Testing the implementation of a flying localization system into emergency response using a tabletop exercise

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ABSTRACT

To optimize the search for trapped victims after building collapses, the authors participated in the development of a localization system based on an unmanned aerial vehicle. The objective of this study is to evaluate an approach to implement this system into the command and control structures during the emergency response after a building collapse. For this purpose, a tabletop exercise, based on a gas explosion scenario in an apartment building, was carried out with emergency response managers of the fire department and the German federal agency of technical relief. Observers have documented the exercise. Additionally, audio and video recordings were used. Thus, statements could be made about the implementation approach and the tabletop exercise method. Based on the results, the implementation approach can be considered appropriate. In addition, knowledge was gained about the appropriateness of tabletop exercises for the purpose of scientific evaluation.

Keywords

Urban search and rescue, unmanned aerial vehicle, command and control structures, tabletop exercise, emergency management

INTRODUCTION

The successful search for trapped victims during urban search and rescue (USAR) operations is affected by different factors. Besides the successful localization of trapped victims, the safety of rescuers is of particular importance (Statheropoulos et al. 2015). The research project "Flying localization system for the rescue and recovery of trapped victims" (German acronym: FOUNT^2) takes up these issues and aims at optimizing the localization of trapped victims as well as at enhancing the safety of rescuers after a building collapse.

To enable a more efficient search for trapped victims after a building collapse, a semi-autonomous, unmanned aerial vehicle (UAV) equipped with automatic landing site detection as well as bioradar is being developed within FOUNT^2. Information about signs of life and the position of trapped victims are generated by the bioradar. The mission planning and the analysis of the bioradar data is carried out via a user interface. By integrating the bioradar into the UAV, trapped victims can be located without rescuers setting foot on the debris structures, thereby reducing the risk of rescuers becoming injured or buried by further building collapses. Furthermore, the UAV can provide a bird's eye overview of the collapse site to support mission planning.

The task of the Institute of Rescue Engineering and Civil Protection (German acronym: IRG) within the project

is, among other things, the development and evaluation of an approach for the implementation of the FOUNT^2 system in the command and control structures during USAR operations. Based on a gas explosion scenario that takes past incidents into account, several implementation approaches have been described by researchers of the IRG and evaluated by four emergency managers in expert interviews. All interviewed experts are full-time or voluntary emergency managers at German fire departments or in the field of civil protection. In addition, all of them are active in higher education for future emergency response managers at TH Köln. In Germany, primarily the fire departments are responsible for emergency response after building collapses. Therefore, all implementation approaches are based on the fire service regulation 100 "leadership and command in emergency operations" (German acronym: FwDV 100) as well as the guideline 03/01 "instructions for actions of the fire service and other emergency responders after building collapses" of the German Fire Protection Association (GFPA, German acronym: vfdb) (AFKzV 1999; vfdb 2005).

Figure 1 shows the final approach for implementing the FOUNT^2 system into the command and control structures that was considered appropriate by the interviewed experts. According to this, the FOUNT^2 system is assigned as a device for technical search to the search subsector, which is part of the search and rescue sector. In this subsector, the sole control of the system is located, which enables control/command input ("full access", marked in dark blue in Figure 1). Control/command input is carried out by the so-called "FOUNT^2 operator" using a tablet computer, which runs the FOUNT^2 user interface. In order to optimize the flow of information, further access options are provided to the command staff, the search and rescue sector commander, the scene protection and safety sector (hereinafter referred to as "safety sector") commander as well as the search subsector commander and the rescue subsector commander. Using these options, information access is available by other devices, but no control of the system is possible ("read-only access", marked in light blue in Figure 1).

