Driving Innovation in Crisis Management for European Resilience

D430.22 - Experiment 40 Design & Report

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Lead Participant	DLR	Lead Author	Dagi Geister (DLR)
Contributors	DLR	Reviewers	Laurent Dubost (TCS)
			Adrien Mangiavillano (POLE)

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Document Information

List of Contributors	
Name	**Partner**
Dagi Geister	DLR
Gunnar Schwoch	DLR
Sandra Detzer	DLR
Hannes Römer	DLR
Julia Zillies	DLR

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List of Acronyms

Abbreviation / acronym	Description
ACCES	Airport and Control Center Simulator
ASPS	Airborne Sensor Processing System
C^3	Command, control and communications
CIS	Common Information Space
CM	Crisis Management
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.
DLRG	German Life Saving Association
EASA	European Aviation Safety Agency
EmerT	Emergency mobility of rescue forces and regular Traffic
EO	Electro Optical
E-OVCM	European Operational Concept Validation Methodology
ERSG	European RPAS Steering Group
EXPE40	Experiment 40
FD	Final Demo
FL	Institute of Flight Guidance
FMS	Flight Management System
GCS	Ground Control Station
HALE	High Altitude Long Endurance
ICAO	International Civil Aviation Organization
IR	Infrared
JE1	Joint Experiment 1
MALE	Medium Altitude Long Endurance
mTDP	Mobile Traffic Data Platform
NM	Nautical mile
OPV	Optionally piloted vehicle
PBN	Performance based navigation
RNP	Required navigation performance
RPAS	Remotely Piloted Aircraft System
RPV	Remotely Piloted Vehicle

SAR	Search and rescue
SOTA	State-of-the-Art
SUMO	Simulation of Urban Mobility
THW	Technisches Hilfswerk (Federal Agency for Technical Relief)
TRL	Technology readiness level
TS	Institute of Transportation Systems
UAS	Unmanned Aircraft System

Project Description

DRIVER evaluates solutions in three key areas: civil society resilience, responder coordination as well as training and learning.

These solutions are evaluated using the DRIVER test-bed. Besides cost-effectiveness, DRIVER also considers societal impact and related regulatory frameworks and procedures. Evaluation results will be summarised in a roadmap for innovation in crisis management and societal resilience.

Finally, looking forward beyond the lifetime of the project, the benefits of DRIVER will materialize in enhanced crisis management practices, efficiency and through the DRIVER-promoted connection of existing networks.

DRIVER Step #1: Evaluation Framework

- **Developing test-bed infrastructure and methodology to test and evaluate novel solutions, during the project and beyond. It provides guidelines on how to plan and perform experiments, as well as a framework for evaluation.**
- **Analysing regulatory frameworks and procedures relevant for the implementation of DRIVER-tested solutions including standardisation.**
- **Developing methodology for fostering societal values and avoiding negative side-effects to society as a whole from crisis management and societal resilience solutions.**

DRIVER Step #2: Compiling and evaluating solutions

- **Strengthening crisis communication and facilitating community engagement and self-organisation.**
- **Evaluating solutions for professional responders with a focus on improving the coordination of the response effort.**
- **Benefiting professionals across borders by sharing learning solutions, lessons learned and competencies.**

DRIVER Step #3: Large scale experiments and demonstration

- **Execution of large-scale experiments to integrate and evaluate crisis management solutions.**
- **Demonstrating improvements in enhanced crisis management practices and resilience through the DRIVER experiments.**

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Executive Summary

DRIVER Subproject 4 experiments on various tools and systems that could strengthen professional responders in Crisis Management (CM). The purpose of this document is to provide the detailed plan for DRIVER Experiment 40 including its scope, goals, activities and evaluation approach. Based on a preceding background analysis, the main results of the experiment are presented and interpreted. Goals and identified gaps from the experiment are described and integrated into forthcoming experimentation campaigns and demonstration.

Among others aerial imaging of a crisis area, immediate image processing and data provision to decision makers and professional responders could add a significant benefit to CM operations. Different sensor systems can be applied and enable high-resolution imagery to map the current situation and analyse imagery with regard to e.g. crisis dynamics, crisis impact and even detect position and movement of relevant objects or people. Especially in a crisis situation it is of great importance not only to get up-to-date information about the current situation, but also to monitor any changes and dynamics over the time. In that context Remotely Piloted Aircraft Systems (RPAS) are becoming increasingly important. The advantage of RPAS is that they can be used even in dangerous or hard-to-reach areas, and enable observation of the affected regions – or regions under threat – over an extended period of time.

Currently, HALE/MALE systems are not allowed to operate in non-segregated airspace. Despite the common appreciation of the importance of these systems, RPAS flight authorizations are still issued on a case by case basis through burdensome procedures and are limited to blocked or segregated airspace. Nevertheless, various legislation initiatives and roadmaps have been initiated on a national level and suggest opening the airspace to RPAS within a timeframe of 2024-2028. Therefore, it is very important to support progress in this context and to promote RPAS operations in CM and civil protection by proving their safety and efficiency in non-segregated airspace while demonstrating their capabilities in a controlled environment.

DRIVER Experiment 40 deals with solutions for airborne situation assessment through RPAS usage and has been conducted in September 2015. It aims to evaluate the safety and efficiency of RPAS operations in non-segregated airspace in the context of a simulated crisis scenario. In addition the potential operational benefit of providing aerial image gathering and processing not only to professional responders but also to different tools that relate to crisis mapping and traffic management is evaluated. The experiment tries to demonstrate potential improvements to various CM tasks including Information Gathering, Situation Assessment and sense-making, or Decision Making. In the context of Information Gathering the objectives for this experiment were specified with regard to RPAS flight maneuvers in CM. Therefore, not only the safety and efficiency of RPAS flights in non-segregated airspace (i.e. RPAS performance in CM specific flight maneuvers), but also the datalink performance (i.e. reliability of automated control and data transmission) and image quality (i.e. sufficient quality for people and traffic detection) have been assessed. Situation Assessment and sense-making is mainly addressed through usage of solutions for traffic management and routing (i.e. availability and duration of rescue routes) and situational awareness maps (i.e.

capability to fuse crisis data into one product). Both aspects were evaluated based on quantitative and qualitative methods. During the flight experiment several data were logged and evaluated quantitatively with regard to applicable success factors.

Besides operating in airspace together with other airspace users, an application of RPAS for CM poses additional requirements on safety and efficiency. The main reason for this is that complex flight maneuvers (e.g. scan patterns) have to be executed to acquire a complete coverage of aerial images. To ensure the operational capability in forthcoming DRIVER experiments the complete data processing chain from RPAS flight, image acquisition, real-time data transfer and processing and display on the ground has been evaluated during Experiment 40.

For the purpose of demonstrating the benefits of RPAS in CM (i.e. with real-time aerial image processing), DLR provides a research aircraft demonstrating the capabilities of RPAS. This research aircraft, a Dornier 228, is equipped with a digital autopilot that is able to follow commands from ground automatically. All steering commands and flight paths can be generated and activated remotely by a ground control station. In contrast to a "real" RPAS, there will always be a safety pilot on board the aircraft who is monitoring the commands and the aircraft's status. Therefore, no legal restrictions apply to the operation of DLR's RPAS demonstrator in non-segregated airspace.

The RPAS demonstrator in Experiment 40 was equipped with high-resolution cameras to gather aerial images of an assumed crisis area over a predefined period of time. During this time the collected images were collected and processed and then transmitted to the ground in real-time. On the ground the imagery were analyzed with regard to possible people enclosed in the flooding, accessibility of roads and traffic situation in the crisis area. This information was displayed to professional responders to evaluate if the provided solutions could provide benefits in CM. In addition the aerial images were fused with the derived crisis information (e.g. water area, available rescue routes, position of trapped people) into a 3D-map for awareness of the current situation in the disaster area.

The flooding itself was simulated, but the experiment included in-field demonstrations located at a local lake, the Lake Tankum. Several volunteers were swimming in the lake while rescue teams from the German Life Saving Association (DLRG e.V.) observed the scenery and provided life-guards and a life boat for the participants in the water. With the intention to get a first insight into the end-users perspective and valued benefit of the provided solutions, different questionnaires were prepared and handed out to observers attending the experiment.

After evaluating the results from the experiment, it can be stated that a real-time aerial image acquisition and information processing can be realized with RPAS in a safe and efficient way. The aircraft's flight performance was found to be compliant to stringent safety requirements. With the achieved quality and coverage of gathered imagery it was not only possible to provide an up-to-date map of the current situation, but also to provide means to detect people in the water and determine the fastest route to their location. The observers who attended the experiment found the solutions to be very beneficial for CM. As a result, all solutions could prove their technical reliability and will be further evaluated on an operational level in the next experiments. Additional sensors (i.e. near infrared) will be equipped in the RPAS to enhance the solutions' capabilities and enable an almost real-time detection of water areas and water levels in the forthcoming experiments.

1 Introduction

This document provides the "Experiment Design & Report" for the DRIVER Experiment 40 (abbr. EXPE40). EXPE40 is part of the SP4 second round of experiments in DRIVER. It is allocated in WP43(0) (Situation Assessment Tools) and related to Task T43(0).2 (Airborne Sensor Processing). In EXPE40 a set of different systems for aerial sensor processing was integrated and evaluated in the context of crisis management (CM). It evaluates and demonstrates functionalities for airborne image data collection with Remotely Piloted Aircraft Systems (RPAS) addressing a modern trend in CM [1]. Systems for ground-based data processing and various mapping capabilities are used to test the potential benefit towards improved decision making and enhanced situation assessment. Ground-based systems for traffic analysis, route planning and rescue simulation are provided to support crisis management logistics. This document presents the experiment design and reports the results of EXPE40. The purpose of this document is to provide a detailed plan for the experiment including its scope, goals, activities and evaluation approach. Based on a preceding data analysis, the main results of the experiment are presented and interpreted. Goals and identified gaps from the experiment are described and integrated into forthcoming experimentation campaigns and demonstration.

1.1 Overview

In DRIVER SP4 experiments are similar to "laboratory experiments", using controlled settings to test new software and hardware solutions, as well as increasingly complex interactions of solutions. SP4 revolves around the needs of the responders and tackles several key issues like interoperability, information sharing, situation assessment, early warning, resource management, capacity building and interaction with citizens. Experiments will take the form of in-field demonstrations, benchmarking and laboratory experiments, but they can also include table-top exercises. In SP4 a "solution" (e.g. a simulation tool) is compared to the current practice in order to assess its potential operational benefits. By gradually stressing the new solution in terms of scenario complexity, the usefulness of the solution is assessed (e.g. a common operational picture is not useful to manage a small incident but it is helpful in more complex situations). In particular, three categories of tools will be taken into account: collaboration and situation awareness tools, early warning tools and communication tools. The tools are assessed with given scenarios using a set of both quantitative and qualitative indicators [2].

In EXPE40 different tools from the SP4 category of situation awareness were integrated and tested. The aerial sensor processing system comprises different on-board and ground-based components, which have been integrated into one experimental system for this experiment. While the output of EXPE40 could potentially improve various CM tasks, EXPE40 has a clear focus of testing and evaluating the complete data processing chain from aerial image acquisition, on-board data processing, data transmission to analysis and display on the ground. EXPE40 is the first of several DRIVER experiments that includes airborne data gathering with the DLR RPAS demonstrator and testing the required functionalities is needed to ensure the operational capabilities to collect airborne sensor data in the subsequent experiments. Different objectives to evaluate the safety of RPAS operations in CM and the benefit of the provided solutions were defined (cf. Sections 2.1 and 2.6.2).

In the context of CM topics or tasks addressed in DRIVER, this experiment includes solutions for "Information gathering", "Tasking and resource management", "Situation assessment & sense-making" and "Decision making". In the category of "Information gathering" solutions for aerial imaging by RPAS and real-time data transmission and processing were integrated and evaluated. In this context, a set of hypotheses to evaluate the safety, efficiency and reliability of RPAS flights during special flight manoeuvres for CM in non-segregated airspace were defined. In addition, the gathered imagery was evaluated with regard to quality and coverage. In the second category "Situation assessment & sense-making", EXPE40 includes solutions for person detection in flooded areas, traffic routing and simulation, up-to-date crisis mapping, and new 3D-map products for improved situation awareness. These solutions were evaluated based on a set of hypotheses that relate to providing the necessary information (e.g., water areas, persons' locations, rescue routes) based on the gathered imagery with high reliability.

The single solutions included in EXPE40 have been tested individually throughout various previous projects. In this experiment the ground-based and airborne components were integrated for the first time in a joint scenario. Therefore, the activities described in this document have aspects of an in-field demonstration with regard to the individual components, but can be more accurately described according to the DRIVER Experiment Design Manual [2] as a technological and operational test, when considering the total system.

The results from EXPE40 have not only impact on the preparation and design of DRIVER Joint Experiment 1 (JE1) and the Final Demonstration (FD), but also help to identify gaps and improvements for forthcoming SP4 experiments. Especially, the ground-based systems for mapping and traffic and logistics management have been extended based on the results from EXPE40 and will be applied in a table-top exercise within DRIVER Experiment 44 (Transport and Logistic Support).

1.2 Document structure and related documents

The document is structured as follows:

- Chapter 1 "Introduction" describes the purpose and **scope of the document, the contextualization of the experiment, and gives an explanation of the abbreviations and acronyms used throughout the document.**

- Chapter 2 "Experiment design" describes the goals and expected outcomes of the **experiment, the criteria for success and the addressed gaps in CM used as basis for the experiment planning and design. In addition, the scenario and schedule are described. An evaluation approach is elaborated with respective metrics.**

- Chapter 3 "**Experiment report**" describes **the experiment activities and the results of the experiment. The applied methods to analyse the collected data are stated and the results are interpreted. The report is completed by elaborating the lessons learned from the experiment.**

- Chapter 4 "Conclusion" summarizes the major outcomes of the experiment and defines the **goals for next experiments, including upraised gaps and solutions for design of forthcoming experiments.**

2 Experiment design

EXPE40 is part of the SP4 second round of experiments in DRIVER. It is related to the Task 43(0).2 (Airborne Sensor Processing). In EXPE40 flight trials were conducted to test the integrated system for aerial data collection and ground-based data processing. The flight experiment took place at the German Aerospace Center (DLR) in Braunschweig. The experiment involved several DLR institutes (Flight Guidance, Transportation Systems, Remote Sensing Technology and the Center for satellite-based Crisis Information), observers from the DRIVER consortium and volunteers from the DLRG e.V. (German Life Saving Association). The experiment activities were scheduled for three days (9th to 11th September, 2015).

2.1 Goals and expected outcomes

In EXPE40 the system for Airborne Sensor Processing was evaluated. Ground-based and airborne systems were integrated to provide improvements to the following CM tasks:

- Monitoring/Information gathering
- Situation assessment
- Decision making
- Tasking and resource management

While the overarching research questions deal with the potential improvements provided to the mentioned tasks, the specific objectives relate to safety and efficiency of the aerial systems and to the potential benefit of the provided functionalities like the delivery of (nearly) real-time information about the crisis or possible rescue plans to responders.

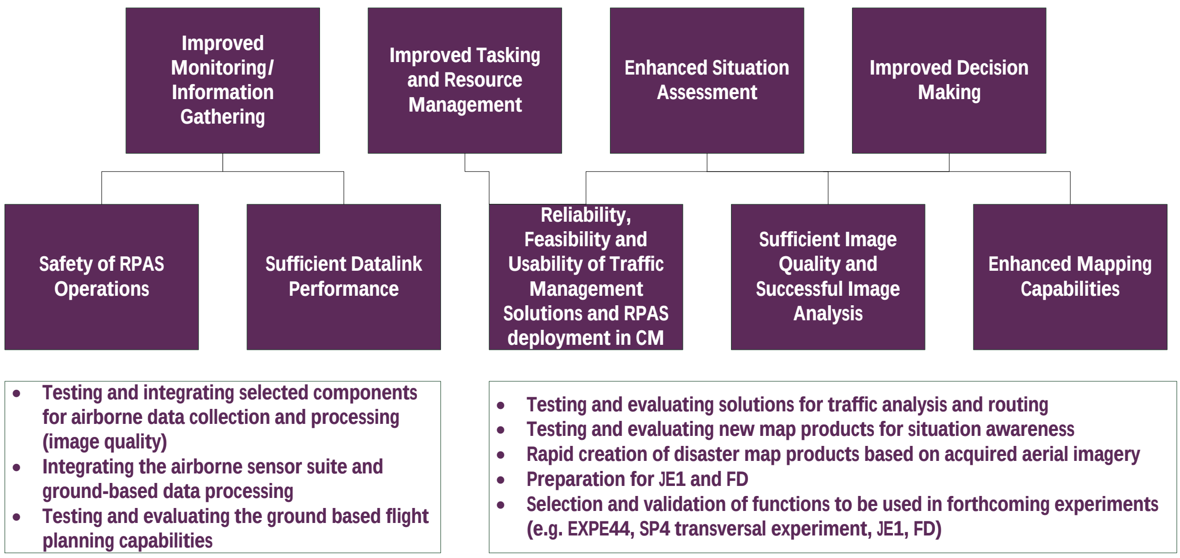

Figure 1: EXPE40 objectives

In addition, an objectives relating to the feasibility and usability of the provided solutions for CM is defined. The evaluation of the usability focusses on aspects like intuitiveness and efficiency in using a solution (see e.g. [3]), whereas the feasibility deals with the assessment of the practicality of a proposed solution (see e.g. [4]). The more specific objectives are outlined in Figure 1.

A pre-defined set of parameters of the Airborne Sensor Processing System (ASPS) was analysed within and after the experiment activities to conclude whether the provided solutions contribute successfully to the selected CM tasks. The set of related hypotheses and success criteria can be found in Section 2.6.2 of this report.

With the capabilities to (a) gather real-time information on crisis dimensions and dynamics, (b) supporting crisis logistics and transport, and (c) providing map products for improved situation awareness, the following European CM Gaps (see [1], [5], [6] and [7]) were addressed:

2. Tools for tasking and resource management: (b)
4. Early warning capabilities: (a) and (c)
5. Understanding specific crisis dynamics: (a) and (c)
10. Acquisition of information from external sources: (c)

EXPE40 not only aims to address the related CM tasks and to close capability gaps but also to demonstrate the safety and efficiency of airborne data collection through RPAS usage. In future large-scale CM operations such systems could be used to support fast situation assessment without endangering human life. In the context of DRIVER, the presented solutions and the experiment set-up will be refined based on the feedback of invited end-users. EXPE40 is expected to provide valuable insights on the potential operational benefit of the provided solutions in relation to the current practice of the DRIVER end-users.

2.2 Background

In total, 7 different solutions were tested and evaluated in EXPE40. These tools, described in more detail in section 2.3.5, can be divided into three categories:

- RPAS mission planning and flight demonstration (U-Fly , D-CODE)
- Real-time aerial imagery and situation awareness maps (3K, ZKI Portal)
- Traffic analysis and route planning (SUMO, EmerT, KeepMoving)

Since EXPE40 has a focus on the deployed airborne system for information gathering, a brief introduction of RPAS usage in CM is given in the further course of this chapter. The additional solutions for satellite imagery, mapping and traffic management were selected to close the capability gaps that have been identified by the State-of-the-Art (SOTA) work of DRIVER SP4 ([1] and [7]). For EXPE40 the potential operational benefit of the solutions from these categories was assessed based on the current practice of the invited end-users. The end-user statements and the added value can be found in Section 3.2. DRIVER EXPE44 has a clearer focus on these solutions and a more comprehensive background analysis will be provided in the related experiment report.

RPAS Usage in CM

Prompt situation assessment is a critical point for the success of a disaster management mission. In the context of DRIVER, real-time aerial imagery and relevant image processing could prove the significant benefit RPAS could bring to an informed situation assessment and decision making in CM. Especially in critical situations RPAS can be deployed to gather various types of airborne sensor data without endangering human life. Common MALE (Medium Altitude Long Endurance) and HALE (High Altitude Long Endurance) RPA can provide a payload capacity of up to 1360 kg [8] to carry multiple sensors. Presently, available sensors range from advanced Electro Optical (EO) and Infrared (IR) camera systems, to radar or gas sensors [9]. Adequately equipped RPAS can execute complex reconnaissance and surveillance missions. Thermal imaging devices support rescue forces to find victims buried under rubble, and enable the forces to continue missions during night. The extensive data is used to support fast and efficient deployment of rescue forces or distribution of relief goods. Remaining payload capacities provide the opportunity to transport special loads to areas with limited access. Conceivable loads range from disaster relief material and humanitarian aid cargo to ground-based sensors that can be deposited in certain areas.

While several studies focus on the deployment of small or rotor-winged systems, the contribution in DRIVER is devoted to the use of HALE and MALE systems for large-scale disaster management [10]. These systems are particularly useful during major disasters, because of their capability to cover very large areas during reconnaissance and surveillance missions. In addition, the maximum flight duration of these systems exceeds the possible flight duration of manned aircraft. For example, the Block 10 production version of the RQ-4 Global Hawk can image an area of a size up to 40,000 nautical square miles during a 24 hours reconnaissance mission and is capable to fly for as long as 35 hours without a break [8]. The current situation in a crisis area can not only be acquired in a short time, but dimensions and dynamics of critical events can as well be detected and provided immediately to crisis managers and professional responders. MALE and HALE systems (e.g., RQ-1 Predator, RQ-4 Global Hawk) have already been successfully employed in US disaster management missions. Global Hawk's first humanitarian mission was to assist firefighters and rescue teams during the wildfires in Southern California in 2007. Advantages of images provided by Global Hawk included real-time and infrared sensors producing clear images, despite smoke and darkness of night [11]. Further participations of these systems in disaster management include e.g., the Earthquake in Haiti in 2010 ([12], [13]) and the Tsunami in Japan in 2011 [14].

Unmanned Aircraft Systems (UAS) are a novel component in the aviation system, offering advancements which may open new and improved civil and military applications. Integration of UAS into non-segregated airspace still remains a major goal to be achieved for future acceptance of these systems. Currently the International Civil Aviation Organization (ICAO) is limiting the scope of its recommendations to RPAS (for use by international civil aviation) [15]. The European roadmap follows the same approach; therefore fully autonomous aircraft are currently not in the scope of legislation considerations[1] [16]. Special requirements for autonomous RPA systems still need to be elaborated and especially pose higher restrictions on certification (see e.g. EASA's Concept of Operations for Drones [17]).

According to the final report published by the European RPAS Steering Group (ERSG) [16], the potential of RPAS is today limited by the fact that RPAS flight authorisations are still issued on a case by case basis through burdensome procedures and are limited to segregated airspace. Since not all key technologies required for RPA to fly in non-segregated airspace are today mature and standardized, the insertion of RPAS will be gradual and evolutionary, i.e. initially restricted access under specified conditions and subsequent alleviation of the restrictions as soon as technology, regulation and societal acceptance progress. Nevertheless, various legislation initiatives and roadmaps have been initiated on a national level and suggest opening the airspace to RPAS within a timeframe of 2024-2028 (see e.g. [16] or [18]). In EXPE40, a research aircraft is utilized for the DRIVER experiments capable of demonstrating flights of an RPAS in non-segregated airspace. With these flight tests, the remote control and data transmission over datalink is tested and will show the safe operation of RPAS in non-segregated airspace together with other airspace users in complex scenarios.

EXPE40 aims to demonstrate the benefits of RPAS for large-scale surveillance in crisis situations. In detail, the provided system for RPAS demonstration (i.e. research aircraft D-CODE and the ground control station U-FLY) enables the gathering of real-time imagery with simultaneous image processing (e.g. water dimensions, people detection, traffic volume and route availability) to support crisis managers and responders. In DRIVER, the aircraft will be able to record an 80 km² area in approximately two minutes. Different sensors from optical cameras to infrared will be utilized. Further on, advanced RPAS mission planning capabilities are demonstrated by optimal flight path planning from the ground. The RPAS flight path is calculated by the U-FLY with the objective of seamless image coverage of the crisis area in the shortest time possible. During flight, the U-FLY operator can monitor the aircraft state, analyse the imagery and dynamically adapt the flight path to new information resulting from image analysis. This reactivity to new arising demands is one of the key benefits of the deployment of RPAS, because the automated and optimized transformation into new mission tasks has the potential to shorten the time needed to provide responders with the most crucial information on the crisis area significantly.

[1] This is consistent with the approach followed by DLR and their contribution to DRIVER. DLR is utilizing a research aircraft demonstrating capabilities of a RPAS. Therefore, no autonomous systems will be utilized; a remote pilot will always be in charge of the aircraft's flight manoeuvres during the DRIVER experiments.

