Factors Influencing Team Performance in the Flight Deck

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Abstract: The safe completion of a Part 121 regional airline flight requires that two pilots form a cohesive flight deck team. Aircraft are becoming more complex, and these advanced flight decks intersect with the emerging trend of today's regional airline crews exhibiting less experience due to factors such as high turnover within regional airlines and a shrinking pilot applicant pool from which to draw new hires. How well a less experienced crew identifies and mitigates threats posed by the human-machine interface is a measure of their overall performance. In addition, pilot performance relative to interaction with glass cockpit technology is influenced by overall Team Situation Awareness. Humans and machines do not always interact at an optimal level, and this report reviews literature to understand how Mutual Performance Monitoring, Crew Resource Management (CRM), and the formation of Shared Mental Models affect Team Situation Awareness and performance in a regional airline flight deck.

1. INTRODUCTION

Regional jet aircraft equipped with glass cockpits such as the Embraer 175 and CRJ 900 present pilots a higher level of complexity than their analog gauge turboprop predecessors. This advanced technology has intersected with an emerging trend of today's regional airline crews exhibiting less experience due to factors such as high turnover within regional airlines and a shrinking pilot applicant pool from which to draw new hires (Smith, Hight & Smith, 2019). Regardless of a pilot's individual experience level or background, the safe completion of a Part 121 regional airline flight requires that two pilots form a professional and cohesive flight deck team.

How well a less experienced flight crew identifies and mitigates threats posed by their human-machine interface is a function of their overall situation awareness (SA) and performance. Indeed, humans and machines do not always interact at an optimal level of trust and competence (Musselman, 2019), and any deficiencies become a direct threat to flight safety.

This report examines human factors literature to explain Team Situation Awareness and pilot-machine interaction and how effective Crew Resource Management (CRM), Shared Mental Models, and Mutual Performance Monitoring can mitigate lower levels of pilot experience.

2. A REVIEW OF SITUATION AWARENESS (SA)

First, a review of SA is necessary to frame the contents of this report. Endsley (1995) provides a well-known and accepted three level definition of SA:

- Level 1 – Perceiving a situation
- Level 2 – Comprehending a situation
- Level 3 – Projecting the situation into the future

In simpler terms, a pilot exhibits SA when he or she understands what is occurring in his or her flight deck environment (Aydogan, Sharpanskhykh & Lo, 2014).

Mission success requires that not only a pilot maintain SA of his or her roles and duties, but he or she must also do the same in the greater context of the other pilot's activities and responsibilities (Salmon et al., 2008). Therefore, if either pilot possesses incomplete or inaccurate SA of a situation or aircraft system, a breakdown in crew performance occurs (Endsley, 1995).

Assessing individual SA relative to system design is an established field. For example, the Situation Awareness Rating Technique (SART) measures how well a pilot understands system states, and the Situation Awareness Global Assessment Technique (SAGAT) assesses the pilot's performance of a task in relation to the three SA levels. Less developed, however, are means to measure Team Situation Awareness (Kaber & Endsley, 1998).

3. FORMING A FLIGHT CREW TEAM

An understanding of the team environment in which pilots operate is important for understanding how well they will potentially work together. A typical flight crew team forms quickly (often the two pilots have never met), performs shared tasks, and dissolves upon successful completion of the flight duty period (Mathieu et al., 2000).

In addition, a flight crew depends on self-directed teamwork to attain the goals set by their organizational management (i.e. understanding of aircraft systems, adherence to standard operating procedure (SOPs), and safe, on-time arrivals) (Kauffeld, 2006). In order to achieve these goals, a crew depends on the rapid formation of a high-level trust in each other to perform tasks safely and competently (Mathieu et al., 2000).

Kauffeld (2006) identifies four team competencies driving trust:

- Professional – Using knowledge to identify and solve problems
- Methodological – The ability to find resources to accomplish tasks
- Social – The ability of a team to communicate and cooperate with each other
- Self-competence – How well a team fosters an environment conducive to growth

4. TEAM SITUATION AWARENESS

Team SA covers several dimensions including individual SA, the SA shared by team members, and the sum of SA across all team members. The depth of individual pilot SA in turn influences overall Team SA (Salmon et al., 2008).

