RDrone
Feasibility Analysis

1. Introduction

The raport contains results of the technical feasibility analysis of RDrone product – the rescue drone equipped with radar for sensing the disaster survivors. The analysis included: specification of intended use and functional requirements, analysis of the state of knowledge and solutions available in the market, initial project risk assessment and regulatory aspects. Based on performed research a technical solution concept was prepared.

The report was prepared for demonstrational and self-improvement purposes.

Cracow, DD-MM-YYYY

2. Intended use

The RDrone is a drone intended for surveillance of the disaster zones and detecting the survivors both on the surface and those trapped underneath debris. The system consists of the drone itself, control station and accompanying software and accessories. RDrone is intended for use by emergency units – appropriately trained professionals in the environment after natural disasters or war zones.

2.1. Functional requirements

Functional requirements were prioritized into three categories:

Must have – the essential requirements allowing the product to achieve its basic goals.

Should have – the requirements addressing important, but not essential aspects of the product, lack of their implementation will decrease the final value of the product.

Nice to have – the requirements increasing the final value of the product, but not deeply connected to the desired principle of work.

Must have:

1. Detection agent allowing for movement through and scanning of the disaster zone.
2. Detection of survivors:
    a. on the surface,
    b. beneath the rubble for 10 meters deep.
3. Manual control.
4. Wireless communication.
5. Continuous work for min. 2 hours.
6. Compatibility with procedures used in disaster zones.
7. Control range for up to 1 km.

Should have:

1. Detection of survivors beneath the rubble for 20 meters deep.
2. Automated detection and counting survivors in specified areas.
3. Live-streaming video from the agent.
4. Continuous work for min. 5 hours.
5. GPS navigation.
6. Control range for up to 5 km.
7. Protection against adverse weather (both control and detection agent).

Nice to have:

1. Communication and data export with the rescue teams.
2. Automated scanning movement through the designated sector.
3. Control range for up to 10 km.

3. State of knowledge

Natural disasters

The disasters can be differentiated from emergencies and catastrophes as[1]:

- Emergency – an event that may be managed without the need of added response measures or changes to procedure.
- Disaster – an event involving more groups than emergency, requiring involved parties to relinquish usual autonomy and freedom to special response measures, changing the usual performance measures and requires closer operations between public and private organizations.
- Catastrophe – an event that destroys most of a community, prevents local officials from performing their duties, causes most community functions to cease and prevents adjacent communities from providing aid.

In other words, disasters are serious disruptions to the functioning of a community that exceed its capacity to cope using its own resources[2] . They can be classified into three types[3]:

1. Natural – resulting from natural forces such as floods, earthquakes, tsunami, volcanic activity etc.
2. Manmade – resulting from human decision, includes: plant and factory failures, explosions, wars, riots, terrorist attacks etc.
3. Hybrid – resulting both from natural and manmade causes like unleashing the forces of nature as a result of technical failure or sabotage.

Beside the original cause of the disasters the subsequent disasters can be distinguished as a result of the previous disaster (such as chemical pollution followed by drought).

The total number of disasters in the world (excluding manmade disasters) seems to be increasing[4]. Based on the Emergency Events Database (EM-DAT) in the years 1900 – 2005 the number has increased from 93 to 4 850 for analyzed periods of 10 years. The disaster in the database is defined as an event causing widespread destruction and fulfilling at least two of three criteria: ten or more people reported killed, 100 or more people reported affected or a

[1] Eshghi, K., & Larson, R. C. (2008). Disasters: lessons from the past 105 years. *Disaster Prevention and Management: An International Journal*, *17*(1), 62-82.
[2] The International Federation of Red Cross and Red Crescent Societies: https://www.ifrc.org/our-work/disasters-climate-and-crises/what-disaster
[3] Shaluf, I. M. (2007). An overview on disasters. *Disaster Prevention and Management: An International Journal*, *16*(5), 687-703.
[4] Eshghi, K., & Larson, R. C. *op. cit.*

call for international assistance or a declaration of a state of emergency from a government. The detailed trends are shown in Figure X.

