ResponDrone

"NOVEL INTEGRATED SOLUTION OF OPERATING A FLEET OF DRONES WITH MULTIPLE SYNCHRONIZED MISSIONS FOR DISASTER RESPONSES"

ResponDrone

D2.2 "Use Case Risk Assessment"

Project Deliverable Report

Deliverable Number: D2.2
Deliverable Title: Use Case Risk Assessment
Authors: Michael Borkowski, Richard van Oorschot, Juan Perrela, Joonas Lieb, Max Friedrich
Work Package Number: WP2
Work Package Title: Risk Assessment & Management

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

RESPONDRONE Project Information	
Project full title	Novel Integrated Solution of Operating a Fleet of Drones with Multiple Synchronized Missions for Disaster Responses
Project acronym	RESPONDRONE
Grant agreement number	833717
Project coordinator	Max Friedrich, DLR
Project start date and duration	1st May 2019, 36 months
Project website	https://respondroneproject.com/

Deliverable Information	
Work package number	WP2
Work package title	Risk Assessment & Management
Deliverable number	D2.2
Deliverable title	Use Case Risk Assessment
Description	An assessment of concrete risks and threats encountered in first response operations, complementing the holistic risk model defined in D2.1.
Lead beneficiary	DLR
Lead Author	Michael Borkowski
Contributors	Richard van Oorschot, Juan Perrela, Joonas Lieb, Max Friedrich
Revision number	V1.2
Revision Date	23th June 2020
Status (Final (F), Draft (D), Revised Draft (RV))	F

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

Dissemination level (Public (PU), Restricted to other program participants (PP), Restricted to a group specified by the consortium (RE), Confidential for consortium members only (CO))	CO

Document History			
Revision	**Date**	**Modification**	**Author**
0.1	2020-06-05	Initial draft	Michael Borkowski
0.2	2020-06-16	Review and revision, final draft	Michael Borkowski
0.3	2020-06-17	Review	Richard van Oorschot
0.4	2020-06-18	Review	Juan Perrela
1.0	2020-06-22	Review	Joonas Lieb
1.1	2020-06-23	Review	Max Friedrich
1.2	2020-06-23	Review and revision, submission-ready version	Michael Borkowski

Approvals				
	Name	**Organisation**	**Date**	**Signature (initials)**
Coordinator	Max Friedrich	DLR	2020-06-23	MF
WP Leaders	Michael Borkowski	DLR	2020-06-23	MB

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

Glossary of Terms and Abbreviations Used	
Abbreviation/Term	**Description**
A2A	Air-to-Air Risk
A2G	Air-to-Ground Risk
AGL	Above Ground Level (Altitude Measurement)
ARC	Air Risk Class
ATM	Air Traffic Management
CDC	Centers for Disease Control and Prevention
CEA	Alternative Energies and Atomic Energy Commission (France)
CR	Common Risk
DLR	German Aerospace Center
EASA	European Aviation Safety Agency
EU	European Union
G2A	Ground-to-Air Risk
G2G	Ground-to-Ground Risk
GCS	Ground Control Segment
GRC	Ground Risk Class
HRO	High Reliability Organization
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
SAIL	Specific Assurance and Integrity Level
SORA	Specific Operations Risk Assessment
TCAS	Traffic Collision Avoidance System
TMM	Traffic and Mission Management

UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
VLL	Very Low Level (Airspace)

Disclaimer

The content of the publication herein is the sole responsibility of the publishers and it does not necessarily represent the views expressed by the European Commission or its services.
While the information contained in the documents is believed to be accurate, the authors(s) or any other participant in the RESPONDRONE consortium make no warranty of any kind with regard to this material including, but not limited to the implied warranties of merchantability and fitness for a particular purpose.
Neither the RESPONDRONE Consortium nor any of its members, their officers, employees or agents shall be responsible or liable in negligence or otherwise howsoever in respect of any inaccuracy or omission herein.
Without derogating from the generality of the foregoing neither the RESPONDRONE Consortium nor any of its members, their officers, employees or agents shall be liable for any direct or indirect or consequential loss or damage caused by or arising from any information advice or inaccuracy or omission herein.

