FLIGHT SAFETY FOUNDATION

Looking to the Future: Safety System Needs for Humanitarian UAS Operations

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1. Introduction

Unmanned aircraft systems (UAS) continue to expand the effectiveness and outreach of humanitarian and public organizations that provide disaster management and first responder services around the globe. Flight Safety Foundation recently reviewed these operations and postulated how use of autonomous and semi-autonomous UAS would be employed in the future. We looked at a number of humanitarian scenarios to better understand the current and future safety risk management needs for these operations to better inform near- and long-term planning for the safety systems that will allow these operations to evolve in both scope and complexity.

As operations grow, the safety community is looking at ways for safety systems to evolve with respect to scalability, new operations and diverse platforms, as well as increasing the emphasis on proactive safety risk management. With the expanding development of cloud-based information access and sharing and the continued emphasis on a just, safety-based approach, there is an opportunity to enable real-time, proactive risk monitoring, assessment and mitigation. This stands in contrast to current forensic, after-the-incident safety analyses. The future system will need to be scalable, supporting operations ranging from single unmanned or manned aircraft operating short missions to much larger and more complex multi-UAS missions flown in coordination with various manned vehicles operating closely with one another in shared airspace.

As a first step to better understand the future needs for safety management and for the future needs associated with delivery of UAS traffic management (UTM) safety-related services, we looked at several humanitarian scenarios involving UAS and a UTM infrastructure to better capture the data needs and to help inform research on the needed services, functions and capabilities associated with assessing the data to manage risks. Section 2 captures the scenarios, while Section 3 describes the methodology we used to postulate future data needs, and our initial results. For more information on the analysis performed and the methodology, contact Flight Safety Foundation.

2. Humanitarian Scenarios

The Foundation has developed three scenarios with the help of groups including UAS, regulatory, humanitarian and other relevant subject matter experts. While we set these scenarios in the United States, they are applicable internationally. The scenarios address post-natural disaster response, wildfire fighting, and urban medical equipment delivery. These scenarios were selected from a larger set, based on feedback from a number of representatives of humanitarian organizations, who felt that they were representative of the types of operations needed in a majority of disaster management and first responder operations. Varying time frames were assigned to each scenario, allowing us to postulate the needs in a future, more capable environment. We also assume the response structure as defined by the U.S.

Federal Emergency Management Agency (FEMA) National Incident Management System (NIMS) and the Incident Command System (ICS). This structure is a good model outside of the United States, as well.

2.1. Post-Natural Disaster Response

Our post-natural disaster response scenario looked at a post-hurricane response in severe flooding conditions with limited communication and infrastructure consistent with a 2023–2025 time frame. The events and needs for this scenario also apply to many other post-event natural disasters such as earthquakes, mudslides, tornadoes and more. After the hurricane has decayed, humanitarian organizations are on site, employing visual line of sight (VLOS) and beyond visual line of sight (BVLOS) UAS flights to identify people in need of help, document damage and assist emergency responders in allocating resources. Much of the population has evacuated the area, leaving fewer than 100 people per square mile. In addition to the humanitarian organizations, several media organizations are also submitting requests to fly their drones within the temporary fight restriction (TFR) airspace that has been established over the affected area (Figure 1).

There is significant infrastructure damage, and direct UTM use is limited to authorized local UAS operators. Due to the presence of multiple missions and organizations, an “air boss” is responsible for airspace coordination and planning.

Figure 1. **Multiple organizations are on site, with minimal coordination capabilities or access to UTM services to coordinate their UAS operations.**

2.2. Wildfire Fighting

Our wildfire fighting scenario takes place in the 2025 time frame during summer in northern California, along the coastal mountain range. This scenario occurs in a remote location and utilizes a variety of complex manned operations to respond to the situation. This large-scale firefighting scenario can also be applied to other similar large rescue response efforts that use fixed-wing and swarm drone operations alongside complex manned aircraft operations in shared airspace. At the time this scenario takes place, the initial fires have not been controlled and are spreading into neighboring counties, and in one area of national forest, two fires have joined to become one large fire. Small fires are being discovered throughout the firefighting effort (Figure 2).

