# Addressing the Spread of Trust and Distrust in Distributed Human-AI Teaming Constellations

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As autonomous systems mature, the applied industry has begun adopting the technology. Many of these applications include the creation of human-artificial intelligence (AI) teams, which promise to increase the already known advantages of working in team environments. The efficacy of the AI agents that make up these teams has always been a significant focus. However, a shift from technical ability to social abilities has occurred. A newfound emphasis on trust within these human-AI teams has prompted research on supporting trust between humans and AI teammates, how AI affects trust between the humans within the team, and how team composition (majority AI versus majority human) influences trust development. Even the efficacy of trust repair strategies, adapted from human-automation interaction, is being explored in human-AI teaming. In the current paper, we examine an essential component of trust that has yet to receive requisite attention: the spread of trust within and across constellations of teams. To this end, we discuss the potential impacts of trust within and across human-AI teams and constellations on team efficacy. From this discussion, several challenges are proposed in five major research questions that should be addressed to enable more effective human-AI teams and human-AI teaming constellations.

CCS Concepts: • **Human-centered computing → HCI theory, concepts and models**;

Additional Key Words and Phrases: trust, human-AI teaming, artificial intelligence, autonomy, contagion

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## 1 INTRODUCTION

It is a common occurrence for current industry initiatives to require the interaction and coordination of multiple teams to achieve a common goal [28]. As autonomous technologies increase in prevalence, human-artificial intelligence (AI) teams (HATs) will become the norm, becoming a driving force across multiple industries (i.e., automotive, healthcare, manufacturing, defense, and retail) [58]. One example is adaptive manufacturing, where humans can focus on important


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environmental factors and observations for predictive maintenance on the manufacturing floor while trusting their AI teammate to monitor the overall factory status. This potential has inspired large organizations to document and outline how HATs will eventually become the gold standard for teaming and task effectiveness, even compared to human-human, or machine-only teams [43, 58, 60]. Importantly, HATs will be required to cooperate and interact with other HATs to tackle increasingly complex tasks. Research on distributed interacting HATs (or HAT constellations) has become critical to understanding and ultimately improving how multiple teams of teams accomplish large-scale tasks.

All teammate relationships in HATs have a high potential to impact the overall state of a team by catalyzing the spread of trust and distrust. Due to the recent emphasis on integrating AI systems into teams, the focus is often placed on the relationships between humans and AI teammates. Unfortunately, this concentration may result in the neglect of the relationships between human teammates, despite uniquely human factors, such as trust, existing within both human-human and human-AI systems relationships [50, 55]. Additionally, these human factors have been shown to spread between teammates in human-only teams through technology [1] and impact the perceptions humans have for different AI systems [25]. Therefore, research initiatives in HAT need to place equal emphasis on human-AI and human-human relationships as they have the potential to impact a variety of humans' perceptions. It is also equally important to pursue an understanding of how human-AI relationships may affect human-human relationships and vice versa in HATs.

Distrust within HATs and its impact will likely increase with the increase in HATs. It has been predicted that AI systems have the potential to be utilized in a high percentage of organizations in varying industries [20]. This growth in breadth may also lead to the possibility that more domains could be potentially harmed by decreased HAT performance, which lower levels of trust can bring about [37]. For example, if the spread of trust and distrust across multiple HATs is not adequately understood, then the distrust in a small number of HATs may negatively impact the trust in other HATs within an organization, much like Microsoft's "Clippy" [57]. Further, a small number of distrusted HATs could produce a lowered, miscalibrated trust in other teams within an organization. It may be challenging to identify and stop the proliferation of distrust within and between HATs if it is not caught early or well understood.

## 2 RELATED WORKS

### 2.1 Human-AI Teaming

Teams and teamwork have always been seen as a necessary and efficient method for organizing individuals throughout human history and remain a vital societal structure today. Consequently, teams and teamwork have remained at the forefront of research, with decades of past research providing a comprehensive understanding of how human-human teams efficiently organize and interact to accomplish a shared goal [48]. This sustained research agenda has also continuously pushed the limits of modern technology and used contemporary advancements to empower teamwork. For instance, teaming environments were some of the first to fully realize the potential of accessible Internet systems by removing the need for co-location and allowing work to be completed through a variety of spatial bounds [15, 32]. Furthermore, the consistent use of these pioneering technologies has often led to new and innovative research efforts centered around understanding how teams can better apply modern technology [24, 39]. HATs serve to be the subsequent innovative use of technology by teams, meaning a new generation of research initiatives have been and will continue to be conceived and realized.