Copyright message

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

Table of Contents

This project is funded by the European Union’s H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

Table of Figures

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717 https://respondroneproject.com/

Table of Tables

1. Executive Summary

In the previous deliverable D2.1, we have defined an abstract holistic risk model used for calculating risk values of missions in first response and emergency scenarios. In this deliverable, we provide an assessment of concrete risks and hazards encountered in such missions. This risk assessment will then be used in later efforts of this work package to implement a software component for Traffic & Mission Management (TMM) to perform risk management for missions based on the RESPONDRONE platform.

2. Introduction and Fundamentals

The purpose of this document is to perform a risk assessment based on the use cases of RESPONDRONE. Specifically, first response scenarios (i.e., crisis or emergency situations) including the use of UAS can entail a number of specific risks and dangers which are unique compared to risks encountered in other unmanned aircraft systems (UAS) missions. Such scenarios include, for instance, a response to a forest fire endangering victims who are trapped in houses nearby, requiring a fire line detection using aerial video streams, while also performing search and rescue operations for the trapped people.

In deliverable D2.1 of RESPONDRONE (Holistic Risk Model), we have presented an abstract risk model allowing for the calculation of a risk value for a given mission in a first response scenario. This abstract risk model provides a high-level tool for calculating risk based on four different risk classes, namely air-to-air risks, air-to-ground risks, ground-to-air risks, and ground-to-ground risks. These risks classes are abbreviated as A2G, A2A, G2A, and G2G, respectively.

For each of these four risk classes, the abstract risk model calculates the initial risk as a numeric value. The precise calculation of these values is not defined in D2.1, instead, it remains abstract at that stage. After calculating the initial risk values, specific risk reduction techniques can be applied to reduce these risk values. These reduction techniques can be *ad hoc*, i.e., when the operator learns that the current risk level is too high, but from an operational point of view, the planned mission is still favourable compared to other missions. Alternatively, reduction techniques can be applied in a strategic or operational manner, i.e., by employing means for reducing the harm caused by certain risk events (e.g., a parachute or autonomous autorotation which reduces the kinetic energy born by a defunct UAV impacting terrain).

Based on this, the *residual* risk levels are determined for all four risk classes, which form the input for the common risk (CR) calculation. **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** provides a graphical overview of this process.

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

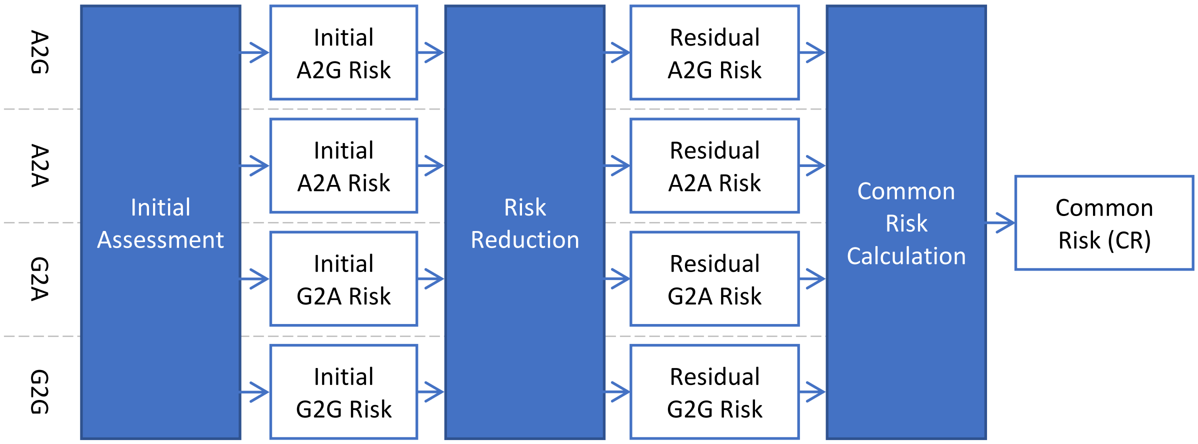

Figure 1: Calculation of common risk from the four individual risk levels

As described in D2.1, the calculation of the CR depends on the situation and the mission requirements. For instance, situations where timing is critical and manned aviation is not expected, the A2A risk can be valued lower than the A2G risk. Such weighing is a viable option for further development of the risk model. However, as a neutral tradeoff, we currently use a method of calculating the CR by using the highest number of the four individual risk values:

$$CR = \max(A2G, A2A, G2A, G2G)$$

Based on the CR value, the operator can select one of many mission alternatives, as exemplified in Figure 2. This can be done either simply by using the mission with the lowest risk value (as is currently planned for the RESPONDRONE implementation) or could conceptually be again realized as a tradeoff between the risk level and the mission plan utility. For instance, certain risks can be seen as acceptable, provided that certain goals are reached with better performance. Nevertheless, since this tradeoff can contain complexities on its own (such as legal or ethical questions), in our current implementation, we do not employ such tradeoffs, and strictly select the mission with the lowest risk level. Ultimately, the operator is the final authority on accepting or rejecting a mission.