2.3 Scenario

In this section the scenario of EXPE40 is described. This includes the basic assumptions made for the experiment planning, the participants and their respective roles in the experiment and a detailed overview of the involved tools incorporated into a joint architecture.

2.3.1 Experiment assumptions

The experiment scenario has been created based on the experiment objectives and the requirements identified according to the ACRIMAS Gaps (see Section 2.1). The crisis area and initial situation in EXPE40 are described by a flooding storyline.

After a long period of heavy rainfall, a large area between the three cities Braunschweig, Gifhorn and Wolfsburg was affected by a serious flooding. The total dimensions of the flooding are assumed to be unknown at the time of the experiment. It is presumed that there are still people enclosed in the flooded areas who need to be evacuated. The traffic infrastructure is damaged as well. Possible evacuation and rescue routes need to be identified. In the simulated scenario, a research aircraft, equipped with an aerial sensor suite and several ground systems for image data processing and traffic analysis, is available. In order to simulate all relevant steps during the experiment, a flood damage map based on satellite data with a fictive scenario was created in advance of the exercise (see Figure 2). Additionally, the flood extent was considered as a fall-back solution, for the case that weather or technical issues would prohibit aerial image acquisition. The assumed crisis area is displayed in Figure 2 and the impact on the road networks is shown in Figure 3.

Figure 2: Assumed crisis area for EXPE40 (provided by ZKI Portal)

The scenario and the associated experiment activities have been subdivided into several individual steps. After a first flight with the research aircraft D-CODE above the scenario area, the complete dimensions of the crisis area were perceived. Based on the aerial sensor data and the perceived dimensions of the crisis area, the RPAS flew a scan pattern above the most flooded areas (in this case the Lake Tankum) to try to identify persons who were enclosed by the flooding. Identified persons were then reported to the ground systems to enable fast coordination of rescue measures. The flight path then concluded with scanning the main traffic infrastructure (federal main road B4, federal motorway A2) of the crisis area. On ground the traffic situation was observed and analysed, and routes for the responders were provided. After the experiment, the collected data were gathered and fused into a map product for situation awareness.

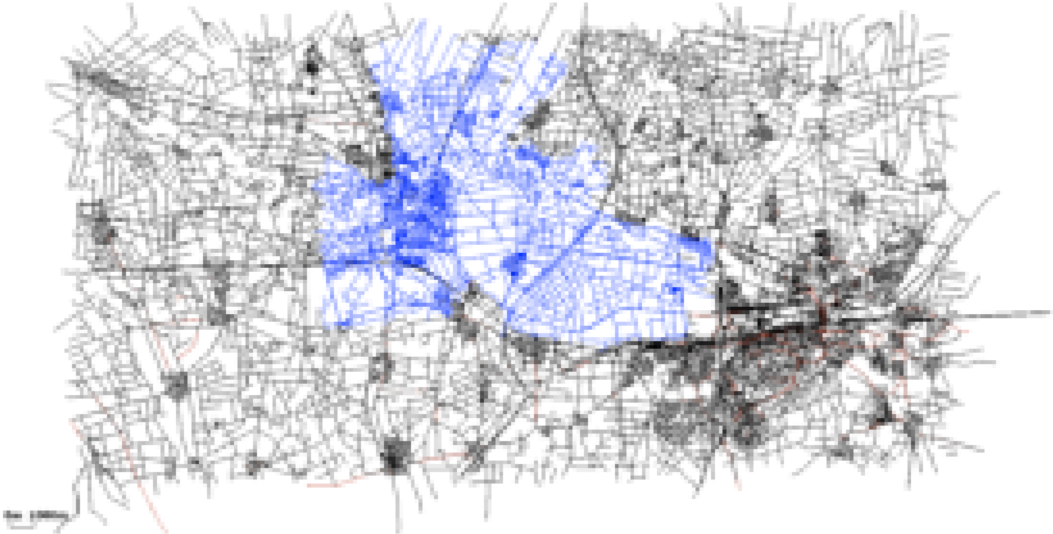

Figure 3: Affected road network for EXPE40 in traffic simulation tool SUMO

The preliminary flight path planning for the flight experiment foresaw a departure from runway 08 from Braunschweig-Wolfsburg airport (ICAO: EDVE) in north-eastern direction. After the departure, the RPAS flew a scan pattern in the area around the Lake Tankum to gather aerial images of the disaster area. After processing the collected imagery, the most affected areas were scanned with the RPAS a second time to find people in the flooded area. To find the fastest route to the disaster area for responders, the main traffic routes were then observed and traffic data gathered. Therefore, the flight plan followed the B4 and the A2 until reaching the Braunschweig area.

Figure 4: Flight plan for scenario (experiment step 1)

Depending on different external influence factors at the day of the experiment (e.g. wind, runway configuration, and visibility conditions) a set of flight plans was prepared for the experiment. In Figure 4 and Figure 5 the flight plans used in EXPE40 for the different experiment steps (see section 2.4.1) are displayed.

The feasibility and informative value of the experiment relies on the following assumptions:

- The remotely controlled aircraft's performance and controllability is representative for the use of RPAS.
- The water surface of the Lake Tankum is similar in its characteristics (e.g. water movement, colour, reflection) to flooded areas.

Historical traffic data available for the Braunschweig area are representative of the traffic occurred at the day of the experiment.

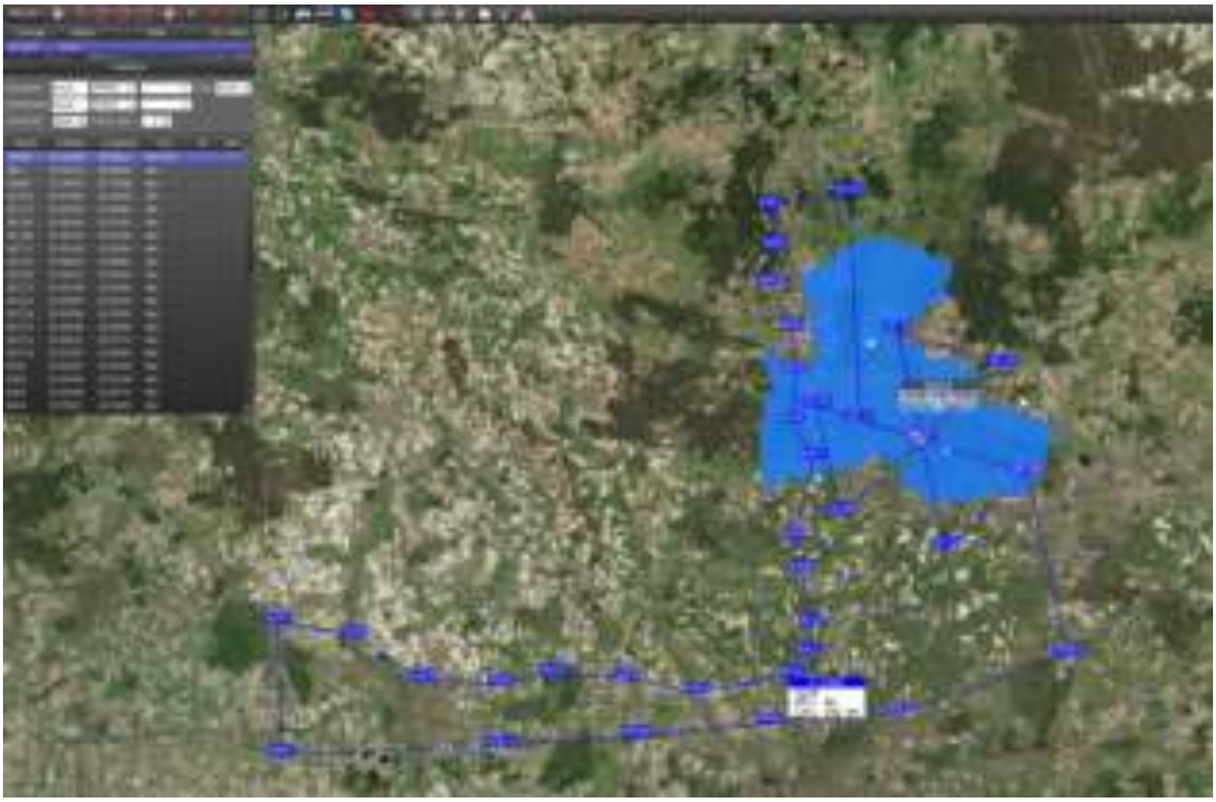

Figure 5: Flight plan for scenario (experiment step 2)

2.3.2 Involved organizations

The experiment was conducted by the DLR institutes Flight Guidance (FL), Transportation Systems (TS), Remote Sensing Technology (IMF) and the Center for satellite-based Crisis Information (DFD-ZKI). In the experiment several people from DLR were involved, including aircraft pilots, RPAS ground operators and system operators for the crisis management tools EmerT, KeepMoving, and SUMO.

Further DLR-personnel was positioned at the Lake Tankum to take on the roles of people in need in the flooding area. The DLRG station at Lake Tankum was informed about the experiment and provided life-guards and a life boat for the participants in the water.

Real-time aerial imaging and traffic analysis capabilities were observed and evaluated by professional responders attending the experiment.

2.3.3 Hosting platform

The experiment activities were performed at Braunschweig-Wolfsburg airport, on an operational platform, from 9th to 11th September 2015.

When researching new flight guidance concepts, it is very important to conduct field tests and demonstrate their use in realistic environments in order to ensure acceptance among future users and decision-makers. To this end, DLR maintains comprehensive installations at Braunschweig airport to explore new aircraft and air traffic management systems in an operational environment.

The installations at Braunschweig research airport, an airport with good technical facilities and comparatively lower traffic levels, allow DLR to implement prototypes and conduct field tests in the direct vicinity, without jeopardising the required safety of flight operations. In the context of EXPE40, which included demonstrations of RPAS flights to gather aerial images, the facilities of Braunschweig-Wolfsburg airport provided optimal and safe conditions.

The Airport and Control Center Simulator (ACCES) acts as a management center with working positions for different operators. The operators can avail different support systems at their working positions depending on the application. The information that is relevant to all participants can be shown on the display wall.

Figure 6: Crisis control room for EXPE40

In EXPE40, the research aircraft D-CODE was operated as an optionally piloted vehicle (OPV) from the Braunschweig-Wolfsburg airport, controlled and monitored from a ground control station, which has been integrated into the ACCES. Further systems for aerial image processing, traffic analysis and rescue planning were integrated into the control center (see Figure 6).

2.3.4 Participants and roles

DRIVER partner / Stakeholder / Customer	External / Internal to the Project	Involvement	Performance expectations	Validation objectives
DRIVER partner (Thales)	Internal	Expert input Observation and feedback	Contribution to the experiment design with expert knowledge	Validate procedures, feasibility and usability of ground systems
Practitioners (THW, Pole Risques/SAFE)	Internal	Expert input Observation and feedback	Contribution to evaluation of the provided system	Validate operational feasibility and usability of ASPS system for CM
DRIVER method support (CNS)	Internal	Methodological expertise in experiment design and validation	Contribution to the experiment design and scenario plan in order to ensure the consistency with the technical requirement and the experimental procedure for DRIVER	Assist in experiment design methodology
DRIVER dissemination (ARTTIC)	Internal	Coordination and regulations for DRIVER dissemination activities	Coordination and contribution to PR activities	-
Aircraft Pilots (DLR)	Internal	Expert input Observation and feedback	Understanding and experience in aircraft performance and safety	Assessment of safety of remotely piloted operations

Table 1: Participants and roles

The solutions presented and evaluated in EXPE40 were operated by the solution providers. External observers (i.e. end-users and professional responders) attended the experiment, were introduced to the functionalities of the individual solutions and provided feedback on the solutions regarding the possible added value for CM.

2.3.5 Architecture

The Aerial Sensor Processing System is composed of several individual components, which were integrated into a complete experimental system for the setup of this experiment. In detail, the following systems were part of the experiment's architecture:

- RPV D-CODE: The research aircraft D-CODE, a modified Dornier 228 with digital autopilot and control/payload datalink, can be controlled via the ground control station (GCS) and used as remotely piloted vehicle (RPV) demonstrator in DRIVER experiments. Equipped with the 3K camera system, the RPV will gather aerial images of a disaster area.

- 3K: The 3K camera system is integrated into the RPV D-CODE and sends down georeferenced images and derived image products to the GCS.
- U-FLY: U-FLY is a ground control station (GCS) for RPV. The capabilities include mission planning and evaluation for single RPAS or swarm formations. It receives aerial sensor data, processes and evaluates sensor data, and dynamically adapts RPV missions to newly received information.
- SUMO: SUMO is a free and open traffic simulation suite. SUMO allows modelling of intermodal traffic systems including road vehicles, public transport and pedestrians. The simulation suite includes a broad selection of supporting tools which helps the user to import common network formats (e.g. OSM), visualize and find the best route in a street network. For EXPE40, SUMO is used to show traffic simulation scenarios based on historical traffic data.
- EmerT: EmerT (Emergency mobility of rescue forces and regular Traffic) is an information system for rescue forces helping them to make decisions based on up-to-date information and forecasts. In EXPE40, EmerT processes aerial images, provides access for the processed images to other systems as U-FLY, and displays the aerial images together with traffic data.
- KeepMoving: KeepMoving provides information about the traffic situation, predicted travel times for specific routes, isochrone maps and general traffic prediction based on actual or historical traffic data.
- ZKI-Portal: The ZKI (Center for satellite based Crisis Information) is a service of DLR - German Remote Sensing Data Center (DFD). Its function is the rapid acquisition, processing and analysis of earth observation data and the provision of satellite or airborne based information products on natural and environmental disasters and for humanitarian relief activities.

In Figure 7 the experiment architecture for EXPE40 is displayed. The 3K camera system was integrated into the D-CODE, which was operated as a RPV during the flight trials. The flight path planning and remote control was provided to the aircraft by the GCS U-FLY. The RPV gathered aerial images and send the data over a datalink to the ground system. Based on the sensor images, EmerT, KeepMoving and SUMO provided traffic analysis and route planning capabilities.

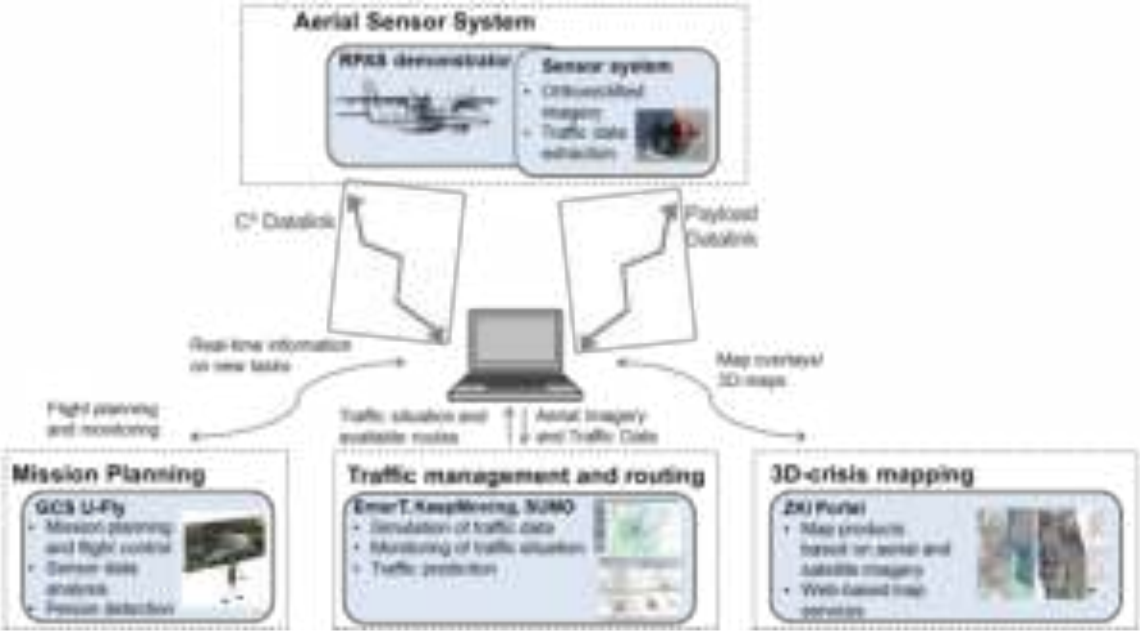

Figure 7: Solutions, functions and experiment architecture

Ground-based system:

The interoperability and usability of the traffic analysis and rescue planning systems (EmerT, KeepMoving and SUMO) have already been validated in several projects (e.g. VABENE, see [19]). According to the EC definitions [20], the components and systems have been validated in a relevant environment. Therefore, the technology readiness level (TRL) of the ground-based systems can be defined as 6. SUMO has already been applied in an operational environment and has a higher TRL of 7.

Airborne system:

The remote control of the research aircraft D-CODE with the GCS U-FLY has been validated in a set of flight experiments in early 2015. The TRL in this context is set to 5.

The operability and interoperability of the complete system comprising airborne and ground-based components has been the focus of EXPE40. Different metrics and indicators were defined to assess the technical functionality and maturity of the provided CM solution.

The crisis management center has been set up with three different workplaces. The first workplace was created for the U-FLY operator. The second and third workplaces were foreseen for the SUMO and EmerT operators. The payload datalink equipment was positioned externally and connected via local network. The ground station of the control datalink was stationed in a separate room, the telemetry, and was connected via local network.

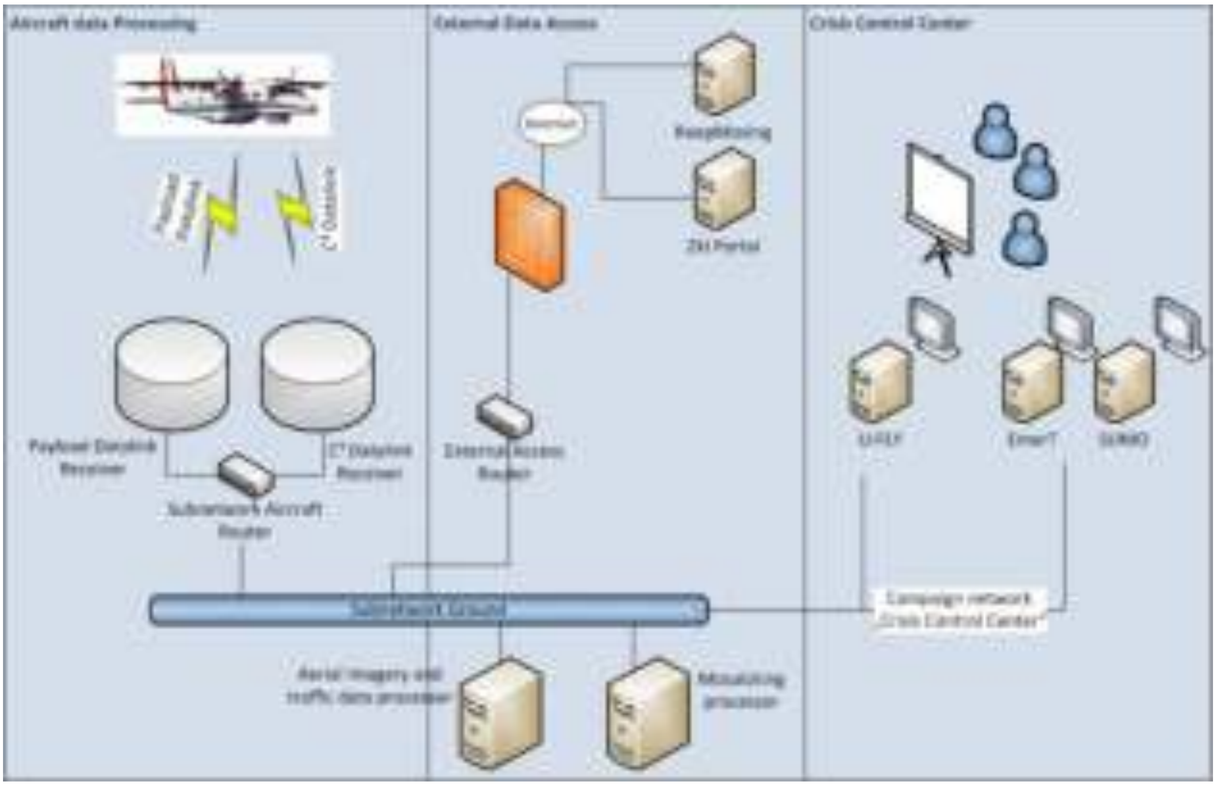

Figure 8: Communication infrastructure

The experimental setup made use of several sub-networks (e.g. crisis control center, aircraft Data processing, and external data access) with well-defined interfaces. Two central servers were used to gather all relevant experimental data and provide them to the solutions. The aerial images were transformed into different data formats (e.g. jpg, geotiff, 3D-pdf) to meet the requirements of multiple post-processing and display systems. These data formats are foreseen to be provided to the Common Information Space (CIS) within forthcoming experiments. The involved systems and the provided communication infrastructure are displayed in Figure 8.

2.3.6 SP2 test-bed integration

The preparation and planning of EXPE40 has been based on methodological support from SP2. During the experiment, an analysis has been carried out to identify possible data that could be relevant for the DRIVER test-bed. These data are foreseen to be provided for the test-bed in the forthcoming EXPE44 (Transport and Logistic Support).

2.4 Running the experiment

The scenario and the associated experiment activities have been subdivided into several individual steps. The outcome of each single step feeds back into the planning and execution of the subsequent step. A description of each experiment step, the schedule and milestones of EXPE40 are presented in this section.

2.4.1 Experiment steps

Step 1	
Description	Notification of Flooding and Scanning of Disaster Area
Goal	The mission for aerial situation assessment will be planned and coordinated (Aircraft departure and flight times, availability of sensor data).
Information to participants	Notification of crisis event with rough dimensions of the crisis area (tri-city area Braunschweig – Gifhorn – Wolfsburg)
Expected reaction	Planning and conducting RPV flight for aerial sensor data collection to get a first overview of the crisis dimensions
Situation after	Detailed knowledge of the affected area (Lake Tankum and nearby towns, e.g. Isenbüttel) will be obtained.
Duration	~ 45 minutes (for a 250 km² area)

Table 2: Experiment step 1

Step 2	
Description	Detecting People in Crisis Area
Goal	The mission for the RPV will be planned to scan the affected area closely for people in need.
Information to participants	Severely flooded areas were detected in the aerial images.
Expected reaction	Planning and conducting RPV flight for scanning the affected area closely for people enclosed in the high waters
Situation after	If people are detected, their position is reported to the GCS.
Duration	~ 30 minutes (for a 120 km² area)

Table 3: Experiment step 2

Step 3	
Description	Traffic analysis and rescue planning
Goal	Based on the location of the people in need (Lake Tankum area), the RPV will fly along the main inbound and outbound routes (B4 and A2) to get aerial images of the relevant traffic infrastructure.
Information to participants	The participants are notified about area that needs to be assessed according to plan rescue and evacuation.
Expected reaction	Planning and conducting RPV flight for aerial sensor data collection to get information about status of the traffic infrastructure. The images are going to be processed by the ground systems EmerT and SUMO. The traffic analysis provides detailed information about availability of traffic routes and traffic density in the observed areas. Different rescue routes can then be simulated.
Situation after	A recommended rescue plan with actual data on flooding dimensions, positions of people in need and traffic infrastructure will be available.
Duration	~ 25 minutes (for a 110 km² area)

Table 4: Experiment step 3

Step 4	
Description	Mapping situational awareness of disaster area
Goal	Preparation of a 2D and 3D situational map composed of aerial images
Information to participants	Post processing of aerial images (no participants involved)
Expected reaction	Post processing of aerial images to provide detailed map products for improved situational awareness on flooded area
Situation after	New kinds of map products (3D-PDF, and 3D video animation) with a surround view of the crisis area. In forthcoming experiments this will be enhanced with further near real time information, e.g. on water levels, flooded infrastructure etc., in order to directly support RPAS mission planning.
Duration	2 days of data processing

Table 5: Experiment step 4

2.4.2 Experiment and scenario schedule

	Description	Date	Duration
1	Ground System Tests (Interfaces, Network, Configurations)	09/07/2015	08:00 – 17:00
2	On-board System Tests (Sensor Processing, Datalink)	09/08/2015	08:00 – 17:00
3	Complete System Test	09/09/2015	08:00 – 17:00
4	Scenario Execution (Step 1)	09/10/2015	14:00 – 15:00
5	Scenario Execution (Step 2)	09/11/2015	09:00 – 09:30
6	Scenario Execution (Step 3)	09/11/2015	09:30 – 10:00
7	Scenario Execution (Step 2)	09/11/2015	14:30 – 15:00
8	Scenario Execution (Step 3)	09/11/2015	15:00 – 15:30
9	Debriefing, Feedback, Discussion	09/11/2015	16:00 – 17:00
10	Scenario Execution (Step 4)	09/11/2015 - 09/15/2015	

Table 6: Experiment and scenario schedule

2.4.3 List of experiment milestones

Milestones	Description	Date
M1	Scenario defined	07/01/2015
M2	Experiment plan defined	07/31/2015
M3	Aircraft equipment certified	09/07/2015
M4	On-board tests completed	09/07/2015
M5	Ground tests completed	09/07/2015
M6	System integration tests completed	09/08/2015
M7	Experiment completed	09/11/2015
M8	Data analysis completed	01/15/2016
M9	D43.22 (Experiment Design & Report) completed	03/31/2016

Table 7: Experiment milestones

2.5 Ethical, legal and societal considerations

RPAS deployment in controlled airspace

The term UAS (Unmanned Aircraft System) refers to those systems which involve the movement of air vehicle without a human operator on board. These systems include not only the aircraft, but also the supporting ground, air, and communications infrastructure. The RPAS is a subcategory of this family, indicating all those UAS that have a human operator (or remote pilot) operating the air vehicle from a remote position (Ground Control Station - GCS) and in constant control of the vehicle [15]. The aerial vehicle, called RPAS, has been considered by ICAO as an aircraft, so it has to comply with the Rules of the Air as any other aircraft.