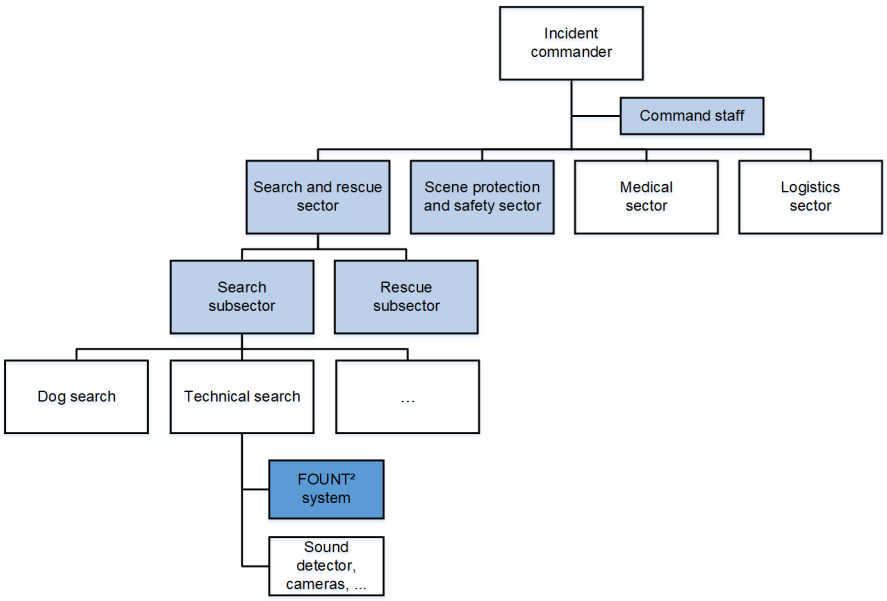

Figure 1. Approach to Implement the FOUNT^2 System into Command and Control Structures
(Own figure based on vfdb 2005)

To evaluate the implementation approach, the authors conducted a tabletop exercise with emergency management experts. Tabletop exercises are used in the field of emergency response for education and training of emergency response managers (Alexander 2002). These exercises provide the opportunity to bring various experts in the field of emergency response together to test coordination and response in a safe environment as well as to identify weaknesses of plans and procedures (Alexander 2002; Smith et al. 1999, qtd. in van Niekerk et al. 2015). In Germany, the command process defined in the FwDV 100 is used in emergency response missions and as basis for tabletop exercises in this field. The focus of tabletop exercises is the decision making of emergency managers. The medium used for the simulation usually is a diorama (shown in Figure 2), on which the incident situation is depicted in an abstract form using building and vehicle models. (Rempe et al. 2015) During the exercise, the participants verbalize relevant aspects of their decision making so that other participants can understand their actions. Additionally, the participants can enter into a dialogue with the exercise instructor.

Within the tabletop exercise conducted in this study, the following research questions were to be answered:

1. Which weaknesses/errors of the implementation approach can be identified?
2. Do the positions within the command and control structures that are addressed directly or indirectly by the FOUNT² system receive the information provided by FOUNT²? Is this information used and forwarded if necessary?

METHODS

The evaluation process was divided in three phases: preparation, conduct of the tabletop exercise as well as debriefing and data analysis.

Preparation

During the preparation phase, an exercises concept, a scenario description and an exercise script were developed. The exercise concept contained information about the objectives, the involved parties and the observation methods. The exercise script was based on the manual for strategic crisis management exercises of the Federal Office of Civil Protection and Disaster Assistance and contained the planned chronological order of the exercise as well as the information to be released during the exercise (BBK 2011). The detailed design of the exercise script also ensured the reproducibility of the tabletop exercise.

In preparation for the exercise, all participants received a presentation of the implementation approach and the emergency response units available in the exercise. Furthermore, information about the functions of the FOUNT^2 system as well as the tasks and procedures of their position according to the GFPA guideline 03/01 was provided to the participants. Additionally, a short presentation of those aspects took place at the day of the exercise.

Adjustments

The implementation approach shown in Figure 1 depicts the command and control structures in a real-life mission. However, the conditions of the exercise required some adjustments in order to realize this approach. The division of the search and rescue sector into two subsectors in the exercise would have been unreasonable and not necessary. Due to the physical proximity of the sector commander to the subsector commanders in the laboratory, everyone receives new information at the same time, although in reality this information must first be communicated from one person to another. For this reason, the subsector search and the subsector rescue are not displayed and the FOUNT^2 read-only access of the rescue subsector commander is transferred to the search and rescue sector commander. The documentation of the command and control structures was given to the participants, so that no alternative structures were used. This is comparable to the definition of a binding tactical standard procedure.

At the time of the exercise, the user interface of the FOUNT^2 system was not yet available in a functional scope that allowed complete interaction. Therefore, the information provided by the system (e.g. measurement diagrams of the bioradar) was released using printouts. Furthermore, a distraction of the participants by the operation of an unknown technical device during the simulation was to be avoided.