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

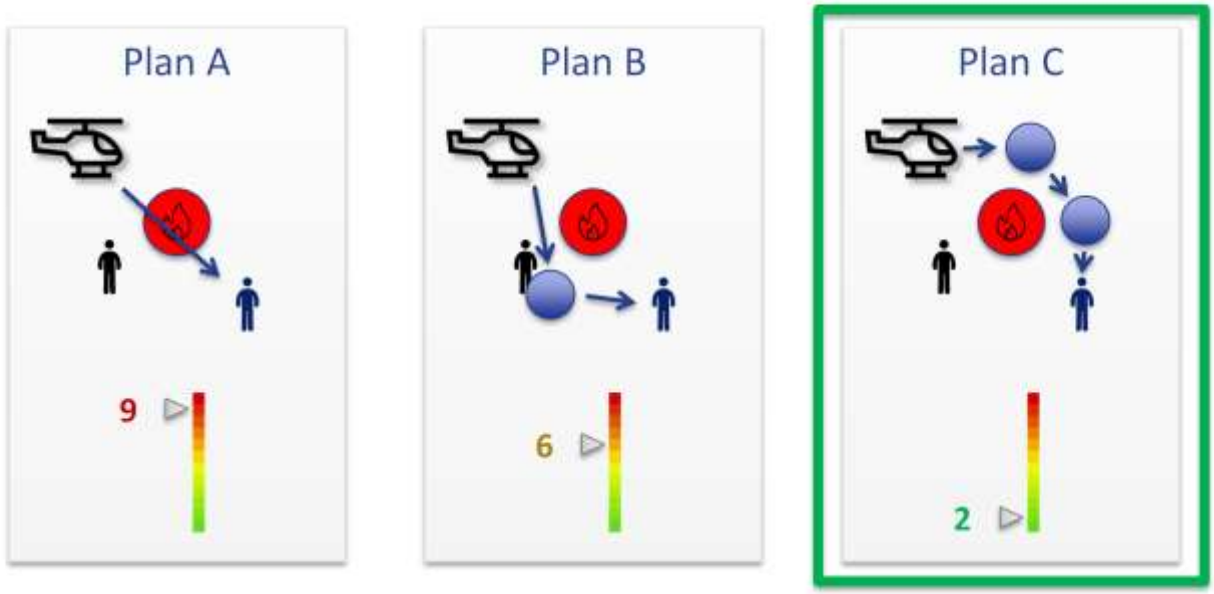

Figure 2: Selection of a mission variant (here: Plan C) based on the lowest CR level

3. Methodology

The aim of this deliverable is to detect and list specific threats which can be used for both the initial risk assessment and the risk reduction stages in the abstract risk model described in D2.1 [1]. As a basis, we have used the deliverables of WP15 (Studies of disaster response operations), which provide an overview of the status quo of first response operations, including both a survey of end users included in the RESPONDRONE consortium, and an extensive literature study covering first response project as well as scientific literature. The primary source of information for this document stems from deliverables D15.2 [2] and D15.3 [3], as well as the CDC's information on Disaster Site Management [4]. In addition, whenever a document referenced a promising source (i.e., further reading), we have taken into account these additional sources. An overview is provided as references throughout this document.

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

4. Analysis of Hazards in First Response Operations

In this section, we provide the primary list of hazards encountered during our literature study. Along with the individual hazards, we provide the source where the risk was primarily found. Note that multiple sources are not being listed, since it's not the goal of this list to provide an extensive survey.

There is a large spectrum of hazards related to first response operations, ranging from general problems which are of an organizational nature (e.g., lack of communication and coordination, problems with data compatibility or uncertain data reliability) over general problems specific to a certain site (e.g., traffic preventing mobility).

