



Investigating the Effect of Conflicting Goals and Transparency on Trust and Collaboration in Multi-team Systems

Verena Vogelpohl^(✉), Carmen Bruder, Jana Schadow,
and Dirk Schulze Kissing

Department of Aviation and Space Psychology, German Aerospace Center,
Sportallee 54, 22335 Hamburg, Germany
{verena.vogelpohl, carmen.bruder, jana.schadow,
dirk.schulze-kissing}@dlr.de

Abstract. In Air Traffic Management (ATM) multiple teams have to collaborate to achieve efficient and safe operation. Multiple-team operations rely on communication and information sharing between the team members. In this field, multi-team systems (MTSs) are the most common form of organization. The interface between the organizations involved (e.g. air traffic control, cockpit crews, airports) is of central importance. Apart from a common goal, different stakeholders may pursue individual goals governed by their own company culture or policies. Therefore, simply sharing all available information may not be enough to ensure safe and efficient operation. As part of the project ITC (Inter-Team Collaboration), an experimental study with 48 teams of three ($n = 144$) has just started to investigate the impact that conflicting goals have on communication and collaboration. Additionally, it examines whether and how transparency in roles, processes, and goals can affect performance, communication, and trust in multi-team systems. In the synthetic task environment (STE) ConCenT (Control Center Task Environment), teams of three have to collaborate to detect system failures in time, determine their causes, and decide on a solution in order to ensure successful production processes. Measurements of performance, perceived trust, communication, and gaze data will be analyzed to examine and compare different coordination and communication patterns on a group level. Results of the study will identify factors that may facilitate or hinder collaborative work processes in an MTS, thus enabling the validation of an approach to improve collaboration through transparency and mutual trust.

Keywords: Air traffic management · Collaboration · Communication · Multi-team system · Trust · Transparency

1 Introduction

1.1 Multi-team Systems in Aviation

With the constant change of working conditions and the rapid development of several technical and economic advances, the successful creation of flexible and adaptive organizational structures and processes is becoming more important than ever (Bell and

Kozlowski 2002). It is now commonplace that a great amount of information needs to be organized and distributed between human and technical actors in a sensible way. Especially regarding the fact that work processes are globalized in this day and age, there is the particular challenge of fostering successful collaboration among human actors from different organizations who pursue their respective goals and have their own perspectives on a system (Schulze Kissing et al. 2018). Particularly in aviation, teams from multiple organizations often work together across their organizational boundaries in what is referred to as a multi-team system (MTS). The tasks to be processed are highly dynamic and strongly linked, thus demanding the ability to respond quickly and flexibly to constantly changing conditions (Mathieu et al. 2004; Langan-Fox et al. 2009). Different stakeholders have to come together in short-term teams and collaborate in order to ensure safe and efficient air traffic operation, such as for example the coordination between a cockpit and a team of air traffic controllers on the ground, or like different stakeholders rescheduling the flight plan due to quickly changing conditions (e.g. strikes, thunderstorms) in airport management.

Considering the multiple potentially differing individual goals of each stakeholder, it is a meaningful challenge for the successful collaboration and cooperation of different operators in aviation not to lose sight of the common goal, namely to manage the current and future air traffic efficiently and safely (Keyton et al. 2012; Bienefeld and Grote 2014). In this area, conflicting goals between the parties involved quite often arise and can significantly affect the quality of communication and decision-making, as well as the development of mutual trust while working together. In order to promote efficient collaboration based on trust among operators in multi-team systems, two approaches are promising: providing system-wide information sharing methods and implementing interventions for improving the transparency of roles, processes, and goals.

1.2 Research Project ITC (Inter-Team Collaboration)

Within the European research program SESAR (Single European Sky Air Traffic Management Research), new operational concepts and technical solutions are being developed and implemented using the approach of “collaborative decision-making” (CDM) as a facilitator. These concepts and solutions rely on system-wide information sharing. But with respect to communication, it became apparent that sharing information alone is insufficient for optimizing the collaborative work processes in air traffic management (ATM). In such highly dynamic work environments, where short-term team members work together in a very interdependent manner under time pressure, it is essential to create an atmosphere where the respective roles, processes, and the individual goals of every agent can be made transparent. Goal conflicts and a lack of transparency in roles and decisions may engender distrust, which in turn has the potential to hinder or even prevent successful collaboration and cooperation within a multi-team system.

This study is part of the project ITC, which aims to provide system engineers with tools and concepts for human factors that enable systemic access to the social side of socio-technical systems. Collaborative work processes across organizational boundaries are investigated in order to develop guidelines on how to build up a more flexible and resilient multi-team system in the dynamic environment of ATM. In this context,

efficient communication as well as the transparency of different roles, processes, and goals may be of critical importance. The experimental study presented here aims to investigate the impact that conflicting goals have on communication and collaboration. Additionally, it examines whether and how transparency in roles, processes, and goals affects the perception of trust, communication, and performance.