Scenario

To obtain a scenario that is both realistic and suitable for the evaluation, the requirements of the various actors in a rescue mission for trapped victims as well as the conditions necessary for the deployment of the FOUNT^2 system were considered during scenario development. An analysis of past real-life missions with trapped victims was carried out based on these criteria. The resulting exemplary scenario was a collapse of an apartment building in a residential area caused by a gas explosion. The scenario used in the tabletop exercise was based on a gas explosion that took place on March 31, 2017 in Dortmund (Germany). Table 1 lists the scenarios' boundary conditions derived from that incident.

To cope with the scenario, the participants had the tactical units listed in the GFPA guideline 03/01 at their disposal. The authors specified the compilation of tactical units, based on the generic terms in the guideline, with regard to the number and type of vehicles and personnel. Table 2 lists the units available in the exercise and their simulated time of arrival. Only emergency response managers who are represented in the exercise are listed. All other managers (e.g. subsector commander) are counted as operational personnel. The times of arrival are based on planning specifications from reality or on the experience of the authors. They were defined in such a way that the command and control structure envisaged in the implementation approach can be formed immediately and no alternative structure is established. For this reason, the incident commander and the search and rescue sector commander as well as the safety sector commander arrived at the same time.

Table 1. Boundary Conditions of the Gas Explosion Scenario

	Description
Localization of the incident	Residential area south of the city center in a town with about 600,000 residents.
Incident cause	Gas explosion intentionally caused by manipulation of the gas pipe
Development	Side street with multi-story terraced apartment buildings on both sides, sidewalks in front of the buildings
Description of the affected building	Partly collapsed, three-story residential building with several residential units Design: masonry with wooden ceilings Front: sidewalk Back: common courtyard with garden and a small playground
Access to the affected building	Front: access via side street, entrance through the front door Back: passage through the house into the courtyard, vehicle access via a passageway between the neighboring houses
Time, Weather	Thursday, May 3, 2018, sunny, clear sky, 22°C / 11°C
Number of trapped victims	5
Number of injured victims	5
Number of uninjured affected	15
Deployable localization means	Physical surface search (hailing) Rescue dogs Endoscopic camera Cell phone localization Bioradar / FOUNT^2 system
Deployable safety means	Site stability monitoring system Shoring system to stabilize adjacent buildings
Types of collapse involved	Lean-to collapse, pancake collapse, cantilever collapse

Table 2. Deployable Tactical Units
(Own figure based on vfdb 2005)

Vehicles	Personnel	Time of arrival
Fire and medical services		
1x command vehicle type 1	1x incident commander, 1x assistant	After 8 minutes
1x command vehicle type 2	1x logistics sector commander, 1x command staff	After 15 minutes
2x fire company[1]	1x search and rescue sector commander, 1x safety sector commander, 20x firefighter	After 8 minutes
1x rescue truck	2x firefighter	After 30 minutes
1x crane	2x firefighter	After 30 minutes
1x FOUNT^2 truck	1x FOUNT^2 operator	After 30 minutes
1x command vehicle	1x medical sector commander	After 15 minutes
3x rapid response car for physician response unit	3x physician, 3x paramedic	1x after 8 minutes 2x after 15 minutes
5x ambulance	10x paramedic	After 15 minutes

[1] A fire company consists of the following units: 1x command vehicle, 1x fire engine, 1x tanker, 1x ladder

1x equipment container for mass casualty incidents	2x firefighter	After 15 minutes
1x ambulance bus	2x firefighter	After 15 minutes
Federal agency of technical relief (THW)		
1x car	1x structural engineer / representative of THW	After 35 minutes
1x technical platoon[2]	22x THW volunteer	After 60 minutes
1x special unit search type A	9x THW volunteer, 4x rescue dog	After 60 minutes
1x special unit broaching	9x THW volunteer	After 60 minutes
Police service		
3x patrol car	6x police officer	After 8 minutes
Others		
1x energy supplier service truck	2x service personnel	After 30 minutes

Conduct of the Tabletop Exercise

The authors conducted the tabletop exercise on a diorama (1.20m x 2.00m) in the Laboratory for Major Emergency Incidents at TH Köln. The tabletop exercise diorama (shown in Figure 2) displayed a complex of several streets with residential and commercial buildings (scale 1:87). The incident site was visualized by a realistic debris model (shown in Figure 3), which had been prepared based on the scenario description from the exercise concept. Tactical units were represented in the simulation by model vehicles and figures.

