments defined by the 4D coordinates of its edges. Based on the received mission trajectories, UTM checks that safety constraints are met and provides operational volumes back to D-NET. The operational volumes represent a buffer around the mission trajectory to help safely separate it from other operations and airspace constraints. These operational volumes are used to strategically deconflict with other operations before departure and are also used to monitor conformance of the aircraft during flight. D-NET visualization tools used by the command centers and UAS operators were notified to include the operational volumes received from UTM. Note that UTM's operational volume generation logic is not communicated to D-NET, nor is the logic according to which missions are generated in D-NET conveyed to UTM. Both systems treat each other as black boxes, which makes the entire integration concept flexible to variations and valid even when either of the systems updates its internal algorithms.

3.1 Considerations for Integrated Operations in D-NET/UTM

Helicopter operations are conducted under visual flight rules (VFRs), which often results in large deviations from the original flight plan that the pilots use only as a reference. This contrasts with UAS operations, which are prescriptive and have a greater degree of navigation precision. In the context of disaster response, UTM's design is uniquely suited for support UAS operations. Therefore, the integration of D-NET and UTM had to assume the need for large buffers for the operational volumes that define operational intent to account for large variability in flight paths of VFR piloted operations.

Additionally, current disaster relief practices prioritize manned over unmanned aircraft operations. To accurately model such practices, the helicopter's operation plan within UTM is assigned a priority status and its operation plan is prioritized over other UTM operations. During preflight planning or during an operation, if a priority user has an operation plan that conflicts in time and/or space with a planned or existing operation of lower priority, then the lower priority mission will be notified to modify their plans to resolve the conflict. UTM facilitates the verification of conflict-free operation plans and the notification of conflicts to all affected parties as part of its strategic deconfliction functionality. Operators with lower priority who plan missions that conflict with a priority user will be notified that UTM cannot accept their operation when the conflict exists with the priority user.

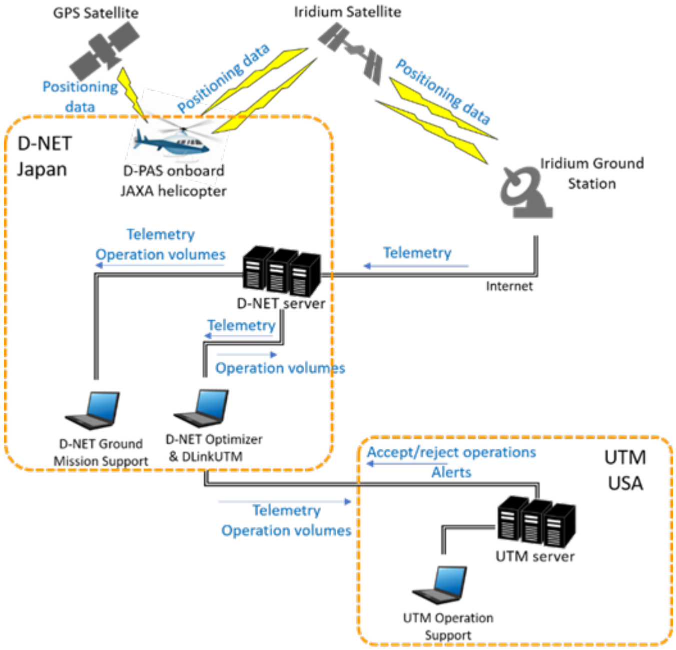

Figure 3 – D-NET and UTM Integration Data Flow

3.2 Integrated System Architecture

Figure 3 presents the architecture and information flow of the integrated D-NET/UTM system. All information exchanges between D-NET and UTM were established through DLinkUTM, which maintains concurrent connections to D-NET servers and UTM. In this collaborative research, the UTM system was hosted from servers at NASA Ames Research Center in California whereas the D-NET system was hosted from JAXA servers in Japan. Operator interfaces and visualizations of airspace operations that took advantage of the integrated system interactions to provide information on the vehicle's ID (e.g., UAV1, UAV2, etc.), the UTM state of the operation (ACCEPTED for a flight plan been accepted by UTM, REJECTED, CANCELLED, etc.), the Globally Unique Flight Identifier (GUFI), location of all operations in the airspace, and visualization of operation volumes for each flight. The integration of D-NET and UTM, therefore, provided for a common operating picture available to the pilot of the manned aircraft and the remote pilot of the UAS to ensure that there is situation awareness of operations within the airspace that may conflict with a current or future missions.