As AI systems grow in both ability and prevalence, their appeal to teams will similarly increase, ultimately culminating in the rapid integration of AI systems into teaming environments [52]. As recent years have shown, the initial application

of these resources will be as simple tools that teammates use to make their lives easier. However, recent research has shown that artificially intelligent systems have the potential to become contributing members similar to a human teammate [2, 13, 40, 41]. Recent empirical research has also provided evidence that these AI teammates, when integrated correctly, can meet, if not exceed, the ability of classical human-human teams [38]. Importantly, if these potential performance benefits are to be garnered, researchers and practitioners of HATs must be continuously cognizant of the requirements for an autonomous teammate. AI teammates must meet the basic requirements of general autonomous systems, such as high levels of autonomy, a distinct role in a team, and interdependence [41, 42]. Additionally, the individual differences and desires of human teammates within a team can vary and carry equal importance to AI teammate acceptance [61]. If these requirements are met, HATs can begin to demonstrate vital teamwork outcomes in addition to merely completing their task, including interactive team cognition [7], situational awareness [6, 46], and efficient communication [56]. Unfortunately, if the requirements of an autonomous teammate are not met, the beneficial outcomes may not be produced, resulting in a degraded performance that falls short of their human-human counterparts.

Once conceptualized and researched, HATs can begin to integrate into applied real-world settings. For instance, manufacturing [49] and complex virtual environments [6, 54] have shown significant potential as research contexts and will similarly become fruitful destinations for applications of HATs. Further, the influence and prevalence of these HATs will continue to grow alongside the AI technologies they leverage. Therefore, foundational research into the factors surrounding HATs must be conducted to provide the best possible direction for their continued growth and development.

### 2.2 Trust in Human-AI Teaming

With the growth of research centered around HATs rapidly expanding over the past few years, increased importance has been placed on the human factors requirements from human-human teamwork. Among these, trust, which has been shown to be a vital component to human-human teaming performance [10], has an empirically verified relationship with team performance in HATs [37]. Thus, it can be shown that the importance of human factors in human-human teamwork can carry over and translate into their human-AI counterparts. In this instance, trust can be defined as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" [29]. Within teaming environments, trust is often seen as a combination of multidimensional constructs that often contains the contributing factors of ability, integrity, and performance [35]. As the importance of trust extends from human-human teamwork to human-AI teamwork, the factors that contribute to trust also extend to HATs. Due to this connection, the field of HATs has seen a recent surge in efforts devoted to building a comprehensive research foundation around trust.

The concept of trust is also not entirely complete without the discussion of distrust, which as a concept is defined by the strength of the belief that another party will act incorrectly or engage in behavior counter to one's goals [31]. As such, distrust causes individuals to be unwilling to accept the risks and vulnerabilities that come with trusting another party and allows the individual to plan for trust violations by taking preventative and defensive measures [8]. Trust and distrust have a complex relationship as the two constructs are closely related to one another, and the distinction between the two has not been entirely settled. Some research chooses to treat the two concepts as entirely separate (i.e., [31]), while others choose to treat trust and distrust as the same concept on opposite ends of a continuum (i.e., [51]). While this topic has not been settled, the current position paper presents these questions with the view that trust and distrust exist as separate concepts on independent continuums.

The importance of trust in fundamental human-machine interaction also transitions to the more complex domain of HATs. Within the field of human-machine interaction, trust is similarly seen as an essential component for humans working with autonomous systems as it becomes a necessary consideration for humans [29]. Within human-human teams, technology is an effective tool for building and spreading trust amongst teammates [1]. Additionally, shared technology tools in human-machine environments also have the unique ability to not only rely on trust's formation but also act as a catalyst for the spread of trust and distrust across other machine systems, which research has coined "system-wide trust theory" [25]. However, this system-wide nature may be seen as both a benefit and a danger as it may help facilitate either the beneficial spread of trust or the harmful spread of distrust based on the actions of a single autonomous entity within a much larger system [17]. Additionally, the recent theory of distributed dynamic team trust emphasizes trust transitivity, that one individual's trust in an AI agent can be transferred to another individual [23]. This trust can be spread throughout a team as interpersonal trust among all related stakeholders, including AI agents, through conversations, training procedures, and performing, directly and indirectly. Therefore, the ability of technology to act as a catalyst for the spread of trust between human teammates and different autonomous systems provides key motivation for understanding the spread of trust within HATs. Additionally, the system-wide trust theory associated with autonomous systems may also extend across human-AI constellations, allowing for system-wide trust to benefit or harm the overall levels of trust within an organization that utilizes HATs.