In the following section, relevant theoretical constructs that are linked to the topic of collaboration in multi-team systems will be defined and explained. Subsequently, an experimental study that is currently being conducted at the German Aerospace Center (DLR) will be presented. Following this, the current status of the study as well as further steps and potential implications for future collaboration in ATM will be described and discussed.

2 Background

2.1 Collaboration in Multi-team Systems

When several agents from different areas and organizations in aviation work together in order to plan and coordinate processes collaboratively or make joint decisions, they can also be conceptualized as a multi-team system. A multi-team system is defined as “two or more teams that interface directly and interdependently in response to environmental contingencies toward the accomplishment of collective goals. MTS boundaries are defined by virtue of the fact that all teams within the system, while pursuing different proximal goals, share at least one common distal goal; and in so doing exhibit input, process, and outcome interdependence with at least one other team in the system.” (Mathieu et al. 2001). This implies that MTSs consist of outcome-interdependent teams, and that they are smaller than the organizations embedding them. In spite of belonging to different organizations, the team members still have to work together across their organizational boundaries. As a result, these systems often tend to share fewer common values and may have less motivation to work together than (intra-) teams that belong to a single organization (Zaccaro et al. 2012). These same potential problems need to be addressed in systemic human factors analyses in order to improve the current and future collaborative processes in air traffic management. This study focusses on the collaboration between short-term teams from different organizations who work together either remotely in different locations or together in a single control center environment.

Together with various other interpersonal factors (e.g. communication or group psychosocial traits), the collaboration between several stakeholders in order to fulfill a common task can essentially affect the outcomes of teamwork processes (Cohen and Bailey 1997). Effective collaboration and communication include, among other things, the accurate and timely exchange of information, regular performance monitoring, cooperative team orientation, adaptability, as well as trust and cohesion within a team (Owen et al. 2013; Wilson et al. 2007). But collaboration and decision-making processes are rarely ideal (e.g. Doyle and Paton 2017). They are mostly influenced by a variety of factors such as uncertain and dynamic working environments, time constraints, as well as poorly defined or competing goals among the different parties

involved (e.g. Doyle and Johnston 2011; Klein 2008). Especially in aviation, multi-team systems often have to make important decisions under time pressure based on an initial subjective assessment of the situation.

In this field, the occurrence of goal conflicts has a great potential to contribute to the development of distrust. Likewise, the differentiation between in-groups and outgroups in multi teams can significantly impair the quality of information exchange, so that information is only shared with intra-team members rather than communicating it to all involved parties (Militello et al. 2007). The resulting lack of transparency in different goals, roles, processes, and decisions during the work can further increase the distrust and fundamentally impair the success of the collaboration and cooperation. On the other hand, trust in teams can have a positive impact on the intention to collaborate and share information between stakeholders (Doyle and Paton 2017). The formation of trust is therefore an essential factor for the successful collaboration of a team and has also been discussed in various studies as a predictor of traditional team effectiveness (for a review, see De Jong et al. 2016; Jahansoozi 2006). The investigation of trust in multi-team systems in particular represents a relatively new aspect of empirical (psychological) research. Since different actors interact and work in a very interdependent manner, the issue of trust within and between different teams becomes more complex (Jones and George 1998).

2.2 Trust and Transparency in Multi-team Systems

Trust is conceptualized as a multidimensional construct (McAllister et al. 2006) and contains a cognitive, an affective, and a behavioral component (Cummings and Bromiley 1996). Trust is important across multiple levels in organizations (Fulmer and Gelfand 2012). It can fundamentally shape the interactions within a team and is able to promote or to limit teamwork, influencing the cohesion, cooperation, coordination, and communication within a team (Holton 2001). Interpersonal trust can be defined as the “willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party” (Mayer et al. 1995). It dynamically develops over time, depending on the attitudes, expectations, and behaviors of the people involved (Holton 2001; Mayer et al. 1995). In early stages of cooperation, trust is described as arising on the basis of cost-benefit analyses (calculus-stage). Later on, other components become more important, such as relying on the transfer of information (knowledge-based trust) or the emergence of trust through empathy and shared values among the team partners (identification-based trust, (Lewicki and Bunker 1996). According to Holton (2001), the individual perception of trustworthiness not only depends on the perception of another person’s abilities, but also on the perception that the other will act according to the interests of the person who is allocating trust, as well as on the perception of integrity.