In addition to the previously mentioned team competencies, Bosstad and Endsley (1999) identify four components influencing Team SA:

- Shared SA Requirements – How well pilots understand which information about tasks and flight status needs to be shared
- Shared SA Devices – The displays or other means that pilots use to share information and communicate within the flight deck
- Shared SA Mechanisms – How well pilots use tools such as CRM and Shared Mental Models to interpret, comprehend, and project information
- Share SA Processes – How well pilots share SA, check each other's work, and coordinate and prioritize tasks

Shu and Furuta (2005) found that earlier studies of Team SA linking individual SA to team cognitive processes do not reach deep enough into examining how cooperative activity influences reciprocal team activities. Endsley's (1995) three level model of SA may accurately reflect the individual pilot's efforts on an objective level (Nonose, Kanno & Furuta, 2000), but overall Team SA is dependent on assessing the level of trust based interaction between the two pilots (Aydogan, Sharpanskykh & Lo, 2014).

Shu and Furata (2005) further conclude that Team SA depends on an additional element of mutual beliefs that enhance the perception, comprehension, and projection of overlapping individual and group frameworks. Each pilot must develop a belief that the other pilot's cognitive and physical abilities are proficient and competent enough to complete a flight mission (Nonose, Kanno & Furuta, 2000). Otherwise performance suffers due to a lack of team cohesiveness.

5. PILOT-MACHINE INTERACTION

While one would expect automation to lead to decreased workloads and increased safety, the opposite often occurs. Endsley (2015) believes this performance decrement arises from reasons beyond complacency. The typical regional pilot has become more of a systems monitor due to advanced interface designs such as the glass cockpit, and this leads to a more passive role for the pilot.

A passive pilot tends to exhibit decreased SA, increased training requirements, and sometimes an accident when interfacing with increased automation (Miller & Parasuraman, 2007). In fact, after studying 24 NTSB accident reports, Endsley (1995) found that a staggering 88% of human error resulted from SA deficiencies rather than poor decisions or issues with task completion.

Similar to Endsley's research, Musselman (2019) found that the ongoing interaction between pilots and aircraft in Part 121 operations leads to hazards and potential performance issues. He identified 123 Part 121 airline reports in the Aviation Safety Reporting System (ASRS) database that revealed human-machine interface hazards.

Musselman's research (2019) confirmed that more incidents occur during the takeoff and landing since these phases require more pilot-machine interaction to configure systems. Mental models related to automation interface and SA related to tasks and demands are the most likely human factors to be negatively influenced by the human-machine interface.

Musselman's findings also relate to Endsley's work (2017) developing the concept of the human-autonomy system oversight (HASO) model. The HASO model places attention allocation at its core, and from there designers determine an optimal level of pilot-aircraft automation interaction. How well the automation performs influences the pilots' trust in it and ultimately the level of individual and team SA they devote to it.

6. CREW RESOURCE MANAGEMENT

Effective Team Situation Awareness is maintained when both pilots form a joint understanding of a given situation (Salmon et al., 2008). Traditional Crew Resource Management (CRM) emphasizes concepts such as open communication to trap and prevent errors. CRM is generally presented on a theoretical level in the classroom with the hope that crews will successfully utilize it on line to maintain SA along all three levels (Holt, Boehm-Davis & Hansberger, 2000).

Major disadvantages to teaching CRM on a theoretical level in the classroom are that a crew may not fully understand CRM concepts or inexperienced pilots could incorrectly apply it when addressing a previously unseen situation such as diagnosing an errant system (Holt, Boehm-Davis & Hansberger, 2000).

With these shortcomings in mind, Ikomi et al. (1999) tested with encouraging results at a regional airline an interesting enhancement to traditional CRM called Advanced CRM (ACRM). CRM is defined by principles, and this ACRM study turned these principles into specific and observable actions written into the airline's Standard Operating Procedures (SOPs), Flight Operations Manual (FOM), and Quick Reference Handbook (QRH) (Holt, Boehm-Davis & Hansberger, 2000).

