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Jenna Korentsides M.S.
Embry-Riddle Aeronautical University, korentsj@my.erau.edu

Joseph R. Keebler PhD
Embry-Riddle Aeronautical University, joekeebler@gmail.com

Crystal M. Fausett PhD
Embry-Riddle Aeronautical University, fausetc1@my.erau.edu

Sabina M. Patel M.S.
Embry-Riddle Aeronautical University, patels77@my.erau.edu

Elizabeth H. Lazzara PhD
Embry-Riddle Aeronautical University, lazzarae@erau.edu

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Human-AI Teams in Aviation: Considerations from Human Factors and Team Science

Jenna Korentsides[1a], **Joseph R. Keebler**[1b], **Crystal M. Fausett**[1c], **Sabina M. Patel**[1d], **Elizabeth H. Lazzara** [1e]
[1]Embry-Riddle Aeronautical University, FL 32114 USA
[a]korentsj@my.erau.edu, [b]joekeebler@gmail.com, [c]fausetc1@my.erau.edu, [d]patels77@my.erau.edu,
[e]lazzarae@erau.edu

Abstract

Artificial Intelligence (AI) has transformed the way human-computer interaction (HCI) teams are able to collaborate and coordinate in various domains, including aviation. AI's transformative capabilities can enhance teamwork, efficiency, and safety, particularly in risk management. AI's ability to process vast amounts of data and provide real-time insights enables informed decision-making and automation of repetitive tasks in aviation. By combining the strengths of AI and humans, outlined in our modified version of the 'HABA-MABA' framework, a dynamic teamwork relationship emerges, provided roles are successfully allocated. AI systems are able to act as intelligent assistants, offering timely recommendations, fostering effective communication, and facilitating coordination among crew members. Its adaptability and capacity for learning improve collaboration abilities, tailoring strategies to meet the team's specific needs. This paper explores the theories, considerations, and implications of human-AI teams in aviation, highlighting potential benefits, training recommendations, and future research directions. While human-AI teams offer numerous benefits, addressing the risks, limitations, and ethical considerations is crucial to ensuring safe and efficient operations. Future research must prioritize transparency, explainability, adaptability, and real-world testing to unlock the full potential of human-AI teams and foster successful integration across diverse domains.

Keywords: *Artificial Intelligence (AI), Teams, Human-AI Teams, Human Factors, Aviation, Aerospace*

Introduction

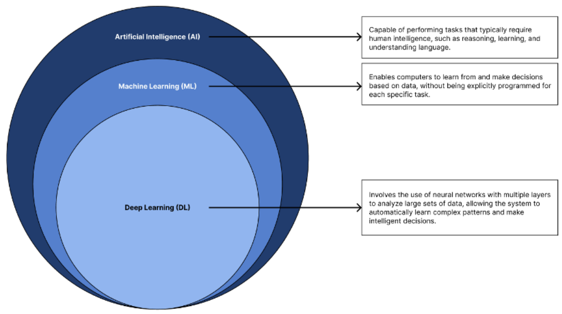
Currently, the body of research surrounding AI in aviation has mostly focused on the effective management of large flows of passengers and aircraft, with little to no research on how teams interact with these technological advancements (Pereira et al., 2022; Tang et al., 2022). Teams are an integral part of modern-day aviation and aerospace organizations, where they bring together individuals with diverse skills, expertise, and perspectives to work toward a common goal or objective. The aviation industry leverages the collective intelligence and collaborative efforts of team members to achieve outcomes that may not be possible through individual efforts alone. Some of the major dynamics that make up successful teams include effective collaboration, communication, and coordination (Tannenbaum & Salas, 2020). In recent years, many industries have seen the advent of AI in human teams (Jarrahi, 2018). In particular, the aviation industry has witnessed a significant integration of AI into various operational aspects, leading to the emergence of Human-AI teams for simple decision-making support and interactive teaming for task completion (Kabashkin et al., 2023). The purpose of this paper is to explore the integration of AI into aviation teams, examining its role in enhancing teamwork, training, and its future implications in the aerospace domain. By investigating the strengths and limitations of human, machine, and AI attributes, we propose a framework for defining roles, fostering trust, and promoting interdependence in human-AI teams. We address potential risks and emphasize the importance of transparent AI models and ongoing research to optimize the collaboration and effectiveness of human-AI teams in ensuring safety and efficiency in aviation and beyond.