Unfortunately, not all research areas concerning trust in teamwork have seen a transition to the field of HATs, despite the importance of trust to HATs. Specifically, trust repair, a field concerned with the reestablishment of degraded trust within a team [30], has not seen as robust an integration in HATs. Within teams, trust can often be broken by mistakes and misunderstandings. Nevertheless, using simple methods such as apologies or denials of one's fault, trust repair techniques attempt to restore previous levels of trust after its degradation [26]. Due to the vital nature of trust to teamwork, trust repair is often seen as a necessary consideration within a teaming environment to ensure the degradation of trust can be detected, stopped, and mended before too much damage is done and a team is unable to recover to previous levels of trust [18]. Unfortunately, these techniques have not been thoroughly explored in HATs, with only a single study on trust repair in human-agent teaming [27], along with minor exploratory studies into human-robot [33, 45] and autonomous vehicle interaction [26]. These techniques should not be limited to human-human teamwork, as humans in HATs are not immune to having their trust degrade [11, 12]. Due to the ability of AI systems to increase the propensity for both trust and distrust to spread, it would stand to reason that trust repair will become just as, if not more, important to teams as they begin to integrate and utilize AI teammates.

In summary, while recent research has taken great strides towards understanding the complex role trust plays in HATs, research concerns must be addressed to fully prepare society for the collaboration of human and autonomous teammates. Specifically, research gaps around (1) the spread and (2) the repair of trust in HATs are imperative, especially considering the possibility of early autonomous teammates not garnering high levels of trust. Once these research gaps are closed, the influence and prevalence of HATs can begin to expand as concerns around their system-wide degradation due to low levels of trust can be scientifically addressed.

### 2.3 Distributed Team Interactions and Team Constellations

While researching and understanding the inner workings of teams is paramount to building a comprehensive foundation of human-AI teamwork, one cannot assume that these teams will operate inside of a vacuum. Teams exist within real-world environments, often including other teams working towards similar or shared goals. Thus, fully understanding teams also necessitates understanding how teams interact with each other.

For instance, large projects often require work to be coordinated between various teams to ensure timely completion. While each team may have an individual assignment or goal, they all (1) contribute to the same overall goal, (2) interact with each other throughout the project, and (3) often utilize shared resources and tools [4]. These all provide opportunities for teams to share experiences and information, which is key to building and leading an effective team constellation or team of teams [21]. Additionally, coordinating teamwork around the use of multiple teams is often a necessity when facing large or highly complex tasks that require varied expertise and a large amount of labor [28, 44]. If done correctly, these large constellations can encompass multiple individual teams without sacrificing their ability to accomplish a shared and unified goal, a key factor to many successful organizational teams [16]. The reasons outlined above are a few examples of why distributed team constellations are common for teaming environments in the real world.

Despite all of the benefits outlined above, managing, coordinating, and executing a shared goal in a multi-team system is not trivial and requires a high degree of shared, inter-team understanding. For instance, the individual tasks and dependencies that each team is reliant on must be properly coordinated to ensure (1) work is not redundant and (2) essential tasks are not forgotten [22]. Thus, coordination between these teams needs to be constant and goal-driven to ensure neither team begins to stray from their individual goal while still maintaining an understanding of the larger picture they are working towards [14, 59]. The research above paints a clear picture of how multi-team systems increase the amount and complexity of necessary coordination and communication within an organization. Unfortunately, these increases, along with a higher number of total teammates, may provide additional opportunities for conflict and disagreement to be driven by individual differences [3]. Therefore, an increased emphasis needs to be placed on individual differences and human factor relationships to ensure conflicts do not arise and degrade the entire multi-team organization [5]. It is thus imperative that research considers the possibility of inter-team interaction, and these considerations should be motivated by the potential ability to scale and handle increasingly complex tasks.

Research should look at teams as individual entities and parts of larger organizations where multiple teams interact. Thus, a new opportunity for the spread of trust and distrust arises as trust could spread both within a single team and between teams within a common organization. Therefore, building a foundational understanding of trust's ability to spread in HAT environments should not be limited to the individual team but rather the entire human-AI teaming organization or constellation. This requirement goes for understanding all aspects of trust and distrust in HATs, including the spread and repair of degraded levels of trust within and across teams.

## 3 CHALLENGES FACING TRUST IN HUMAN-AI TEAMING CONSTELLATIONS

### 3.1 RQ1: How Does Trust or Distrust Spread Between Teammates in the Same Human-AI Team?

As noted, trust is not just an individual human factor but rather a factor that can characterize an entire team as an emergent state [34]. While each individual may have a personal level of trust, those levels do not exist alone, especially because teams are often tightly coupled individuals whose interactions have lasting effects on each other. Therefore, fully understanding trust requires understanding how all team interactions can affect the trust humans have for their teammates. While modern research has focused on how human-AI interactions can modify human-AI trust [53], which is a necessary component of understanding HATs, considerations for how human-human interactions may affect human-AI trust still require exploration [23].