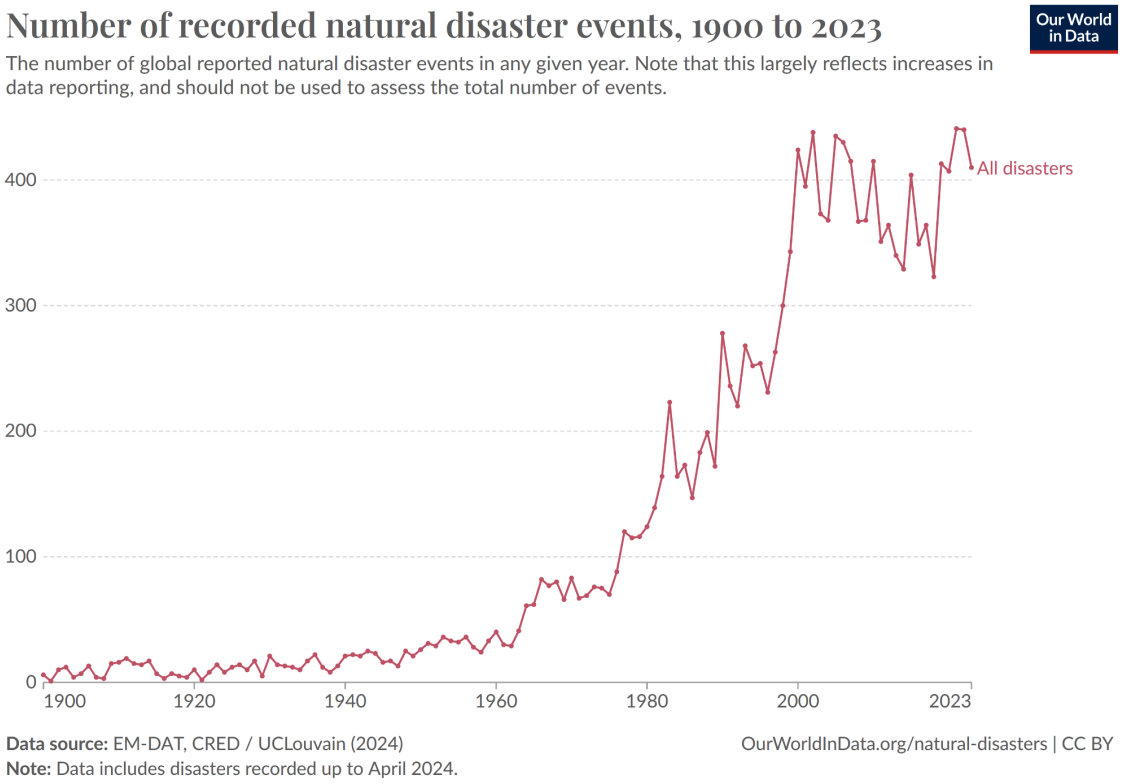

Fig. X. Number of recorded natural disasters in 1900 – 2023[5]

Eshghi et al.[6] points out that the increasing number of the disasters can be explained by developing more accurate detection technology, communications and media. This however does not explain the increase between 1990 – 1999 and 2000 – 2005 periods. Another possible explanation is the increase of the human population and growth in the areas more vulnerable to hazards. Those claims seem to be supported by further analysis shown in *Alimonti et al.*[7] pointing out the declining trend later to 2022 and attributes the increase to the

[5] "Data Page: Number of recorded natural disaster events", part of the following publication: Hannah Ritchie and Pablo Rosado (2022) - "Natural Disasters". Data adapted from EM-DAT, CRED / UCLouvain. Retrieved from https://ourworldindata.org/grapher/number-of-natural-disaster-events [online resource]
[6] Eshghi, K., & Larson, R. C. *op. cit.*
[7] Alimonti, G., & Mariani, L. (2023). Is the number of global natural disasters increasing?. *Environmental Hazards*, 1-17.

better reporting, refuting the UNDRR report[8] about the upcoming increase of natural disasters, caused by global warming.