Background

Artificial Intelligence (AI) encompasses a broad range of computational systems designed to perform tasks that typically require human intelligence, such as reasoning, learning, and understanding language. Within the field of AI, Machine Learning (ML) is a subset that focuses on enabling computers to learn from data and make decisions without being explicitly programmed for each task. Further specializing within ML is Deep Learning (DL), which utilizes neural networks with multiple layers to analyze large datasets, automatically learning complex patterns and making sophisticated decisions. For a visual depiction of this taxonomy, see Figure 1.

Figure 1

Taxonomy of Artificial Intelligence



AI has revolutionized the way humans collaborate and coordinate tasks in various domains. For instance, within organizations, it has been reported that AI is being applied for a range of objectives including enhancing and creating products and services, improving decision-making through ideation, and lowering costs for processes (Benbya et al., 2020). According to Benbya et al. (2020), while executives have initially focused on using AI to automate workflow processes, it is being expanded to more nonsystematic cognitive tasks as well. In the context of aviation, the capabilities of AI are truly transformative, enabling the enhancement of teamwork, efficiency, and safety (National Academies of Sciences & Medicine, 2021). Further, the use of AI can provide a number of opportunities that strengthen human efforts in the field of aviation, including areas such as risk management (Kolasa-Sokołowska, 2021; Zhang et al., 2021), where the primary need for AI lies with risks that are already present but have become more challenging for humans to detect (Kolasa-Sokołowska, 2021). For example, some risks that have become more challenging for humans to detect include identifying mechanical failures of an aircraft and predicting adverse weather conditions when flying (Kolasa-Sokołowska, 2021; Zhang et al., 2021), where the primary need for AI lies with risks that are already present but have become more challenging for humans to detect (Kolasa-Sokołowska, 2021). For example, some risks that have become more challenging for humans to detect include identifying mechanical failures of an aircraft and predicting adverse weather conditions when flying.

One key capability of AI is its ability to process vast amounts of data and provide real-time insights. In aviation, AI systems can analyze data from multiple sources, such as aircraft sensors, weather reports, and air traffic control, to generate accurate and up-to-date information (Bansal et al., 2019; Kolasa-Sokołowska, 2021; National Academies of Sciences & Medicine, 2021). This information can be shared with human crew members, enabling them to make informed decisions and coordinate their actions effectively. AI also excels in automating repetitive tasks, freeing up human crew members to focus on more critical aspects of their roles. For example, AI systems can assist with flight planning, monitoring fuel consumption, and managing routine checklists (Agency, 2020; Flathmann et al., 2021). This advancement in automation reduces the cognitive workload on humans, allowing them to allocate their attention and energy to tasks that require complex decision-making and problem-solving (Bansal et al., 2019; Endsley & Kaber, 1999; Flathmann et al., 2021). Moreover, when it comes to risk preparedness, one of the most promising aspects of AI is its capacity to learn, self-develop, and apply acquired information to situations or issues not previously experienced (Kolasa-Sokołowska, 2021). Combining the strengths of AI and humans yields a dynamic teamwork relationship, as long as roles are allocated successfully (Cummings, 2014; Flathmann et al., 2021; Kolasa-Sokołowska, 2021).