- Human-based hazards
    - Crowd movements, aggression and violence [3]
    - Large-scale migration [3]
    - (Large-scale) traffic accidents [3]
    - Plane crashes [3]
    - Radio interference [2]
    - Rogue UAVs [2]
    - Unrelated air traffic [1]
    - Psychological hazards (e.g., trauma-inducing sights) [4]
    - Musculoskeletal hazards (e.g., heavy lifting) [4]
    - Terrorist attacks (e.g., Boston Marathon Shooting) [2]
- Geological
    - Earthquake (e.g., Nepal) [2] (Sub-references: 15, 28, 30)
    - Landslides/rockslides [2]
    - Debris avalanche [5]
- Weather
    - Hurricanes (e.g., Hurricane Michael) [2]
    - Tsunamis [5]
    - Rain-induced flood [2]
    - Thunderstorms, extreme weather [2]
    - Winter Storm (e.g., Xynthia) [2]
    - Snow [2]
    - Heavy heat [2]
    - Wildfires (e.g., Portugal Wildfires) [2] (Sub-reference: 32)
    - Volcanic eruptions [6]
    - Sandstorms [8]
- Structural hazards
    - Fires of structures (e.g., buildings) [2]
    - Multiple fire triggers [3]
    - Collapsing structures (e.g., buildings) [2]
    - Dam break [2], resulting in flood [3]
    - Electrocution [4]

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

- Bio-chemical hazards
  - Chemical spills (e.g., toxic fumes) [2]
  - Chemical, biological, radiological and nuclear threats [2]
  - Toxic substances (e.g., asbestos, carbon monoxide) [4]
  - Oil explosions (e.g., Buncefield Oil Explosion) [2]
  - Explosion danger (gas, petrol) [2]
  - Explosion of legacy weapons [2]
  - Epidemic/pandemic [9]
- Site-related hazards
  - Inaccessible places (forests, gorges, mountains) [2]
  - Confined spaces [4]
  - Falling hazards [4]
  - Population-based vulnerability (schools, hospitals, refugees, etc.) [2]
  - Time-based vulnerability (day time, school period, etc.) [2]
  - Traffic preventing mobility [2]
  - Industrial sites needing special protection [2]
- Organizational hazards/issues
  - Power outage [9]
  - Lack of communication [2]
  - Lack of coordination [2]
  - Compromised cellular infrastructure [2]
  - Insufficient asset tracking [2]
  - Destroyed/compromised emergency operation centers [2]
  - Data compatibility [2]
  - Data reliability [2]

At this point, we note that some types of hazards can be made a concrete part of the risk model (e.g., fires, floods, electrocution hazards, etc.) while some hazards are rather organizational or higher-level hazards which are not specific to a given region in the disaster site, but which are equally present in the entire disaster site. Such hazards do not make sense in the context of ranking the risk level of a given mission. For instance, the issue of data compatibility and reliability is not a specific hazard for one variant of a mission, but rather a general problem that must be taken into account in a first response organization.
We therefore classify each of these hazards into hazards which do not make sense as part of the risk model for evaluating the immediate risk of a given mission variant. In addition, we classify the remaining risks according to the four risk classes (A2G, A2A, G2A, G2G). Note that a given hazard can be part of more than one class, since it can apply to both air and ground. We have also summarized certain related hazards (e.g., rain-induced floods and floods caused by a breaking dam).

We have not assigned the following hazards to any risk class:

- Terrorist attacks: While such attacks can be performed from both the ground and the air, and can be a hazard to both ground and air, they are hardly predictable. Furthermore, such attacks usually are the primary reason for first response operations, and do not pose a risk in addition to an existing risk. Therefore, we do not include them in hazards used for our risk model.

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

- Epidemic/pandemic: The risk of infections causing an epidemic or pandemic is naturally a very crucial one, but, similar to the risk of terrorist attacks, not something that can be regarded as localized to a given area. Note that we do include biological threats as localized G2G risks.
- Industrial sites needing special protection: While this threat has been listed in D15.2 [2], we do not classify it as a risk on its own. Instead, the risk stemming from, e.g., UAVs can be mapped to industrial sites using the “Plane or UAV crashes” A2G risk class, or empty buildings can be represented as a lower A2G risk class.

Furthermore, we provide the following explanation for our classifications:

- Thunderstorms, extreme winds, hurricanes: While hurricanes happen in the air, we classify them as ground-based risks (G2A and G2G), since our classification understands “air” as regarding air traffic (UAVs and manned traffic).
- Heat: In the same manner as the previous point, we categorize heat as a ground-based risk (G2A and G2G), since it does not fit the classification of “air” as in UAVs or manned traffic.
- Organizational hazards (power outages, lack of communication/coordination, etc.): Such hazards, similar to the previously named ones, again cannot generally be localized in a specific site. Instead they pose organizational challenges which need to be addressed in a strategic manner.