Despite the increased number of people affected, according to the *Ourworldindata*[9] service the number of deaths in the last century has drastically dropped to about 40 000 deaths. The decadal average of deaths from disasters is shown in Figure X.

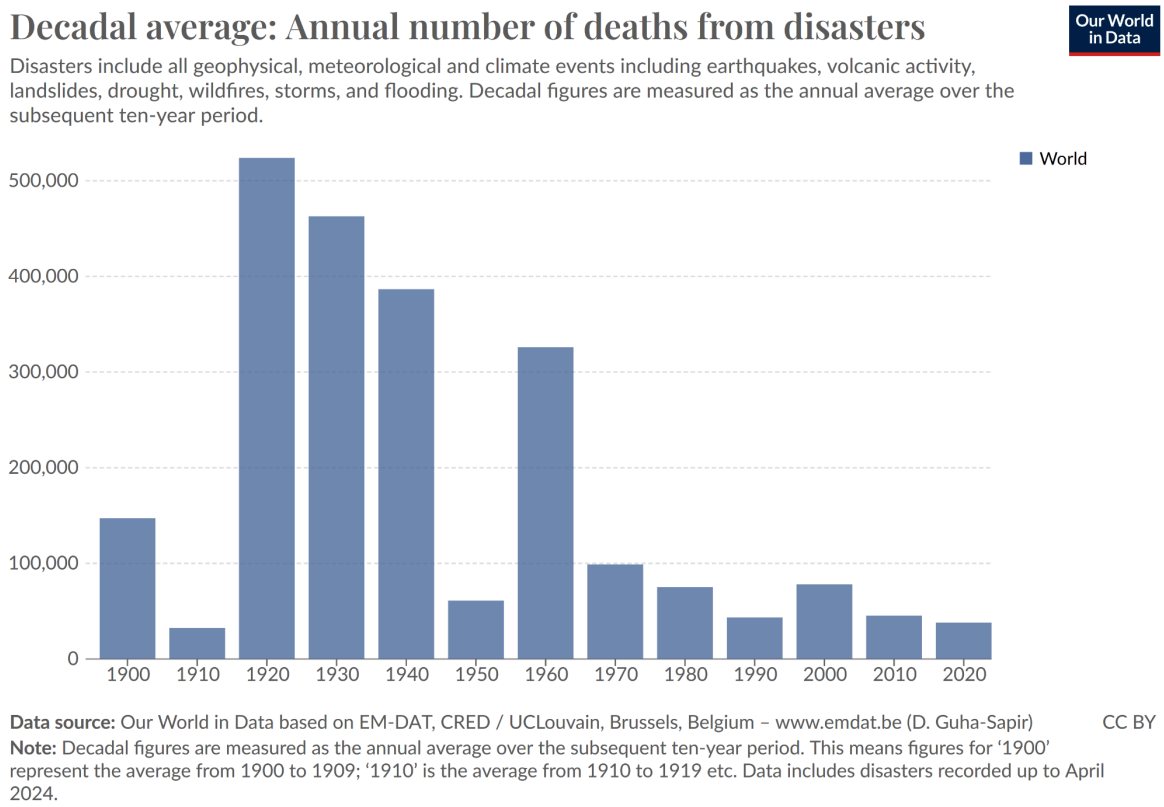

Fig. X. Number of recorded deaths from natural disasters in following decades since 1900[10]

The disaster management is covered by four phases: Mitigation, Preparedness, Response and Recovery, shown in Figure X.