Given that AI possesses several strengths that may surpass those of humans, effective coordination becomes essential to ensure successful task completion (Jarrahi, 2018). For instance, an AI-powered Crew Resource Management (CRM) tool could identify potential risks or conflicts among crew members, provide suggestions to improve communication, and help foster a collaborative and cohesive team environment (Jarrahi, 2018; Kolasa-Sokołowska, 2021). For instance, a noteworthy collaboration exists between Dassault Aviation and ISAE-SUPAERO, a leading research institution focusing on the enhancement of human-machine interaction (Systems, 2022). This partnership is dedicated to examining various dimensions of human-machine collaboration, with a particular emphasis on automated decision-making, systems engineering, and neuroergonomics. The overarching goal of this collaboration is to augment the efficiency and safety of both military and civilian aviation operations, ensuring that despite the integration of advanced AI systems, human pilots retain ultimate authority and control (Systems, 2022). This initiative underscores the potential of AI to revolutionize CRM by optimizing team dynamics and decision-making processes, thereby reinforcing the critical role of human expertise in managing complex, high-stakes environments. In this context, AI can facilitate effective communication and coordination among crew members. It can enable seamless information sharing through integrated platforms and interfaces, ensuring that everyone has access to the same information in real-time. Another notable capability of AI is its ability to adapt and learn from human interactions. Through ML algorithms, AI systems can observe and analyze human behavior, understand patterns, and continuously improve their performance (Agency, 2020; Kolasa-Sokołowska, 2021). This adaptive capability enables AI to tailor its collaboration and coordination strategies based on the specific needs and preferences of the human-AI team, enhancing overall teamwork and productivity. The overarching goal of this collaboration is to augment the efficiency and safety of both military and civilian aviation operations, ensuring that despite the integration of advanced AI systems, human pilots retain ultimate authority and control (Systems, 2022). This initiative underscores the potential of AI to revolutionize CRM by optimizing team dynamics and decision-making processes, thereby reinforcing the critical role of human expertise in managing complex, high-stakes environments. In this context, AI can facilitate effective communication and coordination among crew members. It can enable seamless information sharing through integrated platforms and interfaces, ensuring that everyone has access to the same information in real-time. Another notable capability of AI is its ability to adapt and learn from human interactions. Through ML algorithms, AI systems can observe and analyze human behavior, understand patterns, and continuously improve their performance (Agency, 2020; Kolasa-Sokołowska, 2021). This adaptive capability enables AI to tailor its collaboration and coordination strategies based on the specific needs and preferences of the human-AI team, enhancing overall teamwork and productivity.

Teamwork in Aviation

Collaboration is an essential component of successful teamwork (Tannenbaum & Salas, 2020). In aviation, collaboration involves the cooperative efforts of team members working towards a shared objective, such as flying the aircraft. Collaboration helps foster an environment where diverse perspectives and skills converge to ensure safety and efficiency. Effective collaboration relies on a shared purpose between team members, seamless communication, coordinated efforts, and defined roles, all of which result in improved safety standards and task success. A shared purpose among team members increases motivation towards common goals, maximizing a team's collective potential and driving them towards effective outcomes (Tannenbaum & Salas, 2020). Communication plays a crucial role in coordinating crew members' efforts by facilitating the timely and accurate exchange of information, instructions, and feedback. It enables sharing critical updates and promotes situational awareness, ensuring optimized team performance (Endsley & Kaber, 1999; Tannenbaum & Salas, 2020). Coordination aligns team members' efforts, manages interdependencies, and integrates individual tasks and contributions. It involves task allocation, effective communication and information sharing, monitoring and feedback mechanisms, and leadership guidance to maximize productivity and enhance team performance (Cummings, 2014; Kolasa-Sokołowska, 2021; Tannenbaum & Salas, 2020). Finally, defined roles are pertinent in teams as they clarify responsibilities, minimize confusion, and enhance efficiency by allowing individuals to focus on their specific expertise and contributions to achieve collective objectives (Cummings, 2014; Schelble et al., 2022). Further, recent research has found that implementing AI technology in teams has the potential to enhance information exchange and collaboration among team members (Agency, 2020). For instance, one study highlights the implementation of an AI Coach in a cardiac operating room, which was developed as part of a collaborative research project by the Massachusetts Institute of Technology (of Technology, 2022). This AI tool was specifically aimed at enhancing team performance by providing real-time feedback and guidance during surgical procedures, thereby improving communication and operational efficiency among team members. Additionally, research discussed by Webber et al. (2019) demonstrates the application of AI in business school student project teams. In this context, AI was used to facilitate better teamwork by providing diagnostics and recommendations tailored to the team's needs. The AI tool enabled the teams to identify strengths and weaknesses within their group, fostering a more effective exchange of information and collaboration (Webber et al., 2019). This not only improved their project outcomes but also prepared the students with valuable skills for managing team dynamics in their future professional environments.