Integration of RPAS into non-segregated airspace is recognized as a major issue to be solved for future acceptance of RPAS in air transport. Up to now most civil and military RPAS operations are taking place in segregated airspace in order to ensure separation and collision avoidance with other traffic. This limitation to segregated airspace limits the exploitation of the potential capabilities of RPAS. Therefore, additional research and experiments are necessary to create and prove concepts for a safe integration.

For the purpose of demonstrating the benefits of RPAS in CM (i.e. with real-time aerial image processing), DLR is providing a research aircraft demonstrating the capabilities of RPAS. This research aircraft, a Dornier 228, is equipped with a digital autopilot that is able to follow commands from ground automatically. This means that all steering commands and flight paths can be generated and activated remotely by a ground control station. In contrast to a "real" RPAS, there will always be a safety pilot on-board the aircraft who is monitoring the commands and the aircraft's status. Therefore, no legal restrictions apply to the operation of DLR's RPAS-demonstrator in non-segregated airspace.

The level of automation and capability of being remotely controlled is implemented in the aircraft in a two-staged process to minimize any potential risks. In the first stage the flight path and steering commands are transmitted to the aircraft over datalink. The flight path is then translated on-board into steering commands for the Flight Director. The Flight Director is an interface system that computes and displays the proper pitch and bank angles required for the aircraft to follow a selected path. Therefore, in this first stage the pilot follows manually the directions provided by the Flight Director. The aircraft is hereby not flying automatically. This allows analysing the functionality, reliability and safety of the remote commands before entering into automated flights. This stage 1 has been implemented for EXPE40 and is evaluated in this report. In stage 2 the flight path and steering commands will be directly transmitted to a digital autopilot and therefore followed by the aircraft automatically. The pilots remain on-board, but have only a monitoring role with the ability to intervene if the aircraft's or other airspace users' safety is endangered. The second stage will be tested and evaluated thoroughly within multiple DLR internal flight experiments before demonstrating the capabilities of the aerial system within DRIVER in Joint Experiment 1 (JE1). A technical overview of the two-staged system can be found in Annex A.4 (see Figure 42 and Figure 43) for more detail.

Privacy and Data protection

EXPE40 envisages the detection of people through satellite images and gathered aerial images from RPAS flights as a means to facilitate the most rapid evacuation possible from a crisis area. Privacy issues in this connection will be addressed in a variety of ways:

- The satellite imagery to be used has an image resolution that is sufficient to detect the location of humans in urgent need of help, i.e. an extent which allows distinguishing between humans and non-humans.
- Actual personal identification of human beings will not be performed. Human beings that are localised will not be identified or tracked. The same is valid for the use of the airborne sensor systems.
- In EXPE40 the group of people to be detected in the water were recruited especially for the experiment. They were informed about the objectives of the experiment and the type of data that was recorded. All volunteers gave their consent to participate.
- The collected data are stored on a password protected server and all personal details of participants have been anonymized.

Another field of application in EXPE40 is the analysis of aerial images regarding traffic density and traffic movement. Privacy issues in this connection will be addressed in a variety of ways:

- The satellite imagery to be used has an image resolution that is sufficient to detect the location and number of cars, i.e. extent which allows distinguishing between cars and non-cars.
- An identification of car license plates will not be performed. Cars that are localised will not be identified. The same is valid for the use of the airborne sensor systems.

This process is completely in line with the applicable legislation for utilization of RPAS and aerial/satellite image collection in Europe (see [21] for more details). The relevant guideline for Germany has been elaborated by the Federal Ministry of Transport and digital Infrastructure (see Annex A.5) and states that geospatial data do not need any special data protection considerations if the following restrictions for image resolutions are met:

- Maps with a scale lower than 1:5000
- Satellite and aerial imagery with a ground resolution of more than 20 cm per pixel
- A squared area of 100 m x 100 m or higher
- Aggregated information on a minimum of 4 households.

These restrictions are completely met in EXPE40.

2.6 Evaluation approach and metrics

The aim of EXPE40 has been the integration of different ground-based and airborne systems for Aerial Sensor Processing to provide improvements to selected CM tasks:

- Situation assessment
- Monitoring/Information gathering
- Decision making
- Tasking and resource management

The experiment has been conducted as an in-field demonstration in combination with technological and operational tests. From a technical perspective the experiment is also seen as a preparation for the subsequent experiments that deploy the DLR RPAS demonstrator to collect airborne sensor data.

The experiment scenario was subdivided into four steps (see 2.4.1):

- Airborne Sensor Processing (scanning of disaster area) – Step 1
- Airborne Sensor Processing (detecting people in need) – Step 2
- Airborne Sensor Processing (observe & analyse traffic and plan routes) – Step 3
- Airborne Sensor Processing (mapping of disaster area) – Step 4

In each step data has been collected that was needed as input for the following scenario steps. The main goal of Aerial Sensor Processing was to provide situational data on a crisis area in reduced time and thus be able to support responders effectively in the planning of rescue tasks. The results from the validation exercise fed back to the Aerial Sensor Processing System and the experiment design of subsequent experiments.

After the trials, feedback from observations, questionnaires and discussions was collected. Evaluation and analysis of these data was performed after the experiment and prepared for the experiment report (see Chapter 3).

2.6.1 Evaluation approach

Both qualitative and quantitative data have been collected. Qualitative data describe the participating pilots’ and professional responders’ ideas and thoughts concerning the experiment objectives. The debriefing questionnaire and feedback is considered as qualitative data. Quantitative data such as datalink quality and detection rate are used in conjunction with the qualitative data to assess the experiment objectives. The resulting data from questionnaires are subjective, whereas the detection rate to identify certain targets in aerial image data are considered as objective data.

The following assessment methods and techniques were used:

1. Evaluation Sheet
2. Data logging

3. Debriefing with a tailor-made questionnaire

Below an example of these methods:

Methods	Metrics	Completed
Research aircraft log recording	Gather information on the research aircraft while performing an experiment scenario e.g. position and speed	During experiment run
Evaluation Sheet	E.g. assess participants' ratings of overall safety etc.	After the experiment run
Debriefing Questionnaire	E.g. assess participants' ratings of the impact of the system under test and/or procedures on feasibility	After the experiment run

Table 8: Methods and metrics

Some data were recorded using electronic devices, whereas the questionnaire and evaluation sheet are paper-and-pencil instruments. Some analyses were qualitative or purely descriptive, but quantitative statistical analyses using well established methods are performed as well. The inputs to the analyses were the logged experiment data (e.g. image quality, datalink latency), the questionnaire and evaluation sheet responses. Given the scope and the design of the trials with only a small sample size and therefore reduced statistical power, most analyses were descriptive or were using non-parametric tests.

The experiment was completed as an in-field experiment. Therefore, a set of dependent and independent variables could be found in the setup.

The independent variables were as follows:

- Traffic events
- Meteorological conditions
  - Clouds
  - Wind
  - Rain
  - The time of day

The dependent variables are defined as follows:

- Objective measurements
  - Data logged by the systems during the experiment
- Subjective measurements
  - Certainty of the answers
  - Answers to the questionnaires after the trial
  - Comments during the debriefing

The most important requirement is the synchronisation of all logged data. Therefore a UTC stamp is used in all the data shown in Table 9.

Logging position	In	Out	Data format
Aircraft	Moving aircraft	GPS position, speed, heading, bank angle	Tailor-made log format
Control Datalink		Datalink quality (roundtrips/sec), Datalink latency	Tailor-made log format
U-FLY	Aircraft State Vector	Flight Path Planning (Trajectory), given commands, Datalink quality	Tailor-made log format
Image Analysis	Aerial Image, Aircraft State Vector	Number and position of identified persons	Tailor-made log format
3K	Aircraft Position	Aerial Images	geotiff, jpg + aux
EmerT	Aerial images and data gained through image analysis, flight positions, maps	Aerial images and data gained through image analysis, flight positions, maps, TMS	geotiff, jpg + aux, data access through jdbc, pdf
SUMO	Historic traffic data	Predictions based on traffic data	Custom
KeepMoving	Traffic data	Traffic situation, travel time and traffic predictions	visual
ZKI	Aerial Images (geotiff)	mapping products for situational awareness	jpg, (3D) geopdf, shp, mp4
Experimental survey	Answers from the participants	Observations, answers in questionnaire, evaluation sheet and given feedback	Tailor-made questionnaire

Table 9: Logged data formats

2.6.2 Indicators and metrics

The experiment analysis was based on a set of predefined objectives. These objectives can be subdivided into technological and operational objectives. On the technological level, the complete Aerial Sensor Processing System was evaluated. On the operational level, the systems' capability to improve the selected CM tasks was evaluated. Five basic experiment objectives were defined by DLR, each evaluated with a set of success criteria. The objectives and the success criteria are formulated as hypothesis with the criteria for null hypothesis. Questionnaires for the debriefing are included in the Annexes A.2 and A.3.

The success criteria are adapted to special situations and the platform used in the experiment. Within this experiment the following five validation objectives were defined. In line with E-OCVM [22], more detailed functional objectives will be defined with growing maturity of the system.

Identifier	Objective
OBJ#1	The safety is maintained or improved under all normal conditions when the D-CODE is remotely controlled by U-FLY.
	Success Criteria
SUCCESS#1	The pilots' perceived safety by following the control and steering commands from ground is comparable to executing the commands automated.
SUCCESS#2	The commands and trajectories generated by U-FLY are accepted by the Flight Management System (FMS).
SUCCESS#3	The actual flight path and aircraft behaviour (in comparison with the planned/commanded data) is in line with existing airspace regulations on safety.

Table 10: Objective 1

Identifier	Objective
OBJ#2	The payload and control datalink performance is sufficient for LOS (Line-of-Sight) operations in crisis management scenarios
	Success Criteria
SUCCESS#1	Control and payload datalink quality and latency sufficient to a) Control the aircraft remotely b) Gather overlapping aerial images

Table 11: Objective 2

Identifier	Objective
OBJ#3	The image analysis system is able to detect persons in flooded areas
	Success Criteria
SUCCESS#1	The aerial image quality is sufficient
SUCCESS#2	The number of persons in the water (Lake Tankum) will be automatically detected

Table 12: Objective 3

Identifier	Objective
OBJ#4	The Aerial Sensor Processing and Traffic Management System are reliable, feasible and usable in CM
	Success Criteria
SUCCESS#1	Short time span from imaging to detection of people
SUCCESS#2	Different variants for rescue routes can be planned based on the traffic situation
SUCCESS#3	Feasibility and usability of Aerial Sensor Processing and Traffic Management System are rated positively by end-users
SUCCESS#4	The predicted traffic situation and travel duration of rescue forces can be provided based on the current traffic situation

Table 13: Objective 4

Identifier	Objective
OBJ#5	The aerial maps (2D and 3D) for situational awareness are a valuable support in CM
	Success Criteria
SUCCESS#1	Newly concepts for 2D and 3D maps for situational awareness are provided
SUCCESS#2	Aerial imagery as well as derived digital surface model offer a great potential for the creation of advanced 3D-cartographic (animated and interactive) information products

Table 14: Objective 5

Steps of Experiment	Description	Objectives	Data collection
Step1	Scanning of Disaster Area	OBJ#1, OBJ#2	Input: Flight Path Output: Aerial Images, Questionnaire, Datalink Logging, Transfer Times
Step2	Detecting People in Need	OBJ#3	Input: Aerial Images, Aircraft Position Output: Number, position and time to detect people
Step3	Observe, analyse	OBJ#4	Input: Aerial Images,

	traffic and plan rescue routes		Points of Interest, traffic data, traffic simulation Output: Questionnaire, current and predicted traffic situation, traffic data, predicted travel duration
Step4	Mapping situational awareness of disaster area	OBJ#5	Input: Aerial Images

Table 15: Objectives for experiment steps

The experiment objectives are defined in Table 10 to Table 14. To complement the experiment description and especially to make a connection between the objective success criterions, Table 16 contains the identifiers and shows their connection to the used indicators and metrics / methods.

Object identifier	Success Criterion Identifier	Indicator	Metric / Method
OBJ#1	SUCCESS#1	Pilots' answers and comments on the aspect of perceived safety reveal mainly positive values.	• Answers to the safety related questions within the debriefing questionnaire • Comments during the debriefing
	SUCCESS#2	Low failure rates for given command and trajectories	• Data logging analysis (failure rate)
	SUCCESS#3	Low deviations from assigned flight plans and steering commands	• Data logging analysis (altitude and cross-track error)
OBJ#2	SUCCESS#1	High datalink performance and reliability	• Data logging analysis (quality, failure events, latency)
OBJ#3	SUCCESS#1	Aerial image resolution of high quality	• Aerial image analysis
	SUCCESS#2	The majority of people in the Lake Tankum were detected automatically.	• Detection rate and time • Visual comparison of aerial images and examination
OBJ#4	SUCCESS#1	Low detection time	• Logging of detection events
	SUCCESS#2	Traffic analysis provides information for rescue routes	• Traffic detection, analysis and prediction

Object identifier	Success Criterion Identifier	Indicator	Metric / Method
	SUCCESS#3	End-user answers and comments on the aspect of feasibility and usability reveal mainly positive values.	• End user questionnaire • Debriefing comments
	SUCCESS#4	Traffic analysis and prediction provides traffic forecasts and planned travel duration of rescue forces.	• Logging traffic situation • Traffic detection and prediction
OBJ#5	SUCCESS#1	Mapping products provide different situational awareness information.	• Aerial Image Analysis • GIS map production
	SUCCESS#2	High quality of imagery and surface models for the creation of advanced 3D-information products	• Creation of 3D-PDF and video animations

Table 16: Indicators and metrics/methods

2.6.3 Evidence

During the experiment, different quantitative and qualitative data have been collected. These data were collected either during or directly after the execution of an experiment step. In Table 17 all collected evidence is listed.

Category	Data types	Data format
Quantitative	aircraft (UTC-time, longitude, latitude, altitude, speed, track, roll, pitch, flight path, steering commands)	ASCII
Quantitative	control datalink (UTC-time, aircraft position, roundtrip packages/second, latency)	ASCII
Quantitative	ground station (UTC-time, longitude, latitude, altitude, speed, track, roll, pitch, flight path, steering commands, datalink status)	text-file (.txt)
Quantitative	payload datalink (UTC-time, aircraft position, roundtrip packages/second)	text-file (.txt)
Quantitative	aerial images (UTC-time, operation mode, resolution, image, position, coverage)	.jpg, .tif, .aux, .coverage, .geotif
Quantitative	traffic planning (UTC-time, position and number of traffic, planned routes)	text-file (.txt)
Quantitative	map products (3D-map, video)	3D-pdf, .avi, .mov
Qualitative	end user questionnaire	.pdf
Qualitative	pilot debriefing evaluation sheet	.pdf

Table 17: Evidence

2.6.4 Level of representativeness/limitations

The limitations of this experiment are limitations generally found in comparable V2 maturity level experiments (see [22]) and also related to any in-field experiment. In general, the maturity assessment dictates the nature of the evaluation and therefore the level of representativeness and limitations. In this experiment, the following limitations were identified:

- The results of the experiment are representative for Aerial Sensor Processing under test on the level of a simulated crisis. Implications are limited to overall conditions, traffic conditions and events similar to this evaluation experiment.
- Only some data regarding different weather conditions can be gathered.
- Due to the limited time, the experiment scenario was only executed once. The multiple execution of the experiment could increase significance of the results (e.g. aerial data quality, datalink quality, efficient traffic monitoring).
- The participating pilots may not feel able to give an opinion, because they have not used the system in complete automation mode yet.
- Another limitation is the limited number of participating professional responders and aircraft pilots used in the evaluation that may influence the weight of the collected results.

2.7 Lessons learned

The preparation of the experiment can generally be seen as a success. The preparation started well in advance (i.e. 6 months) and gave all participants sufficient time to prepare the scenario, the system architecture and the evaluation approach. The scenario was adequately defined, not only to evaluate the proposed solutions from a technical perspective, but also to demonstrate their benefit for CM. The system architecture was defined in several iterations until all communication interfaces were properly specified. In addition, a fall-back simulation architecture was established for the case that flight trials would have been cancelled due to external circumstances (e.g. weather, airspace restrictions, and aircraft certification). The evaluation approach and the applied metrics were discussed thoroughly and proved to be adequate for the experiment.

One major issue in the preparation phase of the experiment was the scheduling of preparation, meetings, and rehearsal, which was difficult to estimate and decide. A preparation phase of six months prior to experiment execution appeared to be sufficient for planning and definition. Frequent preparation workshops and face-to-face meetings could help to facilitate a common understanding of the experiment.

Final system tests turned out to be very important. However, not all experiment participants were available in the weeks prior to execution. Therefore, minor technological failures occurred during the first experiment runs and needed to be fixed while simultaneously proceeding with the scenario. As a result the experiment started with high workload for several participants. A mandatory rehearsal, taking into account local holidays and other restrictions, should be negotiated and prepared.

3 Experiment report

In this chapter the main results of EXPE40 are presented and interpreted based on a preceding background analysis (see section 2.2) and a set of experiment objectives (see section 2.6). Identified gaps from the experiment are described and potential measures for improvement are presented. The experiment report concludes with a section on the lessons learned.

3.1 Data analysis and evaluation - Quantitative analysis

3.1.1 Objective 1: Safety of RPAS operations

The safety of the RPAS flights executed in EXPE40 can be assessed by three different factors. The most important factor is that the RPAS operations have to meet the regulations and procedures defined for the respective airspace category at all times (SUCCESS#3). A second factor is the validity and feasibility of the transmitted data between the ground station and the aircraft (SUCCESS#2). Another important factor to consider is the perception of the aircraft's pilot. The operation can be considered safe, when the pilot states that the steering commands and flight paths transmitted from the ground station are similar to him/her flying manually (SUCCESS#1). This factor is addressed by a questionnaire and is further discussed in the section about qualitative analysis (see 3.2).

A primary function of the Flight Management System (FMS) is the in-flight management of the flight plan. Using various sensors, the FMS determines the aircraft's position and translates the flight plan into steering commands to follow the planned route. Commands from ground are passed to the FMS and checked for feasibility and validity before activating them. The commands and trajectories generated by U-FLY were accepted by the FMS in EXPE40 at all times. No errors were recorded on-board the aircraft or at the ground control station. Conclusively, the steering commands and flight paths generated were always valid and feasible. Success factor 2 is completely satisfied.

Aircraft operations in controlled airspace can be considered safe if they meet the regulations and procedures defined for the respective airspace category. The concept of Performance Based Navigation (PBN) defines navigation requirements applicable to aircraft conducting operations on specific routes, on an instrument approach procedure, or in a designated airspace. PBN also refers to the level of performance required for a specific procedure or a specific block of airspace. The level of navigation performance is defined by allowed lateral deviations in km or nautical miles (NM) from a specified route. These limitations are categorized according to the flight phase the aircraft is currently operating in. According to ICAO (Procedures for Air Navigation Services – Aircraft Operations) [23] the following lateral deviations are allowed:

a) ±3.7 km (2.0 NM) in en-route mode;

b) ±1.9 km (1.0 NM) in terminal mode; and

c) ±0.6 km (0.3 NM) in approach mode.

The aircraft is required to operate in conjunction with a flight director system or coupled autopilot system to ensure the required level of performance is provided. The highest requirements are specified for the areas around airports (Terminal Areas) and during approach. A required navigation performance (RNP) of 0.3 means the aircraft navigation system must be able to calculate its position to within a circle with a radius of 3 tenths of a nautical mile (~0.5 km). This can be taken as a measure of safety for the evaluated RPAS system. In detail, cross-track errors are measured and compared to the performance level required for RNP 0.3.

Figure 9: Cross-track error (experiment step 1)

In Figure 9 the cross track error (showing lateral deviations from the planned flight path) is displayed over the time (in UTC) for experiment step 1. Analysis of the data shows that deviations occur periodically in the positive and negative direction. This can be explained by comparing the data to the corresponding flight path. In experiment step 1, a search pattern with creeping lines, including alternating flight turns in left and right directions, were performed. These turns were planned with bank angles of up to 30 degrees. The FMS accepts these kinds of high values for bank angles, because the aircraft theoretically is able to execute them according to the aircraft's performance parameters. In the flight experiment this maximal bank angle turned out to be higher than the aircraft is able to execute safely when considering weather influences (e.g. strong winds). In forthcoming experiments the value of maximal bank angles for the RPAS will be reduced to 25 degrees. Nevertheless, the deviations in EXPE40 never exceeded values of 0.22 NM. Therefore, the performance requirements for PBN 0.3 are completely satisfied. When comparing the data for experiment steps 2 and 3 these even show average deviations of 0.04NM. These deviations are extremely low and demonstrate a very high precision. In experiment steps 2 and 3 search patterns similar to a three-leaf clover were executed. The flight paths relating to these patterns include several flight turns with lower bank angles. These commands could easily be followed by the aircraft and resulted in a very high precision level.

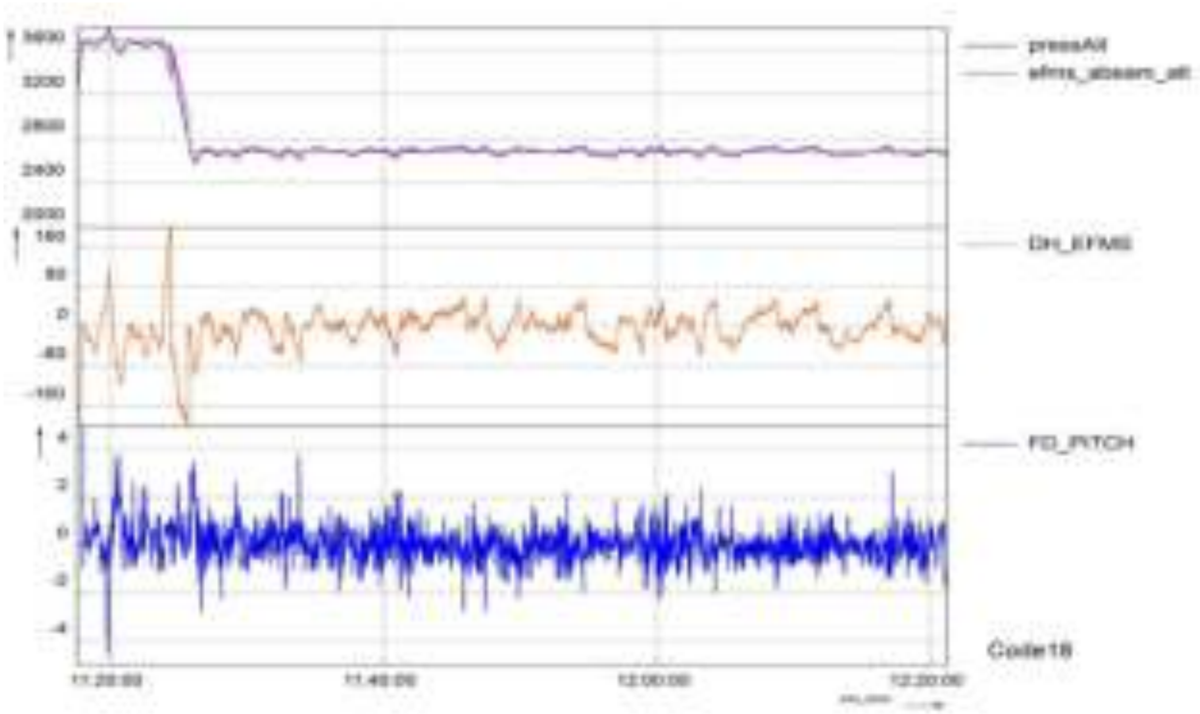

Figure 10: Altitude error (experiment step 1)

Besides keeping the lateral path, it is as much important for safe RPAS operations to be able to maintain a planned vertical path. In order to ensure safe transition between regions, a global height-keeping performance specification was developed and defined for aircraft in EASA AMC 20-27A [24]. According to EASA, the aircraft's performance should demonstrate on a 99.7 per cent probability that vertical errors should be less than:

- At or below 5000 ft (MSL): < 100 ft
- 5000 ft to 10000 ft (MSL): < 150 ft
- 10000 ft to 15000 ft (MSL): < 220 ft.