Figure 2. Tabletop Exercise Diorama

Figure 3. Debris Model "Gas Explosion"

An experienced emergency response manager with brigade commander qualification from a fire department, who is also active in higher education for future emergency response managers at TH Köln, moderated the exercise (hereinafter referred to as "instructor"). This should increase the participants' acceptance of the exercise and make sure that the exercise was run according to its intended purpose. The instructor decided on his own on script adaptions necessary for continuing the exercise. To research information in the exercise script and document decisions deviating from the planned procedure, an assistant was available to the instructor. Furthermore, the assistant released information requested by the participants (e.g. results of a mobile phone location). Due to the amount of information provided by the FOUNT[2] system, an additional assistant was assigned for this purpose.

The focus of the exercise was on the activities in the search and rescue sector and the safety sector as well as on the activities of the incident commander and the FOUNT[2] operator. Two rounds of the exercise were performed with eight participants in total. In each round, the roles of incident commander, search and rescue sector commander, safety sector commander and FOUNT² operator were performed by different emergency response managers. The medical sector and the logistics sector as well as the tasks of the command staff were performed by participants, but only to enable the others to interact with them. The same people played these roles in each round. The tasks of the structural engineer and the representative of the federal agency of technical relief were combined

[2] The technical platoon consists of the following units: 1x personnel transporter, 2x rescue truck, 1x truck with wooden shoring system

and were also performed by one person in both rounds. A total of twelve participants were involved in the exercise.

Prior to the start of the exercise, all participants waited outside the laboratory so that they could not see the situation displayed on the diorama. The exercise began when the first participants entered the laboratory. The instructor first transmitted the information available at the time of the alarm that could not be displayed on the diorama (type of call, time, weather etc.). Then the participants approached the diorama. From this point on, the participants took over the incident response, discussed their reconnaissance results, decisions and measures, presented them on the diorama and received additional information from the instructor. At predefined times, further participants and simulated response units entered the exercise. Each round ended when all trapped victims had been located. At the end of a round, a debriefing was held with the participants.

Observation Procedure

To document the tabletop exercise and the debriefing, audio and video recordings as well as observers were used.

Observers

To reduce possible distractions during the exercise, four of the seven observers performed their task from a separate observation room. Three of the observers were deployed to the laboratory. The perspectives of all video recordings were transmitted live to the observation room and displayed with video projectors in front of the observers. The audio recording in stereo was transmitted as well. The coordination of the observers was carried out by the observation management, which was also based in the observation room. Arrangements between personnel in the observation room and in the laboratory were possible via telephone.

The task of the observers was to document the flow of information and the decisions being made by the participants. Four observers were assigned to positions in advance. One observer documented the search for trapped victims. Two other observers had no specific objective and documented the entire exercise. An objective could be assigned to them at any time during the simulation. Observations were documented by recording the time on a prepared observation sheet. Table 3 shows the location of the observers as well as their assignment to the position observed. The selection of observers was based on their personal experience in the field of emergency response. In addition, the observers were prepared for their task in the preparation phase of the exercise by participating in a trial run. During the trial run, each observer performed the position to be observed in order to become familiar with its tasks and procedures.

Table 3. Locations and Assignments of the Observers

	Position observed	Location of the observer
Observer 1	Incident commander	Observation room
Observer 2	Search and rescue sector commander	Observation room
Observer 3	Safety sector commander	Observation room
Observer 4	FOUNT² operator	Laboratory
Observer 5	Process of the search for trapped victims	Observation room
Observer 6 and 7	No specific mandate	Laboratory

Audio and Video Recording

Five cameras with wide-angle lenses were set up in the laboratory for audio and video documentation, recording the events from several perspectives synchronously. In the area in front of the diorama, two directional microphones were placed and aligned in such a way that the conversations of the participants could be recorded. To facilitate the observers' tasks in the observation room, a camera also recorded the frontal view on the participants. Figure 4 shows the positions of the cameras and microphones in the laboratory.