However, not only can trust arise in human-human interactions, but also in human-technology interactions (trust in technology, Bonini 2001). In aviation, trust in technology also plays a crucial role, but human actors are and also will in the future have to communicate with other human actors to coordinate the current and upcoming air traffic. In air traffic control, for example, a system of different agents (air traffic

controllers, pilots, technology) works together to ensure safe and efficient air traffic. This can mainly be achieved by exchanging information as well as through the emergence of trust between the various parties. The development of trust in aviation, in turn, depends on the transparency of the different methods of operation as well as on the possibility of anticipating the behavior of the actors involved (Bonini 2001).

In order to generate trust when collaborating in multi-team systems, the establishment of a transparent working environment can be a promising approach. Transparency in work contexts can be understood either as a relationship characteristic or as an environmental condition for organizational processes (Jahansoozi 2006). Organizational transparency has the potential to increase trust and accountability in teams, as well as improve the quality of collaboration and cooperation (Cremer and Dewitte 2002). Jahansoozi (2006) assumed that when there is less trust, the need for transparency increases, which in turn has the potential to increase trust. Various studies found a close relationship between trust and transparency. For example, previous research on traditional teamwork showed that teams with little trust tended to share their information and ideas less frequently (Costa et al. 2001). Similarly, virtual teams tended to be less productive while working together with lower levels of trust (Jarvenpaa et al. 1998). Peters and Karren (2009) assume that virtual teams with a high level of trust, by cooperating and sharing more information with the other team members, were better able to deal with their generally lower shared understanding within the team.

However, the mere exchange of information is not sufficient for successful collaboration within teams or multi-teams. As Keyton et al. (2010) already stated: "Collaboration can only happen through communication." Communication is more than mere information exchange. Communication is multidimensional, highly dynamic, and interdependent. It occurs naturally in socio-technical systems. The method of communication and its dynamics always depend on the situation and the people involved. Different messages can be both explicitly and implicitly transmitted through verbal or non-verbal communication (Cooke and Gorman 2009; Keyton et al. 2010). In order to enable successful cooperation and collaboration between the members of a multi-team, it is necessary that team members have adequate knowledge of the situation, as well as of everyone's intentions, goals, and actions. This method of creating meaning can arise through fruitful communication (Klein et al. 2006; Lewis 2003). Taking into account the previous considerations, promoting trust through transparency and good communication during the collaboration could be a promising approach to building up an efficient, flexible, and resilient multi-team system, despite conflicting goals between the actors involved.

The approach of developing an intervention that is intended to promote a communicative exchange and trust between different team members has already been pursued by Peñarroja et al. (Peñarroja et al. 2015). In that study, it was shown that providing space for reflection and communicative exchange can, especially in early team phases, have a positive impact on the quality and frequency of interactions and on the perception of interpersonal trust. Here, virtual teams had to complete a problem-solving task where they had to collaborate and coordinate their behavior. After each session, the participants received feedback on their plans, their strategies for communication and information sharing, as well as on socio-emotional processes. In the process, each group discussed its strengths and weaknesses in order to develop

strategies to improve their cooperation in future sessions. Through the joint elaboration and reflection phases, especially in teams with a higher degree of trust, positive effects on team learning and tasks processing were found. Likewise, Jarvenpaa et al. (1998) developed a training approach intended to increase the perception of trustworthiness in virtual teams by using exercises where information was shared concerning previous behavior and the team member's motives. Virtual teams that participated in these exercises significantly initiated more exchange and responded more often to the other team members. Furthermore, the subjective perception of the skills, integrity, and benevolence of the other team members increased. In another study, Prichard and Ashleigh (Prichard and Ashleigh 2007) found that team training in ad-hoc teams can significantly increase interpersonal trust across all dimensions (i.e. cognitive, affective, behavioral).

2.3 ITC Use Cases for Multi-team Systems in Aviation

The operational concepts and technical solutions of the European research program SESAR already aim to implement the approach of collaborative decision-making in ATM through system-wide information sharing. Various large-scale simulations with experienced operators have been conducted since 2019 in order to validate these methods. Furthermore, the methods presented here will be investigated in the context of three use-cases that have been developed as part of the DLR's contribution to SESAR. The three use cases are, firstly, the Airport Operation Control Center (APOC) for Airport Management, secondly the sector-less, time-based air traffic control, and thirdly the Multiple-Remote-Tower Center.

In order to gain initial insight into the processes of collaboration in multi-team systems in aviation, APOC case studies were investigated at DLR in Brunswick, Germany (Papenfuß et al. 2017). Real-time simulations with operational experts were conducted (Piekert et al. 2019) for two purposes: on the one hand to test and to validate new technical support systems based on the concept of system-wide information sharing, and on the other hand to measure and analyze the interactions and behaviors of the human actors involved. In a control center environment, all relevant key players of an airport (i.e. stakeholders of an airport, airlines, ground handlers, air traffic controllers) came together to jointly derive and reschedule plans for the current and future air traffic. Here, close cooperation and coordination between the different stakeholders are of vital importance.