4. Prior D-NET and UTM Integrated Testing

Several D-NET/UTM integrated flight campaigns were conducted to test and verify the manned-unmanned aircraft integration using both systems. The first major flight test was conducted as part of a large-scale disaster drill in Ehime Prefecture, Japan in 2018 [15]. In this flight test, integration was demonstrated at both planning(pre-flight) and in-flight stages. The flight involved a helicopter and two UASs. Both manned and unmanned vehicle mission assignments and trajectory generations were done in D-NET. The generated UAS trajectories consisting of multiple time-constrained line segments were submitted to UTM. Based on the received UAS trajectories, UTM confirmed that safety constraints were met and sent operation volumes back to D-NET. Helicopter operations, however, were visual flight rules (VFR) operations, and their plans were submitted to UTM not as line segments, but as relatively large operation volumes. User priority was also taken into account to reflect current disaster relief practices which prioritize manned over unmanned aircraft operations. Flight plan modifications were also executed and communicated successfully to the ground support systems. In the test, D-NET delivered optimal route planning for UAS disaster relief operations, and UTM enabled the resolution of potential airspace conflicts while providing tracking and UAS operator situational awareness. Connecting two remote systems (D-NET and UTM) in real time validated the mobility of the concept. It was the first time to have a manned aircraft as a planned operation in UTM, a demonstration of concept and technology which went very successfully. This first test, however, highlighted the potential and challenges of manned operations integration in UTM environment, and this motivated the second major flight test, conducted a year later in December 2019.

The second flight test was conducted using JAXA's research helicopter [16] to examine the concept of mission-information-based design of operation volumes when applied to manned flight operations under VFR within a D-NET and UTM-integrated environment. The flight test simulated point-to-point movement, reconnaissance, and SAR missions and designed volumes based on typical flight patterns indicated by pilots in their interviews preceding the flight test. Test results and pilot feedback suggest that the approach taken to operation planning may have helped the pilots maintain conformance with their operation volumes [17].

The above flight tests led to several key findings, described below.

5. Key Findings

Prior flight testing primarily looked at the interactions between the UAS operator, helicopter operator, and the D-NET and UTM systems. The testing was intended to inform how UAS can be integrated safely into the disaster response aircraft operation workflow using mission planning and airspace management automation technologies. In addition, it explores how best to inform the UAS operator and the helicopter operator of potential conflicts in the airspace, given the distinctly different nature of how their operations are conducted. This following are key findings from the prior flight testing and observations from the helicopter pilots on value and limitations of sharing operational intent during disaster response:

Key Finding 1): During pre-departure, the timeliness of information sharing using D-NET/UTM was a clear improvement over the existing workflow. The raised awareness of existing and planned operations allowed UAS operators, helicopter operators, and the Operations Center to have visibility into the intent of other missions, and when these missions are expected to start and end to facilitate more efficient strategic planning.

Key Finding 2): Communication between D-NET and UTM was effective in providing sufficient and timely information exchange for disaster recovery support. Flight planning is crucial for efficient disaster relief, and this collaborative test demonstrated that UTM and D-NET can be used for both strategic and tactical planning. The immediate response from UTM, the ability to replan operations using D-NET, and a common operating picture shared by all the relevant users enabled a more adaptive response to changes occurring due to an evolving disaster response.

Key Finding 3): A helicopter pilot spends significant time looking out the flight deck windows, and it would be impractical to actively track their conformance to a UTM volume with a heads-down display. The display of operational volumes on a supplementary screen such as D-NET's mission support system or on a set of paper instructions that might require significant head-down time could be a potential limitation to the implementation of this technology. However, the pilot indicated that they have sufficient awareness of their position during operations. So, in most cases, occasional checks of their relative position with respect to their assigned operational volume would be sufficient. The incorporation of heuristic landmarks into the operation volume definitions would reduce the likelihood of conformance violations of the VFR operations as it more closely mimics the flight behavior of the pilots. Future work is needed to assess more automated replanning and human factors assessments around how information can be provided to a pilot in an effective way that does not distract from their existing tasks and provide information in intuitive ways corresponding to geographic references rather than flight paths.

Key Finding 4): Helicopter pilots preferred to be alerted to the presence of UAS at distances within 3–5 km (3–5 min) before a predicted conflict. These distances would allow for approximately 5 min of lead time that would assure that the pilot has sufficient time to plan contingency actions in case a conflict occurs. Regardless of UAS behavior, the pilot will take actions to avoid encounter no later than 1 min before the predicted collision. If the pilot can look at D-NET's mission support tool onboard, they will use D-NET/UTM information along with visual confirmation to identify the position of the UAS. The pilots reported that during all disaster response mission stages (preflight and during flight), they would need information on planned and active UAS missions. Knowledge of the UAS location and mission type would further aid their awareness and decision making. In disaster response, knowing the UAS mission type helps the helicopter pilot predict the UAS intended mission and expected behavior. Given that UAS are difficult to visually acquire from the flight deck, The D-NET/UTM tools can help a pilot reduce the search time necessary for locating the UAS given the operation information provided through the D-NET/UTM technology.

