Augmented Helicopter Rescue Operation with Air2X and Virtual Infrastructure

November 09, 2020

DLR

Abstract

This paper describes current operational procedures, circumstances and challenges of rescue helicopter landings on highways and is dedicated to present the technological solution of a communication interface between aerial and ground vehicles for increasing safety and efficiency. While a direct communication link between both sides would be the preferred option, this paper provides a solution that allows a near-term implementation and deployment. Consequently, a translating unit is required to merge the different expected communication standards of both domains. For the temporary establishment of a safe exclusive landing zone without ground support, the concept requires a low number of highly automated ground vehicles in a mixed traffic, guaranteeing a foreseeable behavior of certain traffic participants. Besides the technical implementation, safety, security and regulatory aspects of the concept are considered.

Table of Contents

Introduction

Digitalization is one of the most challenging movements of the early 21st century. On the one hand, promising opportunities arise by sharing knowledge, information and data; while on the other hand, it lacks willingness and preparedness to establish common standards for exploiting the full potential. That applies also to traffic systems, especially concerning the communication across the respective domains. Developments in digitalization and networking are chiefly restricted to a single area, where different conceptions and positions already impede a harmonization. A broad view for other potentials is therefore often neglected.

In the course of the project Verkehr 5.0, DLR identifies key enablers for future traffic systems with a special focus on cross-domain communication and collaboration. Solutions from other projects like City-ATM, TransAID or Digitaler Knoten 4.0 are considered, adapted and deployed to leverage synergies. Demonstrating the capabilities of such overarching approaches and thereby revealing the potential for further improvement, this work shall serve as a guide for future developments of modern traffic systems.

The most promising use-cases for introducing new technologies are the ones that offer elementary benefits at reasonable efforts. That often applies to the field of emergency and rescue. Consequently, this paper proposes the thesis that the communication between aircraft and ground vehicles allows more efficient, safe and independent helicopter rescue missions. The framework and its requirements will be investigated to subsequently present the identified solution, allowing coordinated helicopter landings on traffic areas. Obviously, a direct communication between the participants would be appreciated. As a direct link is not yet realistic, the concept provides a workaround via communication interface. Safety, security and regulatory aspects are considered next to the technological approach. Concluding, several other future applications are presented that are based on communication and cooperation between participants from different traffic domains.

The Highway Helicopter Rescue Mission

Air rescue has been established decades ago to guarantee time critical emergency care, even when the accident site has an impeded access, for example due its remote location, a rough terrain or traffic jams. Emergency doctors and rescue teams can be airborne within 2 minutes and are transferred to the respective site. Due to the coverage provided by different air rescue providers in Germany, each destination can be reached in less than 15 minutes flight time. [1]

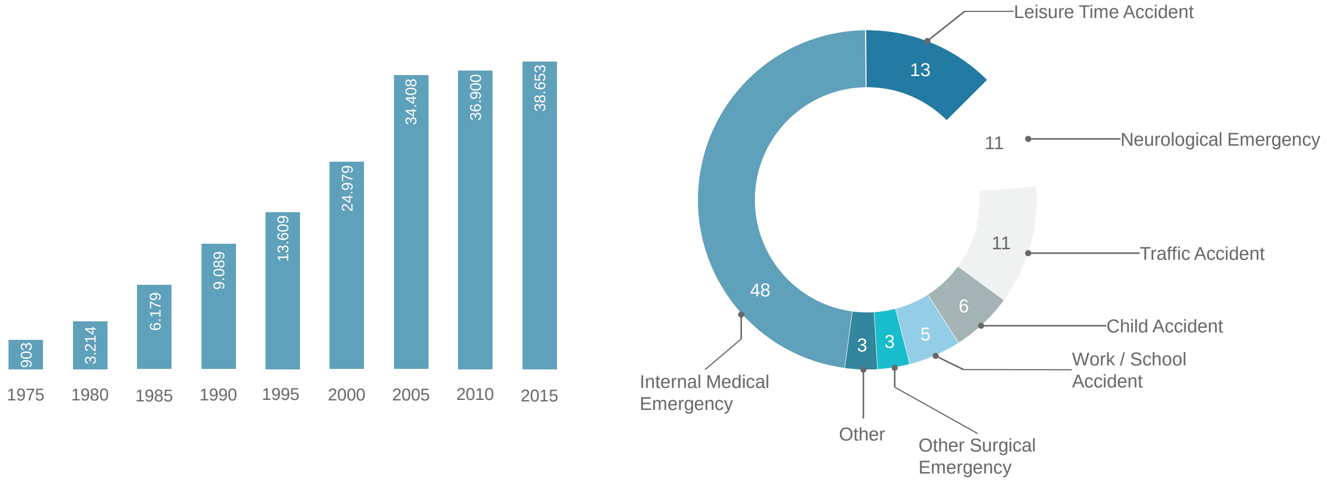

Figure 1: Development of primary air rescue demand of DRF [1] and distribution of emergency causes registered by ADAC Luftrettung [2]

The demand for primary air rescue missions has steadily increased over the years. ADAC counts more than 54.000 operations in 2018, almost half (48.8 percent) of which are caused by internal medical emergencies like heart attacks, while eleven percent are due to traffic accidents [2]. With 95 percent, almost all of the operations registered by ADAC Luftrettung refer to severe or fatal injuries [3]. Appropriate medical treatment and the transportation to the most suitable hospital have to be provided as quickly as possible after such injuries to increase the likelihood of preventing death or avoidable long-term damage. Accordingly, as time is elementary, air rescue requires an efficient coordination. Relevant quality indicators of the rescue mission are the "time to assistance" (period between emergency call and beginning of medical treatment) and the "prehospital time" (period between emergency call and arrival at trauma center). Accordingly, experts and consortia recommend that the prehospital time should not exceed 60 till 90 minutes [5], [6].