Human-AI Teams in Aviation

In 1951, the National Research Council committee initially defined human-computer interaction (HCI) to support the development of a national air traffic control system (Fitts, 1951). This early effort led to the creation of a set of heuristics, known as the MABA-MABA list, which delineated the respective strengths and limitations of humans and machines, identifying tasks where ”men are better at” and those where ”machines are better at” (Cummings, 2014). With the rapid advancements in artificial intelligence, we have updated and expanded this heuristic framework to include AI-specific capabilities, resulting in a revised table named 'HABA-MABA-AABA.' This new designation stands for humans are better at, machines are better at, and AI are better at (see Table 1). The expanded framework aims to clarify the distinct capabilities of humans, machines, and AI, highlighting how each can be optimally utilized across various domains as AI continues to grow in prominence and influence. Sometimes, the role of human factors is not introduced until it's too late. Therefore, before the aviation domain experiences drawbacks in the use of AI or other forms of technology, this table is meant to become a starting point for identifying the proper uses of each entity present within a team. It is important to note that this table highlights the strengths and weaknesses of each entity with respect to specific attributes, without suggesting that any one of them should be exclusively responsible for such tasks.

Although these heuristics provide some insight into the attributes that are better suited for humans, machines, and AI, many tasks will benefit from some combination of all three. As a result, it can also be useful to determine the necessary degree of AI integration based on the type of task. Cummings' (2014) degrees of automation framework maps four different task types (i.e., *skill-based, rule-based, knowledge-based*, and *expertise-based*). We will elaborate on each of these tasks below, but for a summary refer to Table 2 for AI integration based on type of task.

First, *skill-based* tasks in aviation, such as flying an aircraft, heavily rely on repetitive actions and motor memory with clear feedback loops (Cummings, 2014). Integrating AI into these tasks can enhance performance and safety. For instance, in a CRM context, AI systems can assist pilots in tasks like autopilot control and navigation, leveraging their ability to surpass human precision and reliability. These AI systems leverage their ability to surpass human precision and reliability in processing vast amounts of sensory data and executing complex maneuvers, which are critical during flight operations. According to a report by the RAND Corporation, AI applications in military settings show that AI-driven autopilot systems can significantly enhance operational efficiency and decision-making under stress, contributing to both safety and mission effectiveness (Morgan et al., 2020).

Second, *rule-based* tasks involve applying predefined rules or procedures based on specific stimuli (Cummings, 2014). Integrating AI into these types of tasks in CRM can support pilots in adhering to protocols and making efficient decisions. For instance, during emergency situations, AI systems can provide real-time guidance based on established rules, assisting pilots in implementing standard operating procedures (SOPs) effectively (Tipaldi et al., 2020). This integration of AI ensures consistency, reduces human error, and promotes effective decision-making in critical moments. Specifically, Tipaldi et al. (2020) found that AI-driven decision support systems can analyze sensor data and flight parameters to recommend the best course of action, such as optimal ascent profiles or engine settings in response to system failures or adverse weather conditions. As another example, AI may assist the crew in the cockpit by advising on routine tasks (e.g., flight profile optimization) or providing enhanced advice on aircraft management issues or flight tactical nature, helping the crew to make decisions in particular in high workload scenarios (e.g. go around, or diversion) (Agency, 2020). These systems use algorithms that process real-time data to optimize flight paths, manage fuel efficiency, and even handle unexpected events such as unplanned diversions or sudden changes in weather conditions. Pilot attitudes on AI-driven systems revealed the perception that AI can greatly reduce pilot workload, but with reservations on not being dependent on the system in place (Zhang et al., 2021). To elaborate on another example within the context of aviation maintenance, AI-based predictive maintenance fueled by enormous amounts of fleet data can allow aircraft personnel to anticipate failures and provide preventive remedies (Agency, 2020). By leveraging AI-powered predictive maintenance assistance, it is estimated that AI-powered predictive maintenance can increase aircraft availability by up to 35% (Agency, 2020). To elaborate on another example within the context of aviation maintenance, AI-based predictive maintenance fueled by enormous amounts of fleet data can allow aircraft personnel to anticipate failures and provide preventive remedies (Agency, 2020). By leveraging AI-powered predictive maintenance assistance, it is estimated that AI-powered predictive maintenance can increase aircraft availability by up to 35% (Agency, 2020).