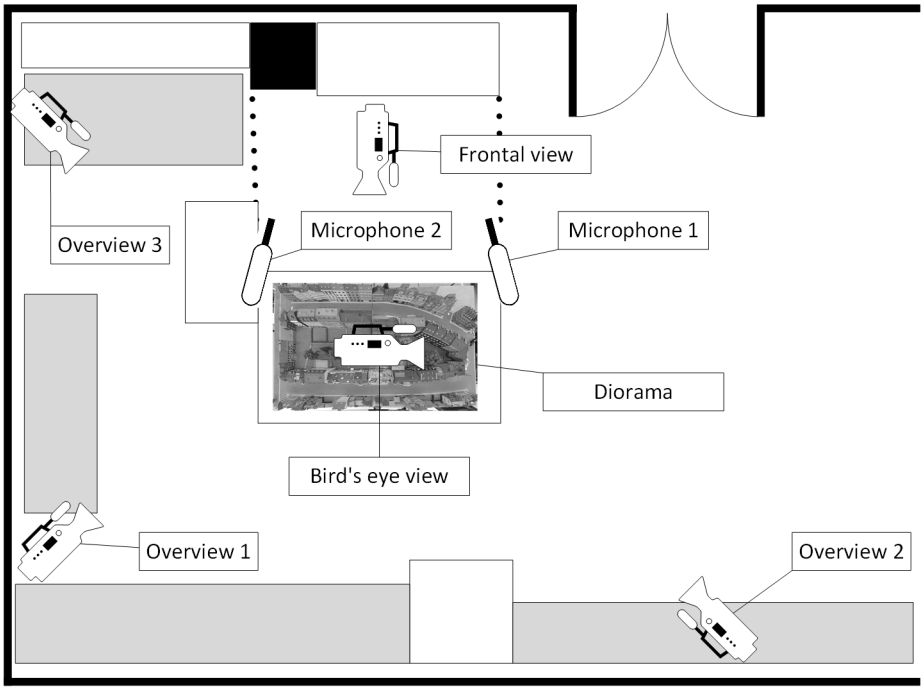

Figure 4. Positions of the Cameras and Microphones in the Laboratory

Debriefing and Data Analysis

In the aftermath of the exercise, the observers summarized their notes in the form of an observation report, which focuses on the main research questions. The authors reviewed those reports and compiled a summary. The audio and video recordings were evaluated and the chronological order of the participants' actions as well as the times at which information was released were documented. Orders, feedback and communicated information were recorded by specifying sender, recipient, time and content. In addition, the participants' debriefings were documented analogously. In a final step, the authors compared the summarized observations to the records.

RESULTS

The first round of the exercise took 1:11 hour, the second round 1:08 hour. Both rounds were carried out without interruption. In the following, the aspects most important for answering the research questions and for assessing the exercise as an evaluation method are listed.

Aspects for Answering the Research Questions

- During both rounds of the exercise, the proposed implementation approach was applied by the participants.
- In both rounds, a regular exchange and a joint discussion of information provided by the FOUNT^2 system (bird's eye overview, bioradar data) took place between the search and rescue sector commander and the FOUNT^2 operator.
- In the first round, the search and rescue sector commander asked the FOUNT^2 operator to independently coordinate his actions with the other search units.
- The FOUNT^2 operator communicated the results of the localization with FOUNT^2 to the incident commander in both rounds via the search and rescue sector commander.
- According to the participants, not all the information presented was relevant to the search and rescue sector commander and the safety sector commander. However, it is useful to be able to retrieve the information as needed.
- According to the participants, the information provided by FOUNT^2 can be interpreted by a single person who has received sufficient training to operate the system. Nevertheless, the use of several persons for this task can be helpful.
- In addition to the FOUNT^2 system, the participants used other search methods in both rounds.

- Errors or weaknesses in the implementation approach were not observed.

Aspects for the Assessment of the Exercise

- The FOUNT^2 operator had to re-sort the information printouts released in the first round. The labeling of the printouts was not sufficient.
- According to the participants of both rounds, the debris model displayed as well as the conditions on the diorama were authentic and realistic.
- The participants perceived the performance of the tasks of the structural engineer and the representative of THW by one person as problematic.
- In the debriefings of both rounds, the participants emphasized the good cooperation with one another.
- From the instructor's point of view, the participants achieved a comparably good incident response in both rounds.