Key Finding 5): Landmark-based operational volumes to define intent for helicopter pilots reduced non-conformance but further exploration of VFR pilot tools is needed to provide more flexibility for VFR operations with heavy workload. During the flight testing, the helicopter pilots noted that given more intuitive landmark-based operation volumes that aligned with their typical flight path behavior they were able to adhere to mission time constraints to maintain UTM conformance fairly easily due to their experience in making speed adjustments to meet mission time constraints. This experience contributed to the success of adhering to the flight plan and expected arrival time. However, for instances in which they were spatially out of conformance, the pilot's workload did not permit looking at a heads-down display. Therefore, alternative means such as auditory cues, heads-up or wearable displays, or automated operational intent modification should be explored in future work to reduce the added workload on helicopter pilots, provide additional flexibility for changing mission intent "on-the-fly," and providing improved situation awareness for both helicopter pilots and UAS operators.

6. Concluding Remarks

The disaster response domain has experienced an increased focus in recent years. As part of this focus, JAXA and NASA have been collaborating on the integration of manned and unmanned aircraft in support of disaster response operations through integrated testing of their respective mission planning and optimization system (Disaster Relief Aircraft Information Sharing Network, or D-NET) and a UAS Traffic Management (UTM) system. Past flight test indicated that remote systems like D-NET and UTM can connect to aid safe and efficient integration of manned and unmanned aircraft operations in disaster response missions.

7. Contact Author Email Address

The contact author email address is andreevamori.adriana@jaxa.jp.

8. Copyright Statement

References

[1] USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

[2] Billion-Dollar Weather and Climate Disasters: Overview, National Oceanic and Atmospheric Administration https://www.ncdc.noaa.gov/billions/ (last visited Dec.10, 2021)

[3] National Police Agency Emergency Disaster Security Headquarters of Japan, “Damage Statistics and Police Activities for 2011 Tohoku earthquake,” 2018. URL: https://www.npa.go.jp/news/other/earthquake2011/pdf/higaijokyo.pdf (in Japanese)

[4] Emergency Response Office, Fire and Disaster Management Agency of Japan, “The 2016 Kumamoto Earthquake, Report No. 114,” 2018. URL: http://www.fdma.go.jp/bn/4dcd38fac5307f09c2f45e0016c29a56c35a0501.pdf (in Japanese)

[5] L. Ozdamar, "Planning helicopter logistics in disaster relief," OR Spectrum , vol. 33, no. 3, p. pp 655–672, 2011.

[6] Murphy, R. R. (2019). Use of Small Unmanned Aerial Systems for Emergency Management of Flooding [techbrief] (No. FHWA-HIF-19-019). United States. Federal Highway Administration.

[7] Quirk, B., & Haack, B. (2019). Federal government applications of UAS technology. In Applications of Small Unmanned Aircraft Systems (pp. 81-113). CRC Press.

[8] S. Adams and C. J. Friedland, "A Survey of Unmanned Aerial Vehicle (UAV) Usage for Imagery Collection in Disaster Research and Management," in 9th International Workshop on Remote Sensing for Disaster Response, 2011

[9] Terra Drone, "Terra Drone Disaster Management," [Online]. Available: https://www.terra-drone.net/angola/domains/disaster-management/.

[10] Use of Small Unmanned Aerial Systems for Emergency Management of Flooding,” U.S. Department of Transportation Federal Highway Administration, 2019, https://www.fhwa.dot.gov/uas/resources/hif19019.pdf

[11] Murphy, R., “Drones Save Lives in Disasters, When They’re Allowed to Fly (Op-Ed),” Sept. 2015, https://www.space.com/30555-beginningwith-katrina-drones-save-lives-in-disasters.html

[12] Vincenzi, D., Ison, D. C., & Terwilliger, B. A. (2014). The Role of Unmanned Aircraft Systems (UAS) in Disaster Response and Recovery Efforts: Historical, Current and Future

[13] G. Woo, D. Truong, and W. Choi, "Visual Detection of Small Unmanned Aircraft System: Modeling the Limits of Human Pilots.," Journal of Intelligent & Robotic Systems, pp. 1-15, 2020

[14] Okuno, Y., Kobayashi, K., & Ishii, H., Development of a helicopter operations management system for disaster relief missions. Journal of the Americal Helicopter Society, 61(1), 1-9, 2016

[15] Andreeva-Mori, A., Kubo, D., Kobayashi, K., Okuno, Y., Homola, J., Johnson, M., & Kopardekar, P. (2021). Operational testing of unmanned aircraft system traffic management in disaster response. Journal of Air Transportation, 29(4), 160-170.

[16] JAXA, "JAXA's Research Helicopter," [Online]. Available: http://www.aero.jaxa.jp/publication/pamphlets/pdf/heli.pdf.

[17] A. Andreeva-Mori, K. Ohga and K. Kobayashi, "Reconnaissance Mission Flight Modeling for Strategic Planning of Manned and Unmanned Vehicle Integrated Disaster Response," in The 40th Digital Avionics Systems Conference, San Antonio, Texas, 2021.