The third type of task is *knowledge-based*. Knowledge-based tasks require higher cognition and involve decision-making with incomplete or ambiguous information (Cummings, 2014). AI integration can greatly assist pilots in analyzing and interpreting complex data from various sources, such as weather conditions and aircraft performance. By organizing and synthesizing this data, AI systems can present pilots with relevant information to support their decision-making process. Although current AI systems in aviation primarily utilize pattern matching and statistical reasoning, where AI analyzes vast datasets to identify correlations and predict outcomes based on observed patterns, these technologies are increasingly integrated into decision-making. This integration allows AI to support knowledge-based processes by synthesizing flight data, weather information, and navigational inputs to offer real-time, context-aware recommendations to pilots (Phillips-Wren & Jain, 2006). For instance, AI can suggest optimal flight paths or adjustments to flight parameters by comparing current conditions against historical data and learned models, enhancing the pilot's ability to make informed, knowledge-based decisions. This collaboration fosters an 'open communication' environment where AI-generated insights and human expertise coalesce, leading to more robust decision-making in dynamic and complex flight situations.

Finally, the fourth type of task is referred to as *expertise-based* tasks, which involve complex reasoning and judgment in uncertain situations, relying on human intuition and the ability to handle vague information (Cummings, 2014). While AI cannot fully replicate human expertise, it can act as a valuable teammate in these tasks. By providing real-time data analysis and insights, AI integration can support the captain's decision-making process during critical moments. This collaborative approach enhances overall situational awareness, empowering the cap-

Table 1

HABA-MABA-AABA - List of Human/Machine/AI Heuristics

Attribute	Human	Machine	AI
Speed	Comparatively slow	Superior	Superior in certain tasks, such as skill and rule-based
Power Output	Comparatively weak	Superior in level of consistency	Superior in processing large amounts of data and performing complex calculations
Consistency	Unreliable learning and fatigue factors	Ideal for consistent, repetitive action	Can provide consistent performance over extended periods without fatigue or learning limitations
Information Capacity	Primarily single channel	Multichannel	Capable of processing and analyzing vast amounts of information from multiple channels simultaneously
Memory	Better for principles and strategies, access is versatile and innovative	Ideal for literal reproduction, restricted access, and formal	Can store and recall vast amounts of data quickly and accurately, enabling advanced pattern recognition and associative learning
Reasoning Computation	Inductive, easier to program, slow, accurate, and good error correction	Deductive, tedious to program, fast and accurate, poor error correction	Can process complex data sets and make sophisticated inferences and predictions
Sensing	Wide ranges, multifunction, judgment	Good at quantitative assessment, poor at pattern recognition	Can process diverse sensory inputs and perform advanced pattern recognition and analysis
Perceiving	Copes with variation better, susceptible to noise	Copes with variation poorly, susceptible to noise	Can handle variation and noise in data better than machines while maintaining contextual understanding and making informed judgments

Table 2

Degree of AI Integration as a Function of Task Type

Cognitive task type	Degree of AI integration
Skill-Based	The best candidate for AI, assuming reliable sensors for state and error feedback
Rule-Based	A possible candidate for AI, if the rule set is reliable and valid
Knowledge-Based	AI can be integrated and used to help organize, filter, and synthesize data
Expertise	Human reasoning is superior but can be aided by AI as a teammate

tain to make informed decisions based on their expertise while leveraging AI's capabilities for data analysis and information synthesis.