Following the simulations, expert workshops were held in order to discuss the experience gained in the APOC scenarios. The following items were jointly identified as important aspects and challenges regarding the processes of collaboration and coordination:

- It was observed that the processes and interactions were dynamically changing during collaboration. The specialized knowledge of each stakeholder was increasingly shared over time and the operators were increasingly able to integrate the existing knowledge of the entire multi-team.
- In the subsequent discussions, it became apparent that the operational experts developed trust in the other stakeholders over time, which was found to be helpful for the team cooperation processes.

- Good communication, knowledge of the different goals and needs of the operators, the opportunity to share and explain information and decision-making processes, as well as the opportunity to involve the other stakeholders in the ongoing processes were also perceived as beneficial.
- A guided debriefing, which took place between each planning session, also led to a subjective improvement in communication and coordination.
- On the other hand, missing or inaccurate information, difficulty understanding the actions of others, and developing trust despite competing goals were perceived as particular challenges for collaboration.

In conclusion, it can be derived that also in multi-team systems in operational practice, where stakeholders with different interests and goals come together and collaborate, the emergence of transparency, interpersonal trust, and good communication within a multi-team seems to be, in addition to the provision of information through technical support systems, of central importance. A promising approach could therefore be the development and implementation of interventions that are able to make various work processes more transparent and create a basis for trust between the operators involved in communication and collaboration.

2.4 Research Questions

Taking the practical conclusions from the investigation of the APOC use case and the theoretical and empirical knowledge and approaches from previous research into account, further exploration of the impact of goal conflicts on communication and collaboration in MTSs turns out to be of central importance in order to build up flexible and resilient multi-team systems in aviation.

Although there is already some research on the relationship between trust, transparency, and communication in both traditional and virtual teams (see Sect. 3.3), research on these processes in multi-teams, where actors with different individual goals need to collaborate, is still underrepresented. This study therefore aims to investigate these relationships during collaboration in short-term multi-team systems with competing goals. Based on the considerations above, it can be assumed that goal conflicts in MTSs could potentially contribute to the development of distrust. As a consequence, our research questions are:

- What effect do goal conflicts have on collaborative processes in Multi-Team Systems (Q1)?
- How do existing goal conflicts affect the development of interpersonal trust (Q2)?
- Based on previous considerations, an intervention promoting transparent and communicative information exchange could be a suitable method to improve the collaborative processes between the actors involved. This leads to the question of whether such an intervention can improve collaborative processes as well as performance and perceived trust in MTSs (Q3).
- In addition, suitable methods for quantifying and describing the processes of collaboration in MTSs need to be compiled and validated (Q4).

3 Method

An experimental study is currently being conducted to examine the influences of goal conflicts and transparency during the collaborative processes of multi-team systems on interpersonal trust, communication, and decision-making under controlled conditions. Together with the findings from the three use cases, the project aims to provide answers to the research questions above as well as to the question of how collaborative work processes in multi-team systems can be successfully designed, measured, and evaluated. The study is being conducted at the German Aerospace Center (DLR) in Hamburg, with a total of 144 participants who are all applicants for aviation professions and took part in selection processes at DLR Hamburg prior to their participation in the study.

3.1 Simulation Tool

The study makes use of a synthetic task environment of a control center, called ConCenT (Control Center Task Environment). It was developed and validated in order to investigate selected requirements for control room operators under controlled conditions (for further information: Bruder et al. 2019; Schulze Kissing and Eißfeldt 2015). ConCenT simulates a control center where the production processes of several spatially distributed technical systems (i.e. factories) have to be monitored and controlled. In small groups of three, the participants have to monitor the operational processes and collaborate in order to detect and remedy system failures within a limited time frame. The causes of the system failures must be then determined collaboratively and the participants have to decide on one of two solutions in order to achieve the common goal of ensuring that the operation processes are successful. The specific tasks in ConCenT are therefore (1) monitoring distributed operations collectively (monitoring task) with the aim of (2) detecting and reporting malfunctions (detection task), (3) determining their causes (diagnostic task), and (4) correcting the malfunctions by means of joint weighting (remedy task). An example depiction of the testing environment can be seen in Fig. 1.