[8] The human cost of disasters: an overview of the last 20 years (2000-2019): https://www.undrr.org/publication/human-cost-disasters-overview-last-20-years-2000-2019

[9] Hannah Ritchie and Pablo Rosado (2022) - "Natural Disasters" Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/natural-disasters' [Online Resource]

[10] Hannah Ritchie and Pablo Rosado, *op. cit.*

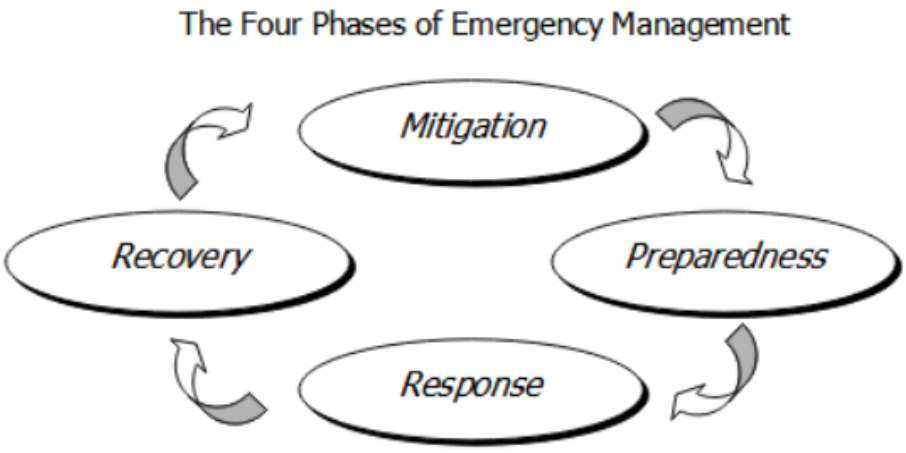

Fig. X. Phases of Emergency Management[11]

The characteristics of phases are as follows:

1. Mitigation concerns activities focused on preventing the emergency, reducing chances of its happening or reducing damages. It can take place before and after emergencies.
2. Preparedness includes plans or preparations made to save lives and to help response and rescue operations (such as evacuation plans or stocking food). It takes place before the emergency.
3. Response is taking actual actions to save lives and prevent further property damage. In other words it is putting preparedness plans into action. Response takes place during an emergency.
4. The recovery phase are actions taken to return to a normal or an even safer situation following an emergency.

Disaster management aims to organize and manage the available resources and responsibilities throughout all of the phases to lessen the impact of the incident. Emergency response involves a mixture of plans, procedures and improvisation[12]. The improvisation should be limited by appropriate preparedness, but because of a certain degree of uniqueness of new disaster it is inevitable. Created procedures should cover as much as they can, but also create space for improvement and learning. They should also not intervene with plans – general articulation and integration of procedures used to assign responsibilities and ensuring that

[11] The Four Phases of Emergency Management, FEMA training: https://training.fema.gov/
[12] Alexander, D. E. (2015). Disaster and emergency planning for preparedness, response, and recovery. Oxford University Press.

people involved understand their and other participants' roles. Therefore the emergency process should be defined as a process, rather a product or outcome.

The functions in the disaster management are[13]:

- hazard and risk identification and management,
- authorities and law,
- resources management and planning,
- collaboration, coordination, command and control,
- communications,
- warnings and public information management,
- logistics and facilities,
- education and training of emergency personnel,
- education, training and exercise of the population,
- administration and finance,
- interoperability service,
- mutual aid,
- managing volunteers and donations,
- surge capacity,
- tactical emergency medical service,
- medical intelligence.

An Incident Command System (ICS) was provided to help with decision-making and commanding by standardization of managing events based on proven practices. As it is one of several systems and research shows it is best suited for routine events and less suitable when respondents have different structure, it can be used as the example of work of emergency units on the organizational level[14].