Understanding the effects that team member relationships can have on other team member relationships requires research into how the perceptions of trust humans form based on their interactions with an autonomous teammate may

be influenced and mediated by expressions of trust made by another (human or autonomous) teammate. This research defines this phenomenon as the spread of trust. This new direction in teaming research is not without empirical support as (1) trust can be infectious within human-human environments that utilize technology mediums [1] and (2) humans have shown a pattern of associating the trust they have for an individual system with other systems they interact with [17]. The first proposed research question merges these two previous findings by targeting HATs, which have not seen empirical research that details how trust spreads within them. Based on previous research on the system-wide trust that humans may develop for autonomous systems, there is strong potential for trust to spread throughout a HAT, specifically concerning autonomous teammates. This research hypothesizes that trust towards an autonomous teammate spreads through other teammates' interactions with each other. If the proposed research confirms this hypothesis, then trust would become one of the most critical considerations in a human-AI environment due to its substantial and prolonged effects on overall team performance and the perceptions of individual teammates.

### 3.2 RQ2: How Does Trust and Distrust Spread Between Teams Who Work Together Within the Same Human-AI Teaming System?

As mentioned previously in this paper, teams generally do not exist in isolation away from each other; in fact, it is often the opposite – multiple teams are usually needed to handle highly complex, real-world tasks (i.e., emergency operation centers). While these larger organizations of teams can be utilized to accomplish distributed, complex tasks effectively, there is an added complexity and difficulty associated with coordinating multiple teams at once [44]. While initial research efforts may ignore this complexity due to the difficulty in the experimental procedure, some research efforts should still be oriented towards observing multiple teams interacting with each other, which will serve to grow the relatability between research environments and real-world teams.

Conducting team research that observes teaming constellations consisting of multiple HATs is necessary to empirically explore the spread of trust between different HATs that work together. The inclusion of multiple teams in a single environment increases the amount of interaction and the complexity of that interaction. These changes in team interaction have the potential to mediate the spread of trust and distrust as (a) trust has more opportunities to spread due to the increased number of interactions; (b) the complexity of between-team interaction, as compared to within-team interactions, may be more susceptible to the spread of trust (see Figure 1). Specifically, individuals on one team may hear exaggerated stories that espouse the negative qualities of an AI teammate, causing teammates on another team to have significant amounts of distrust in an AI teammate, much like Microsoft's "Clippy" [57]. Additionally, the potential for the development of distrust and its spread stemming from the increased interactions can significantly alter the behavior of team members if they engage in preventative protective action (in anticipation of poor behavior or performance by the other party), which could significantly degrade individual and multi-team effectiveness. Thus, ignoring the possibility of trust and distrust spread between teams would yield incomplete research results as a large portion of interactions present in real-world teams would be ignored. Accommodating these interactions may strengthen the empirical evidence of the pervasive nature of trust and distrust.

### 3.3 RQ3: What Environmental Factors Mediate the Spread of Trust or Distrust in Human-AI Team and Teaming Systems?

Understanding the spread of trust in HATs should not be limited to only identifying the ability and pace at which trust can spread between teammates. Teaming and environmental factors may potentially influence trust's spread and should become a consideration as well. For instance, trust may spread differently in human-human relationships than

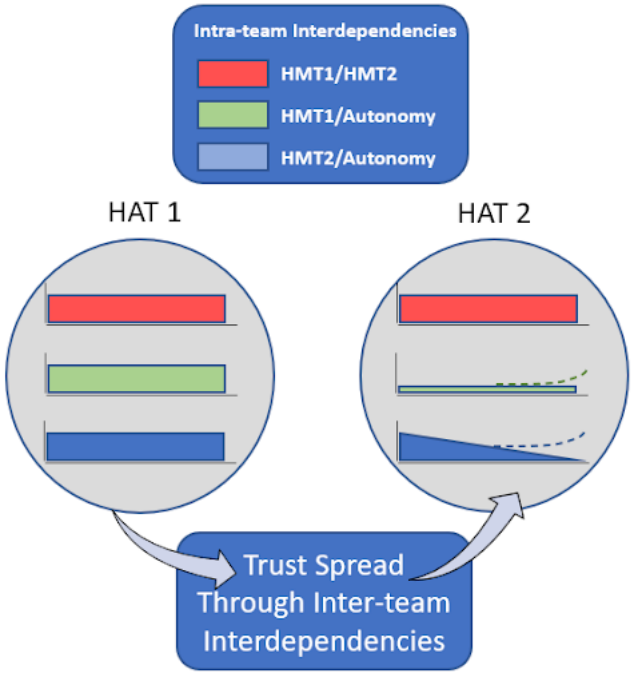


Fig. 1. Trust spread between two teams in a human-AI teaming constellation.