Ikomi et al.'s study followed 50 crews divided into traditional CRM and ACRM participants to observe their performance. The best performing crews utilized ACRM as SOP, and this study indicates that ACRM leads to a higher level of team SA (Holt, Boehm-Davis & Hansberger, 2000). ACRM is a potential application to mitigate decreased pilot experience levels at a regional airline by utilizing heightened standardization at a procedural level.

7. SHARED MENTAL MODELS

CRM's principles of communication, task management, and team cohesiveness become even more effective when combined with shared mental model structures (Reynolds & Blickensderfer, 2009). Salmon et al. (2008) describe the relationship between Endsley's three level model of SA and the role of mental models in achieving and maintaining SA. A pilot develops mental models through his or her training and experience. The depth of experience and effectiveness of training will determine how proficiently an inexperienced pilot notices critical cues from an aircraft system (Level 1), how well he or she processes these cues to understand their meaning (Level 2), and the accuracy he or she can predict a future state of the system (Level 3).

Mental models also provide a means for pilot-machine interaction by structuring their individual knowledge into patterns. A shared crew mental model is the extent which individual pilot mental models overlap with each other as the pilots form their team to complete tasks or interface with the aircraft (Reynolds & Blickensderfer, 2009).

The increased technology in regional aircraft has led to an increase in task complexity. Mathieu et al. (2000) found a link between shared mental models and team performance while studying 56 teams flying simulated combat missions on a desktop flight simulator. Much like some less experienced regional airline crews, Mathieu et al.'s study examined novice participants performing complex tasks. The study provides evidence that the depth and similarity of knowledge shared by two pilots does determine how well they perform as a team regardless of experience level.

Bosstad and Endsley (1999) also tested shared mental models in relation to how well a team develops SA by studying sixteen teams of two. One group of teams was provided their counterpart's job description and time to ask each other questions. The other set of teams was given only information regarding their individual tasks. Teams were then assigned to shared displays or non-shared displays. The highest performance levels came from teams with either shared displays or shared mental models. Non-shared displays and no mental model teams exhibited a highly noticeable performance decrement.

SA is the state in which pilots find themselves at any given time during a flight, and mental models provide information from a pilot's long term memory to aid in comprehension (Level 2) and projection (Level 3) (Endsley, 1995; Aydogan, Sharpanskykh & Lo, 2014). Therefore, a regional airline crew's overall Team SA and Shared Mental Model are directly affected by the experience of either pilot in terms of how developed his or her knowledge is.

8. MUTUAL PERFORMANCE MONITORING

Mutual Performance Monitoring in the flight deck occurs when each pilot can effectively handle his or her own tasks while monitoring those of the other pilot at the same time (Albon & Jewels, 2012). Decreased experience at the regional level combined with Musselman's (2019) and Endsley's (2017) investigations into pilot-machine interaction indicate catalysts for a potential accident resulting from automation, decreased Team SA, and ineffective Mutual Performance Monitoring.

Shu and Furuta's (2005) found that mutual awareness and its advanced state, Mutual Performance Monitoring, evolve either directly from two way verbal communication or are inferred implicitly by non-verbal communication. Albon and Jewels' (2012) research also affirms the importance of communication by explaining how Mutual Performance Monitoring ties in with Endsley's (2005) SA model. Study participants were better able to perceive what others were doing (Level 1 SA), comprehend what progress teammates were making (Level 2 SA), and project any changes that might need attention (Level 3 SA) once they understood the importance of monitoring each other's work.

One interesting aspect of Mutual Performance Monitoring relates to shared mental models. Each pilot does not necessarily need all of the information and knowledge to complete mutual tasks such as understanding the underlying causes of an aircraft system fault since complementation and robustness can overcome gaps (Nonose, Kanno & Furuta, 2009).

Complementation allows for some knowledge and skills to be distributed across the crew. What one inexperienced crewmember may lack is made up for by the other who possesses it. Furthermore, robustness defines how well a pilot reacts to stress, failures of a system, or other high workload events such as configuring an aircraft for landing or takeoff (Nonose, Kanno & Furuta, 2009).