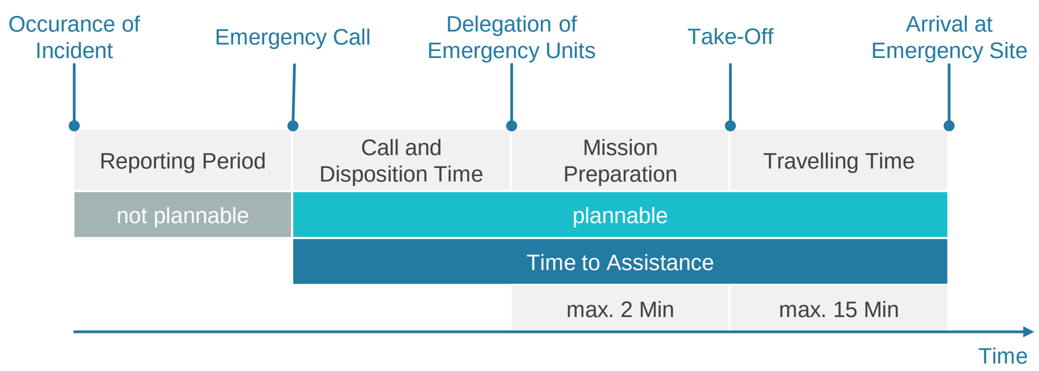

Figure 2: Timeline of rescue operation with respect to the "time to assistance", according to [1], [4]

Facing this time-dependency, helicopters offer crucial advantages over ground units and can be beneficial for certain injuries due to the gentle transport. The respective decision for the deployment and the subsequent delegation of an air rescue helicopter is made by the dispatcher in a rescue and coordination center. Neither the exact location nor the entire circumstances of the emergency are known in the first place. Accordingly, after arriving at the site, the pilot has to examine the scene from the air to select an appropriate landing area. It is not uncommon that a safe landing in the vicinity of the emergency site is only feasible on traffic areas. In 2018, about 1450 landings on traffic areas had to be performed by ADAC Luftrettung [7] . As helicopters are often requested when they offer a temporal advantage over ground units or when the emergency area is not accessible, there are occasions where the helicopter has to land on traffic areas before security or other supporting measures can be installed. It is assumed that this applies for almost every fifth landing on streets or highways. Still, safety has to be guaranteed for the helicopter and ground traffic without the presence of the competent authority. Intended or not, adverse behavior of vehicle drivers has to be expected [5], [8].

Concept for Augmented Air Rescue Operations

DLR proposes to make use of the development of digitalization in both the aerial and ground-based traffic domains for supporting air rescue operations. If landing on a traffic area is required, the helicopter shall broadcast the determined landing site automatically, thereby informing and instructing ground vehicles that have a respective communication interface. A digital barrier prevents those vehicles from entering the desired landing site. Thereby, they form a physical barrier for all following cars on their lane. If the verification is positive, the pilot can initiate the final approach. That allows air rescue operations to become more independent of the presence of a competent authority at the emergency site. The time to assistance can be decreased essentially in a corresponding case while safety for the helicopter and third parties is ensured.