In Figure 10 the results from experiment step 1 are displayed. The figure is composed of three parts. The part on top shows the planned altitude in red (in ft) compared to the actual uncorrected pressure altitude (in ft) in blue over the time. The figure in the middle shows the actual deviations (in ft) between the planned and actual altitude values. The figure at the bottom shows the deviations between the planned and the actual vertical speed (in meters per second). It can be seen from the figures that the highest deviation (~158 ft) occurred shortly after the departure of the aircraft. Due to bad weather conditions at the day of the experiment (low visibility and low cloud ceiling) the flight altitude had to be reduced significantly to be able to collect images with adequate quality. This sudden change of altitude caused these deviations that were handled and managed fast. During the remaining flight the altitude deviations stayed well beneath 80 ft. These results are similar to the data recorded for experiment step 2 (see Annex A.1 Figure 28) and experiment step 3 (see Annex A.1 Figure 29). With altitude errors below 80 ft, the requirements on safety for RPAS operations are satisfied even for low altitude operations. Conclusively, the third success factor is satisfied completely.

The figures displaying the results (i.e. cross track error and altitude error) for experiment steps 2 and 3 are enclosed in 0.

3.1.2 Objective 2: Datalink performance

The safety of RPAS operations is highly dependent on a robust and reliable C³ (Command, Control and Communications) datalink. All relevant data on aircraft status, flight steering commands, failure modes and flight path directions, Detect & Avoid and avoidance manoeuvring are transmitted over this connection. Whereas the communication link can be established over alternative lines, the command and control link is considered as critical for safe RPAS operations. Depending on the cause of the datalink outage (e.g. screening terrain or buildings, natural interference, human error, equipment failure or aircraft manoeuvres), the loss of control of the RPAS requires different measures. Examples can be special manoeuvres to retain the datalink, termination of the flight, returning directly to the departure airport, or following the last transmitted and accepted flight path. An important aspect to consider is the duration of the datalink outage. As long as the aircraft's behaviour is predictable and the aircraft poses no risk to other airspace users or people on the ground, a short timespan (up to 10s) without datalink connection might be acceptable [15]; especially if on-board systems have Detect & Avoid methods implemented, which can be initiated and followed automatically. The aircraft used in EXPE40 has appropriate safety procedures implemented on-board. These would be initiated and followed automatically, if a datalink loss occurred. A complete datalink loss is assumed in this experiment after a transmission outage of more than 3 seconds. In case the datalink could be recovered and maintained stable afterwards, the control would be reassigned to the ground control station and the intended flight path would be re-entered.

In EXPE40 the C³ datalink always had a stable connection to the ground station. No datalink losses were recorded. The RPAS performed complex flight manoeuvres in which attitude-induced antenna screenings were very likely (e.g. high bank-angle turns). Even during these manoeuvres, the datalink quality (roundtrip packages per second) remained at a medium (green) or high (blue) level. The scale (roundtrip packages per second) of the quality data ranges from

- low (red – orange): < 1.5
- medium (yellow – green): ≥ 1.5 and < 3.0

- high (blue): ≥ 3.0

The results of the datalink quality at the respective aircraft position are displayed for experiment step 1 in Figure 11.

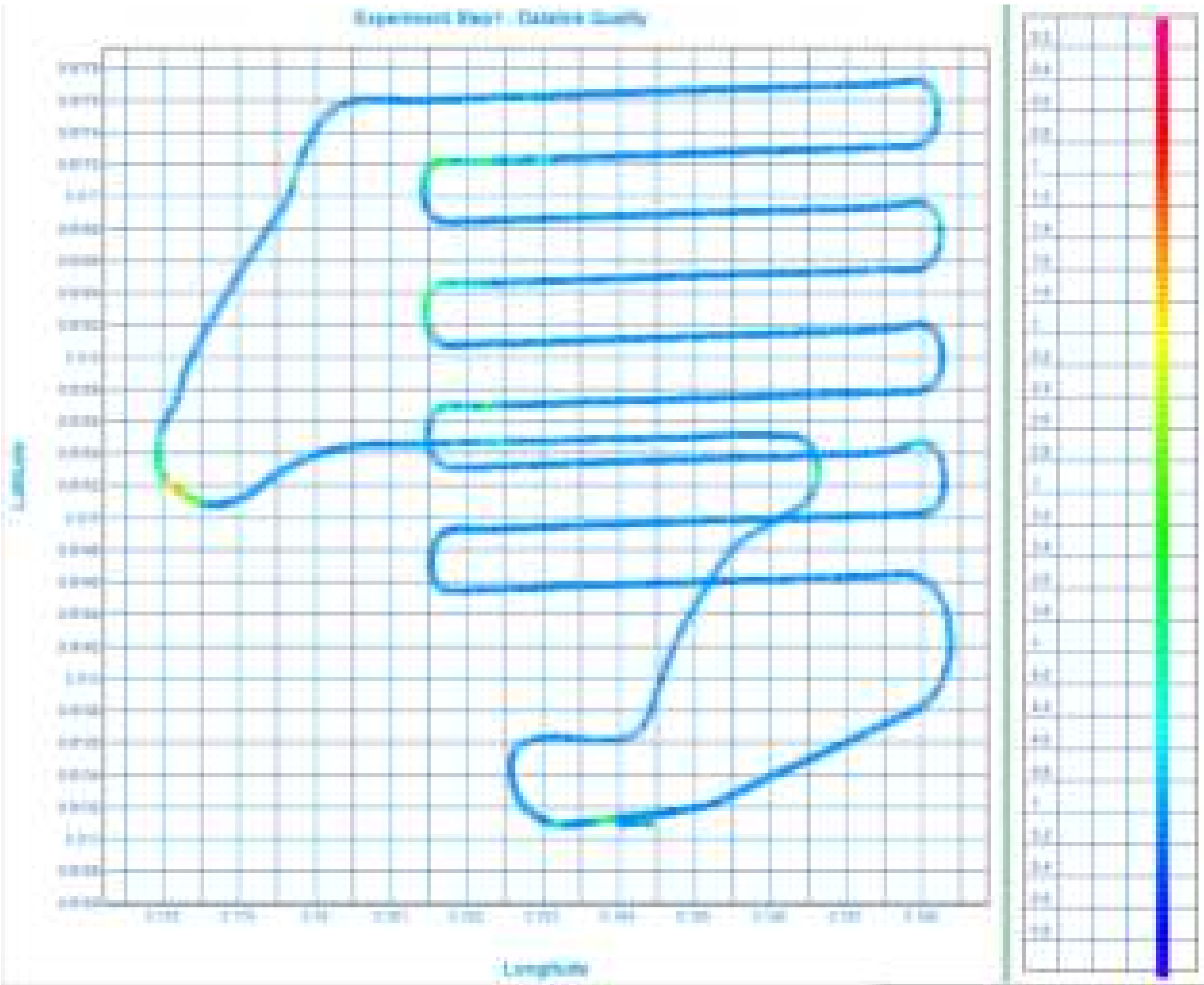

Figure 11: C³ datalink quality (experiment step 1)

The latency of a data transmission from the ground to the aircraft is another indicator for the safety of an RPAS operation. Long transmission times may cause an agglomeration of data and in this regard a transfer and acceptance of invalid data on-board the aircraft. Special procedures for checking the validity of transmitted data are therefore mandatory. The scale (transmission times in ms) of the latency ranges from

- high (red – orange): > 0.35
- medium (yellow – green): ≤ 0.35 and > 0.15
- low (blue): ≤ 0.15.

In EXPE40 the latency of the datalink remained at a very low level (< 0.08 ms) during most of the flight. Only in cases of communication transmissions the latency increased to levels of 0.2 to 0.28 ms.

This can be explained with the comparably high data rates needed for transmitting speech sequences. But even while transmitting speech sequences, the datalink latency was always at a medium level and therefore completely sufficient for interchanging aircraft status and command data with the aircraft simultaneously.

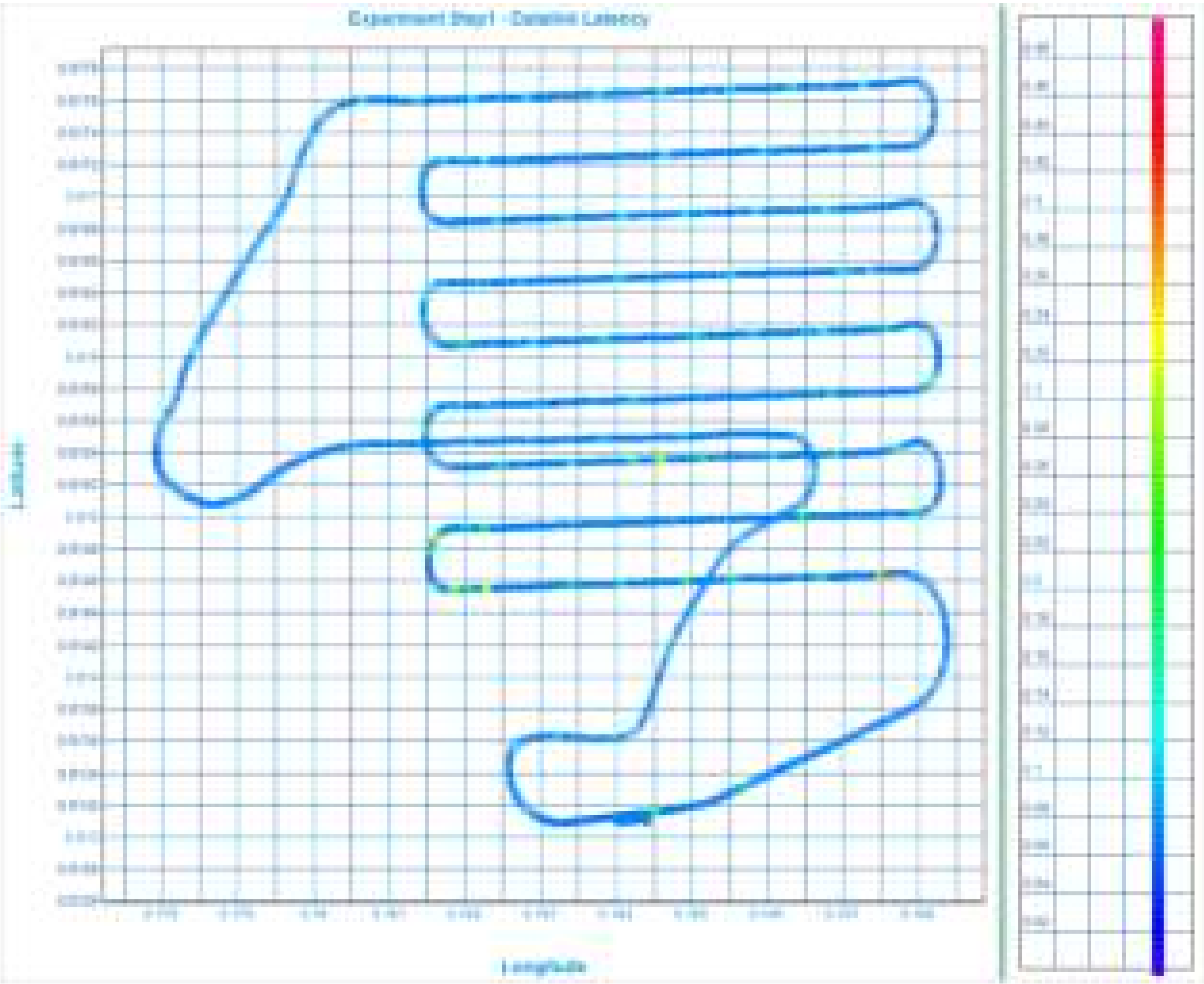

Figure 12: C³ datalink latency (experiment step 1)

In Figure 12 the datalink latency (transmission time in ms) is displayed. The analysis of the flight data for experiment step 2 and experiment step 3 (see section 2.4.1) shows similar results. The figures displaying these data are enclosed in 0.

The resulting data from the quality and latency analysis show that the C³-datalink has a very high reliability and can be considered as very safe even in complex scenarios.

Further on, the reliability and robustness of the proposed system for real-time image analysis and map creation is highly dependent on the performance of the payload datalink. In this context a high data transmission rate and no occurrences of transmission disruptions or even losses are both necessary to ensure a continuous transfer of aerial images to the ground. In EXPE40 flight paths have been defined (see Figure 4 and Figure 5) to optimize image quality and image coverage. These flight paths include aircraft manoeuvres that pose high requirements on the robustness and reliability of the datalink. Especially while performing manoeuvres with higher bank angles, the geometry of the aircraft may prohibit a direct connection between the datalink antenna and the ground station and therefore influence the datalink performance. This factor always needs to be considered in the flight path planning. Nevertheless, in case of the payload datalink small disruptions are of no concern. The aerial images would then be transmitted with a short delay. In addition, the image quality and geographical reference during flight turns are in general not sufficient for a detailed image analysis. Therefore, datalink disruptions or even losses (when limited to a short time) during turns are considered as negligible. In Figure 13 the payload datalink quality (roundtrip packages per second) at the respective aircraft location for experiment step 1 (see section 2.4.1) is displayed.

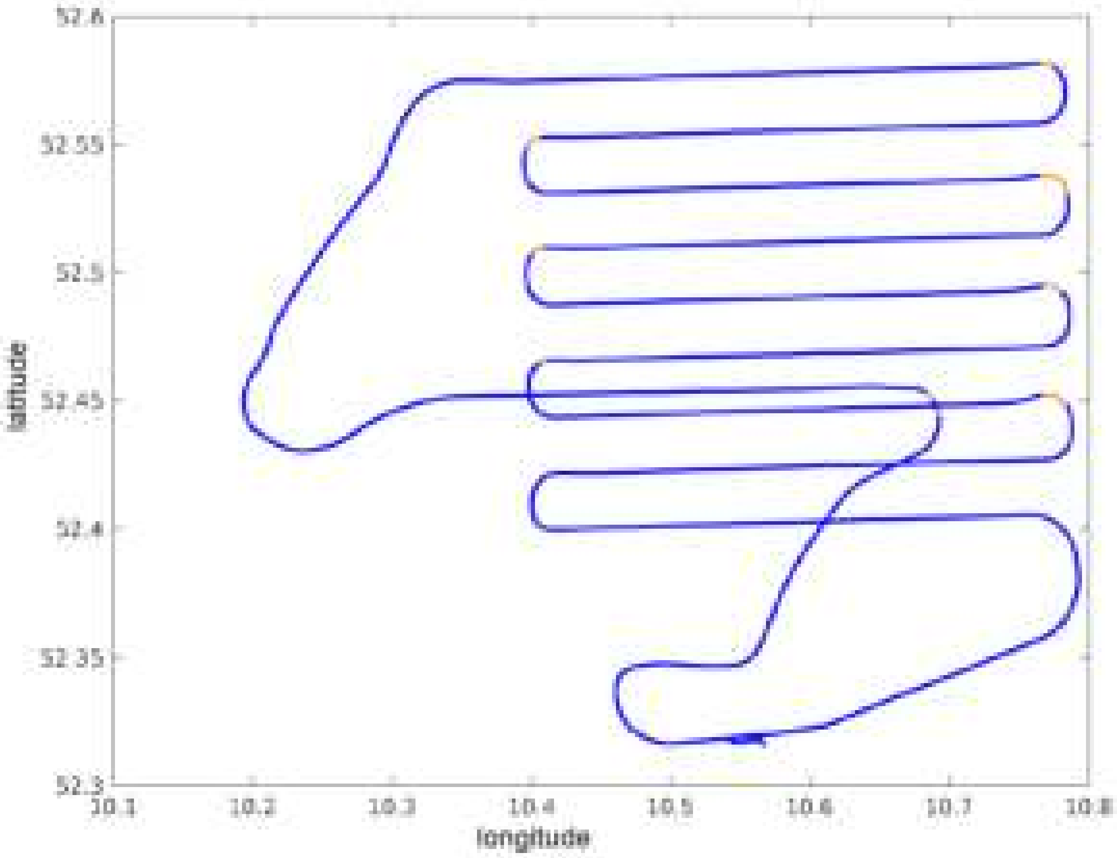

Figure 13: Payload datalink performance (experiment step 1)

The figure shows that the payload datalink connection remained stable during the complete flight. There were no datalink losses recorded during the flight. The quality of data transfer was reduced during flight turns with bank angles exceeding 25 degrees (orange areas in the flight path). The reduction in quality (from 100% (blue) to ca. 40% (orange)) resulted in a slight delay in the transmission of aerial images. Overall the datalink quality can be assumed to be more than sufficient for the gathering of aerial images in a crisis scenario with complex flight manoeuvres. Similar results were recorded for experiment step 2 and experiment step 3. The figures displaying these results are enclosed in 0 (Figure 34 and Figure 35). Conclusively, the objective on performance of payload and the command datalink is satisfied completely.

3.1.3 Objective 3: Image quality and image analysis

The image quality and image processing are important success factors, influencing primarily the objectives 4 and 5. The images (and the deduced information from analysing them) are a necessary input not only to the creation of real-time crisis information, but also to the solutions for person detection and route planning. For each of these tasks, an experiment step has been defined optimizing the flight path to match the different image collection requirements. In experiment step 1 and experiment step 2 the camera system has been configured to a mapping mode, which means that the camera was triggered continuously to provide a complete coverage with sufficient image overlapping. This mode poses the highest requirements on the complete system, because a huge amount of data has to be continuously processed and transmitted to the ground. In experiment step 3, however, the main goal has been the determination of traffic data. A complete coverage is hereby not necessary. In contrast, the camera needs to be configured to trigger multiple images within seconds to be able to detect number and movement of traffic. In Table 18 the results from different experiment steps are displayed.

Step	flight strip / modes	Number of images	along overlap	ground sampling distance	field of view (across/ along)	flight height above ground	strip length
1	A: mapping B-G: mapping H: mapping	98 236 37	50% no overlap 80%	20cm(12cm) 20cm(12cm) 20cm(12cm)	±52°,±13° ±52°,±13° ±52°,±13°	890m 890m 890m	25km 25km 3km
2	A-C: mapping	35	no overlap	20cm(12cm)	±52°,±13°	890m	7km
3	A-C: mapping D: traffic	167 243	10% 25%	20cm(4cm) 20cm(4cm)	±52°,±13° ±52°,±13°	310m 310m	7km 14km

Table 18: Image analysis results

The realized image quality and processing in EXPE40 were highly dependent on a set of factors:

- Weather (e.g., visibility, wind, cloud ceiling)
- Data communication network (e.g. airborne-to-ground transmission, ground-based processing and ground-based data dissemination)

Due to varying flight altitudes, the recorded ground sampling distance varied during the flight experiment. To get a comparable data basis for the image processing and to meet data protection requirements (see section 2.5), the ground sampling distance was downsized on-board the aircraft to 20 cm. An image frequency of 0.5 Hz to 2 Hz could be achieved. This relatively low frequency is a result of the requirement of real-time data transmission.

Figure 14: Aerial image collection (experiment step 1)

In experiment step 1, aerial images could be provided for the complete assumed crisis area. The image quality was good (i.e. resolution of 20 cm) and the images were processed and provided to the ground immediately. The coverage of the collected images ranged from 50% to 80%. The results are displayed in Figure 14.

In experiment step 2, the same configuration was used and therefore similar results were recorded. The main difference was that the camera was triggered to produce less coverage. This adaptation was made to evaluate if the real-time processing of images could be made more efficient by reducing data traffic. Therefore a smaller amount of images was produced and the system was able to process and transfer the images in a shorter time. The results for experiment step 2 are displayed in Figure 15.

Figure 15: Aerial image collection (experiment step 2)

A comparison of the results in Table 18 shows deviating results from experiment step 3. In experiment step 3, aerial images above main traffic roads were collected and analysed with regard to traffic density and movement. At the day of experiment step 3, very bad weather conditions were present. The cloud ceiling was very low (~1100 ft), the visibility was limited, and strong winds were present. This had an effect not only on the flight approval but also on the allowed flight altitude. The altitude was reduced for this flight to 1000 ft respectively. Even if the camera system operates optimally in a flight altitude of 3000 ft, the recorded results from the flight for experiment step 3 were still acceptable. During this flight images were collected and analysed. But due to the low flight altitude the realized overlap between the images was too small for automated traffic detection. Further on, some difficulties in the communication network prevented the transmission of the aerial images to the traffic planning solutions during the flight execution. These difficulties were analysed and appropriate measures are in process. The aerial image processing system will be made more robust for different flight altitudes and mode changes.

Reliable and robust object recognition from aerial images is highly dependent on the quality and frequency of the provided images. The resolution of images with a minimum of 20 cm can be considered as very high for recognizing objects from images (i.e. cars on main traffic roads, people in flooded areas). A main challenge within this experiment was the relatively low frequency of images. In continuous mode of the camera (experiment steps 1 and 2) a frequency of 0.5 Hz (ca. 1 image every 2 seconds) was realized, whereas in traffic mode the frequency was increased to improve detection rates up to 1.7 Hz (ca. 1 image every 0.6 seconds). Generally, the difficulty in recognizing objects from images is that the objects may vary somewhat in different viewpoints, different sizes and scales. To detect people on water surfaces with a high certainty, the system has to determine not only that there is an object in the water, but additionally that this is a person and not something else (e.g. boat, bird or buoy). This can only be achieved by comparing closely spaced sequences of images of a certain region. Based on this comparison, suspicious areas in an image can be further isolated and analysed regarding to shape, colour and movement to increase detection certainty. With the relatively low rate of images provided in EXPE40 the detection of irregular objects on water surfaces is a complex problem. The process is eased by providing map data in high resolution that is in addition geo-referenced and orthonormal. Combined with the provided maps on water masks, the shape and location of flooded areas were fused with the aerial image data to further distinguish between people inside and outside the water. False positive detections were mostly avoided by Kalman filtering[2], since only detections are considered that stay stable over a longer duration (around 3 image frames). In the experiment the certainty of image detection was increased by flying several times above areas in which the system already identified possible detections. This was realized by the clover-like search pattern in experiment step 2, in which the aircraft always returned to the assumed recognition area until people were detected with certainty. As a result of EXPE40 it was possible to detect possibly endangered persons within the images, and mark and track their positions (see Figure 16).

Figure 16: Person detection in Lake Tankum (experiment step 2)

One of the main parameters for processing efficiency is the input rate of aerial images. A higher frequency usually implies larger areas of common coverage in succeeding images. This enables a reliable detection of position candidates in more than one frame, further stabilizing the Kalman filtering fusion. Since the source of candidates for person detection does not necessarily need to be

[2] Kalman filtering describes an algorithm that increases precision of measurements over time. For further information on this topic, commonly applied in technology, see https://en.wikipedia.org/wiki/Kalman_filter

the same sensor, one could also use more than one camera, for example an additional infrared (IR) camera. In this way, detected positions would be stabilized and false positives would be reduced. An option for future experiments would be to use a higher-framerate IR camera. As frames from this IR camera would foreseeably not be geo-referenced, some additional effort would have to be planned for pre-processing these images. Another important parameter is accurate geo-referencing. A high-precision navigation solution has been proven to be useful in previous experiments. However, such high precisions possibly cannot be reached in an actual implementation. Here, an augmentation solution with pre-acquired map data could be helpful. In forthcoming experiments (i.e. JE1) it is foreseen to implement additional sensors. In detail, an optical camera together with an IR camera will be utilized and the aspect of accurate geo-referencing will be considered adequately.