Fig. 1. Depiction of the Control Center Task Environment (ConCenT)

3.2 Procedure

Three participants were tested in separated rooms or were separated by room dividers to prevent direct contact between the participants. After reading comprehensive instructions and completing several exercises for the ConCenT tasks, teams performed three subsequent test scenarios. Over the course of a scenario, a malfunction occurred at three different times during the monitoring task. Each malfunction had to be reported by every single team member within four seconds. If it was not reported by all members within the four-second interval, the system would automatically switch to the diagnosis task. Finally, they had to decide on their remedy (either to repair or exchange the affected technical system). In each test scenario, each participant is responsible for final decision once; the sequence in which the three participants are in charge differs in each test scenario. Figure 2 provides a schematic illustration of the basic design of the test scenarios.

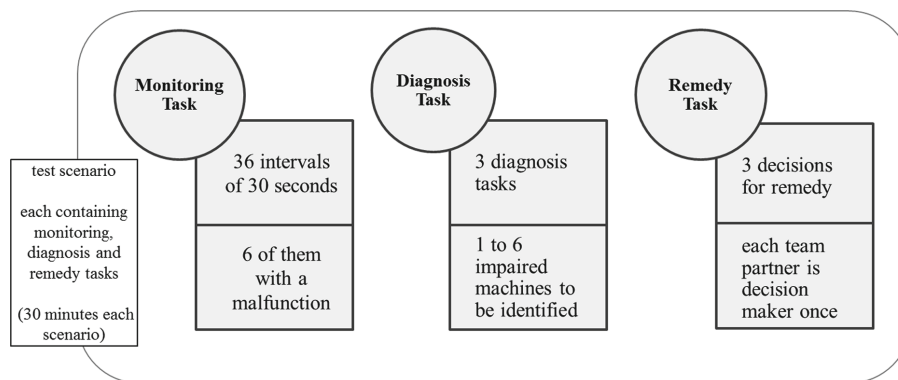


Fig. 2. Schematic illustration of the test scenarios

3.3 Study Design and Transparency Intervention

To examine the effect of conflicting goals, half of the groups work as teams of three and have no conflicting goals (control group), whereas the other half of the teams have to deal with conflicting goals (experimental group). Written instructions introduce the participants to their general roles, tasks, and responsibilities. These instructions differ between the control group and experimental group with regard to their role description and goals. In the control group, the participants are informed that they are part of a team that pursues the common goal of making the best possible decisions for the entire organization. In the experimental group, the three participants work in a multi-team system representing three different organizations and have to deal with a conflict between their own company's goals and the overall goal of the multi-team system in which they all have to work together. In consequence, the participants with conflicting goals have to both successfully handle the production processes and achieve the most beneficial result for their own company. The effect of goal conflict is further enhanced

by a bonus system that gives the participants the opportunity to gain additional funds for egoistic or cooperative decisions. Finally, the participants are instructed to support their team (control group) versus their individual organization (experimental group) by detecting, diagnosing, and solving the emerging malfunctions as fast and efficiently as possible and to choose the cheapest solutions.

Derived from the previous findings and based on the experience with the simulation of the APOC use case (see Sect. 2.3), an intervention for a transparent and communicative information exchange was developed and will be validated in this study. It consists of both a moderated exchange of information between the team members and a systematic expansion on the information provided. This means that immediately after the first test scenario of the study, a ten to fifteen-minute, semi-standardized debriefing is conducted for one condition (transparency). Guided by a moderator, the team members are given the opportunity to exchange information and reflect on their respective roles, goals, and previous decision-making processes. In the process, the team members are able to share their role-specific knowledge and experience, to increase trust, and to talk openly about their common tasks, processes, and interactions in order to improve the processes of team collaboration and coordination. Table 1 provides an overview of the different experimental conditions.

Table 1. Overview of the experimental conditions.

Experimental condition	Goal conflicts	No goal conflicts
<i>No transparency</i>	Sample size (n) = 12 no intervention	n = 12 no intervention
<i>Transparency</i>	n = 12 debriefing and introduction of an information window after the first scenario	n = 12 debriefing and introduction of an information window after the first scenario

In order to further achieve greater transparency in the exchange of information, in this condition, a new information window is introduced after the first scenario. It contains additional information on the previous decisions and individual outcomes of the three team members and after each simulation round it appears periodically. In the other condition (no transparency), the participants neither receive an intervention nor additional information through the information window.

3.4 Measurements

In order to examine the various processes of collaboration, data on performance, eye gaze, and communication are being collected. Statistical comparisons between the different conditions (goal conflict, transparency) will be calculated. Table 2 provides an overview of the dependent variables and their measurements. From a multidimensional view, the data is gathered on both an individual and a group level and will be analyzed on a group level.

Table 2. Overview of the dependent variables and measurements.