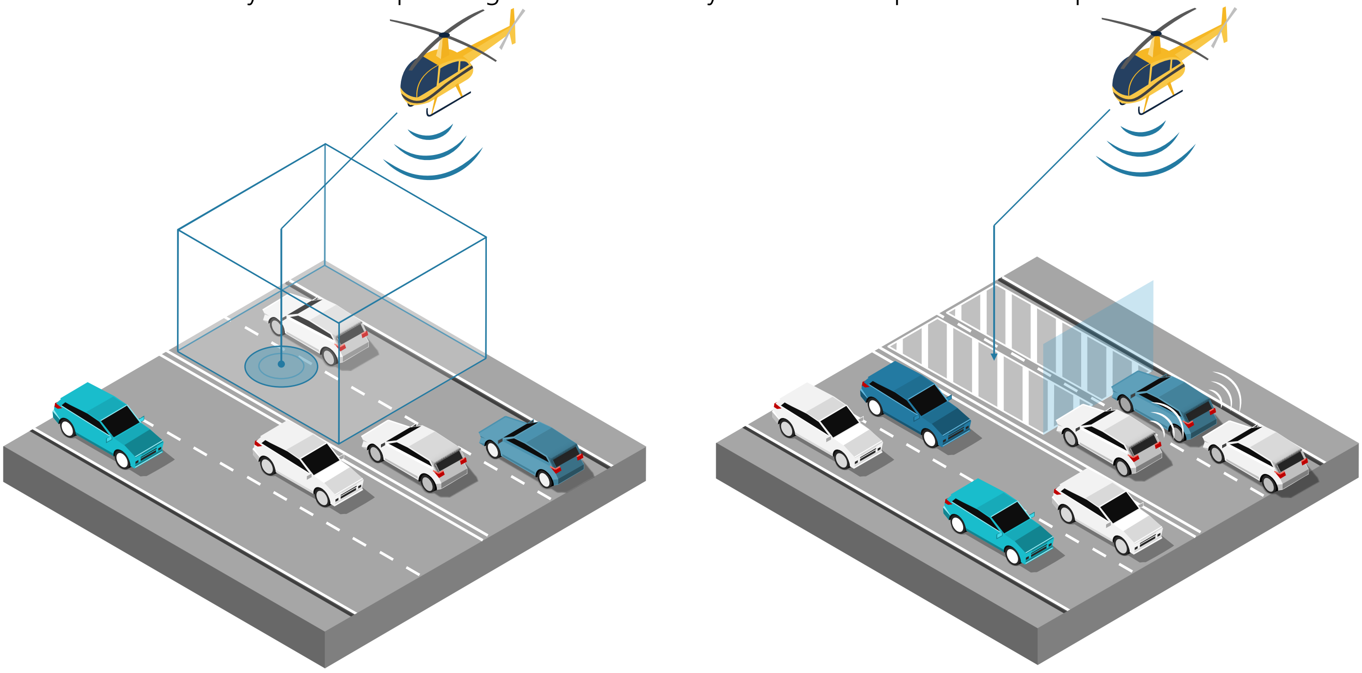

Figure 3: Concept of Air2X communication for air rescue operations

For a first approach, this paper merely focuses on the landing on highways. Other use cases are listed in the chapter future operations, taking into account other environments and different combinations of communicating vehicles.
The aspects in the following list will have to be addressed for accomplishing the implementation of the proposed concept. They will be treated in detail subsequently.

1. Operational and Regulatory aspects
2. (Virtual) Infrastructure
3. Communication
4. Safety & Security

Operational and Regulatory Aspects

In Germany, rescue coordination centers (RLSt) are exclusively entitled to delegate rescue helicopter missions [9]. The decision is made by the responsible dispatcher and based upon the rough picture transmitted during the emergency call. If there is an indication for the requirement of an emergency doctor, a helicopter is deployed when:

- ground-based emergency units are not sufficient or unavailable
- time to assistance cannot be guaranteed by ground units
- helicopter has a medically relevant time advantage

If there is no indication, the helicopter can still be deployed if there is no or limited access to the emergency site (e.g. remote locations, woodland or adverse road conditions like black ice, flooding or traffic jams). [10]

Emergency units are dispatched according to a specific arrangement (AAO) that includes information on location, type and severity of the emergency. The quality is dependent on the accuracy of the emergency report. For the highway rescue mission, usually the direction of travel and mileage are known. In that case, the pilot is provided with possible landing sites in the area of the accident, but depending on the circumstances (size of landing site, wind, visibility conditions, ground conditions) they are not always adequate. Above, sometimes the localization of the emergency site is merely vague and no detailed information on possible landing sites is available.

Consequently, the helicopter crew performs an aerial reconnaissance. Typical altitudes for the sighting of the area lie within 150 ft and 500 ft, to ensure both a good inspection of the terrain and avoidance of collision with any ground obstacles. During night operations, an initial exploration already starts at 1500 ft. During rescue missions, the helicopter has regulatory permission to land in any desired location. Basically, the responsibility for the selection of an appropriate landing site rests with the helicopter pilot, as alternative areas can be observed better from the air [10]. Moreover, there are several requirements on the characteristics of the landing site, as summarized in Table 1.

Table 1: Requirements for landing site [10]

Obstacles	The approach shall not be endangered by any obstacle like masts, towers, wind turbines, trees or high buildings. To avoid transmissions lines, a lateral separation of at least 300 meters is recommended
Resuspension	Moveable small objects accelerated by the helicopter downwash might harm the vehicle itself, its crew or third person
Terrain	The ground must be sound and stable. In free terrain, an area of 35 m x 70 m is required.

In general, landing a rescue helicopter is possible without specific temporal barriers arranged by the competent authority. The responsibility is with the aircraft pilot. He determines the landing area and requests support by the ground forces. This approach is a common practice. Only in certain situations, more extensive safety measures are applied. Because the mentioned requirements for the landing area are not easy to meet, roads and highways also apply as landing sites. In that case, a strong collaboration between pilot and ground forces is desirable. The landing site has to be indicated in advance using emergency lights and must be secured properly. Table 2 shows the rules for safety.

Table 2: Helicopter landing requirements for road closure in dependence of highway characteristics [10]

Characteristics	Operational Requirement
No road barrier to separate the opposed traffic flows.	Both directions of traffic are to be blocked.
Six-lane highway with additional emergency lane.	It is sufficient to block only one direction of traffic flow.
Four-lane Highway with road barrier.	Blocking both directions temporally might be required to avoid endangerment of helicopter and ground traffic during arrival and departure.