Training and Preparations for Human-AI Teams in Aviation

Insight on how to best perform human-AI team training may be garnered through an examination of traditional human team training methods. These insights will be useful as we prepare teams to collaborate with AI and consider what the future of aviation teams and CRM will hold with the addition of AI agents. Undoubtedly, AI will change the fundamental nature of teams and team training within aviation.

Teams and team training are a focal area for aviation since accident investigators began to cite the non-technical skills of pilots (i.e., communication and coordination) as causal factors in airplane accidents and incidents in the 1970s. These incidents highlighted that it is not enough for pilots to have the technical skills to fly an aircraft, they must also be able to act as a team to ensure safety. To comprehend the role of AI in aviation teams, it is beneficial to first consider the teamwork between human pilots in a civil aircraft cabin. We will now elaborate on key characteristics that could be targeted in training efforts: interdependence (Lawless et al., 2019), trust (Ulfert et al., 2023), and defined roles (Siemon, 2022). However, for a summary of the key characteristics needed to train human-AI teams and associated examples of training in aviation, please view Table 3 below.

Interdependence

To ensure efficient task performance, teams must function as an integrated and interdependent unit (Salas et al., 1997). Interdependence refers to the collective workflow, objectives, and results achieved through the efforts of team members (Kozlowski & Ilgen, 2006). The field of team science is dedicated to understanding the critical processes of teamwork (such as communication and coordination) and their associated competencies (such as mutual trust, shared mental models, and backup behavior) (Salas et al., 2010). As AI becomes more advanced in its capabilities and ability to adapt and respond to various contexts, it seems natural to consider it part of the team (Christoffersen & Woods, 2002; Prinzel, 2003). It should be noted that some have argued against treating AI as an additional team member, citing a lack of affective and cognitive processes that are present in humans. However, AI systems may come to meet these criteria with the integration of ML. AI systems and processes may be able to possess the knowledge and engage in the behaviors required for effective teamwork.

If human teamwork can be defined as a group of individuals working interdependently towards a shared goal, then human-AI teams should meet that same standard. This implies that a human-AI team should (1) require collaboration between humans and AI for task performance, where AI must be capable of interpreting human inputs and responding with contextually appropriate actions. This necessitates AI systems equipped with advanced natural language processing and machine learning algorithms that can understand and predict human intentions; (2) necessitate the integration of the specialized KSAs each team member (human or artificial) possesses, where AI systems must be programmed with decision-support capabilities that complement human cognitive strengths and compensate for human limitations; and (3) allocate complimentary responsibilities between human aircrew and AI, even if those responsibilities are reallocated between team members to meet changing task demands. For instance, current AI technologies such as adaptive automation systems can dynamically adjust their level of autonomy by analyzing task complexity and operator workload in real-time (Abbott, 2023).

Trust

There must be a trusting and open climate for effective teamwork between humans and AI (Burke et al., 2006). There are several factors that can aid in team trust, such as psychological safety, team orientation, and transparency. One of the factors that is key to improving trust is the concept of psychological safety, which refers to how safe individual team members feel to speak up or take interpersonal risks (Edmondson, 1999). Evidence of someone who has high psychological safety would be their ability to speak up to the team when they find a mistake in the flight plan or when they feel that there is a better way to adjust the flight plan due to unforeseen weather conditions. In the same way, a human team member in a human-AI team would be able to speak up and disagree with the perspective of the AI agent with reason. Additionally, team members with a team orientation trust their teammates and believe in their competence, pursuit of common goals, and non-harmful behavior (Goodwin et al., 2004; Salas et al., 2005).

Trust between humans and AI is grounded in functionality and design features, such as observability, predictability, and directionality. Observability enables teamwork behaviors and involves making relevant aspects of one's status and knowledge observable to others (Johnson et al., 2014). Predictability of human and AI system behavior facilitates coordinated action and mutual understanding. Directability refers to the capacity of team members to influence each other's behavior. Therefore, human trust in AI systems is enhanced by transparency, providing information on the system's state, goals, understanding of pilot objectives, and confidence in presented information.