3.1.4 Objective 4: Reliability, feasibility and usability in CM

The portfolio of tools provided in EXPE40 has the potential to improve the situational awareness regarding the crisis area and to support routing and logistics of responders. In detail, the added value of this portfolio is assumed to lie in a rapid and reliable availability of information regarding:

- Crisis area (e.g. dimensions, water levels)
- Location of people (e.g. people enclosed in flooded areas, gatherings)
- Traffic infrastructure (e.g. flooded roads, heavy traffic)
- Best routing options to crisis area

The actual benefit in these areas can be assessed by evaluating recorded data from the flight trials and by evaluating the answers to the questionnaires. The results of the questionnaires can be found in section 3.2.

One important factor, influencing the evaluation of several other objectives, is a sufficient image quality and an efficient image processing. The image quality was sufficient to determine the crisis dimensions, flooded areas and traffic density. Nevertheless, the detection of people in the flooded areas was found to be challenging as already discussed in the context of Objective 3. The detection of people was part of experiment step 2 and was executed by flying clover-like turns above the crisis area. Experiment step 2 was executed twice during EXPE40 to get valid results. In both runs the aircraft needed three flights above the assumed rescue area to get the necessary certainty of detection. After each overflight, the location and number of people was determined with a higher certainty, because the areas of suspected people could be narrowed and the flight path of the aircraft was modified accordingly. In both runs of this experiment step the number and location of people volunteering in the water were detected with a sufficient accuracy. This detection took 10 - 15 minutes after arrival of the aircraft at the assumed crisis area. This process of detection has some room for improvement regarding the process duration, image quality and the type of sensors used. With different sensors higher image resolutions can be achieved and more indicators can be derived to detect people with a higher certainty and less time. These issues are currently managed and will be implemented until forthcoming experiments. The success factor relating to this aspect is therefore moderately satisfied.

Another aspect proving the added value of the provided tools for CM is the support of responders in the planning and execution of rescue missions. Transport and logistics can be better planned with up-to-date information on the crisis area and the actual traffic situation.

The traffic management tool KeepMoving provided different routing options for EXPE40 and displayed the current traffic situation based on real-time data. In comparison with similar routing applications, e.g. Google Maps, the data of KeepMoving are based on more than one data source (Probe Vehicle Data (PVD), aerial images, induction loop and commercial traffic data). Moreover, the origin of the data is known as far as possible, i.e. the provided traffic information is mainly based on real-time measurements without historical or model-based components. Thereby the provided traffic information is more reliable, which is an important criterion for the end-user (see section 3.2). Figure 17 shows a comparison of the current traffic situation provided by KeepMoving and Google Maps. Slight differences can be observed especially in the area of the intersections and on minor roads. During the experiment it could not be proved which information provider is more reliable because no real comparative measurements took place. However, experiences from other experiments showed that, in reality, traffic information and actual traffic situation sometimes differ from each other, e.g. (commercial) traffic information indicate jams that do not exists in reality due to corrupt, static or outdated traffic data. Such can be avoided if the origin and reliability of the traffic information is a-priori known and multiple data sources are used.

Figure 17: Comparison KeepMoving (left) and Google Maps (right): current traffic situation Braunschweig

Figure 18: Comparison general routing (left side) and rescue routing (right side)

Furthermore the tool took into account different parameters to provide an efficient and optimal routing for rescue forces. The routing algorithm optimizes the reliability of travel times and considers several criteria, e.g. network geometry, number of lanes, right of way et cetera. For EXPE40 not all criteria could be considered due to lack of data. Figure 18 shows a comparison between regular routing and rescue routing, regarding the above mentioned criteria, provided by the tool. It can be seen that two different routes were offered. For the upcoming experiments more data and a larger road network will be available and more criteria can be considered.

The tool SUMO provided a traffic simulation for EXPE40. The simulation of the flood situation in the SUMO system led to the conclusion that no significant shortcomings in the transport system performance occur; no bottlenecks could be identified that would not have arisen otherwise. The explanation of this behaviour is that the (simulated) travellers received information about the flood well in advance resulting in predictable traffic conditions that all impacted travellers could adjust to.

One shortfall of this simulation analysis is the incomplete data basis available. Due to this difficulty the travel demand data was mostly based on common sense considerations. The network was taken from open street map with only limited adjustments to the characteristics of the concrete scenario. Overall, SUMO provided insights into the traffic flow and network congestion structure that informed the implementation of this experiment.

The tool EmerT was used in the experiment to display the current traffic status with the help of aerial images of the aircraft. During the experiment EmerT worked well. However, the modules both for receiving the actual aerial images as well as the extracted traffic data were flawed due to configuration problems. For this reason, aerial images could not be utilized for traffic detection and information. No up-to-date traffic information from aerial images could be processed. Aerial images did not cover the entire region under investigation. Nevertheless, this error has not limited the validity of the experiment because other data sources (see KeepMoving) were used to provide actual traffic information.

Based on the information of the current traffic situation, different options for rescue routes could be shown within KeepMoving during the experiment. Due to the location of the Lake Tankum and the circumstance that there is only one access road, no more than three options were announced. Assumption for the display of the options had been fused with traffic data from different sources (induction loop, commercial data and aerial images, which came from the aircraft). It has to be mentioned, that due to missing images, the aerial images could not be considered in the displayed traffic situation during the experiment. Nevertheless, the success criterion (i.e. success factor 2) could be fulfilled, because different variants for rescue routes were selectable and displayed (see Figure 19).

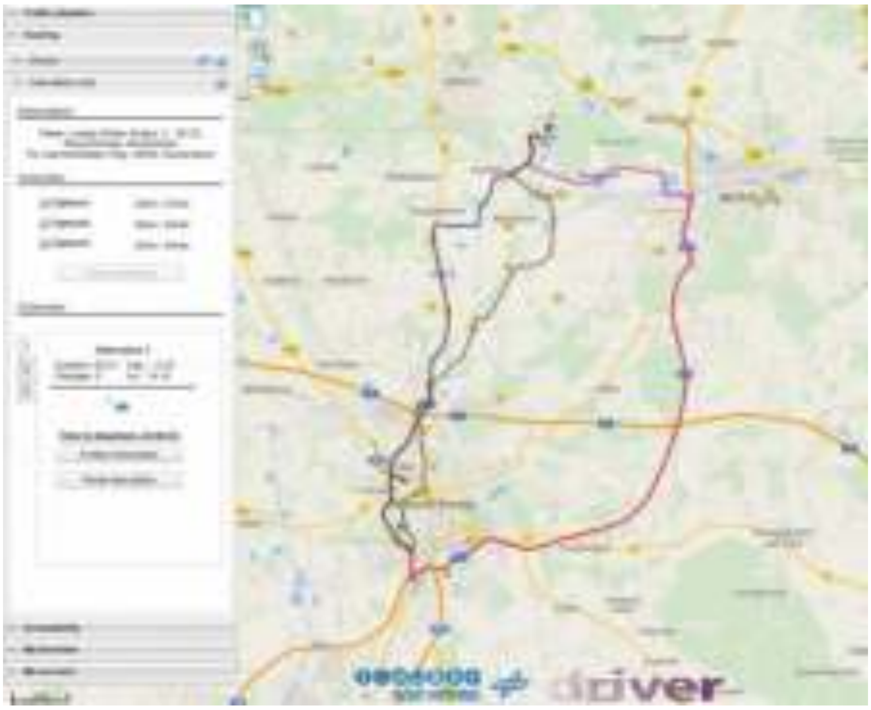

Figure 19: Routing options for rescue forces

The forecast of the traffic situation was provided by the simulation tool SUMO. SUMO predicted the traffic situation based on historical traffic data and travel demand models. During the experiment two simulation scenarios were shown. The first scenario was linked to the scenario of the experiment and showed the predicted traffic behaviour in case the water of the Lake Tankum flooded the adjacent streets (see Figure 20).

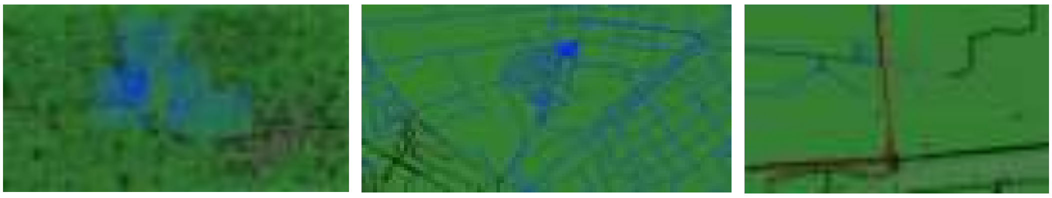

Figure 20: Overview of the flooded area and affected roads in SUMO (blue colour); Lake Tankum and flooded surroundings; closer look to the affected roads and traffic behaviour (left to right)

The simulation ran like expected and the predicted traffic behaviour could be provided to the end-users and the success criterion could be met (i.e. success factor 4). But it has to be remarked, that due to less traffic density in the observed area and consequently less availability of traffic data, the traffic simulation was not completely reliable. Therefore another simulation scenario was shown to demonstrate the functionalities of SUMO with more reliable data. The second scenario showed a bomb alert at the central station of Braunschweig and illustrated an evacuation (see Figure 21). Like the first scenario everything worked out like expected and the simulated evacuation could be provided. The predicted travel duration of the rescue forces was provided by KeepMoving. It has to be remarked, that the predicted travel duration did not consider the changing traffic conditions due to the flooding of the Lake Tankum. It was planned to consider the changing conditions in the travel prediction, but because of incomplete data it was not achievable. Bearing in mind that fewer vehicles are on the road during a flood and that in general the traffic density is slightly increased around the crisis area, the travel times can be assumed as representative for the scenario in EXPE40. The success factor associated with the routing and traffic prediction is consequently fulfilled to a moderate level.

Figure 21: Affected area and roads (blue colour); simulated traffic situation (left to right)

3.1.5 Objective 5: Enhanced mapping capabilities

There have been created different information products based on aerial as well as satellite imagery addressing different aspects in situational awareness. The three dimensional products based on aerial imagery and elevation models provide a basis for the intuitive inspection of the disaster area, which is of importance for the planning and preparation of rescue activities in the field (see Figure 22 and Figure 23). The thematic flood maps (see Figure 24 and Figure 25) offer diverse thematic information such as on infrastructure, flood extent and settlements, and thus contribute to decision support in terms of logistics, damage assessment and evacuation planning. Hence, the first success criterion of Objective 5 was fully achieved during this experiment. Additionally, it has turned out in the experiment that the map product derived from aerial imagery (see Figure 22) was created and disseminated with delay, i.e. several hours after image acquisition has taken place. Thus, a further acceleration of map production can be expected with technical improvements regarding the ground-based mosaic processor. The fall-back map product with the fictive base flood scenario (basis for RPAS mission planning) is shown in Figure 25.

Furthermore, it turned out, that aerial imagery and derived surface models provide valuable and high quality data sources for the creation of advanced 3D information products, such as video animations and 3D-PDFs, allowing an interactive approach for the inspection of the impacted areas. Therefore, the second success criterion of Objective 5 was fully met within this experiment. Moreover, the exercise provided a good starting point for the standardized provision of 3D information products during future experiments and applications in general. Furthermore, a near-real-time creation and dissemination of flood layers based on aerial imagery is currently under development and planned to be prototypically demonstrated in JE1. This development would (among others) significantly contribute to the RPAS mission planning supporting search and rescue (SAR) activities during flood events.

Figure 22: 3D-PDF showing the near surroundings of lake Tankum

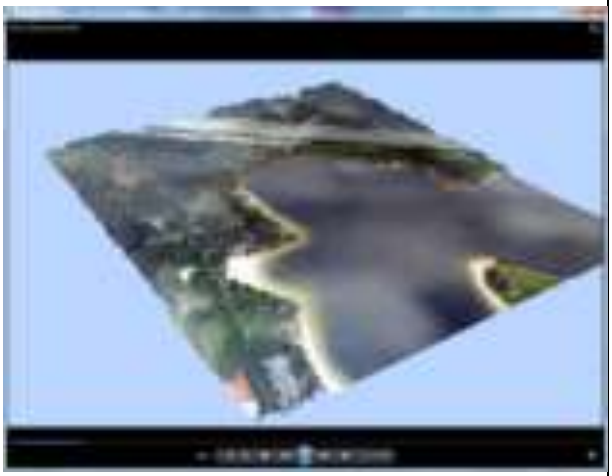

Figure 23: 3D video animation of Lake Tankum based on aerial imagery and derived digital surface model

Figure 24: Flood map based on aerial imagery acquired on 29 July 2015

Figure 25: Flood map based on satellite imagery with a fictive flood scenario (fall-back case)

3.2 Data analysis and evaluation - Qualitative analysis

3.2.1 Objective 1: Safety of RPAS operations

In addition to the quantitative analysis in 3.1, objective 1 can also be assessed qualitatively. One success factor for objective 1 is the safety as perceived by the pilots when following the control and steering commands from the ground (SUCCESS#1). For this purpose, a set of questions was presented to the pilots after each phase of the flight experiment. The filled questionnaires can be found in Annex A.3.

The questionnaires that were handed out were dived into four different sections:

- Overall feeling of safety
- System reliability

- Loss of skills
- Situational awareness

Each question had to be answered with a number ranging from 1 (strongly disagree/at no time) to 5 (strongly agree/very often). Free text boxes gave the opportunity to give remarks not covered by the questions.

Both experimental pilots involved in the flight experiment filled out the questionnaire for each of the two experiment phases. As it is assumed that situational awareness does not change from phase 1 to phase 2, these questions were only handed out and answered once.

In the section Overall feeling of safety, the most critical questions regarding safety (Q5 and Q8), were positively answered with 1 and 2, respectively. This indicates that the safety was not endangered during the flight experiments. In phase 1, one pilot stated that he sometimes had to diverge from the uplinked 4D trajectory. In phase 2, this situation occurred seldom or at no time. Commands from the ground could sometimes not be adopted in both phases due to non-conformity to the aircraft's performance characteristics. Both pilots stated that they needed to stay in the control loop at most or all times and felt responsible for the aircraft. They would not feel completely safe if the aircraft was controlled by the GCS exclusively. Feedback on topics like feasibility of instructions, feeling of safety when following commands, and feasibility of the provided 4D trajectory, can be seen as positive.

In the section System reliability, all four questions were responded very positively to, with a 1 (at no time) or 2 in all cases. In phase 2 of the flight experiment, both pilots answered all questions with a 1. System reliability can be seen as high and mature for this kind of flight experiment.

In the section Loss of skills, it is remarkable that both pilots strongly agree to the statement that a pilot needs the same qualification for aircraft operation from a GCS as on-board the aircraft. However, the role of the pilot is also rated as a monitoring and scanning role in most cases. The pilots both fear the deterioration of flying skills when using higher automation.

In the section Situational awareness, only one of the pilots answered the questions. A slightly higher situational awareness requirement with increased automation is expected.

The opportunity to add additional remarks using free text boxes was not utilized.

3.2.2 Objective 4: Reliability, feasibility and usability in CM

The potential operational benefit for CM of the provided solutions was assessed through the statements given by the invited end-users. Previous to the experiment, the Technisches Hilfswerk (Federal Agency for Technical Relief, THW) provided its current practice describing the usually provided information, available technology and the process of crisis resource planning and logistics. The following section outlines the collected statements.

Aerial Imagery and Maps – THW Current Practice:

During a flood, THW uses maps (on scene: primarily paper based, in crisis rooms: digital maps such as Google Maps[3] and Top 50[4]). The advantage of paper maps is that they are not depending on electricity or a functioning internet connection. However, paper based maps can be outdated and are not adjusted to the changing dynamics of a scenario (flooded streets, bridges that can no longer be passed etc.). That means crisis managers with a coordinating function will have to rely on information about the area before the crisis took place when they attempt to dispatch units to a scene of operations. Generally, no real time information will be available. This is also true for the digital maps since THW has very limited access to time-delayed satellite images.

Hence the demonstrated systems can possibly offer the following advantages:

- Real time information allows in consequence more accurate decisions.
- Updates on crisis dynamics and changes over time can be provided. For example, in situations with dykes breaking and water spreading, road blockages could occur and would require new need for response.
- Additional mask layers can be placed on top of the real time map, indicating how former floods progressed, allowing for predictions and precautionary actions.
- Solutions allow improved training, as the maps can be combined with mask layers showing a scenario's development, teaching CM how to respond to different dynamics.

Traffic Management and Routing – THW Current Practice:

During any large crisis where THW's extensive assistance is needed, units from all over Germany have to be sent to the affected area. That entails gathering requested units in convoys that then drive to an assembly area near the scene of operation. These convoys commonly consist of 15-20 vehicles, most of them trucks, sometimes pulling trailers with heavy equipment.

Once the convoys have arrived at the assembly area, the units wait for their orders and deployment. THW can only use open access programs such as Google Maps, in order to guide units to the desired destination. However, Google Maps does not feature real-time maps during a crisis that lead to an adjustment of a route. Furthermore, it lacks important information such as the height and bearing

[3] www.google.com/maps
[4] electronic cartography of the Land Survey Administration in Germany

capacity of bridges for example. This is particularly relevant when directing vehicles through an affected area.

Hence the demonstrated systems can possibly offer the following advantages with their real time information based on the aerial maps (how fast flood water spreads and which streets will be available at what time):

- More efficient logistics planning and execution
- Additional information such as height and bearing capacity of bridges
- Possibility to calculate how fast certain units will arrive at their destination
- Information on gas stations and the availability of truck pumps

As a result, these advantages allow the planning of routes to be more effective (technical halts, respecting resting periods etc.).

THW certainly would appreciate access to a technological solution that allows for better logistical planning. However, so far the cost-benefit assessments never lead to the procurement and maintenance of such a system.

Experiment results

During the execution of the experiment the utilization and adaptability of the traffic management tools had been explained and demonstrated to the end-users based on the scenario. The end-users had the chance to use the tools by themselves while the execution was running. Due to the fact that two end-user attended EXPE40 in Braunschweig the evaluation of the interviews is not reliable. Nevertheless, the feedback of the end-users gives a first impression of their opinion. The interview (open questions) showed that the demonstrated traffic management tools would provide an added value for the end-users. Especially the functionalities routing, forecast (e.g. evacuation situation) and current traffic situation are seen as beneficial. During the experiment and in the questionnaire, the end-users suggested further functionalities, which have to be taken into account in the upcoming experiments:

- Consideration of blocked roads (due to roadworks, flooding etc.) for the routing
- Display the traffic information directly over the aerial images
- Consideration of current weather conditions for a more reliable estimation of travel times
- Consideration of more criteria for the rescue routing.

The usability of the three traffic tools (SUCCESS#3) was seen as simple but the end-users posed the question, if it would be possible to integrate the tools in one common interface. For the sake of easy usability, one interface for traffic information would be easier to handle than three separate interfaces. Another important remark was the reliability of the traffic information. The questionnaire pointed out that this is an important factor for the feasibility (SUCCESS#3) of the tools. Trust is an important criterion for the rescue forces, and the traffic information needs to be up-to-date.

Otherwise, the tool would be useless for crisis management. Another remark was that the usage of the tools requires training. Due to the fact that the tools are easy to use, the training would be not too complex and should be manageable for the end-users. Further suggestions from the end-users to increase the feasibility of the tools were as follows:

- Low costs to use the tools: Currently, the tools are for free
- Higher availability: Currently the tools are usable in some German cities, but the aim is to have a Europe-wide availability
- Ensured IT-security
- Less maintenance effort, preferably only operate the system via a link/web service: Currently, the tools have different accessibility options. The aim is to offer a web service.
- Interoperability with the SGOs (operation management systems), so that the system automatically integrates vehicle information: This could be manageable via a web service.

In summary, the feedback showed that the presented traffic management tools would generate a benefit for the end-users and could be practicable. Before it is used, some adjustments, for example one common interface and further features (e.g. blocked roads), would be needed to increase the feasibility and usability.

Regarding the feasibility and usability of an RPAS (SUCCESS#3), the interviewed end-users rated as the most beneficial aspects:

- Overall situation assessment of the affected area in real-time
- Precise localization of victims
- Traffic situation assessment in real-time

Especially in flooding scenarios, the use of RPAS is seen as highly important, as areas might not be reachable due to flooded streets and bridges. A large area can be assessed in a short amount of time, and the decision-making process could be significantly improved by RPAS. Usability improvements and possibilities were also pointed out:

- LIDAR equipped RPAS could enable to assess topography, hydraulic capacity etc.
- Thermic or infrared cameras could detect people under water
- Freight operations with RPAS could provide crisis relief material

Some challenges and concerns were also pointed out by the end-users. Legal issues could hamper the usage of RPAS, or ethics or privacy could be invaded due to person recognition. High costs (or a low cost-benefit ratio) have to be taken into account.

The complete quantitative and qualitative results of EXPE40 are displayed in Table 19. The table gives an overview of the applied metrics and the degree to which each of them has been satisfied in the experiment.

Indicator	Metric	Degree of satisfaction
High perceived safety by pilots	• Answers to the safety related questions within the debriefing questionnaire • Comments during the debriefing	Completely (feeling of safety) Partly (system reliability) Completely (loss of skills) Partly (situational awareness)
Low failure rates by FMS	• FMS failure rates	Completely
Low deviations from flight path	• Altitude and cross-track error	Completely
High datalink performance and reliability	• Quality, failure events, latency	Completely
Aerial imagery of high quality	• Aerial image quality and coverage	Partly (frequency) Completely (resolution) Completely (coverage)
Successful detection of people in water	• Position of people	Partly (detection certainty)
Low detection time	• Time of detection events	Completely
Traffic analysis provides information for rescue routes	• High reliability in providing traffic volume, route availability, route simulation	Completely
End-users see high benefit of RPAS in CM	• Positive answers in questionnaire with regard to benefit of RPAS	Partly (concern about cost-effectiveness and legislation)
End-users see high benefit of traffic management solutions	• Positive answers in questionnaire with regard to benefit of traffic management solutions	Completely
Traffic analysis and prediction provides traffic forecasts and planned travel duration of rescue forces	• High reliability in traffic detection, forecast and travel times for different routes	Partly (delayed traffic data)
Mapping products provide different situational awareness information.	• High reliability in creation of different map products for different solutions	Completely
High quality of imagery and surface models for the creation of advanced 3D-information products	• High reliability in creation of 3D-PDF and video animations	Partly (time consuming mosaicking process)

Table 19: Experiment results overview

3.3 Lessons learned

The execution of the experiment and the post-processing of the results can generally be seen as a success. All steps of the experiment could be executed according to the scenario schedule. This can especially be seen as a success, because (a) the complete on-board and ground-based systems were integrated into a joint data processing chain for the first time, (b) several external circumstances could have hampered the experiment, and (c) experiment objectives were highly dependent on the availability and readiness of volunteers and their rescuer teams.

In EXPE40, quantitative and qualitative data was recorded and analysed. The results from the qualitative data show that the professional responders have a great interest in the proposed solutions. Only small remarks were stated to further improve the solutions' usability. Up-to-date aerial imagery and visualization solutions present a 2D/3D picture of the crisis area that helps responders to gain a better understanding of the current crisis situation and has the potential to improve situation awareness. While the benefit of the presented solutions is evident, the communication and coordination in using them is not as readily accessible. New solutions have to be intuitive and easy to use to be broadly accepted. These considerations will be implemented until forthcoming DRIVER experiments.

The results from the quantitative data show that some improvements have to be implemented with regard to the technical aspects to guarantee a more robust and reliable system. Several issues with the technical infrastructure appeared shortly before and even during the experiment execution. Checklists and test mechanisms for involved systems before the beginning of each experiment step (e.g. availability, configuration, interfaces, and connection) seem plausible. In detail, the following technical gaps and potential measures for improvement were identified:

Traffic Management and Routing

- It has to be remarked, that traffic data and traffic models are not always available for the entire region and all roads, e.g. for the region around Lake Tankum. It is also possible that data are available but cannot be integrated due to restriction in format, incomplete meta data descriptions, administrative barriers or costs.
- Further, it has to be mentioned that not all criteria for the rescue routing could be considered for the experiment due to size, location and type of the road network.
- The provision of data is not always facile and partly related to high time exposure. The procurement of needed traffic data should start before the experiment preparation phase.

Aerial Imaging and Image Processing

- The communication between the on-board camera system and ground-based processor did not work flawlessly during the experiment. Consequently, not all aerial image products could be received contemporaneously at the corresponding ground solution. Dedicated troubleshooting and diagnostics allowed quick resolution of some of the technical problems.