Aerial search and rescue operations constitute special circumstances from an air traffic control (ATC) point of view. To support respective flights, they are prioritized over other air traffic participants. Merely aircraft in emergency situations or for defense purposes have higher priority. Air traffic control is responsible for the coordination of rescue missions and redirects the surrounding traffic. The flight is performed according to visual flight rules (VFR), but excluded from SERA.5001, defining regulations on visibility and the minimal distances to clouds, and SERA.5005 b), defining that take-off and landing is prohibited outside of control zones [11], [12].

The concept of augmented rescue helicopter landings on highways raises several questions from a regulatory and legal point of view, which have already been met in this or a similar way in the controversy over autonomous and connected driving. Being still a subject of discussion, consolidated answers cannot be provided yet. Instead, this paper is confined to merely refer to the challenges that have to be met in the future by listing the respective questions:

- Are certain (emergency) forces allowed to send V2X messages with mandatory provisions?
- What is the consequence of a violation of these provisions?
- How is the legal situation in case of consequential accidents due to these provisions, e.g. rear-end collisions?
- How is the legal situation in case of accidents between aerial and ground vehicle?
- From a security point of view, should highly automated vehicles allow this kind of access for mandatory provisions?
- From a legal perspective, if the concept was implemented extensively, would helicopter landings on highways be completely independent from the presence of ground units, or would the approach be limited to be a back-up?

(Virtual) Infrastructure

Different virtual and physical infrastructure is relevant for the proposed concept. This chapter shall give a brief summary of concepts, systems and technologies.

GEOFENCE

A geofence corresponds to a virtually bounded air volume defined by GNSS technology, intended to be used as an instrument in unmanned air traffic management. Generally, it is defined by a 2D area on the ground (e.g. circle, rectangle, polygon) und a certain vertical extension. The bounded volume exhibits characteristics that differentiate it from the surrounding air space. Approaching or crossing the virtual border can induce specific system actions or requirements, but in general, geofences are defined to prohibit or restrict access for airspace users to this part of the airspace. Geofences can be established permanently, temporally or periodically.

In the considered use-case, two types of geofences will have to be created:

1. Usually, the helicopter rescue mission is supported by air traffic control, guaranteeing separation to other traffic participants, especially during the aerial inspection phase where aircraft movement cannot be anticipated. Nowadays, the increasing numbers of incidents with micro drones emerges to become a severe safety issue, as a system for interfering with the drone pilot's action has not yet been established. In the future, a geofence created by a respective entity will prohibit drones from entering the operational area and ensure a safe scouting mission. It is probable that this geofence moves with the helicopter during the whole mission.
2. Having determined an intended landing position during the scouting phase, the pilot creates or requests a geofence around this point of interest to allow a safe approach and touchdown on the traffic area. All ground and air vehicles will be prohibited from entering the volume.

BLOCKED LANE

To prevent interlinked ground vehicles from entering a certain region, either a two-dimensional virtually restricted area is defined or the usage of lanes beyond a certain point is prohibited. Ground vehicles usually are forced to use roads for their movement. This limitation reduces the degrees of freedom significantly compared to air traffic. It is therefore sufficient and more efficient to block a route segment. Additionally, that allows closing single lanes in a respective scenario, as inaccuracies in GNSS localization, which would otherwise impede a clear assignment of coordinates and lanes, are circumvented.

As was mentioned above, it is not always required to block both driving directions for the helicopter landing. However, it would be challenging to create a geofence that omits the unconcerned direction. Therefore, either a proper translation from geofence to the blocking of lanes depending on the helicopter intentions has to be performed or both air and ground vehicles should communicate in a joint manner.

VARIABLE TRAFFIC SIGNS

Variable traffic signs (VTS) are a special form of automotive traffic signs that can be switched or annulled as desired by the traffic management. Especially on highways, they are widely installed to adapt speed limits, alert in case of impeded road conditions or traffic jams and block or open single lanes. Yet, they are not intended to block the complete traffic in one direction. Anyway, for the purpose of a secure helicopter landing, the density would not be sufficient. Instead, VTS can be used in the course of the use-case to inform traffic participants sufficiently early about the risk posed by the respective accident or the helicopter mission. They allow raising the awareness of drivers for avoiding rear-end collisions.

Communication

While communication among vehicles or between vehicle and infrastructure has been researched extensively during the last decades [13], [14], [15] and implementations are established today in both ground- and air-based traffic, new areas of application arise and require further investigation or adaption. That applies for the intended use case of augmented helicopter rescue operations, where communication is required across both domains.

A direct link between aerial and ground vehicles is the preferred option as it is independent of auxiliary infrastructure or systems and eliminates additional sources of error, thereby increasing the availability and reliability of the solution. Unfortunately, history has shown that the willingness to establish common communication standards across domains is limited and the future development is uncertain.

Therefore, the current state-of-the-art and near-term development of communication standards for rescue helicopters and automotive vehicles is examined first to derive a solution that is operational at present.

RESCUE HELICOPTER COMMUNICATION

Communication is a crucial capability for safe and efficient air traffic. Certain information or instructions, usually provided by air traffic management, are required to navigate and guarantee separation between aircraft. For civil aviation, voice and data (tansponder, ACARS, ADS-B) communication is deployed.