Defined Roles

Human-AI teams require clearly defined roles for both humans and AI systems. The operation of AI should be human-centric, considering human cognitive processes and performance. This implies that the design of AI systems should take into account cognitive variables, such as workload, mental models, situation awareness, and memory of human team members (Endsley & Kaber, 1999). AI systems may also want to consider other human performance variables, such as psychophysiological state and variations in expertise. Adaptations in the presentation of information should occur based on changes in the task or functional state of the human, including fatigue levels (Wilson & Russell, 2003). With the above considerations, AI systems can effectively support and enhance the performance of humans in their roles.

Table 3

HABA-MABA-AABA - List of Human/Machine/AI Heuristics

Human-AI Training Characteristic	Potential Examples of Training in Aviation
Interdependence	The AI system assists with monitoring critical parameters during takeoff and ascent, providing suggestions for optimized climb profiles based on real-time weather and traffic information (Lvasjuk, 2023). During simulation of in-flight system failures, the AI system helps diagnose the issue, offers potential solutions, and assists in executing emergency procedures (Bovice & Baker, 1988).
Trust	The AI co-pilot system assists in creating the initial flight plan based on real-time weather data, while the human pilots validate and adjust the plan collaboratively, encouraging open communication and feedback during this phase (Tokadli, 2021). Simulate emergencies such as engine failure or severe weather changes. Clearly define the AI co-pilot system's role in providing real-time information and suggestions, while human pilots remain responsible for final decision-making and executing emergency procedures (Wang, 2021).
Defined Roles	Simulate emergencies such as engine failure or severe weather changes. Clearly define the AI co-pilot system's role in providing real-time information and suggestions, while human pilots remain responsible for final decision-making and executing emergency procedures (Wang, 2021).

Future Implications of Human-AI Teams

The integration and utilization of human-AI teams is still in infancy, and many considerations for optimizing human-AI teams remain. As explained in the previous sections, aviation is one domain where AI integration may be imperative to improve team performance and task capabilities. Beyond aviation, yet within the aerospace domain, there are a number of areas specific to aerospace that may use AI integration to enhance performance and aid in human needs as well. Moreover, there are still several risks to take into account and future research that needs to be conducted to fully optimize the use of AI in a team setting for use in aviation and other aerospace domains.

Aviation to Aerospace

Human-AI teams can be utilized in other aerospace domains, aside from aviation. For instance, human-AI teams in the context of Low Earth Orbit (LEO) and Long Duration Space Exploration (LDSE) offer significant benefits to space missions. In LEO, human-AI collaboration can enhance operational efficiency and safety by leveraging AI systems for tasks like system monitoring and data analysis, allowing astronauts to focus on critical decision-making. Moreover, AI also facilitates CRM and communication between astronauts and ground control, all of which are critical components of any mission. Further, in LDSE, where humans are exposed to extended periods of isolation, human-AI teams are crucial for mission success as AI supports autonomous tasks, like navigation, along with resource management, and adaptive decision-making by processing data, analyzing patterns, and aiding in problem-solving. The symbiotic relationship between humans and AI combines computational power with human expertise, intuition, and adaptability, resulting in enhanced situational awareness, operational efficiency, and risk reduction, all vital aspects to the success of aerospace missions (Chai et al., 2021; Shukla et al., 2020).

Risks

While the use of human-AI teams in aviation offers many benefits, certain risks must be addressed to ensure safe and efficient operations. Some of these risks include a dependence or reliance on AI, data quality and bias, the effectiveness of human-AI interaction and communication in relation to certain tasks, and concerns related to cybersecurity and privacy (Agency, 2020; Cummings, 2014; Kolasa-Sokołowska, 2021; National Academies of Sciences & Medicine, 2021). To mitigate these risks, it is crucial to avoid excessive dependence on AI by maintaining human decision-making skills and readiness to take over in case of AI system failures. Ensuring data quality and minimizing bias in training data can be achieved through rigorous data collection, cleaning, and validation processes. Effective human-AI interaction and communication can be fostered by providing comprehensive training to human operators on AI system capabilities and limitations. Further, cybersecurity and privacy concerns can be addressed by implementing robust security measures, regular vulnerability assessments, and strict data protection protocols. Ongoing monitoring, system design improvements, and the establishment of clear protocols for human-AI collaboration are essential mitigators of the various risks of the implementation of AI in aviation.