- Further improvements of the ground-based processor for image mosaicking, in terms of robustness, would further accelerate the creation of flood maps and thus contribute to situational awareness.
- Additional sensors will be utilized in forthcoming experiments (i.e. infrared) to enable more reliable image recognition with special regard to flood spreading and people detection.

RPAS Flight Control

- The safety of the RPAS flight was guaranteed throughout all flight manoeuvres at all times. Small deviations regarding cross track were especially recorded during flight turns. These deviations will be counteracted by adapting the flight performance parameters for the aircraft in forthcoming experiment to meet even higher requirements in RNP.

4 Conclusion

EXPE40 brought together different solutions from partners, and successfully linked them in one big experiment. Preparation and design of the experiment were started well in advance of the execution, and no major difficulties were encountered. All participants knew their role, and gave input to the scenario and experiment design and planning. During the experiment, quantitative data were recorded and analysed in detail, and are used to learn limitations and ways around for the future. Qualitative analysis was limited due to a rather small number of external participants. However, important and valuable feedback was given by the pilots and attending end-users.

From a solution point of view, the following can be summarized:

- U-FLY and the RPAS demonstrator worked nearly flawlessly, with only small deviations in turns, which are planned to be minimized by small adaptations.
- Aerial imaging provided valuable input for ground-based systems. Person detection was able to recognize volunteers in the assumed flooded area.
- The demonstrated traffic management tools worked as intended. They have been encountered with great interest and the end-users mentioned that the provided solutions could be a valuable support for crisis management.
- Map products in different formats have been identified to be important for the planning and preparation of rescue activities in the field. Advanced 3D map products, video animations and 3D-PDFs, have successfully been created and should help with the inspection of crisis areas.

All success criteria of the targeted objectives were fulfilled to a medium to high extent. Success criteria for objective 1 were mostly satisfied completely, while the pilots' perceived safety in terms of system reliability and situational awareness was improvable. The criterion of objective 2 was satisfied completely. For objective 3, success criteria were fulfilled completely for resolution and coverage demands, while frequency and detection certainty showed room for improvement. Three success criteria for objective 4 were satisfied completely, but cost-effectiveness and legislation issues were questioned, and some traffic data were received with a delay. The final objective 5 was satisfied well, while the time consuming mosaicking process could be improved. Furthermore, the various functionalities of the task Airborne Sensor Processing were demonstrated: aerial image assessment of a large area, detection of people in need, traffic assessment and management, and post-processed 3D products of a crisis area. Thus, EXPE40 can be seen as a success in all related aspects. Some solutions encountered technical difficulties during the experiment that could not be foreseen, such as data processing issues. These difficulties were resolved if possible, which will improve the system for upcoming experiments. Feedback of the end-users will be taken into consideration and it will be attempted to adjust the demonstrated solutions to the given remarks (e.g. one common interface, additional sensors). Improvements on post-processing of aerial images for map products is targeted to be near real-time for JE1, which should demonstrate the significantly enhanced usability of such products in operations.

The results of this technical experiment will be exploited in further DRIVER experimentation, namely EXPE44, JE1, and the FD. Regarding the deployment of the RPAS demonstrator in other countries than Germany (i.e. Netherlands in JE1, and France in the FD), several organizational tasks have to be clarified, such as allowed frequencies for the data links, or restricted airspace.

Overall, convincing evidence of the great benefit of the provided solutions with regard to situation awareness, monitoring and information gathering in CM could be provided by EXPE40.

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Annexes

A.1 Experiment results figures

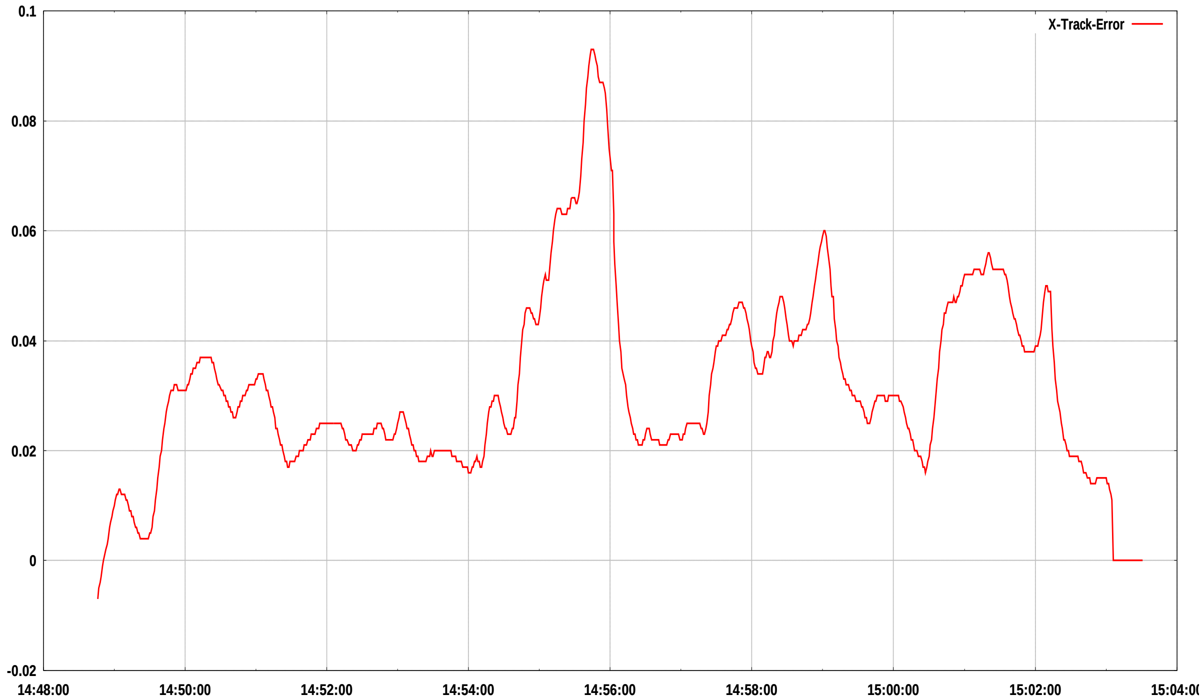

Figure 26: Cross-track error (experiment step 2)

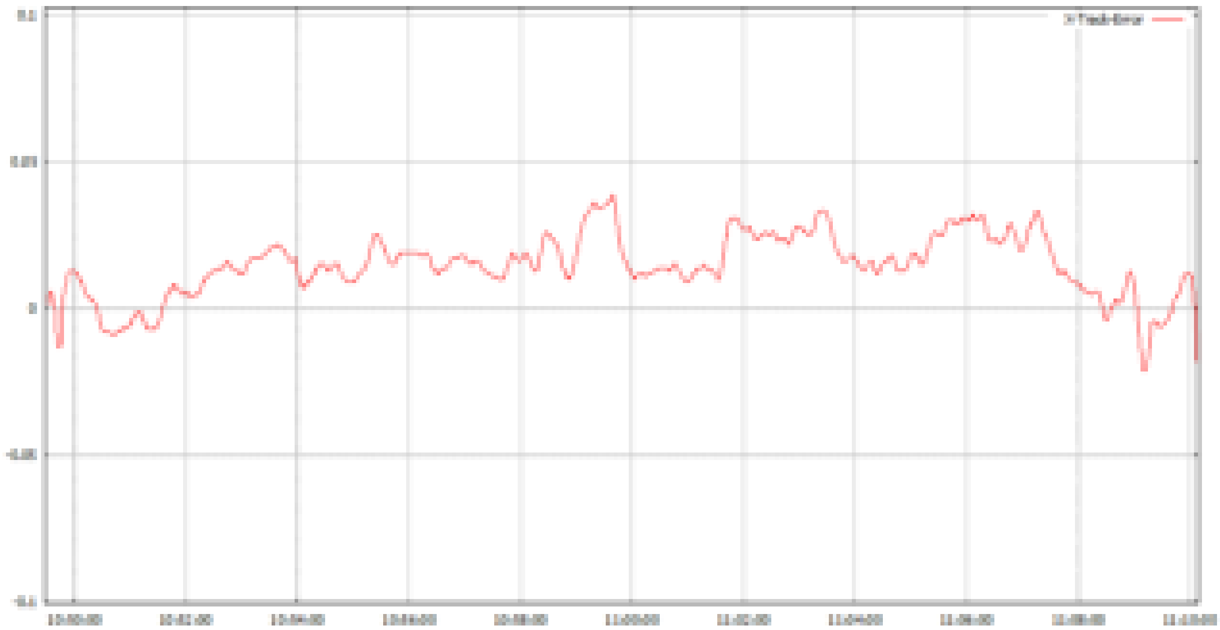

Figure 27: Cross-track error (experiment step 2 and 3)

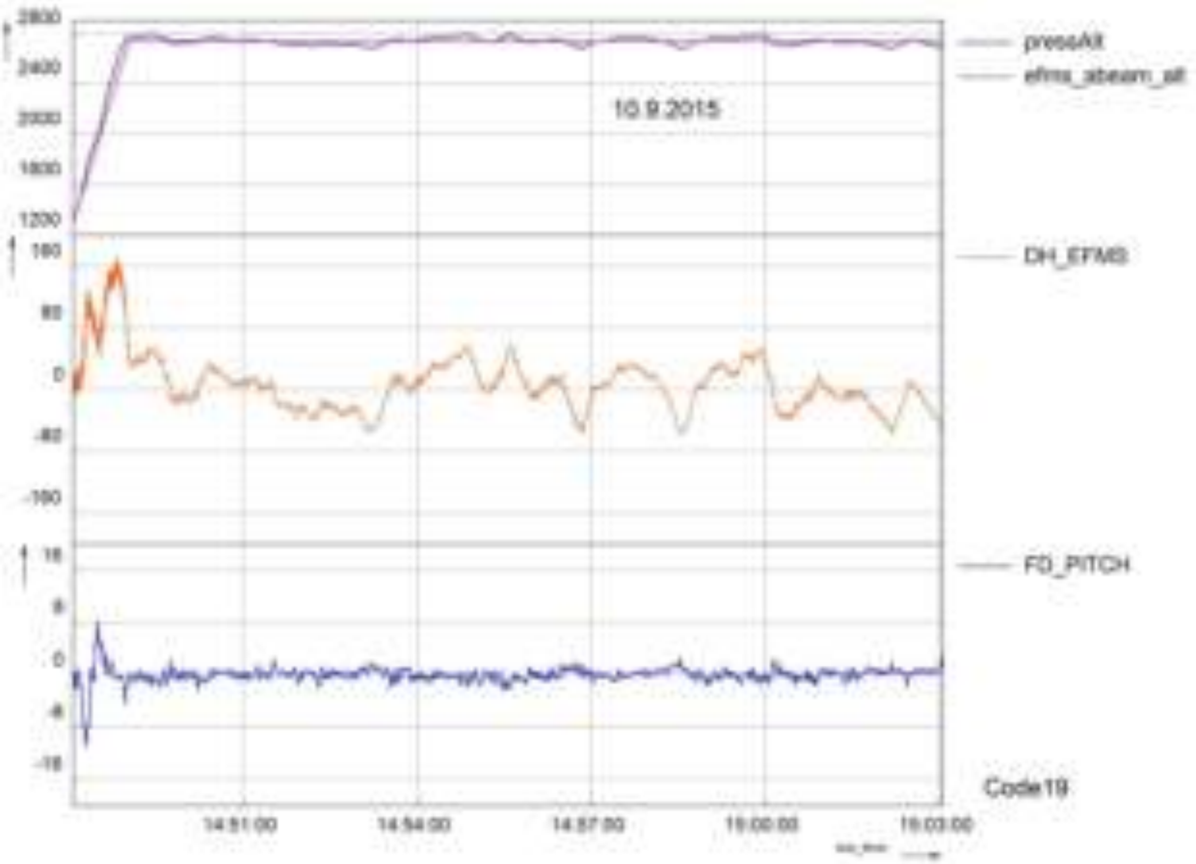

Figure 28: Altitude error (experiment step 2)

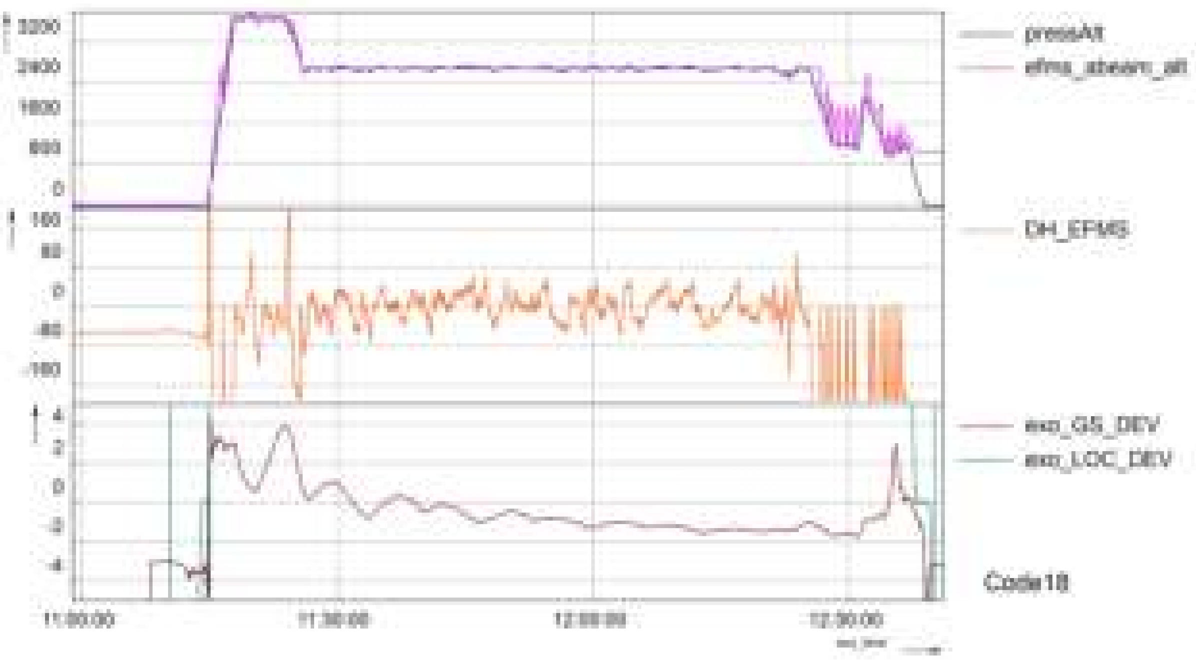

Figure 29: Altitude error (experiment step 2 and 3)

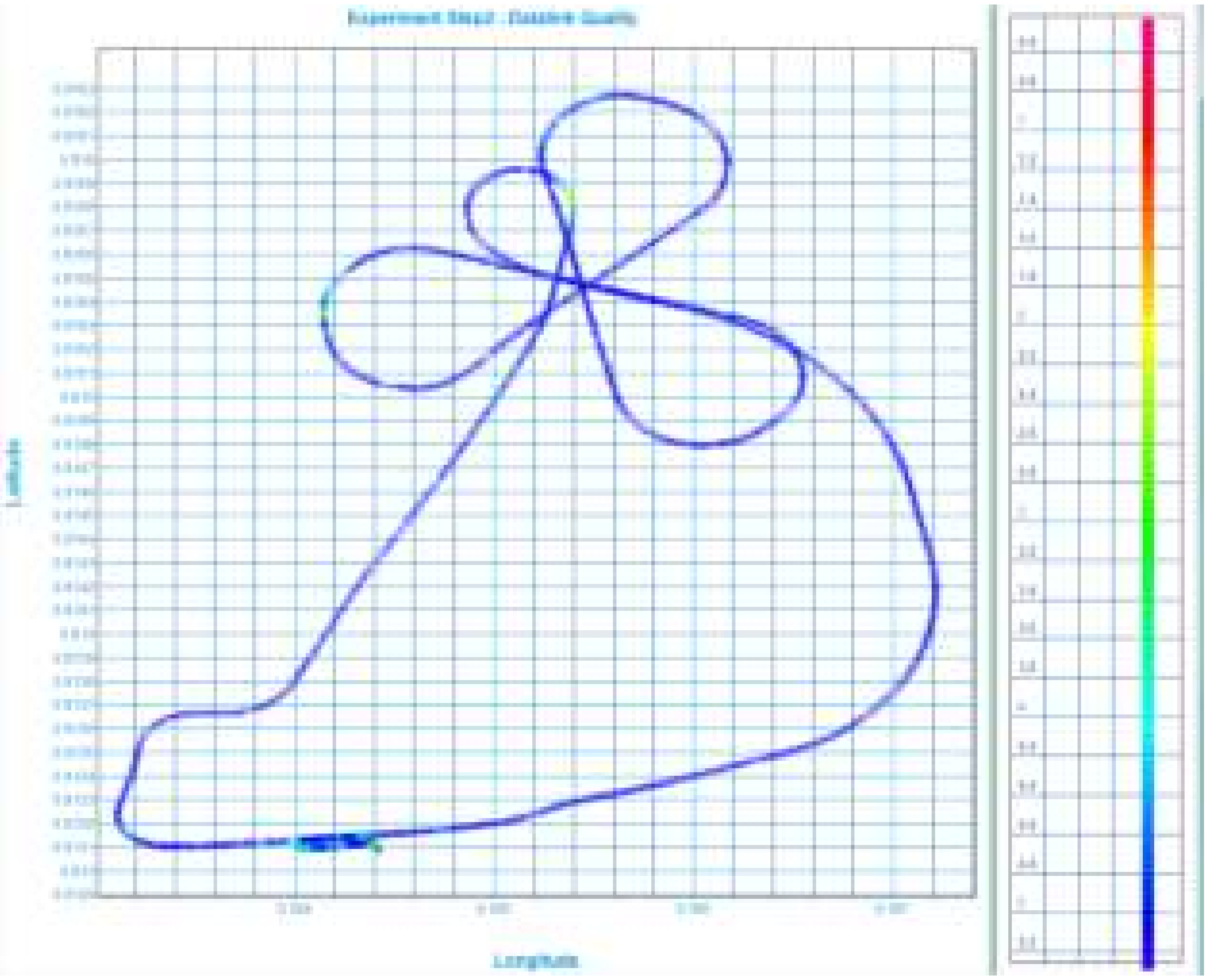

Figure 30: C^3 datalink quality (experiment step 2)

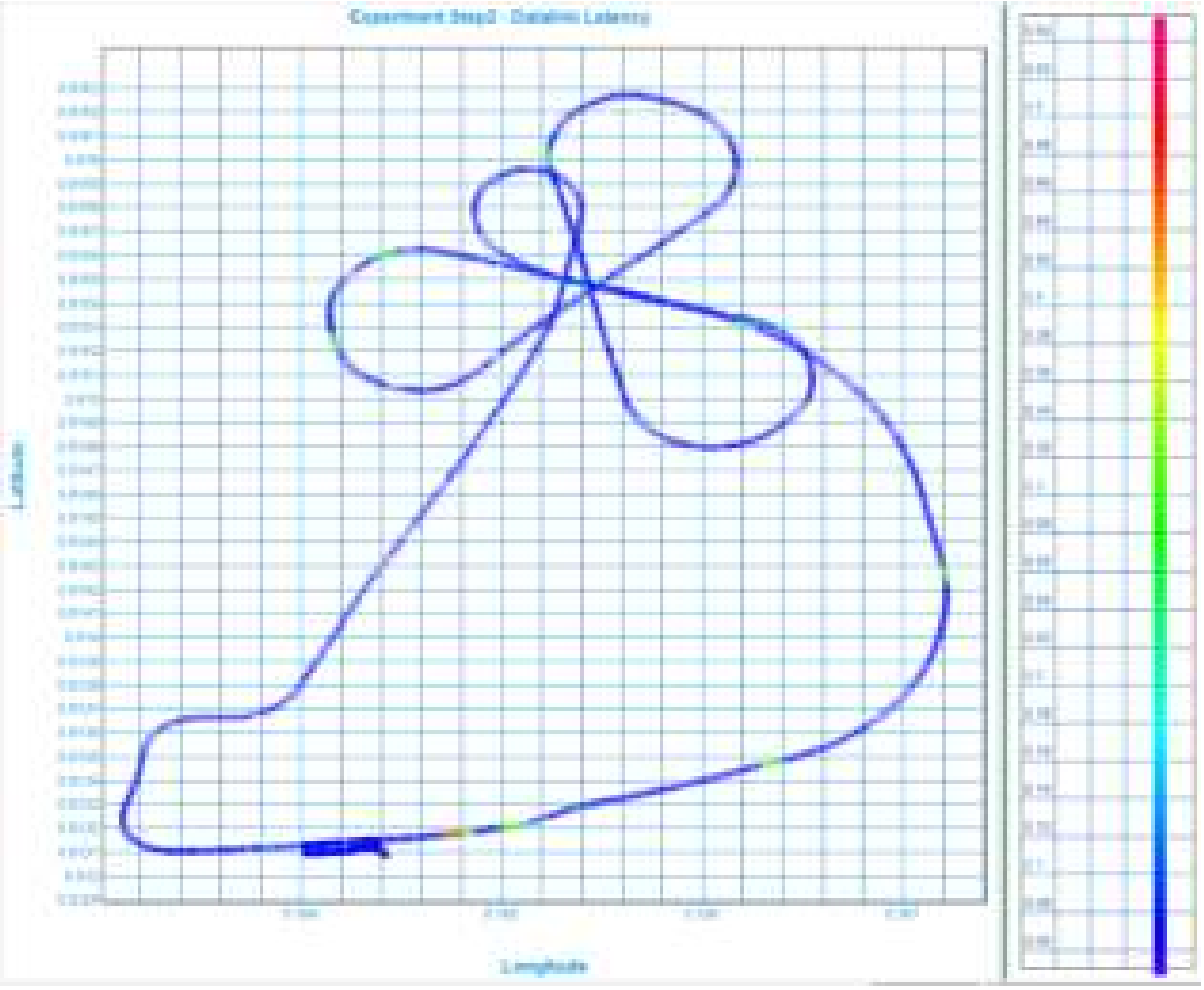

Figure 31: C^3 datalink latency (experiment step 2)

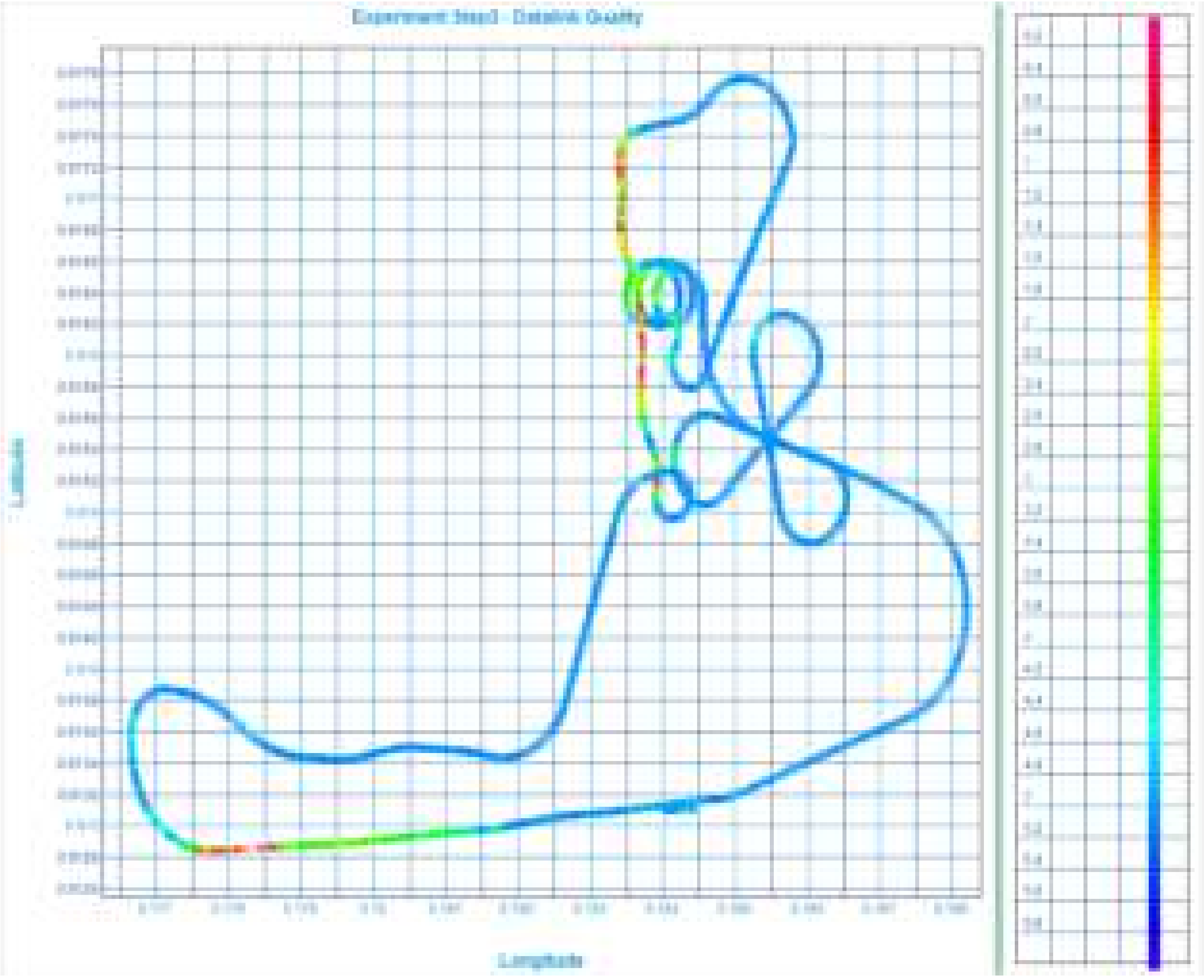

Figure 32: C³ datalink quality (experiment step 2 and 3)