Dependent variable	Measurement (per task and team)
<i>Task performance</i>	
Accuracy	Number of malfunctions detected Number of diagnoses performed correctly Remedy decisions made
Processing duration	Time needed to perform monitoring, diagnosis, and remedy tasks
<i>Subjective ratings</i>	
Personality	NEO-FFI (Costa Jr and McCrae 2008)
Interpersonal trust	Interpersonal trust scale (Costa and Anderson 2011)
<i>Oral communication, i.a.</i>	
Accuracy	Number of speech units containing false and correct information
Efficiency	Time needed for communication
Transparency	Number of shared intentions, decisions, and conclusions
<i>Eye tracking data, i.a.</i>	
Gaze pattern	Gaze recurrence quantification analysis (Zbilut 2007)

Performance measures include the number of correct and false actions, decisions made in the remedy task, and response times in seconds. The oral communication between the team members is recorded and timestamps for each speech unit are logged in the ConCenT file. Based in this, oral communication will be analyzed with respect to the accuracy, efficiency, and transparency when sharing intentions, conclusions, and decisions. In order to check potential confounding variables, personality is also collected using NEO-FFI. Interpersonal trust is assessed by means of the Interpersonal trust scale (Costa and Anderson 2011).

Eye gazes are recorded with the Eye Tracking System manufactured by LC Technologies, Inc. The raw data is managed using NYAN software. The system operates at 120 Hz and is combined with the simulation tool ConCenT to ensure that both systems use the same timestamp. Gaze data is collected at the individual level and will be analyzed on the group level. Analyzing the gaze patterns of teams under different conditions by means of recurrence quantification analysis is a promising approach to understanding the emergence of coordination in dyads, and even in small groups (see also Schulze Kissing and Bruder 2016). For this purpose, a method for analyzing eye-movement patterns in cooperating people is used (Recurrence Quantification Analysis, Zbilut 2007). This method was already tested in a previous DLR study designed to investigate collaboration and communication in teams (Schulze Kissing and Bruder 2017).

This enables the potential influences of transparency and trust during coordination and collaboration in multi-teams to be examined and compared from a multidimensional perspective.

4 Status Quo and Further Steps

At present, the study is being conducted at DLR Hamburg and expected to run until December 2020. Data concerning performance, communication, and eye gaze are being collected on an individual basis as well as on the group level. Following this, various statistical tests, correlations, and comparisons between the conditions will be carried out on a group level to examine the influence of goal conflicts on MTS communication and collaboration from a multidimensional view. Likewise, the effect that transparency regarding roles, processes, and goals has on communication, performance, and perceived trust will be analyzed. Moreover, the intervention that aims to promote communicative and transparent exchange of information while working as a team will be validated.

As the project ITC progresses, data from the large-scale simulations of other use cases involving operational experts – namely the Multiple-Remote-Tower center (Papenfuss and Friedrich 2016) and sector-less, time-based air traffic control (Capiot and Korn 2019) – will be analyzed and related to the findings of this study. These use cases have been developed as part of the DLR contribution to the European research program SESAR in order to support and optimize the processes of collaboration and decision-making in multi-team systems in aviation. Here, the interactions, as well as performance, communication, and eye gaze data have been gathered and will be analyzed. The integrated results of the various studies will then be discussed, with the aim of deriving appropriate guidelines and measures to improve MTS collaboration processes.

Not only despite, but also due to the constant development of technical systems in an increasingly globalized work environment, it is necessary to continue considering the social nature of the group processes involved in teamwork. Together with the findings from the real-time simulations with operational experts, this study will provide answers to the question of how collaborative MTS work processes can best be designed, measured, and evaluated. By combining the analysis of communication and gaze data, as well as performance measurements, this study will provide different methods to describe and quantify collaborative processes at a group level from a multidimensional viewpoint. Factors that have the potential to either promote or impair the collaborative MTS work processes can be identified and addressed.

Moreover, the study examines and validates an approach to improving MTS collaboration by enhancing transparency and mutual trust through communicative exchange. Based on the results, different behavioral norms and interventions can be developed and optimized to support the development of trust and collaborative decision-making in (short-term) multi-team systems. Appropriate interventions and methods can be pursued in order to further ensure efficient and safe coordination processes in current and future air traffic. As a result, existing obstacles arising from rivalries or conflicting goals during collaboration can be reduced or even prevented.