The local fire department has deployed a swarm of commercial off-the-shelf fixed-wing drones for BVLOS flight to monitor and identify areas upon which to focus operations. UAS are being used to support firefighter beacon location transmission. This is coordinated around a C-130 tanker actively dropping fire retardant and a manned helicopter that is transporting personnel and supplies to and from the operations. During the night, remote pilots are conducting operations to maintain situational awareness on the spread and locations of the multiple fires. The air boss fills aircraft management and coordination needs, but all users continuously share information with one another and the larger aviation network.

Figure 2. **Complex air operations involving both UAS and traditional manned aircraft are coordinated to monitor fire progression, track firefighter locations and deliver fire retardant.**

2.3. Urban Medical Equipment Delivery

Our urban medical equipment delivery scenario looks at long-term (for example, 2030) urban airspace operations in complex and dense airspace. The city center is under Class C controlled airspace. The operational objectives are to maintain airspace safety while aircraft are rerouted and navigated. Unmanned vehicles need to yield right of way to manned aircraft and advanced autonomous vehicles carrying passengers. With the complexity of this environment, we look at what onboard fail-safe operations might look like during this scenario (Figure 3).

The scenario starts when a medical emergency is called in at a park and an unmanned aerial vehicle (UAV) is deployed carrying a defibrillator to the scene. While in flight, the UAV is rerouted around a helicopter. After executing the reroute, it loses its connection to the ground station; preset onboard fail-safe procedures then go into effect, allowing it to continue the mission. Two advanced air mobility (AAM) vehicles are in the vicinity, and the UAV directly receives route amendments from the UTM service network to ensure adequate separation from the AAM vehicles. Later, a command-and-control connection to the UAV is restored with the operator's ground control station, and the mission is completed without further incident.

Figure 3. **UAS carrying critical medical equipment operate in a complex urban environment that includes autonomous operations and low-altitude manned flights.**

3. Identifying Data Needs for Humanitarian UAS Operations

As UTM services are developed, the unique operating environments and conditions in which UAS are deployed will add additional requirements beyond traditional flight services to allow full realization of these benefits. Through these humanitarian scenarios, the Foundation conducted an initial assessment of the services that will likely be needed and the associated data, using a number of approaches. First, we looked at the monitoring and assessment needs associated with the general operational risks that were identified by humanitarian and other subject matter experts. We also looked at the transactions between different actors to understand the data exchanges, and then compared the overall data needs identified with a set of data elements developed by the U.S. National Aeronautics and Space Administration (NASA). NASA postulated these requirements and organized the data into 16 information classes that are captured in their concept of operations for the in-time aviation safety management system (IASMS).

3.1. Common Risks Identified

Flight Safety Foundation hosted a series of workshops with humanitarian and other subject matter experts to lay out the key safety risks that must be considered in operating a UAS for a disaster management or first responder mission. The risk discussion addressed both risks to other airborne traffic and risks to infrastructure and people on the ground. This was not a formal risk analysis — the relative risks and consequences will vary, depending on the actual environment. However, by looking at the 14 risks that were identified, we could identify what data were likely to be needed to monitor presence of the risk and assess its severity (Table 1).

Table 1. **Common Risks Across Humanitarian Scenarios**

Reference altitude calculation errors	Ground station loss of power or functionality	Separation deterioration (cooperative and non-cooperative)
Failed information sharing	Loss or degraded GPS/navigational aid	Human pilot loss of situational awareness
Loss of command and control (C2) link, single unit failure	Airframe and component failure	Physical ground interference (for example, rock throwing)
Systemwide C2 loss, ground or air	Weather — rapid deterioration or change	Out of date reference information on terrain and obstacles
Physical air interference (for example, rogue aircraft)	Cyber security attack	

3.2. Transaction Assessment

Our second step in understanding the data needs was to look at the interactions that occur while planning for and operating a UAS mission. The actions taken and the information that is collected, requested and shared during the course of an incident response can all be monitored to assess and mitigate potential risks. The following transaction diagrams illustrate the communications that take place in the three scenarios, focusing on the UAS operations and the interactions between different participants and systems. Each transaction diagram (Diagrams 1, 2 and 3, p. 4–5) is split into preflight, flight and post-flight (note that the timeline is not to scale).