Air rescue missions are spontaneous and therefore might interfere with un- and preplanned flights. The coordination of the prioritized rescue flights is performed by air traffic control (ATC). Digital radio and satellite telephone are deployed onboard for communication between the pilot and respectively ATC or rescue coordination center. Above, for a better coordination between helicopter crew, RLSt and ground units, the application *rescuetrack*, using a cellular connection over GSM[1], is deployed additionally [16].

Helicopter rescue missions and especially the final approach chiefly take place in low altitudes. In this airspace, most of upcoming drone flights are foreseen. There have already been several occasions where drones interfered with air rescue flights [17], [18]. To regulate, support and manage drone flights, a set of services under the name of U-space will be implemented in the near future across Europe [19]. The system shall allow safe and efficient operations for all airspace users (unmanned and already existing manned). That requires a proper interface between rescue helicopter and U-space, whereby the communication standard is yet to be defined. A potential messaging protocol for communication within U-space is the Micro Air Vehicle Link (MAVLink). Limiting the future modification expense for the helicopter, it is assumed here that the same communication standard is deployed for the air-to-ground communication.

As shown in figure 3, the pilot establishes a geofence around the desired landing point. The extensions should be defined in dependence of the highway characteristics (see table 2). The geofence is broadcasted via MAVLink to ground vehicles and the U-space system, thereby creating an exclusive volume for safe execution.

GROUND VEHICLE COMMUNICATION

Within the European Union (EU), the European Telecommunications Standards Institute (ETSI) is responsible for the establishment of V2X[2] communication standards. The working group Intelligent Transport Systems (ITS) provides a collection of standards that describe the communication system. Messages are transmitted by an adapted Wireless Local Area Network (WLAN) standard, which takes into account the requirements for automotive applications. The standard can be found under the term 802.11p in the WLAN standard family, while the special configuration of 802.11p in the EU for automotive purposes can be found under ETSI ITS-G5. The transmitted or received data is processed with various protocols which are organized in several layers. Different types of messages lay the foundation for the vehicle communication. At present, vehicles transmit two types of messages in regular operation. The Cooperative Awareness Message (CAM) periodically broadcasts information on the vehicle's position and movement to inform other communicating traffic

[1] Global System for Mobile Communications
[2] V2X means Vehicle to X, where the X stands for either vehicle or infrastructure

participants. The Decentralized Environmental Notification Message (DENM) is a special message which informs drivers or vehicles about incidents, including bad weather conditions, roadworks, accidents etc.

The DENM already contains the option to encode the use case "rescue and recovery work in process - rescue helicopter landing" and can consequently be deployed for this purpose. For automotive applications, the DENM type intends to block specific lanes beyond a certain point, as that offers the flexibility to address single lanes instead of a geofence. Still, both concepts follow the same idea of a virtual boundary and can consequently be translated into one another.

The V2X message receiver in the ground vehicle will be an original equipment device. This device is capable to process messages according to the standards provided by ETSI-ITS. Algorithms in the car derive the subsequent actions according to the content. In case of a low degree of automation, the virtual road block will be displayed to the driver properly to request an appropriate behavior. For the desired high degree of automation (SAE Level 3 and above [20]), the human behavior as a factor of uncertainty can be excluded and the vehicle immediately follows the instructions of the DENM. Coming to a halt at the defined virtual point, the vehicles thereby form a physical barrier for following traffic. For verification, the helicopter can receive and interpret the broadcasted CAM messages that include the current vehicle state, ensuring that the landing area is secured. To avoid accidents on ground, the vehicles communicate their intention to decelerate and halt via V2V DENM.

CROSS-DOMAIN COMMUNICATION INTERFACE

As described above, a common communication standard for ground vehicles and certain aircraft is not foreseeable. Consequently, an interface, denoted here as "Cross-Domain Communication Interface" (CDCI), is required to allow the air-to-ground communication, as shown in figure 4.

A D2X[3] board provided by NXP[4] allows the ground-based CDCI to receive messages transmitted by the helicopter in the MAVLink communication protocol. The board is capable to communicate over 802.11p in the same or a different frequency compared to V2X communication. Inside the CDCI, the received message is decoded, processed and encoded to the ETSI-ITS format. The application unit (AU) checks all MAVLink messages received by the D2X board and triggers a DENM in case of a planned helicopter landing. An original equipment device for V2X communication is deployed in the CDCI, called communication control unit (CCU). This device encodes and decodes V2X messages which can then be transmitted to surrounding vehicles. In our scenario, the CDCI is placed in one of the autonomous driving cars.