References

- Bell, B.S., Kozlowski, S.W.: A typology of virtual teams: Implications for effective leadership. *Group Organ. Manage.* **27**(1), 14–49 (2002)
- Bienefeld, N., Grote, G.: Speaking up in ad hoc multiteam systems: Individual-level effects of psychological safety, status, and leadership within and across teams. *Eur. J. Work Organ. Psych.* **23**(6), 930–945 (2014)
- Bonini, D.: ATC do I trust thee?: referents of trust in air traffic control. In: CHI 2001 Extended Abstracts on Human Factors in Computing Systems, pp. 449–450. ACM (2001)
- Bruder, C., Schadow, J., Schulze Kissing, D.: Oral communication as a performance indicator in control rooms. In: Proceedings of the 33rd Conference of the European Association for Aviation Psychology. European Association for Aviation Psychology, pp. 133–147 (2019)
- Capiot, K., Korn, B.: Cognitive work analysis of the sectorless ATM concept with the Introduction of Teams. In: 38th Digital Avionics Systems Conference, DASC 2019 (2019)
- Cohen, S.G., Bailey, D.E.: What makes teams work: group effectiveness research from the shop floor to the executive suite. *J. Manage.* **23**(3), 239–290 (1997)
- Cooke, N.J., Gorman, J.C.: Interaction-based measures of cognitive systems. *J. Cogn. Eng. Decis. Making* **3**(1), 27–46 (2009)
- Costa, A.C., Anderson, N.: Measuring trust in teams: Development and validation of a multifaceted measure of formative and reflective indicators of team trust. *Eur. J. Work Organ. Psychol.* **20**(1), 119–154 (2011)
- Costa, A.C., Roe, R.A., Taillieu, T.: Trust within teams: the relation with performance effectiveness. *Eur. J. Work Organ. Psychol.* **10**(3), 225–244 (2001)
- Costa Jr., P.T., McCrae, R.R.: *The Revised NEO Personality Inventory (NEO-PI-R)*. Sage Publications, Inc., Thousand Oaks (2008)
- Cremer, D., Dewitte, S.: Effect of trust and accountability in mixed-motive situations. *J. Soc. Psychol.* **142**(4), 541–543 (2002)
- Cummings, L.L., Bromiley, P.: The organizational trust inventory (OTI). In: *Trust in organizations: Frontiers of theory and research*, vol. 302, no. 330, pp. 39–52 (1996)
- De Jong, B.A., Dirks, K.T., Gillespie, N.: Trust and team performance: a meta-analysis of main effects, moderators, and covariates. *J. Appl. Psychol.* **101**(8), 1134 (2016)
- Doyle, E.H., Johnston, D.: Science advice for critical decision-making. In: Charles, C. (ed.) *Working in high risk environments: developing sustained resilience*, pp. 69–92 (2011)
- Doyle, Emma E.H., Paton, D.: Decision-making: preventing miscommunication and creating shared meaning between stakeholders. In: Fearnley, Carina J., Bird, Deanne K., Haynes, K., McGuire, William J., Jolly, G. (eds.) *Observing the Volcano World*. AV, pp. 549–570. Springer, Cham (2017). https://doi.org/10.1007/11157_2016_31
- Fulmer, C.A., Gelfand, M.J.: At what level (and in whom) we trust: trust across multiple organizational levels. *J. Manage.* **38**(4), 1167–1230 (2012)
- Holton, J.A.: Building trust and collaboration in a virtual team. *Team Perform. Manage. Int. J.* **7**(3/4), 36–47 (2001)
- Jahansoozi, J.: Organization-stakeholder relationships: Exploring trust and transparency. *J. Manage. Dev.* **25**(10), 942–955 (2006)
- Jarvenpaa, S.L., Knoll, K., Leidner, D.E.: Is anybody out there? Antecedents of trust in global virtual teams. *J. Manage. Inf. Syst.* **14**(4), 29–64 (1998)
- Jones, G.R., George, J.M.: The experience and evolution of trust: implications for cooperation and teamwork. *Acad. Manage. Rev.* **23**(3), 531–546 (1998)
- Keyton, J., Beck, S.J., Asbury, M.B.: Macrocognition: a communication perspective. *Theor. Issues Ergon. Sci.* **11**(4), 272–286 (2010)