Future Research

While significant progress has been made in human-AI team research, several gaps and challenges remain that need to be addressed for future advancements. One key aspect lies in establishing trust through transparent AI models and enhancing explainability, as these are essential for fostering effective collaboration (Omrani et al., 2022). As previously mentioned, trust is a fundamental component of any interpersonal relationship, be it between humans or humans and technology. Some AI models have been criticized for their "black-box" nature, meaning only the input and output are accessible to the human operator. These AI systems involve poor transparency and acquire ethical concerns that must be addressed (Omrani et al., 2022). Furthermore, ethical considerations must also be prioritized to ensure the responsible and fair use of AI in collaborative settings. To counter these issues with transparency, recent research has focused on the subject of "Explainable AI (XAI)," which consists of techniques used to create models that produce explanations and interpretations while achieving a high predictive performance (Arrieta et al., 2020; Gunning et al., 2019; Omrani et al., 2022). These explainable models enhance trust between the AI system and operator by providing information on how and why it arrived at the conclusion (Ribeiro et al., 2016). Additionally, to effectively handle dynamic situations, the adaptability and flexibility of AI systems are vital. This can be achieved by incorporating real-time feedback from humans, which helps refine and improve the performance of AI. Moreover, training and education programs are necessary to equip individuals with the skills needed to work seamlessly with AI. Overall, real-world testing and validation in relevant domains, such as aerospace, will evaluate the effectiveness of human-AI teams. Therefore, continued research and collaboration are imperative to enable the full potential of human-AI teams and pave the way for successful AI integration across various domains.

Conclusion

The integration of AI into aviation teams has the potential to revolutionize collaboration, efficiency, and safety in the aerospace domain. AI's ability to process vast amounts of data in real-time and automate repetitive tasks allows human crew members to focus on critical decision-making and problem-solving. AI systems can act as intelligent assistants, providing timely recommendations and insights to enhance decision-making and communication among team members. Although, the successful implementation of human-AI teams requires careful consideration of several factors, including interdependence, trust, and clearly defined roles. This research contributes by detailing a systematic approach to integrating AI into aviation teams, demonstrating how AI can be deployed to augment human capabilities and facilitate more effective decision-making processes. Training efforts should focus on fostering collaboration between humans and AI by building mutual trust and ensuring well-defined responsibilities for each team member.

As AI continues to advance, its integration into aerospace domains beyond aviation, such as LEO and LDSE, can further enhance operational efficiency and risk reduction in space missions. However, certain risks, including overreliance on AI, data quality, and cybersecurity concerns, must be addressed to ensure safe and effective operations. Further, ethical considerations, transparency, and explainability of AI models are crucial aspects in establishing trust between humans and AI agents, as well as the responsible use of AI agents in human-AI teams. Our research addresses these issues by introducing innovative methods for enhancing the transparency of AI systems, which are crucial for building trust and ensuring ethical use in sensitive aerospace operations.

Looking forward, future research should focus on enhancing transparency and explainability of AI models, fostering adaptability and flexibility in AI systems through real-time feedback, and developing training programs to equip individuals with the necessary skills for successful collaboration with AI systems. Our findings underscore the importance of real-time feedback mechanisms in AI systems to enhance their adaptability and responsiveness, thereby improving human-AI interaction in high-stakes aerospace environments. Real-world testing and validation in relevant domains will be able to evaluate the effectiveness of human-AI teams and further optimize AI integration in various industries, including the aerospace domains. By embracing the strengths of AI and harnessing the collective intelligence of human-AI teams, the aviation and aerospace industries can unlock new opportunities for improved teamwork, safety, and efficiency. This paper makes a significant contribution to the ongoing conversation of AI integration into human teams by identifying key areas for future research and practical implementation of

AI in aviation and aerospace, setting the stage for the next generation of AI-enhanced human collaboration.

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