DISCUSSION

Due to the exercise's boundary conditions, a statement regarding the suitability of the implementation approach can be made for the simulated scenario only. Since the assignment of the FOUNT^2 system to the technical search methods is scenario-independent, the applicability of the implementation approach to similar incidents with other causes can be assumed.

The assumption that the incident commander, the search and rescue sector commander as well as the safety sector commander arrive on scene at the same time, is fundamentally unrealistic. In reality, the complete establishment of the simulated command and control structure would be delayed. For the conduct of this simulation, however, a more realistic presentation would have had no benefit. Furthermore, this would have jeopardized the establishment of the command and control structure required for the evaluation, as the participants are not sufficiently familiar with the structure specified as the tactical standard. It is assumed that this is caused by the artificiality of this exercise.

The technical realization of the audio and video transmission into the observation room had negative effects on the observers' work. However, the number of microphones was too low. This made it difficult to differentiate between the individual contributions when several participants were talking at the same time. Furthermore, audio and video signals could not be synchronized. The observers perceived this time lag as distracting. This may have had a negative influence on the quality of the observation. In the aftermath of the exercise, however, the video recording could be synchronized with the audio track. Therefore, synchronized audio and video recordings were available for the evaluation. The information contained in the observation reports was verified during the follow-up process.

The representation of the user interface's information in paper form led to a large number of printouts, which had to be managed by the respective participants. It is assumed that the display of the information via the user interface itself will simplify the information management.

CONCLUSION, OUTLOOK AND FURTHER RESEARCH

Answering the Research Questions

1. Which weaknesses/errors of the implementation approach can be identified?

No errors could be identified in the implementation approach. However, it should be kept in mind that only the results of the evaluation of bioradar data should be displayed to managers with read-only access, so that the amount of information is kept manageable. Furthermore, it should be considered to have several persons operate the FOUNT^2 system, as evaluation, operating and communication tasks may have to be performed simultaneously. A crew commander for the FOUNT^2 system could facilitate the coordination with other units. Moreover, it is conceivable that he or she could act as an advisory function for superior commanders.

2. Do the positions within the command and control structures that are addressed directly or indirectly by the FOUNT^2 system receive the information provided by FOUNT^2? Is this information used and forwarded if necessary?

In both rounds, the directly or indirectly addressed functions received the information provided by FOUNT^2. The information was discussed and used to cope with the mission. The information was passed on in joint briefings for all managers as well as in reports of the search and rescue sector commander to the incident commander.

Tabletop Exercise as Evaluation Method

The conduct of the exercise shows that it is possible to simulate a complex incident like a building collapse that requires an extensive command and control structure, using a tabletop exercise diorama. Also, the method used is suitable for testing an approach to implementing information gathering systems in an existing command and control structure.

Additionally, the realized observations show that it is possible to perceive observation orders in a separate observation room using audio and video transmission. Although, the technical realization used can still be improved. For example, the use of personal or position-related microphones could improve observations and expand the possibilities for the evaluation of the exercise.

Also, this study shows that in the context of using a tabletop exercise as an evaluation tool, the conduction of a trial run supports both the detailed exercise script and offers observers the opportunity to prepare for their observation objectives. However, carrying out a trial run requires that the observers have a basic tactical knowledge of the simulated incident response. This knowledge can also facilitate the classification of the perceived observations during the exercise.

Substituting digital devices with printouts appears mostly unsuitable. The excessive number of printouts caused a distraction in the exercise, so that the goal of avoiding a distraction by an unknown digital device could not be achieved completely. In the future, it will be necessary to investigate which form of information display is more suitable.

The participants' feedback also showed that the use of a realistic debris model in combination with an authentic scenario is appropriate to make it easier for the participants to immerse themselves. This could have a positive effect on the validity of the evaluation.

Summary and Outlook

The developed approach of implementing the FOUNT^2 system into the command and control structures in USAR operations can be considered suitable. During the validation of the research results, it has to be evaluated carefully whether the possibility of a read-only access to the FOUNT^2 user interface by the search and rescue sector commander and the safety sector commander offers a tactical added value. The instrument of a tabletop exercise seems to be useful for the simulation of complex incidents for research purposes.

For the further progress of the FOUNT^2 project, findings were obtained for the design of a tactical unit to operate the FOUNT^2 system. Also, new aspects for the optimization of the previous development steps could be identified. The next step is to test the FOUNT^2 system in a real-life exercise and to validate its benefits.

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