- Keyton, J., Ford, D.J., Smith, F.L.: Communication, collaboration, and identification as facilitators and constraints of multiteam systems. In: *Multiteam Systems*. Routledge, pp. 186–203 (2012)
- Klein, G.: Naturalistic decision making. *Hum. Factors* **50**(3), 456–460 (2008)
- Klein, G., Moon, B., Hoffman, R.R.: Making sense of sensemaking 2: A macrocognitive model. *IEEE Intell. Syst.* **21**(5), 88–92 (2006)
- Langan-Fox, J., Canty, J.M., Sankey, M.J.: Human–automation teams and adaptable control for future air traffic management. *Int. J. Ind. Ergon.* **39**(5), 894–903 (2009)
- Lewicki, R.J., Bunker, B.B.: Developing and maintaining trust in work relationships. In: *Trust in Organizations: Frontiers of Theory and Research*, vol. 114, 139 (1996)
- Lewis, K.: Measuring transactive memory systems in the field: scale development and validation. *J. Appl. Psychol.* **88**(4), 587 (2003)
- Mathieu, J., Marks, M.A., Zaccaro, S.J.: Multi-team systems. In: *International Handbook of Work and Organizational Psychology*, vol. 2, no. 2 (2001)
- Mathieu, J.E., Cobb, M., Marks, M.A., Zaccaro, S.J., Marsh, S.: Multi-team ACES: A research platform for studying multi-team systems. *Scaled worlds: Development, validation and applications*, pp. 297–315 (2004)
- Mayer, R.C., Davis, J.H., Schoorman, F.D.: An integrative model of organizational trust. *Acad. Manage. Rev.* **20**(3), 709–734 (1995)
- McAllister, D.J., Lewicki, R.J., Chaturvedi, S.: Trust in developing relationships: from theory to measurement. In: *Academy of Management Proceedings*, vol. 1, pp. G1–G6. Academy of Management Briarcliff Manor, NY 10510 (2006)
- Militello, L.G., Patterson, E.S., Bowman, L., Wears, R.: Information flow during crisis management: challenges to coordination in the emergency operations center. *Cogn. Technol. Work* **9**(1), 25–31 (2007)
- Owen, C., Bearman, C., Brooks, B., Chapman, J., Paton, D., Hossain, L.: Developing a research framework for complex multi–team coordination in emergency management. *Int. J. Emergency Manage.* **9**(1), 1–17 (2013)
- Papenfuß, A., Carstengerdes, N., Schier, S., Günther, Y.: What to say when: guidelines for decision making. an evaluation of a concept for cooperation in an APOC. In: *Proceedings of the 12th USA/Europe Air Traffic Management Research and Development Seminar, ATM 2017* (2017)
- Papenfuss, A., Friedrich, M.: Head up only—a design concept to enable multiple remote tower operations. In: *IEEE/AIAA 35th Digital Avionics Systems Conference (DASC) 2016*, pp. 1–10. IEEE (2016)
- Peñarroja, V., Orenge, V., Zornoza, A., Sánchez, J., Ripoll, P.: How team feedback and team trust influence information processing and learning in virtual teams: a moderated mediation model. *Comput. Hum. Behav.* **48**, 9–16 (2015)
- Peters, L., Karren, R.J.: An examination of the roles of trust and functional diversity on virtual team performance ratings. *Group Organ. Manage.* **34**(4), 479–504 (2009)
- Piekert, F., Carstengerdes, N., Suikat, R.: Dealing with adverse weather conditions by enhanced collaborative decision making in a TAM APOC. In: *6th ENRI International Workshop on ATM/CNS*. Tokyo, Japan, 29–31 September 2019
- Prichard, J.S., Ashleigh, M.J.: The effects of team-skills training on transactive memory and performance. *Small Group Res.* **38**(6), 696–726 (2007)
- Schulze Kissing, D., Bruder, C., Carstengerdes, N., Papenfuss, A.: Making multi-team systems more adaptable by enhancing transactive memory system structures – the case of CDM in APOC. In: Ahrm, T., Karwowski, W., Taiar, R. (eds.) *IHSED 2018*. AISC, vol. 876, pp. 215–220. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-02053-8_33

- Schulze Kissing, D., Bruder, C.: Der Einsatz Synthetischer Aufgabenumgebungen zur Untersuchung kollaborativer Prozesse in Leitzentralen am Beispiel der "generic Control Center Task Environment" (ConCenT). *Kognitive Systeme 2016* (2016)
- Schulze Kissing, D., Bruder, C.: Interactive team cognition: do gaze data also tell the story? In: *19th International Symposium on Aviation Psychology*, p. 512 (2017)
- Schulze Kissing, D., Eißfeldt, H.: ConCenT: Eine Simulationsplattform zur Untersuchung kollaborativer Entscheidungsprozesse in Leitzentralen. *DGLR-Bericht* **01**, 157–170 (2015)
- Wilson, K.A., Salas, E., Priest, H.A., Andrews, D.: Errors in the heat of battle: Taking a closer look at shared cognition breakdowns through teamwork. *Hum. Factors* **49**(2), 243–256 (2007)
- Zaccaro, S.J., Marks, M.A., DeChurch, L.A.: Multiteam systems: an introduction. In: *Multiteam Systems*, pp. 18–47. Routledge (2012)
- Zbilut, J.P.: Recurrence quantification analysis: Introduction and historical context. *Int. J. Bifurcat. Chaos* **17**(10), 3477–3481 (2007)