With both pilots engaged as a team monitoring each other's performance, one of them can detect a system failure or aircraft misconfiguration the other may not perceive (Nonose, Kanno & Furuta, 2009). Though a pilot lacking any procedural knowledge or experience is not the best situation, a crew properly backing each other up can overcome some minor aspects of inexperience.

9. AN INTERESTING LIMITATION ON CREW PERFORMANCE AND TEAM SA

This report has thus far explored the positive contributions CRM, Shared Mental Models, and Mutual Performance Monitoring make towards an inexperienced regional airline crew's interaction with technology and/or Team SA. One dynamic not easily overcome is the human element. No amount of ACRM or HASO modeling can fill the safety vacuum created by a crewmember who does not use CRM principles to speak up when he or she notices an issue.

In fact, the NTSB found that in 37 accidents between 1978 and 1990, the failure of the First Officer to speak up contributed to 84% of them. Another analysis of 19 accidents between 1991 and 2000 found a failure to speak up in 68% of them (Bienefeld & Grote, 2012).

Bienefeld and Grote (2012) interviewed 1,751 pilots and flight attendants at a European airline to look for causes of crewmember silence. Overall these crewmembers stated that they spoke up in only about half of events warranting a CRM intervention.

Bienefeld and Grote's research found that the main reason for a Captain's failure to speak up is his or her desire to maintain a positive team atmosphere with the First Officer. The main reason for a First Officer's failure to speak up is the fear of harming a relationship with the Captain and damaging the team atmosphere. This hesitancy is in spite of pilots recognizing that speaking up is paramount for Team SA and safety.

CRM is the primary way pilots are trained to facilitate communication, teamwork, and task management and is required by all 193 International Civil Aviation Organization (ICAO) member states (Reynolds & Blickensderfer, 2009; Member States, 2019). Given the importance of CRM, the study's results are shocking since effective team performance depends on the safe completion of technical tasks and team processes based on CRM and Shared Mental Models (Bosstad & Endsley, 1999).

10. A CAUTIONARY TALE OF TEAM SA FAILURE

Colgan Flight 3407 is one of the most high-profile regional airline crashes in recent times and resulted in the deaths of all 49 on board and one person on the ground as it approached the Buffalo Airport on February 12, 2009. The aftermath of Flight 3407 revealed shortcomings in areas such as pilot proficiency and CRM and led to an increased regulatory focus on pilot licensing and training (Zremsky, 2019).

NTSB Chairman, Robert L. Sumwalt (2010) provides an overview of the accident, and we can relate the crash of the Dash 8-400 aircraft to the ideas presented in this report regarding team SA:

First, the crew lacked a Shared Mental Model of flight in icing conditions. The Captain set icing speeds for landing and the First Officer non-icing. This discrepancy led to the First Officer unknowingly monitoring speeds below the stall threshold in the icing conditions. Second, neither the Captain nor First Officer noticed the rising low-speed cue in their instrument scans, thus indicating a lack of mutual performance monitoring. Third, the Captain did not instill a strong CRM environment as evidenced by weak leadership and violation of sterile cockpit. Finally, the Captain did not interact correctly with the Dash 8's technology when he pulled repeatedly against the stick pusher rather than correctly reducing angle of attack to break the stall.

11. CONCLUSION

The measurement of individual SA using methods such as SART and SAGAT is a well-developed domain. A reliable system to evaluate team SA at a regional airline level relative to flight crews and their interaction with flight deck systems is an opportunity for future research. In the absence of effective assessments of team SA, our question becomes, “How can we ensure that crewmembers maintain a high level of team situation awareness while completing systems oriented tasks?”

One way forward is through Federal Aviation Administration (FAA) initiatives such as Advanced Qualification Program (AQP) and Line Operations Safety Assessments (LOSA) that provide data points to regional airlines to determine the efficacy of training and crew coordination, respectively. Finally, regional airlines can enhance training and awareness in areas such as Mutual Performance Monitoring, Crew Resource Management, and Shared Mental Models to mitigate lower levels of experience and to better monitor the human interaction with technology.

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