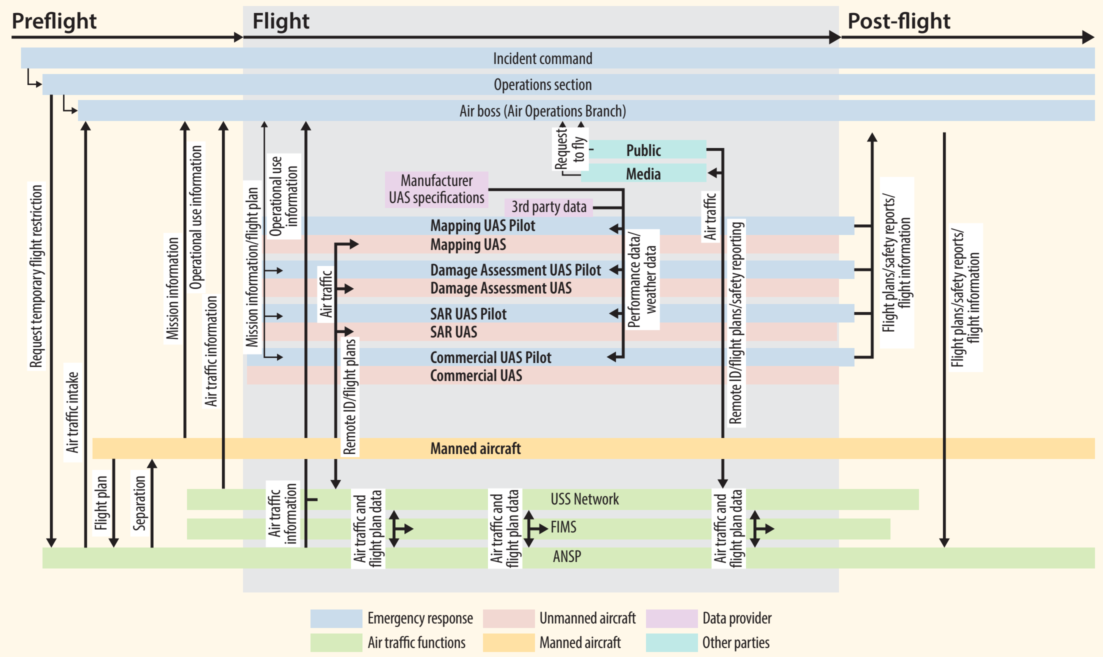
3.3. Overall Information Needs

After assessing data needs from a risk perspective and from a transaction basis, we compared the needed data elements with a previous data catalog proposed by NASA. This resulted in an expanded set of information needs that could generally be allocated to the information class categories, as illustrated in Figure 4 (p. 6). The initial allocation of data types to the 16 information classes contained 70 items; our analysis identified an additional 170 items for a total of 240 data parameters.

The updated data needs include expanding flight planning to include more detailed aircraft performance information, flight plan routing information and remote ID identifiers. New weather data elements include microclimate monitoring that affects UAS specifically. Finally, navigational performance was expanded to include information regarding specific navigation sources, such as real-time kinematic GPS and terrestrial signals of opportunity. These are just a few of the many expansions identified within the additional 170 data parameters.

One data class that was not addressed in the original NASA assessment is the use of procedural documents (Figure 5, p.6). This information class would include things like checklists, operational handbooks and maintenance manuals. Being able to track compliance and use of checklists and maintenance procedures, for example, not only encourages their use but also provides the user with the most accurate history of the vehicle and best practices. This is an essential safety practice.