Table 1. Classification of encountered hazards

Risk class	Hazards
A2G: Air-to-ground risk	• Plane or UAV crashes • Radio interference • Rogue UAVs
A2A: Air-to-air risk	• (Mid-air) plane or UAV crashes • Radio interference • Rogue UAVs • Unrelated air traffic

This project is funded by the European Union’s H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

Table 1. Classification of encountered hazards	
Risk class	**Hazards**
G2A: Ground-to-air risk	• Obstacles and crashing risks for UAVs • Radio interference • Landslides/rockslides • Debris avalanches • Hurricanes • Tsunamis • Thunderstorms, extreme winds • Snow, snowstorms • Extreme heat (including ascending air currents from fires) • Fire (wildfire or structural fire) • Ash and smoke from volcanic eruptions or fires • Sand, sandstorms • Chemical, biological, radiological, nuclear threats • Explosion danger (oil, gas, petrol, legacy weapons)

Table 1. Classification of encountered hazards

Risk class	Hazards
G2G: Ground-to-ground risk	• Crowd movements, aggression and violence • Large-scale migration • Traffic accidents • Radio interference • Psychological hazards • Musculoskeletal hazards • Earthquakes • Landslides/rockslides • Debris avalanches • Hurricanes • Tsunamis • Floods (rain-induced, or caused by breaking dam) • Thunderstorms, extreme winds • Snow, snowstorms • Extreme heat • Fire (wildfire or structural fire) • Ash from volcanic eruptions • Sand, sandstorms • Collapsing buildings • Electrocution risks • Chemical, biological, radiological, nuclear threats • Toxic substances • Explosion danger (oil, gas, petrol, legacy weapons) • Inaccessible or confined spaces, falling hazards • Traffic preventing (ground) mobility
Non-classified hazards	• Terrorist attacks • Epidemic/pandemic • Industrial sites needing special protection • Organizational hazards (insufficient power supply, lack of communication and coordination, etc.)

5. Discussion and Limitations

In the previous sections, we assessed the risks of first response operations and listed the resulting concrete hazards encountered in literature, consisting of scientific literature, government documents as well as project deliverables (both from RESPONDRONE and from other projects).

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717 https://respondroneproject.com/

The resulting list has been classified into the four risk classes stemming from the holistic risk described in D2.1 [1].

We note that there are still remaining limitations that need to be addressed. First, while we collected a primary list of hazards, there are also complex scenarios which are not yet reflected in this list. For instance, the risk of a UAV affected by fire (G2A), crashing into a structure (A2G) and causing a collapse (G2G) poses such a complex risk, which is resulting from compound action across multiple risk classes. In reality, such a risk is very hard to assess, and we do not expect a risk model for UAV-based first response operations to cover all possibilities, but in general, complex risk scenarios are worth investigating in more detail.

The most crucial challenge to the risk model developed within RESPONDRONE, however, is the sourcing of data. While we have collected a relatively extensive list of risks and threats, detecting the actual hazards remains an open issue. We aim to address this issue within RESPONDRONE by using some threats as exemplary risk types which we aim to detect, either automatically using video analysis, or manually using a domain expert for data entry. The automatic video analysis is part of WP5 ("Video Analytics"), where efforts are made to automatically detect fire lines, people, vehicles, and floods. The actual performance of this video detection is still to be determined throughout this project. The manual data entry is envisioned to be implemented by providing a domain expert (possibly off-site) with a possibility of annotating video footage or map overlays with hazards. Such manual entry has the upside of being able to use the domain expert's knowledge in detail, however, it also poses downsides. First, manual data entry is a laborious task and requires human time and attention, which are scarce resources in an emergency situation. Second, keeping data up to date is tedious, and the human expert must make sure to de-annotate or change hazards once they no longer apply, or have changed in nature.