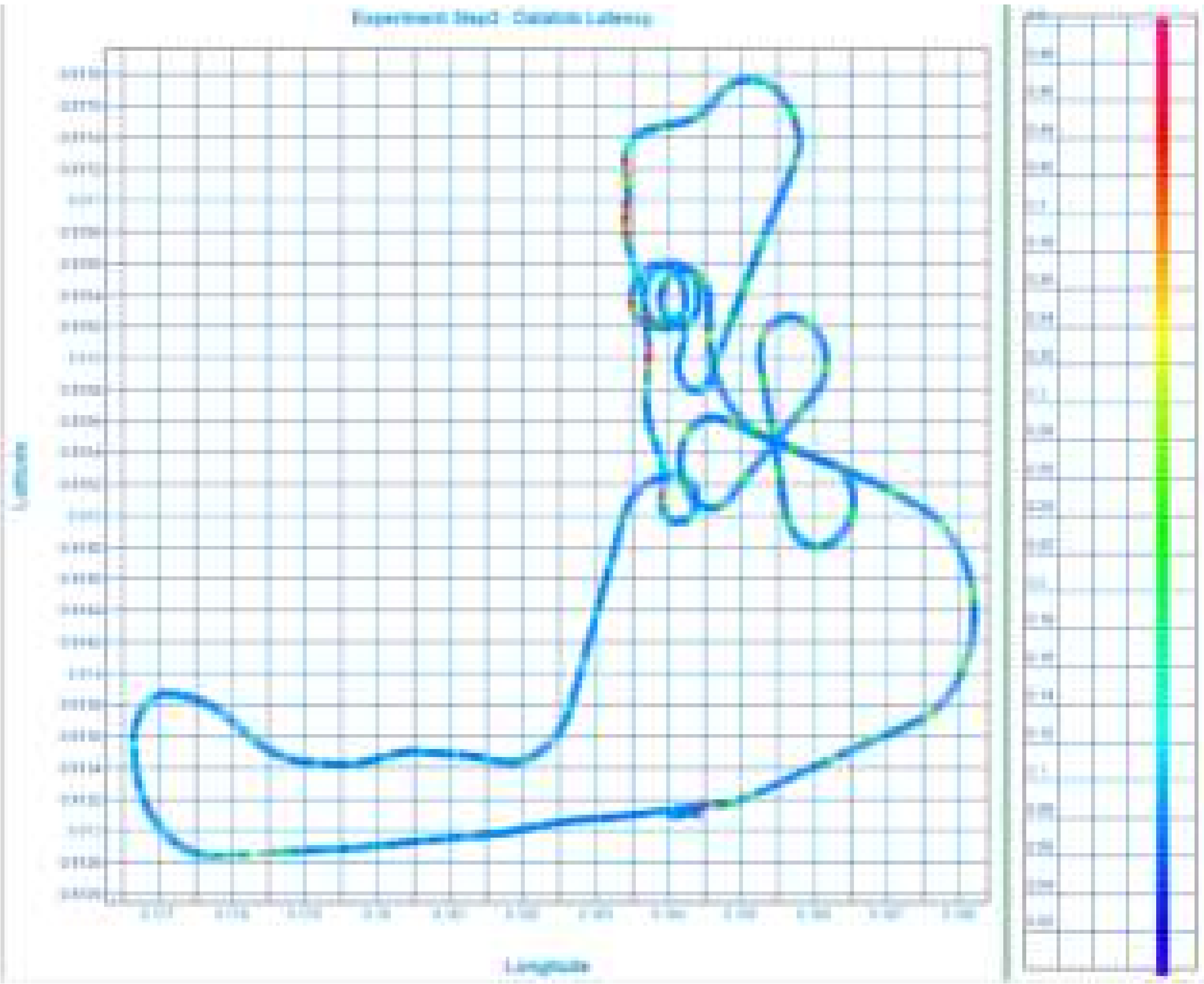

Figure 33: C³ datalink latency (experiment step 2 and 3)

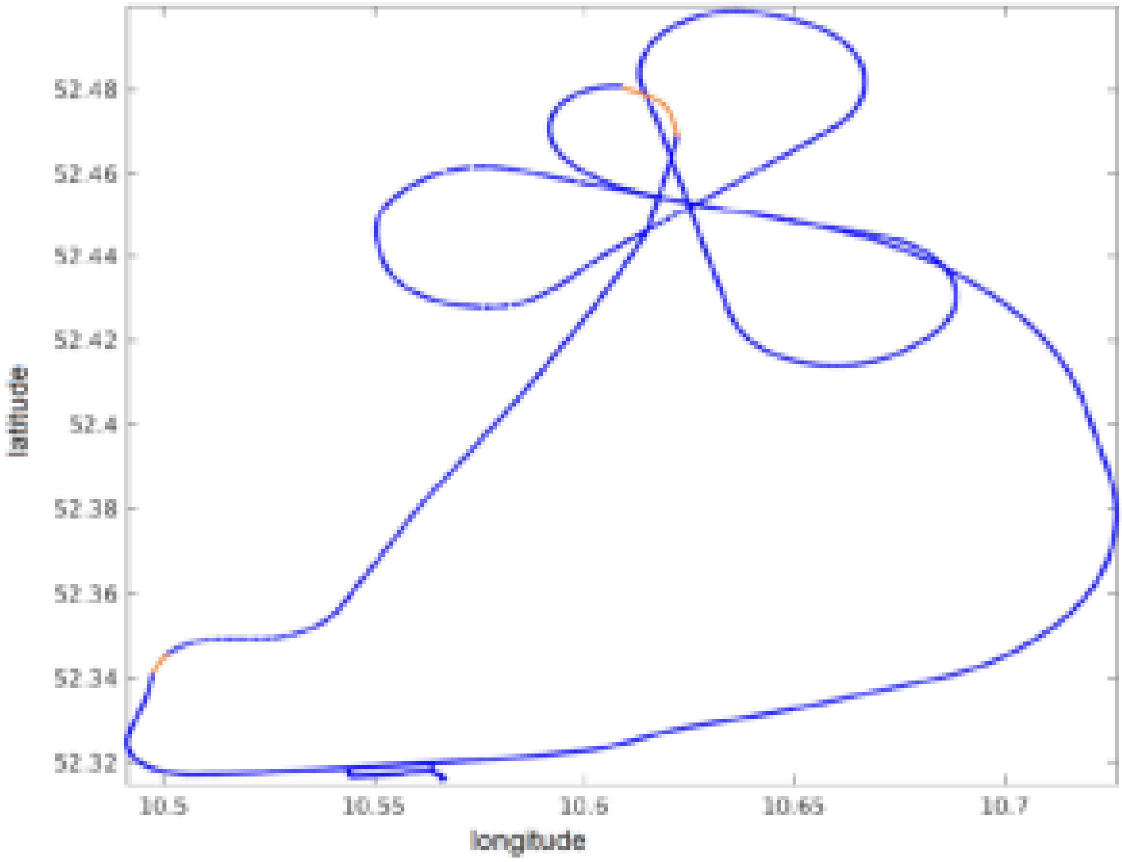

Figure 34: Payload datalink quality (experiment step 2)

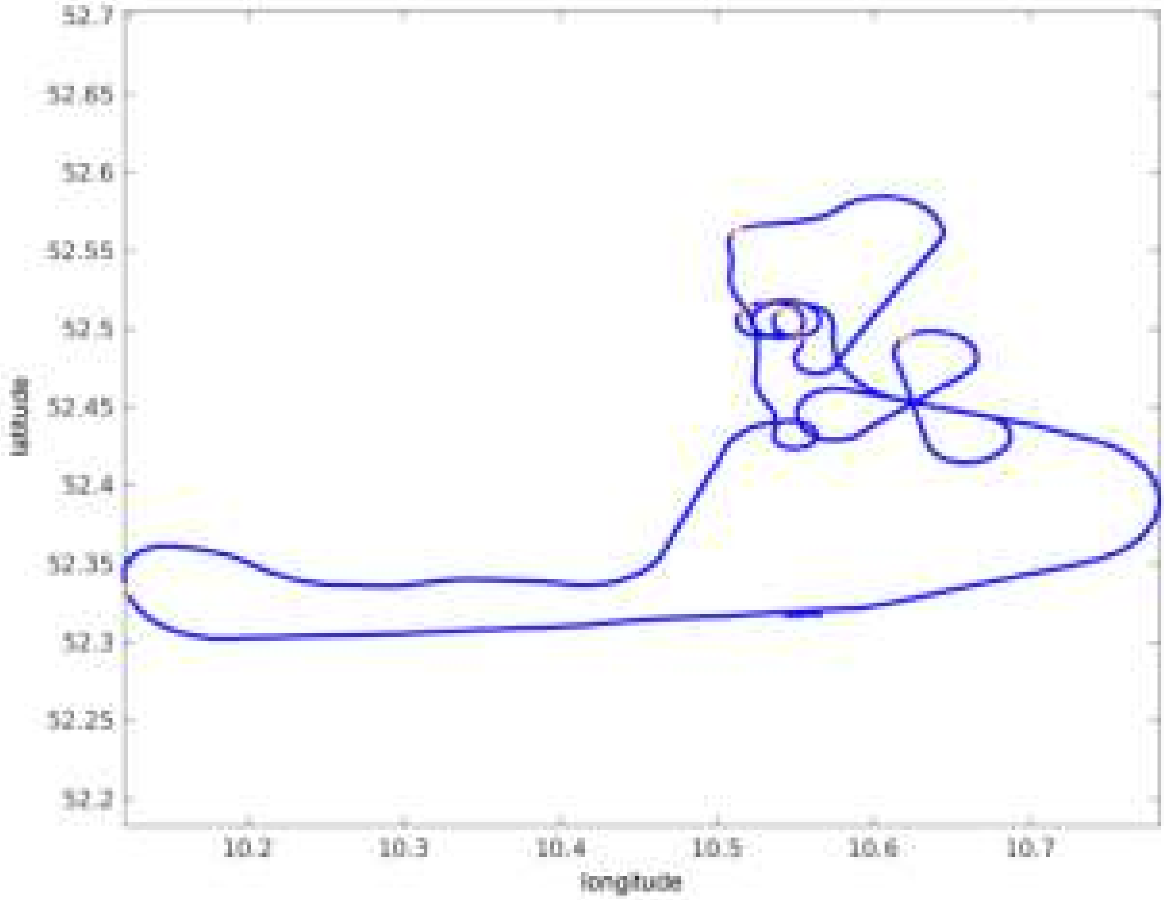

Figure 35: Payload datalink quality (experiment step 2 and 3)

A.2 End-user questionnaires

DRIVER Experiment40
Interview for End Users

Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center

Date: 11.09.15 Participant: [redacted]

Optional details:

Organization: THW
Job title/role: EXECUTIVE OFFICER
Years of Experience: 5 ½

Interview to End Users

Instructions

In the following interview feedback on the Experiment 40 will be collected.

Please respond carefully and as accurately as possible.
Please don't leave any question unanswered.

Your information will be treated confidentially.
If you have questions you can always contact a member of the DLR staff.

DRIVER Experiment40
Interview for End Users

Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center

Added value of RPAS in Crisis Management

1	Which aspects of the application of RPAS in the executed scenario were most beneficial? (If none, please elaborate)
	It is very beneficial to receive an overview of an affected area, especially if the images are real-time images.
2	What makes the application of RPAS in flooding scenario valuable?
	The aerial images are very beneficial in case of a flood scenario, as it is impossible to reach certain areas by car (flooded roads and bridges). Also, the plane is capable to produce an overall image of a large area in a short amount of time.
3	What concerns do you have in applying RPAS in CM?
	~ cost ~ possible privacy concerns
4	What possible contributions can RPAS make to CM?
	~ Receiving real-time images of a large area in a short amount of time could greatly benefit CM. It would allow us to make better decisions, quicker. ~ There would also be a benefit for our training sessions, as we can access historical data, learning from the development of the crisis.

DRIVER Experiment40
Interview for End Users

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

5	Do you have any further suggestions/remarks/ comments on the execution of the RPAS flights in Experiment 40?
	~ keep in mind that you can only [illegible] certain tasks through [illegible] due to communicate this aspect to the 'organisation' that requests your help. ~ Be up front about the cost involved.

Added value of EmerT/SUMO/KeepMoving in Crisis Management

6	Would the provided features for traffic monitoring and route planning be helpful in CM?
	~ yes, as we are currently not using any software for routing our vehicles, except google maps, top 50, [illegible] satellite images.
7	What aspects/functionalities of the provided tools did you find helpful for THW/MSB/DWR missions? What additional features could you imagine?
	~ The routing option that allows to take existing situations and developments ([illegible]) into account. ~ suggestions – take into account the dimensions of the vehicles – turning radius – the [illegible] of [illegible] [illegible] → [illegible] in of vehicles, pumps.
8	What aspects of the provided tool did you find too complex for everyday use?
	~ the usage of your tools requires training but I do not consider it too complex. ~ It is just important to determine where your software runs ⇒ i.e. on the internet, on a server (cloud – [illegible]) ... we do not have the personnel to run it, we could only operate it.

driver

DRIVER Experiment40
Interview for End Users

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

9	What concerns do you have with using the provided tools in real CM scenarios?
	see question/answer N° 8. + cost. – IT security → how safe is possibly sensitive data?
10	Do you have any further suggestions/remarks/ comments on the execution of the traffic monitoring and planning tools provided in Experiment 40?
	~ respecting privacy laws and data protection laws.
11	How can the presented capabilities be integrated into existing operations?
	~ I am not aware how easily the technology can be integrated → we ~~[illegible]~~ would have to discuss this with the IT specialists.

Added value of entire system-of-systems (ground-based and onboard)

12	What preconditions would have to be fulfilled to use the presented system-of systems in CM?
	~ availability ~ cost ~ training ~ personnel to operate and maintain
13	Which aspects of the presented system-of-systems would be most beneficial (new or more efficient capabilities) for CM operations?
	~ all

driver

DRIVER Experiment40
Interview for End Users

Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center

Additional remarks

Thank you for a well prepared experiment and
the insights into DLR's house.
Your tools are very interesting and have great
potential!

Thank you for your time and cooperation!

Figure 36: End-user questionnaire (No. 1)

DRIVER Experiment40
Interview for End Users

Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center

Date: 11/09.2015 Participant: [redacted]

Optional details:

Organization:	Pôle Risques
Job title/role:	European Project Manager
Years of Experience:	5

Interview to End Users

Instructions

In the following interview feedback on the Experiment 40 will be collected.

Please respond carefully and as accurately as possible.
Please don't leave any question unanswered.

Your information will be treated confidentially.
If you have questions you can always contact a member of the DLR staff.

DRIVER Experiment40
Interview for End Users

Deutsches Zentrum
DLR für Luft- und Raumfahrt
German Aerospace Center

Added value of RPAS in Crisis Management

1	Which aspects of the application of RPAS in the executed scenario were most beneficial? (If none, please elaborate)
	In order of importance: 1/First recognition of the area affected by the flooding to get an overall situation assessment 2/ precise localization of the victims 3/ Real time traffic situation (flooded roads/bridges…) to access to the area and rescue the victims
2	What makes the application of RPAS in flooding scenarios valuable?
	The difficulty to reach the area and to get the "big picture". RPAS could be used at different steps: - for risk knowledge: equipped with LIDAR or I sensors it would enable to get precise information on the topography, the hydraulic capacity and the soil moisture and therefore characterize the risk even before the rain starts. It could help to assess before the crisis starts the state of the infrastructures (bridges, dykes, embankments…) affected by the flood - for recognition: mapping of the flooded area and detection of potential hazards like dykes ruptures; communication with loudspeakers to assess the needs of people surrounded by water; detection of bodies under water (with thermic or IR camera) - for intervention: bring food, first aid kits to stuck people and life buoys to victims
3	What concerns do you have in applying RPAS in CM?
	Legal concerns about flying restrictions (over populated area notably…) Ethics concerns about the images taken by the RPAS including cars & people that may be recognized and identified. Data protection concerns: Usage of the images (who gets to access the images?) and storage/destruction Practical concerns: in case of bad weather, some RPAS are not able to fly / or cannot be enough stabilized to send precise and accurate images
4	What possible contributions can RPAS make to CM?
	Improve knowledge of the risk (better distater preparedness) Improve situation assessment and therefore preparedness of intervention Reduce time of intervention (quicker detection and identification of victims or other "points of interests"; quicker access to the area) Increase effectiveness of intervention
5	Do you have any further suggestions/remarks/ comments on the execution of the RPAS flights in Experiment 40?

DRIVER Experiment40
Interview for End Users

Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center

	One remark: There was a pilot and a co-pilot on the plane, so is the term RPAS really appropriate? And having such an airplane without a pilot flying over Germany is forbidden, so are we not afraid to send a wrong message? One comment: This issue of using RPAS is on top of the agenda at French ministerial level and Pole Risques with his members is coordinating the national working group on this topic on behalf of the directorate general for civil protection. There is a very high level of interest among the practitioners (mainly fire-fighters).

Added value of EmerT/SUMO/KeepMoving in Crisis Management

6	Would the provided features for traffic monitoring and route planning be helpful in CM?
	Yes, both at the preparation, response and recovery phases.
7	What aspects/functionalities of the provided tools did you find helpful for THW/MSB/DWR missions? What additional features could you imagine?
	- Keep Moving: to check road traffic in preparation of an intervention and select the quickest way, and maybe re-route vehicles during the intervention - SUMO functionality to plan and organize the evacuation of a zone (during preparation or response phases), and to monitor the return to normal around the affected area - EmerT functionality to check which path is possible for which vehicle
8	What aspects of the provided tool did you find too complex for everyday use?
	It seems like the use of each tool individually is easy, but I wonder whether it will still be the case when they are all integrated into one common interface.
9	What concerns do you have with using the provided tools in real CM scenarios?

	- The interoperability of these tools with SGOs (operation management systems) in use by the civil protection units - The traffic management system needs to be really up to date on the road network state (work in progress, new roads open, changing in the sense of circulation…) to be reliable and actually used by the first responders (trust is an important criteria).
10	Do you have any further suggestions/remarks/ comments on the execution of the traffic monitoring and planning tools provided in Experiment 40?
	Questions: - Do the tool take into account work in progress on the roadway? - Do the tool take into account the weather conditions for the timing of travel options (for instance, reduced speed when there is snow or an icy patch)? - It would be good if it could be integrated with the SGO so that the traffic management system automatically integrates the length, weight and bending radius of the available / selected vehicles
11	How can the presented capabilities be integrated into existing operations?
	Through a link to the SGOs and GIS systems in use.

Added value of entire system-of-systems (ground-based and onboard)

12	What preconditions would have to be fulfilled to use the presented system-of-systems in CM?
	- Electricity network and internet connection are effective - CM practitioners are trained to use the tools - The tools are smoothly integrated in the information flow and the command and control chain; and recognized in the national intervention doctrine - The interface is user-friendly - Such RPAS are legally authorized to fly over populated areas
13	Which aspects of the presented system-of-systems would be most beneficial (new or more efficient capabilities) for CM operations?
	Wishlist: 1/ The 3 traffic management tools are running on a common interface (so the user gets the impression that he only uses one tool) 2/ Acquisition of one integrated picture providing (in real time): - the traffic situation directly displayed over the aerial images - points of interest are automatically detected through the filters applied to the aerial images and displayed on the image - the routing possibilities are automatically applied to the detected points of interest - monitoring of the situation evolution (if the RPAS has enough autonomy to fly

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	over the zone before and during the intervention) 3/ The whole system is instinctive, easy to use (importance of the Human-machine interface)

Additional remarks

The experiment was very well organised and prepared, using the templates and guidelines provided by the project. It will certainly be very usefull for providing input to EXPE 44, to JE 1 and to the Final Demo. To ensure a smooth interaction between this EXPE and the JE and Final Demo, Pôle Risques will try to involve a French end-user from the region in which the final demo will take place so to provide feedback on the feasability of using these systems for FD.

Thank you for your time and cooperation!

Figure 37: End-user questionnaire (No. 2)

A.3 Questionnaires on safety

Date: Participant: [redacted]

Years of experience (optional):

Questionnaire for remotely controlled flights

Instructions

In the following questionnaire feedback on the remotely controlled flights at the [illegible] will be collected.

Please respond carefully and as accurately as possible.
Please don't leave any question unanswered.

Your information will be treated confidentially.
If you have questions you can always contact a member of the DLR staff.

Thank you for your feedback!

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Overall feeling of Safety

Q1	The instructions of the Flight Director were feasible at all times.	☐ 1 (strongly disagree)	☐ 2	☐ 3	[x] 4	[x] 5 (strongly agree)
Q2	Sometimes I needed to diverge from the instructions of the Flight Director	☐ 1 (strongly disagree)	☐ 2	[x] 3	☐ 4	☐ 5 (strongly agree)
Q3	I always felt safe following the given steering commands (i.e. heading, speed, altitude)	☐ 1 (strongly disagree)	☐ 2	☐ 3	[x] 4	☐ 5 (strongly agree)
Q4	Sometimes the given commands from ground (i.e. heading, speed, altitude) couldn't be adopted, because they weren't conform to the aircraft's performance characteristics.	☐ 1 (strongly disagree)	☐ 2	[x] 3	[x] 4	☐ 5 (strongly agree)
Q5	Sometimes the given commands from ground (i.e. heading, speed, altitude) couldn't be adopted, because they could have endangered the safety of the operation	☐ 1 (strongly disagree)	[x] 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q6	The provided 4D trajectory by the Flight Director was flyable without restrictions of any kind.	☐ 1 (strongly disagree)	☐ 2	☐ 3	[x] 4	☐ 5 (strongly agree)

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Q7	In some cases I had to deviate from the provided 4D-trajectory, because it wasn't conform to the aircraft's performance characteristics	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q8	In some cases I had to deviate from the provided 4D-trajectory, because it would have endangered the safety of the operation	☒ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q9	I generally feel much safer operating a highly automated aircraft than a traditional one with less automation	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)
Q10	I needed to stay in the control loop and to have the overall responsibility in controlling the aircraft	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q11	If I imagine the aircraft being flown completely by the Ground Control Station without any pilots' interaction, I would feel completely safe	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)
Q12	Automation systems should only be implemented when immediate action is needed in certain emergency situations (e.g. Datalink loss leads to immediate return to home base)	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)

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German Aerospace Center

Comments and remarks regarding safety:

System reliability

Q1	Please select how often unfeasible data instructions (e.g. wrong DH1 indication, wrong heading indication etc.) were experienced during a flight.	☐ 1 (at no time)	☒ 2	☐ 3	☐ 4	☐ 5 (very often)
Q2	How often have you experienced an unexplainable event from the Flight Director during a flight (e.g. sudden deviation from previous instructions or displayed information)	☐ 1 (at no time)	☒ 2	☐ 3	☐ 4	☐ 5 (very often)
Q3	Please state the frequency of poorly transmitted or even lost ground commands and/or instructions	☒ 1 (at no time)	☐ 2	☐ 3	☐ 4	☐ 5 (very often)

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Q4	How often did the command datalink stall or even get lost completely	☒ 1 (at no time)	☐ 2	☐ 3	☐ 4	☐ 5 (very often)

Comments and remarks regarding the system's reliability:

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Loss of skills (imagine being in the role of a remote pilot)

Q1	A pilot operating an aircraft from the Ground Control Station, will need the same qualification as a pilot onboard the aircraft	☐ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☒ 5 (strongly agree)
Q2	A pilot operating an aircraft from the Ground Control Station, will mainly be in a monitoring and scanning role	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q3	Flying skills will be deteriorated by the excessive use of automation	☐ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☒ 5 (strongly agree)
Q4	I am concerned of losing basic stick and rudder skills because these skills are practiced less often and may be called upon in the most demanding emergency situation	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q5	Remote Control can limit the pilot's ability to discover, understand and repair an automation error	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)

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Comments and remarks regarding the loss of skills:

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Situational Awareness

Q1	An increased distribution of pilot tasks to the automation system (Flight Director) requires a higher situational awareness of the pilots.	☐ 1 (strongly disagree)	☐ 2	☐ 3	☑ 4	☐ 5 (strongly agree)
Q2	With increasing confidence in the automation system (Flight Director), I less often feel the need to check the instructions' plausibility.	☐ 1 (strongly disagree)	☐ 2	☑ 3	☐ 4	☐ 5 (strongly agree)

Comments and remarks regarding situational awareness:

Figure 38: Questionnaire on safety (Phase 1, Pilot No. 1)

Date: [illegible] Participant: [redacted]

Years of experience (optional):

Questionnaire for remotely controlled flights

Instructions

In the following questionnaire feedback on the remotely controlled flights of the D-CODE will be collected.