[3] Further information on the deployed D2X board can be found in [15]

[4] NXP contributes to the DLR project City ATM, providing hard- and software solutions for drone communication

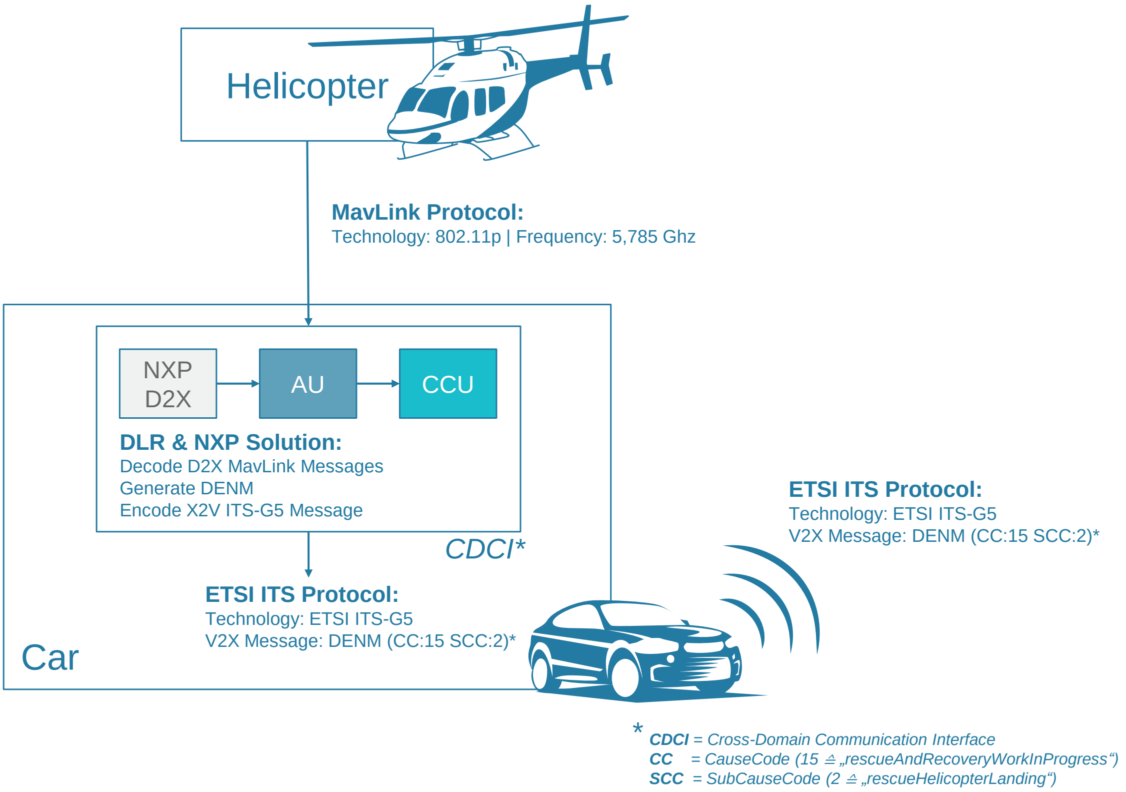

Figure 4: Flowchart for Communication between Rescue Helicopter and Ground Vehicles

Although this workaround is a functioning solution, it introduces dependency on special equipped cars. Therefore, the future implementation of direct air-to-ground communication is intended and shall be fostered by the demonstration of augmented rescue helicopter operations.

Safety & Security

Evidently, landing on high speed traffic areas entails a serious risk for air and ground vehicles. The proposed supporting communication concept is intended to reduce this risk and enable safe and efficient operations for the air rescue crew. To achieve that, the functionality must be stable under all conditions. Accordingly, some aspects concerning safety and security shall be considered briefly.

SECURITY

An interface for communication always poses a risk with respect to cyber security. As the helicopter on-board device is a self-sufficient system, it does not need to be connected to the main avionics that are responsible for critical flight tasks. Consequently, this shielding inhibits unauthorized access. That might be different in case of highly automated vehicles. When appropriate actions are derived independently based on the received information, unwanted access to the system is possible. Manufacturers across all traffic domains have to deal with this issue in the course of digitalization and are responsible to ensure that critical instructions, like the one required in the context of this paper, are not misused by unauthorized parties. In V2X communication a public key infrastructure (PKI) is used to add a digital signature to the messages [21].. With this signature, addressees (in this case the ground vehicles) are able to verify the authority of the sender of the message. The proposed approach of Air2X communication represents a weighty intervention in ground traffic and should therefore only be permitted for authorized parties, including police and rescue forces. A corresponding distinction between different parties has already been foreseen in the European PKI for V2X, allowing to authorize the rescue helicopter with the degree of rescue forces. [22] A pilot PKI system is already deployed in Germany, ensuring reliable and trustful certificate handling. [23]

SAFETY

In order to maintain the lane blocking during the whole rescue and recovery process, the message validity duration exceeds the expected operating time. After take-off, the helicopter negates the former provisions via DENM. If further ground processes like rescue or clearing work continue after take-off, additional DENMs are transmitted by the involved ground unit, thereby transferring the responsibility from the helicopter.

Future Operations

Communication between vehicles across traffic domains will become more and more important in the future. It allows safe and efficient operation and coexistence of different vehicles while boundaries between traffic domains converge or start to vanish. Some potential examples shall be mentioned briefly to trigger more research and development in this field.