Another open issue is the risk value attached to each hazard. In the holistic risk model, we have used exemplary values between 1 and 10 to determine the risk level. It is not possible to generally assign such values for all possible first response missions. However, over time, experience and empirical data can be used to find and refine values. These numbers will initially be based on educated guesses and can only be refined over time and with increased experience. The same issue is faced by SORA and by other regulatory bodies; strictly speaking, risk is based on probabilities, and can therefore only be calculated based on observation, which requires sufficient empirical data. The contemporary usage of UAS – in itself, as well as in first response operations – is relatively young, and UAS have not yet been used in crisis management in a degree that allows for extensive quantitative analysis, since not enough data has been collected. When defining SORA, JARUS approached this issue also by first using (educated) best guesses for risk numbers, and subsequently adapting these numbers based on additional experience and based on observations from users of SORA [1].

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

The remaining effort of WP2 will be used to implement the results from D2.1 [1] and this deliverable, i.e., the risk model together with the use case risk assessment into the RESPONDRONE platform in order to provide both the UAV-based missions and the first responder missions with risk assessment and management capabilities. This is currently envisioned to be realized using a dedicated software component, called Traffic & Mission Management (TMM). The TMM component will be embedded in the software infrastructure as a gateway between requests originating from the end users and the UAV GCS itself. A detailed description is provided in D7.1 [10] and the upcoming D7.2 [11].

6. References

[1] RESPONDRONE, *D2.1: Holistic Risk Model,* 2019.

[2] RESPONDRONE, *D15.2: Report of Field Studies,* 2019.

[3] RESPONDRONE, *D15.3: Set of Scenarios and Simulation Data,* 2019.

[4] The National Institute for Occupational Safety and Health (NIOSH), "Emergency Response Procedures: Disaster Site Management," 30 11 2018. [Online]. Available: https://www.cdc.gov/niosh/topics/emres/sitemgt.html. [Accessed 15 06 2020].

[5] B. D. Collins and R. W. Jibson, "Assessment of existing and potential landslide hazards resulting from the April 25, 2015 Gorkha, Nepal earthquake sequence," U.S. Geological Survey, 2015.

[6] S. M. Adams and C. J. Friedland, "A Survey of Unmanned Aerial Vehicle (UAV) Usage for Imagery Collection in Disaster Research and Management," 2011.

[7] A. Restas, "Drone Applications for Supporting Disaster Management," *World Journal of Engineering and Technology,* vol. 3, no. 3, 2015.

[8] M. Erdelj, E. Natalizio, K. R. Chowdhury and I. F. Akyildiz, "Help from the Sky: Leveraging UAVs for Disaster Management," *IEEE Pervasive Computing,* vol. 16, no. 1, pp. 24-32, 2017.

[9] SAYSO, *D2.3: Preliminary Reference Scenarios,* 2017.

[10] RESPONDRONE, *D7.1: General Architecture Design.*

[11] RESPONDRONE, *D7.2: RESPONDRONE Integration Plan (upcoming).*

[12] Joint Authorities for Rulemaking on Unmanned Systems, *JARUS Guidelines on Specific Operations Risk Assessment (SORA),* 2019.

[13] K. Roberts and D. Rousseau, "Research in Nearly Failure-Free, High-Reliability Organizations: Having the Bubble," *IEEE Transactions on Engineering Management,* vol. 36, no. 2, pp. 132-139, 1989.

[14] European Aviation Safety Agency, *Introduction of a Regulatory Framework for the Operation of Unmanned Aircraft,* 2015.

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/

[15] E. Ancel, F. Capristan, J. Foster and R. Condotta, "Real-time Risk Assessment Framework for Unmanned Aircraft System (UAS) Traffic Management (UTM)," in *17th AIAA Aviation Technology, Integration, and Operations Conference*, Denver, Colorado, 2017.

[16] E. Ancel, F. F. J. Capristan and R. Condotta, "In-Time Non-Participant Casualty Risk Assessment to Support Onboard Decision Making for Autonomous Unmanned Aircraft," in *AIAA Aviation 2019 Forum*, Dallas, Texas, 2019.

[17] "Ground Risk Assessment Service Provider (GRASP) Development Effort as a Supplemental Data Service Provider (SDSP) for Urban Unmanned Aircraft System (UAS) Operations," in *38th Digital Avionics Systems Conference*, San Diego, California, 2019.

[18] A. Landi and M. Nicholson, *ARP4754A/ ED-79A - Guidelines for Development of Civil Aircraft and Systems - Enhancements, Novelties and Key Topics,* SAE International, 2011.

This project is funded by the European Union's H2020 Research and Innovation Programme and the Korean Government under Grant Agreement No. 833717
https://respondroneproject.com/