Please respond carefully and as accurately as possible.
Please don't leave any question unanswered.

Your information will be treated confidentially.
If you have questions you can always contact a member of the DLR staff.

Thank you for your feedback!

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Overall feeling of Safety

Q1	The instructions of the Flight Director were feasible at all times	☐ 1 (strongly disagree)	☐ 2	☒ 3	☒ 4	☐ 5 (strongly agree)
Q2	Sometimes I needed to diverge from the instructions of the Flight Director	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q3	I always felt safe following the given steering commands (i.e. heading, speed, altitude)	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q4	Sometimes the given commands from ground (i.e. heading, speed, altitude) couldn't be adopted, because they weren't conform to the aircraft's performance characteristics	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q5	Sometimes the given commands from ground (i.e. heading, speed, altitude) couldn't be adopted, because they would have endangered the safety of the operation	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q6	The provided 4D-trajectory by the Flight Director was flyable without restrictions of any kind	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)

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Q7	In some cases I had to deviate from the provided 4D-trajectory, because it wasn't conform to the aircraft's performance characteristics	☒ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q8	In some cases I had to deviate from the provided 4D-trajectory, because it would have endangered the safety of the operation	☒ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q9	I generally feel much safer operating a highly automated aircraft than a traditional one with less automation	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)
Q10	I needed to stay in the control loop and to have the overall responsibility in controlling the aircraft	☐ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☒ 5 (strongly agree)
Q11	If I imagine the aircraft being flown completely by the Ground Control Station without any pilots' interaction, I would feel completely safe	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)
Q12	Automation systems should only be implemented when immediate action is needed in certain emergency situations (e.g. Datalink loss leads to immediate return to home base)	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)

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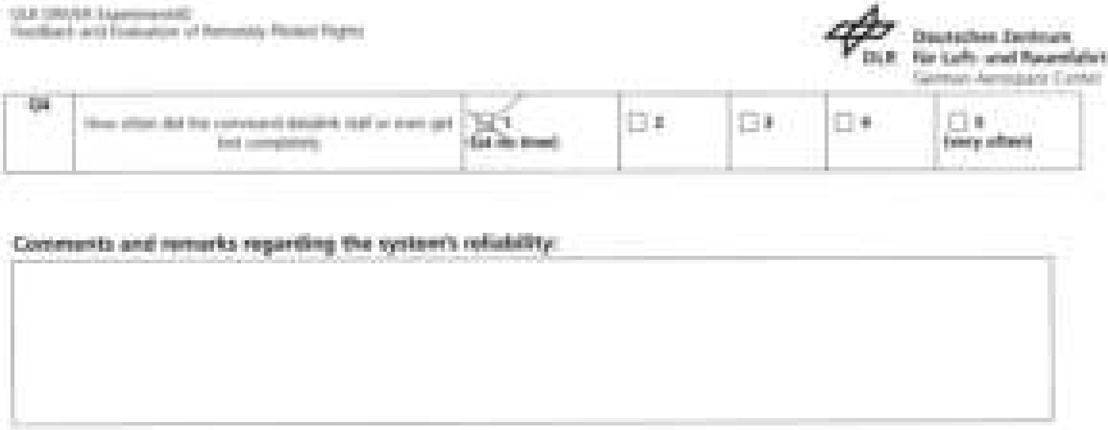
Comments and remarks regarding safety:

System reliability

Q1	Please select how often unfeasible data instructions (e.g. wrong DME indication, wrong heading indication etc.) were experienced during a flight	☐ 1 (at no time)	☒ 2	☐ 3	☐ 4	☐ 5 (very often)
Q2	How often have you experienced an unexplainable event from the Flight Director during a flight (e.g. sudden deviation from previous instructions or displayed information)	☐ 1 (at no time)	☒ 2	☐ 3	☐ 4	☐ 5 (very often)
Q3	Please state the frequency of poorly transmitted or even lost ground commands and/or instructions	☐ 1 (at no time)	☒ 2	☐ 3	☐ 4	☐ 5 (very often)



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Q4	How often did the command datalink stall or even get lost completely	☒ 1 (at no time)	☐ 2	☐ 3	☐ 4	☐ 5 (very often)

Comments and remarks regarding the system's reliability:

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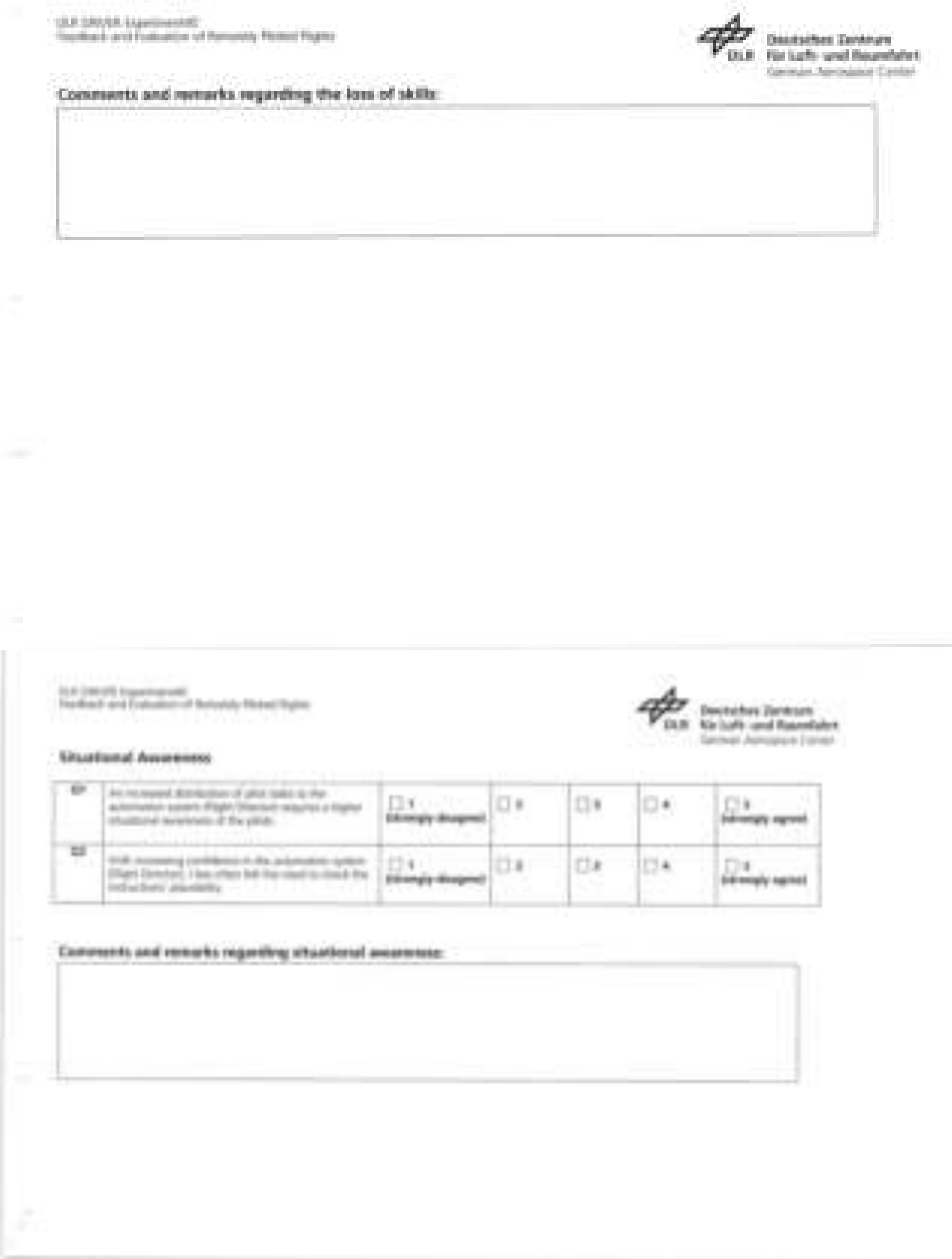
Loss of skills (imagine being in the role of a remote pilot)

Q1	A pilot operating an aircraft from the Ground Control Station, will need the same qualification as a pilot onboard the aircraft	☐ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☒ 5 (strongly agree)
Q2	A pilot operating an aircraft from the Ground Control Station, will mainly be in a monitoring and scanning role	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q3	Flying skills will be deteriorated by the excessive use of automation	☐ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☒ 5 (strongly agree)
Q4	I am concerned of losing basic stick and rudder skills because these skills are practiced less often and may be called upon in the most demanding emergency situation	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q5	Remote Control can limit the pilot's ability to discover, understand and repair an automation error	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)


Comments and remarks regarding the loss of skills:

Situational Awareness

Comments and remarks regarding situational awareness:

Figure 39: Questionnaire on safety (Phase 1, Pilot No. 2)

→ Flight Phase 2
Clover

Date: [illegible] Participant: [redacted]

Years of experience (optional):

Questionnaire for remotely controlled flights

Instructions

In the following questionnaire feedback on the remotely controlled flights of the D-CODE will be collected.

Please respond carefully and as accurately as possible.
Please don't leave any question unanswered.

Your information will be treated confidentially.
If you have questions you can always contact a member of the DLR staff.

Thank you for your feedback!

DLR DRIVER Experiment[illegible]
Feedback and Evaluation of Remotely Piloted Flights

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Overall feeling of Safety

Q1	The instructions of the Flight Director were feasible at all times.	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q2	Sometimes I needed to diverge from the instructions of the Flight Director.	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q3	I always felt safe following the given steering commands (i.e. heading, speed, altitude)	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q4	Sometimes the given commands from ground (i.e. heading, speed, altitude) couldn't be adopted, because they weren't conform to the aircraft's performance characteristics	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)
Q5	Sometimes the given commands from ground (i.e. heading, speed, altitude) couldn't be adopted, because they would have endangered the safety of the operation	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q6	The provided 4D trajectory by the Flight Director was flyable without restrictions of any kind	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)

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Q7	In some cases I had to deviate from the provided 4D-trajectory, because it wasn't conform to the aircraft's performance characteristics	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q8	In some cases I had to deviate from the provided 4D-trajectory, because it would have endangered the safety of the operation	☒ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q9	I generally feel much safer operating a highly automated aircraft than a traditional one with less automation	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q10	I needed to stay in the control loop and to have the overall responsibility in controlling the aircraft	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q11	If I imagine the aircraft being flown completely by the Ground Control Station without any pilots' interaction, I would feel completely safe	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)
Q12	Automation systems should only be implemented when immediate action is needed in certain emergency situations (e.g.: Datalink loss leads to immediate return to home base)	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)

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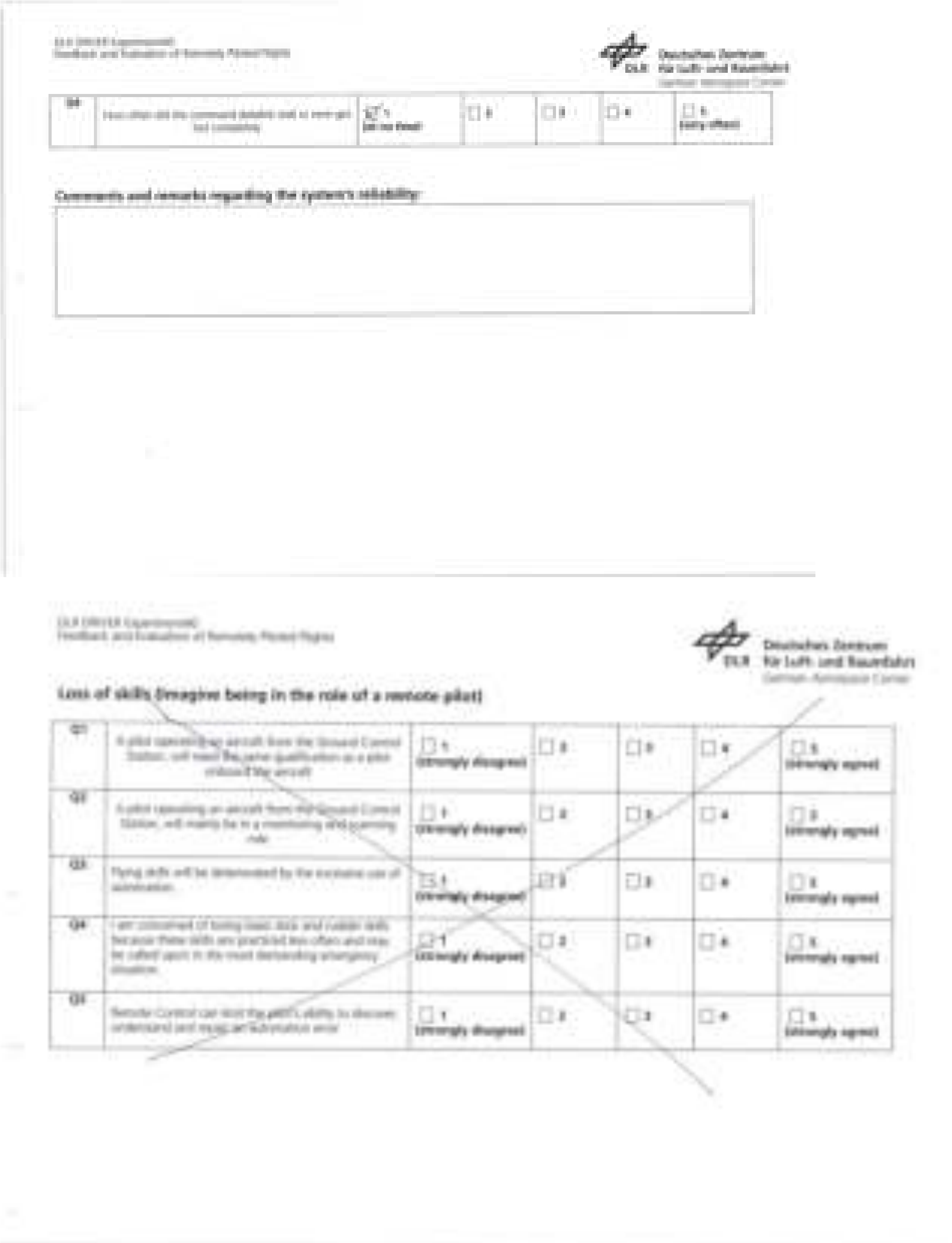
German Aerospace Center

Comments and remarks regarding safety:

System reliability

Q1	Please select how often unfeasible data (instructions (e.g. wrong QNH indication, wrong heading indication etc.) were experienced during a flight	☒ 1 (at no time)	☐ 2	☐ 3	☐ 4	☐ 5 (very often)
Q2	How often have you experienced an unexplainable event from the Flight Director during a flight (e.g. sudden deviation from previous instructions or displayed information)	☒ 1 (at no time)	☐ 2	☐ 3	☐ 4	☐ 5 (very often)
Q3	Please state the frequency of poorly transmitted or even lost ground commands and/or instructions	☒ 1 (at no time)	☐ 2	☐ 3	☐ 4	☐ 5 (very often)



Deutsches Zentrum für Luft- und Raumfahrt

Comments and remarks regarding the system's reliability:

Deutsches Zentrum für Luft- und Raumfahrt

Loss of skills (imagine being in the role of a remote pilot)

Figure 40: Questionnaire on safety (Phase 2, Pilot No. 1)

Flight 2

Date: [illegible] Participant: [redacted]

Years of experience (optional):

Questionnaire for remotely controlled flights

Instructions

In the following questionnaire feedback on the remotely controlled flights of the D-CODE will be collected.

Please respond carefully and as accurately as possible.
Please don't leave any question unanswered.

Your information will be treated confidentially.
If you have questions you can always contact a member of the DLR staff.

Thank you for your feedback!

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Overall feeling of Safety

Q1	The instructions of the Flight Director were feasible at all times	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q2	Sometimes I needed to diverge from the instructions of the Flight Director	☒ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q3	I always felt safe following the given clearing commands (i.e. heading, speed, altitude)	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)
Q4	Sometimes the given commands from ground (i.e. heading, speed, altitude) couldn't be adopted, because they weren't conform to the aircraft's performance characteristics	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q5	Sometimes the given commands from ground (i.e. heading, speed, altitude) couldn't be adopted, because they would have endangered the safety of the operation	☒ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q6	The provided 4D trajectory by the Flight Director was flyable without restrictions of any kind	☐ 1 (strongly disagree)	☐ 2	☐ 3	☒ 4	☐ 5 (strongly agree)

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Q7	In some cases I had to deviate from the provided 4D-trajectory, because it wasn't conform to the aircraft's performance characteristics.	☒ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q8	In some cases I had to deviate from the provided 4D-trajectory, because it would have endangered the safety of the operation.	☒ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q9	I generally feel much safer operating a highly automated aircraft than a traditional one with less automation.	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q10	I needed to stay in the control loop and to bear the overall responsibility in controlling the aircraft.	☐ 1 (strongly disagree)	☐ 2	☐ 3	☐ 4	☒ 5 (strongly agree)
Q11	If I imagine the aircraft being flown completely by the Ground Control Station without any pilots' interaction, I would feel completely safe.	☐ 1 (strongly disagree)	☒ 2	☐ 3	☐ 4	☐ 5 (strongly agree)
Q12	Automation systems should only be implemented when immediate action is needed in certain emergency situations (e.g.: Datalink loss leads to immediate return to home base)	☐ 1 (strongly disagree)	☐ 2	☒ 3	☐ 4	☐ 5 (strongly agree)

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German Aerospace Center

Comments and remarks regarding safety:

System reliability

Q1	Please select how often unreliable data (instruction) (e.g. wrong QNH indication, wrong heading indication etc.) were experienced during a flight	☒ 1 (at no time)	☐ 2	☐ 3	☐ 4	☐ 5 (very often)
Q2	How often have you experienced an unreasonable event from the Flight Director during a flight (e.g. sudden deviation from previous instructions or displayed information)	☒ 1 (at no time)	☐ 2	☐ 3	☐ 4	☐ 5 (very often)
Q3	Please state the frequency of poorly transmitted or even lost ground commands and/or instructions	☒ 1 (at no time)	☐ 2	☐ 3	☐ 4	☐ 5 (very often)

Figure 41: Questionnaire on safety (Phase 2, Pilot No. 2)

A.4 RPAS flight system

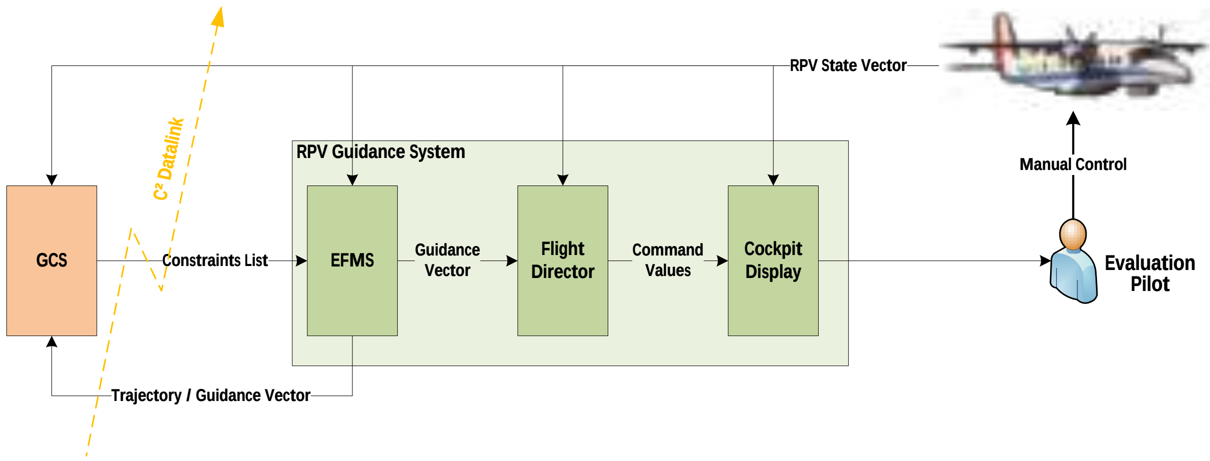

Figure 42: RPAS flight system with manual control (stage 1)

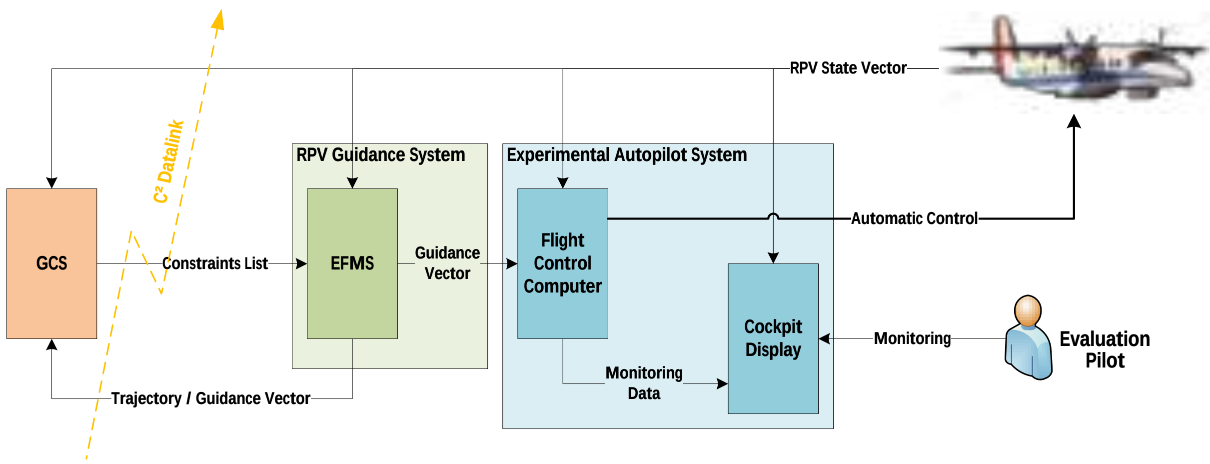

Figure 43: RPAS flight system with automated control (stage 2)

A.5 Data protection guideline

Bundesministerium
für Verkehr und
digitale Infrastruktur

Behörden der BVBS

(nur per E-Mail)

Dirk Jacke
Leiter des Referates LR 01

Robert-Schuman-Platz 1
53175 Bonn

Postfach 20 01 00
53170 Bonn

TEL +49 (0)228 99-300-4520
FAX +49 (0)228 99-300-4599

ref-lr01@bmvi.bund.de
www.bmvbs.de

Behördenleitfaden zum Datenschutz bei Geodaten und -diensten

Aktenzeichen: LR 01 – 6196.11/5
Datum: Bonn, 13.01.2014

Anlage: 1

Seite 1 von 1

Anbei sende ich zu Ihrer Kenntnis und Beachtung den auf der 25. IMAGI-Sitzung verabschiedeten „Behördenleitfaden zum Datenschutz bei Geodaten und –diensten". Danach fallen Geodaten nicht unter den Datenschutz, wenn folgende Auflösungsschwellen eingehalten werden:

- Karten mit einem Maßstab kleiner als 1:5000
- Satelliten- oder Luftbildinformationen mit einer Bodenauflösung von 20 cm oder größer pro Bildpunkt
- Eine gerasterte Fläche auf 100 m x 100 m oder größer, oder
- mindestens auf vier Haushalte aggregierte Informationen.

Im Auftrag

Dirk Jacke

Dirk Jacke

Figure 44: Data protection guideline for geodata acquisition (aerial and satellite imagery)