RESCUE HELICOPTER IN OTHER ENVIRONMENTS

The focus of this paper is on highway rescue missions, but of course helicopter landings also interfere with ground based vehicles in other environments. Urban areas or rural roads can be mentioned exemplarily. In contrast to the highway scenario, those are non-exclusive areas where a variety of other participants are encountered (pedestrians, cyclists etc.). That increases complexity, as the virtual boundary cannot be transformed to a physical one as easily as described above. Therefore, other safety and security enablers have to be considered.

RESCUE DRONE OPERATIONS

In future, medical assistance can also be provided or supported using unmanned aerial vehicles (UAS). For instance, TU Delft has developed an ambulance drone that carries lifesaving technologies like Automated External Defibrillator (AED), medication and Cardiopulmonary Resuscitation (CPR) [24]. Above, ADAC Luftrettung investigates the potential to deploy a *Voloocopter* air taxi for rescue missions [25], which will be initially piloted. In the future, such vehicles are operated either with a remote pilot or highly automated. In case the medical drone support is required on a highway, the proposed solution for helicopter landings seems sufficient and can be adopted. The communication between drone and vehicle becomes even more important, as drones have a significant lower noise footprint than helicopters. Moreover, micro drones are visually less noticeable, so these vehicles will not attract the same attention.

EMERGENCY LANDING OF AERIAL VEHICLE

Based on recent development of Distributed Electric Propulsion (DEP) and light weight inexpensive avionics systems, drones offer the opportunity to implement more redundant designs in comparison with conventional aircraft. For certified drones, as they will be deployed for the transportation of passengers and freight, that allows to maintain at least limited control over the aircraft in most events of failure. Dependent on the type of failure, it might still be required to abort the mission immediately and perform a controlled emergency landing to reduce the risk for both air and ground. The decision for a save landing area is not trivial, especially if the failure occurs in an urban environment. If either the transported good is sensitive (blood, medicine etc.) or life of people aboard or on ground are at stake, landing on traffic areas seems reasonable and should be considered in the decision process. In that case, the landing area has to be evacuated instantly. V2X communication should be used to support that.

INSPECTION OF INFRASTRUCTURE

Avoiding scaffold construction and allowing the continuation of operation, drones enable a more efficient and faster inspection of infrastructure like wind turbines, bridges and skyscrapers. Especially in case of traffic infrastructure, these aircraft coexist with other vehicles and interference has to be avoided accordingly. For example, pursuing a potential retrenchment of 40 million Euros, Deutsche Bahn AG intends to deploy remotely piloted drones in Beyond Visual Line of Sight (BVLOS) drones for the inspection of their infrastructure and transport network, accumulating more than 33,000 km of track length [26], [27]. Flying directly above the tracks to be examined, drone operations have to be coordinated not only with train movements, but also with cars, which, depending on the type of drone mission, might interfere at railway crossings. Again, a proper communication between vehicles supports safety and efficiency.

Conclusion

The analysis of current operational and regulatory demands and the accompanying challenges revealed that developments in digitalization and automation can support rescue helicopter landings on highways. The proposed concept, using an interface for establishing a cross-domain communication, allows more efficient and safe helicopter rescue missions while being independent of ground units. The virtual barrier, requested by the pilot to segregate the landing area, prevents highly automated cars from entering the zone. Coming to a halt at the virtual border, they form a physical barrier for the following non-automated traffic. The optimal solution foresees a direct V2X communication link between air and ground, as defined by the ETSI ITS-G5 standard. Still, as both domains have established or are developing their own standards, a translating unit is required for near-term application.

For exploiting the full potential of digitalization and automation, DLR promotes a holistic approach when developing future traffic systems. These require common cross-domain communication standards for certain applications to prevent dependence on additional infrastructure, equipment or devices and thereby the introduction of potential sources of errors.

Consequently, DLR will continue to work on the maturity of the presented concept and develop an independent direct communication link between air rescue helicopter and ground vehicles to act as a motivation for further cross-domain harmonization.

Contributors

Authors

Marc Simon May	DLR Institute of Flight Guidance
Maik Bargmann	DLR Institute of Transportation Systems
Bernhard Fehr	DLR Institute of Transportation Systems

Contributors and Reviewers

Tobias Hesse	DLR Institute of Transportation Systems
Dagi Geister	DLR Institute of Flight Guidance

Special thanks to

Daniel Hecht	ADAC Luftrettung
Gerald Peklar	NXP

References

[1] DRF Luftrettung, Jahresbericht DRF e.V. 2016, Filderstadt, 2017.

[2] ADAC Luftrettung GmbH, Wieder mehr als 54.000 Einsätze der ADAC Luftrettung, 2019.

[3] T. Unger, Konstellation bei Auffahrunfällen, in: Berichte der ADAC Unfallforschung, 2011.

[4] M. Fischer, et al., Eckpunktpapier zur notfallmedizinischen Versorgung der Bevölkerung in der Prähospitalphase und in der Klinik, Notfall & Rettungsmedizin 2016 (1998-) 387–395.

[5] Schenker. Frerk, Autofahrer hindern Rettungshubschrauber an Landung, 2019, https://www.haz.de/Nachrichten/Der-Norden/Uebersicht/Autofahrer-hindern-Rettungshubschrauber-am-Landen, accessed 9 September 2019.

[6] ÄLRD Auschuss Bayern, Dispositionsleitfaden Luftrettung: Empfehlungen des ÄLRD-Ausschusses Bayern an das StMI Version 1.0, 2015.