The basic function of the ICS is establishing 5C – command, control, communication, collaboration and coordination. The first step is establishing C2 being command and control in order to identify the incident, the needs and initiate the reaction response chain. Later the performance of C2 is dependent on remaining C's: communication, collaboration and coordination. All of the actions strongly rely on the informations, as presented in respective article[15]:

> *When a disaster occurs, there is a continuous tension between the time needed to understand a complex scenario and the urgent need for an emergency*

[13] Khorram-Manesh, A., Goniewicz, K., Hertelendy, A., & Dulebenets, M. (Eds.). (2021). *Handbook of disaster and emergency management*. Kompendiet.
[14] Faccincani R., Khorram-Manesh A. (2021). *Incident command system and decision-making* in: *Handbook of disaster and emergency management*. Kompendiet.
[15] Khorram-Manesh A., Carlstrom E., (2021). *Information collecting and sharing* in: *Handbook of disaster and emergency management*. Kompendiet.

response. Usually, presenting more information than necessary raises the need for channeling and coordinating the information process. The main goal is to get relevant information on time to the right decision makers. The process of information sharing belongs to the domain of communication and is recognized by the IFRC as one of the three primary issues in coordination (other two are collaboration and joint strategic planning).

A large volume of information is being shared between a large number of respondents. The safety management should take into consideration the information about:

- hazard environment,
- responder workforce,
- present safety issues,
- safety equipment,
- information sharing process.

The Search and Rescue (SAR) is one of the most important and dynamic processes in disaster management[16]. Its goal is to rescue the greatest number of casualties in the shortest amount of time with minimum risk to the rescuers.

The majority of SARs operations are performed in the urban area. The typical Urban SAR comes in three phases:

1. Assessment – collecting facts about types of structure, extent of damage, buildings layout, hazards and requirements for rescue personnel.
2. Search – focusing on locations of victims and entrapment areas. After identification of the entrapment area the potential number of victims is estimated and systematic search patterns are utilized.
3. Rescue – before removing victims from traps it is often necessary to move or stabilize debris. The freeing victims focus on avoiding further injury. Triage may be used to prioritize assistance.

The

Stucchi et al. highlighted the importance of technology support in SAR operations. Especially mentioned Unmanned Aerial Vehicles (UAV) being able to quickly scan the area, locate the victims, differentiate vital functions, detect the signals from mobile phones dramatically increasing their capacity. The other technological measures are Artificial Intelligence surveying the area for victims' movement or remotely operated robots allowing them to enter collapsed buildings, increasing the safety and capacity of the rescue teams.

[16] Stucchi R., Faccinani R., (2021). *Search and Rescue (SAR)* in: *Handbook of disaster and emergency management*. Kompendiet.

- the definition of disaster? – for description of the environment
- the emergency units action protocols
- the equipment used

Survivors detection

- surface detection methods
- rubble detection methods

State of knowledge summary

4. Market research

Life detection equipment

- probably some probes or radars for rubble
- radars for warfare, through-wall detection

Life detection systems

- probably some drones with cameras and thermal imaging
- maybe warfare drones with radars?

INACHUS??? here or in chapter 3

Market research summary

5. Risk analysis

Users and survivors health and safety

- missing the survivor – low detection accuracy
- loss of control over UAV – training required, backup procedures, backup connectivity,
-

System’s effectiveness

- false positives of detection – wasting resources
- insufficient battery
- inappropriate use – training required

6. Regulatory aspects

Market introduction

- is it MDR? or appropriate aerial regulations? or both?

Standards and legal requirements

- regulations
- applicable standards (harmonized would be best)
- flight permission

Accredited tests

- if applicable
- RED tests will be for sure
-

7. Technical solution concept

System architecture

Detection agent

- vehicle platform, requriements - UAV
- maybe some ready UAV with enabled modifications???

Sensory detection units

- proposed algorithm
- exemplary sensors

Vehicle control units

- like accelerometers, motors etc.

Power management

- brief estimations of required power
-

MCU

- examples of MCU's
- recommended one

Connectivity units

- satellite module
-

Control station

Movement control

- mcu and
- joystick or what is required to steer

Connectivity

- the same as in detection agent

- probably some serious antenna

User interface

- screen
- example of existing user interfaces

Industrial design

- examples of drones
- examples of controllers
    - recommended design
-

Efficiency and safety verification

- validation procedure?

8. Conclusions