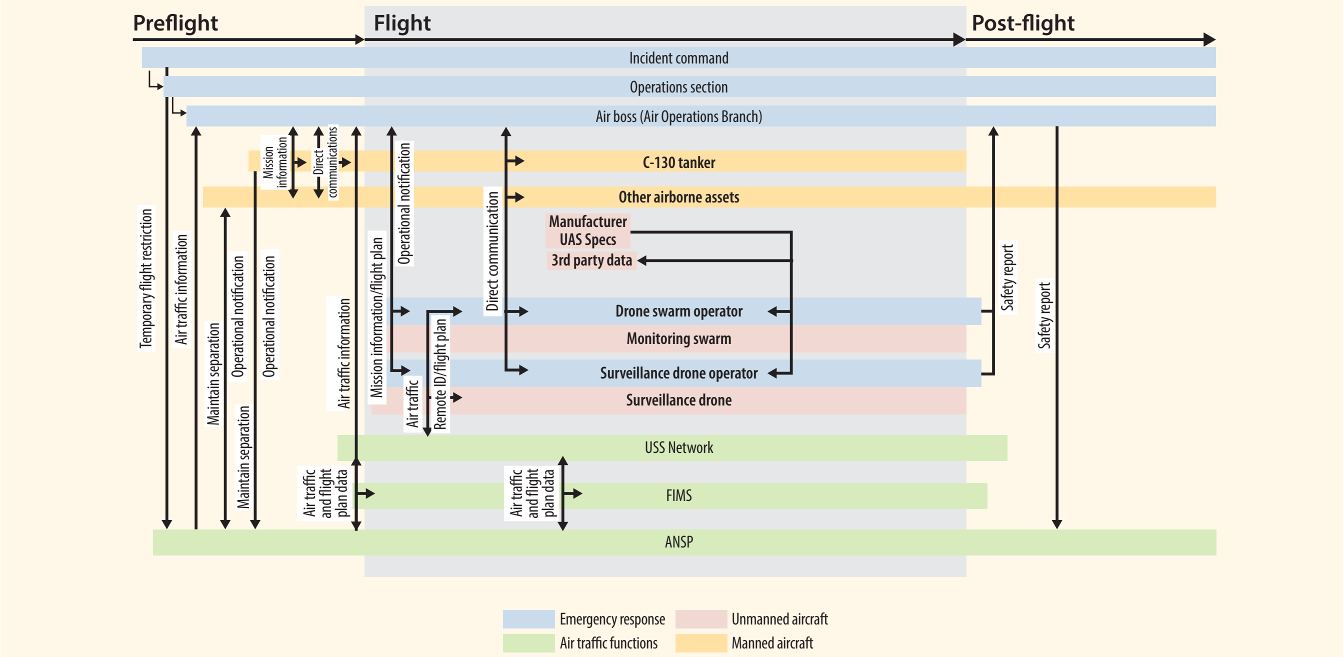
Transaction Diagram Scenario 1. **Natural Disaster Post-Event Response**



ANSP = air navigation service provider; FIMS = flight information management system; SAR = search and rescue; UAM = urban air mobility; UAS = unmanned aircraft system; USS = UAS service supplier

Source: Flight Safety Foundation

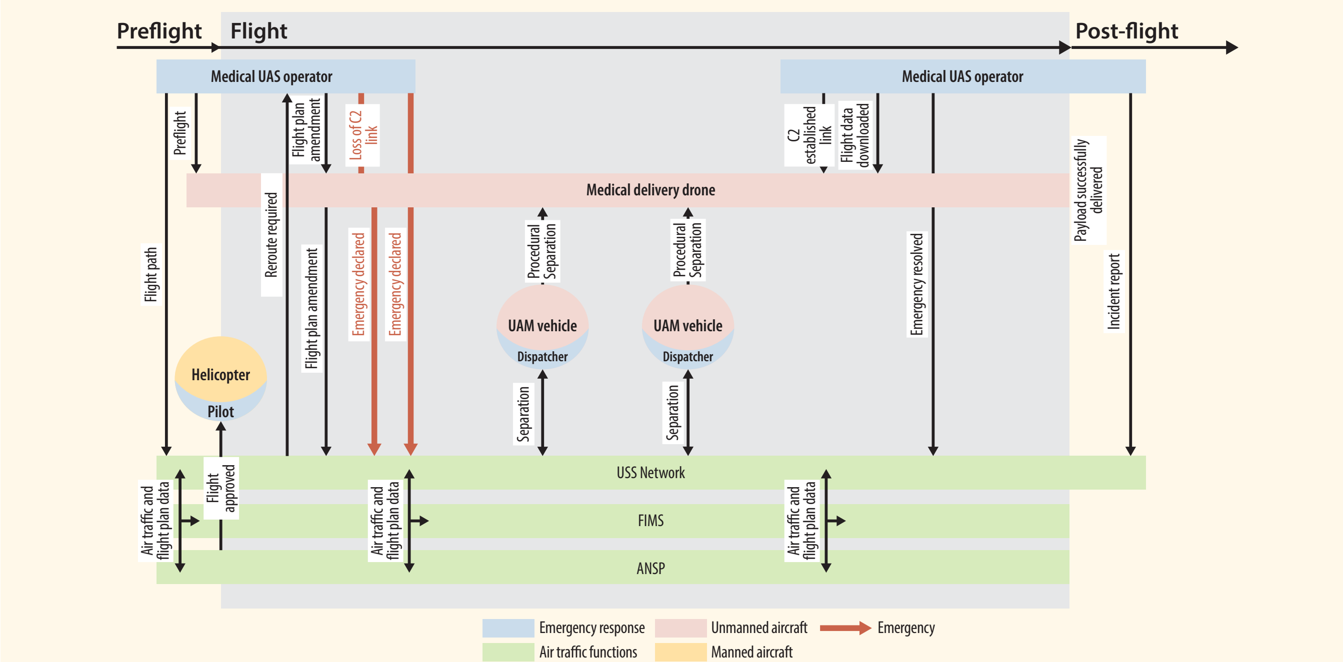
Transaction Diagram Scenario 2. **Wildfire Fighting**