[7] D. Hecht, ADAC Luftrettung. Email-Interview, 2019.

[8] dpa, Rettungshubschrauber kann nicht landen, 2017, https://www.focus.de/regional/rheinland-pfalz/unfaelle-rettungshubschrauber-kann-nicht-landen_id_7471000.html, accessed 9 September 2019.

[9] Bayrisches Staatsministerium des Inneren, Leitfaden zum Einsatz von Rettungstransporthubschraubern, 2013, http://www.stmi.bayern.de/assets/stmi/sus/rettungswesen/id3_24_luftrettung_ar_leitfaden_rth_20130222.pdf.

[10] Technisch-Wissenschaftlicher Beirat (TWB) der Vereinigung zu Förderung des Deutschen Brandschutzes e.V (Ed.), Merkblatt zur Zusammenarbeit Feuerwehr – Luftrettung, Altenberge, 2014.

[11] Europäische Union, Verordnung zur Anpassung nationaler Regelungen an die Durchführungsverordnung (EU) Nr. 923/2012 vom 26. September 2012 zur Festlegung gemeinsamer Luftverkehrsregeln und Betriebsvorschriften für Dienste und Verfahren der Flugsicherung und zur Änderung der Durchführungsverordnung., 2012.

[12] Europäische Union, Durchführungsverordnung (EU) Nr. 923/2012 vom 26. September 2012 zur Festlegung gemeinsamer Luftverkehrsregeln und Betriebsvorschriften für Dienste und Verfahren der Flugsicherung und zur Änderung der Durchführungsverordnung, 2012.

[13] Z. Machardy, et al., V2X Access Technologies: Regulation, Research, and Remaining Challenges, in: IEEE COMMUNICATIONS SURVEYS & TUTORIALS,

[14] E. Valovage, Enhanced ADS-B Research, Portland, Oregon, 2006.

[15] J. Lieb, G. Peklar (Eds.), Evaluation of an Unique Communication Interface System D2X for Uavs Intercommunicating with air and Ground UTM Users. 2019 Integrated Communications, Navigation and Surveillance Conference (ICNS), 2019.

[16] G. Lichy, J. Braun, C. Schulze, G. Geldner, Schnittstellenoptimierung durch den Einsatz von RescueTrack® in Notaufnahmebereichen und Intensivstationen, Notfall Rettungsmed 17 (2014) 511–514.

[17] cls, Drohne stört Hubschrauber. Flugsicherung registriert immer mehr Drohnen, 2018, https://www.stuttgarter-nachrichten.de/inhalt.flugsicherung-registriert-immer-mehr-drohnen-drohne-stoert-hubschrauber.7028dffb-f14e-42c3-81b7-ba6274768ff1.html, accessed 10 September 2019.

[18] DRF Luftrettung, DRF Luftrettung warnt vor Gefahr durch Drohnen – Rettungshubschrauber beim Start behindert, 2017, https://www.drf-luftrettung.de/de/leben/aktuelles/drf-luftrettung-warnt-vor-gefahr-durch-drohnen-rettungshubschrauber-beim-start, accessed 10 September 2019.

[19] SESAR Joint Undertaking, U-space: Blueprint, Luxembourg, 2017.

[20] SAE, Taxonomy and Definitions for Terms Related to On-Read Motor Vehicle Automated Driving Systems, 2014.

[21] M. Klaassen, T. Szuprycinski, Security for V2X, in: Y. Dajsuren, M. van den Brand (Eds.), Automotive Systems and Software Engineering, Springer International Publishing, Cham, 2019, pp. 283–294.

[22] ETSI, Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management, 1st ed., 2018.

[23] M. Ullmann, T. Strubbe, C. Wieschebrink, Vernetzter Straßenverkehr: Herausforderungen für die IT-Sicherheit, in: A. Roßnagel, G. Hornung (Eds.), Grundrechtsschutz Im Smart Car: Kommunikation, Sicherheit und Datenschutz Im Vernetzten Fahrzeug, Springer Vieweg. in Springer Fachmedien Wiesbaden GmbH, Wiesbaden, 2019.

[24] A. Momont, Ambulance Drone, https://www.tudelft.nl/en/ide/research/research-labs/applied-labs/ambulance-drone/, accessed 25 October 2019.

[25] ADAC Luftrettung, ADAC Luftrettung prüft Einsatz von bemannten Multikoptern im Rettungsdienst, 2018, https://presse.adac.de/meldungen/adac-stiftung/luftrettung/einsatz-von-volocopter.html, accessed 25 October 2019.

[26] Deutsche Bahn, Daten und Fakten 2017, 2017, https://www.deutschebahn.com/resource/blob/1774446/455c0e001500b567cc0010d53e52cccf/Daten---Fakten-2017-data.pdf, accessed 25 October 2019.

[27] P. Thomas, Die Bahn geht in die Luft: Einsatz von Drohnen, 2017, https://www.faz.net/aktuell/technik-motor/motor/deutsche-bahn-setzt-drohnen-zum-inspizieren-ueberwachen-ein-15098620.html, accessed 25 October 2019.