ANSP = air navigation service provider; FIMS = flight information management system; UAS = unmanned aircraft system; USS = UAS service supplier

Source: Flight Safety Foundation

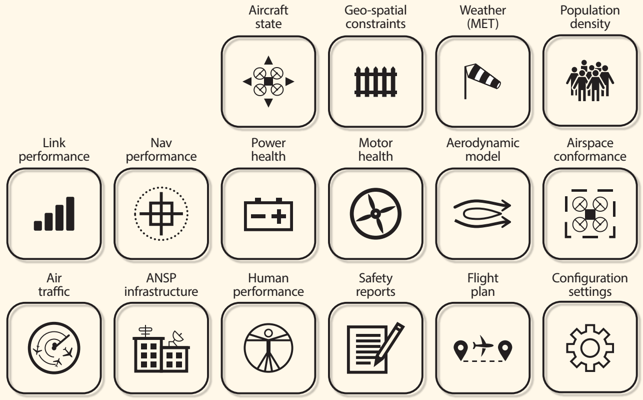
Transaction Diagram Scenario 3. **Medical Delivery**



ANSP = air navigation service provider; C2 = command and control; FIMS = flight information management system; UAM = urban air mobility; UAS = unmanned aircraft system; USS = UAS service supplier

Source: Flight Safety Foundation

Figure 4. **UAS Safety Information Classes**



ANSP = air navigation service provider; IASMS = in-time aviation safety management system; UAS = unmanned aircraft system

Source: IASMS Concept of Operations, U.S. National Aeronautics and Space Administration

Figure 5. **A procedural documents category helps to capture an important addition to the UAS Safety Information Classes**

Source: Kaleb Gould, Flight Safety Foundation

3.4. Humanitarian UAS Operations and Service Groups

In reviewing the transactions between different actors, we grouped the interactions into nine different service classes. These are:

- Maintenance management service;
- Medical and experience certification;
- UAS navigation/network infrastructure monitoring/maintenance auditing;
- Aerodynamic and structural standards service;
- Terrain, weather and other supplemental services;
- UAS flight plan filing;
- Deconfliction: strategic and tactical;
- UAS equivalent safety data reporting services; and,
- Cyber security management.

These services capture the interactions among UAS operators and other actors. This postulates a diverse set of responsible parties, ranging from air navigation service providers to operators. While terrain, weather and other supplemental services are already in place to a varying degree, we predict that they will need to be expanded to cover these new data elements. The other service groups would address UTM needs that are important as UAS adoption grows within the National Airspace System.

4. Summary

Flight Safety Foundation's review of UAS in disaster management and first responder scenarios provides a better understanding of the current and future safety risk management needs for these operations, as well as for other commercial or civil UAS operations. Strengthening UAS safety is envisioned as a real-time, proactive process that capitalizes on broad information-sharing as part of a just, safety-based approach. This analysis is an early step to inform the near- and long-term planning for the safety systems that will allow these operations to evolve in pace of operations, scope and complexity.

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