in human-AI relationships, i.e., is a human more likely to modify their level of trust based on the opinions of a fellow human teammate rather than a fellow AI teammate? Additionally, whether trust or distrust is being observed may determine its ability to spread. For instance, distrust may spread more efficiently than trust. If true, this difference would make maintaining high levels of trust difficult, but destroying established levels of trust within an entire team due to a single teammate's distrust could be fairly easy. The current position paper hypothesizes that (1) trust will spread more easily between human teammates due to trust being a factor commonly associated with human teammates, and (2) distrust for AI teammates will spread at a faster rate than trust for a human teammate, especially since humans tend to trust AI teammates less than human teammates [36, 50]. If confirmed, this finding would serve as a cautionary demonstration of how easily trust could break down in HATs. Additionally, this research question can be addressed twice, once for understanding the mediating effect of these factors on trust's spread within a single HAT and again for the effects on trust's spread between HATs.

### 3.4 RQ4: How can the Spread of Trust and Distrust Within and Between Human-AI Teams be Measured in Real-Time?

While the proposed research utilizes a mixed-methods approach to encapsulate trust's ability to spread in HATs fully, an additional effort exists to consolidate the gathered data into a quantitative tool that can be rapidly and reliably deployed in human-AI environments. If trust and distrust can be spread both within and between HATs, real-world HATs will need a way to efficiently detect the spread of trust or distrust within their teams. This research proposes that the most efficient method for doing so is utilizing a metric that specifically targets the spread of trust within a HAT

dynamically, much like recent work on measuring real-time team cognition [19]. While a simplistic approach to this may target the utilization of common trust metrics, such as organizational trust [9] or interpersonal trust [47], this would be ineffective as these tools were designed to measure current levels of trust and not the changes to one's trust. Therefore, the development, validation, and implementation of a metric specifically designed to measure the spread of trust between teammates would provide the greatest opportunity to identify and prevent the spread of distrust (as low trust could be an indicator of potential distrust development), or possibly promote and measure the spread of trust. The development of this tool should happen in parallel with experiments investigating the possibility of trust contagion within HATs to better inform its development by providing (1) empirical validation for its ability to measure trust's spread and (2) practical examples of how to implement the measurement tool and analyze the data collected.

### 3.5 RQ5: Do Common Trust Repair Techniques Extend to Preventing and Repairing Damage Caused by the Spread of Distrust?

Once the spread of trust has been sufficiently quantified and analyzed, this research focuses on repairing the possible damage caused by the spread of distrust. Due to the hypothesized damage the spread of distrust may cause, methods to prevent and repair that damage should be explored. While identifying the spread of trust and distrust is a significant priority, identification is not enough to ensure high levels of trust are maintained in a HAT environment. Thus, research should also incorporate common trust repair techniques to stop the spread of distrust and prevent the further degradation of trust in a HAT environment. Answering this research question yields two important contributions: (1) trust repair techniques can be validated in their effectiveness to stop continued, and dynamic losses in trust, rather than simply repairing a large portion of damage after the fact, and (2) additional empirical backing can be provided for trust repair's effectiveness in multi-HAT constellations, as opposed to the single isolated teams that trust repair is often studied. For (1), while trust repair may seem effective in restoring previous levels of trust lost by human-AI interaction, the effectiveness of such techniques may not prevent losses of trust that come from distrust being spread between teammates. This position paper hypothesizes that the incorporation of trust repair techniques in AI teammates will (a) slow down the degradation of trust brought about by distrust express [26, 27] and (b) speed up the establishment of trust brought about by trust spread initiated by a fellow teammate [23]. Alternatively, the second contribution provides an additional opportunity to validate the effectiveness of trust repair in multi-HAT settings, which will help strengthen the contribution (1). While the effectiveness of trust repair may be considered minor compared to the primary research questions focusing on the spread of trust, it is still worth discussing, as it provides important empirical backing to scientific and applied research fields and studies that utilize trust repair techniques.

## 4 CONCLUSION

The predicted rapid expansion of human-AI teaming has not yet begun, but contemporary research continuously demonstrates the increasing importance of trust in HATs [41]. Therefore, the proposed research questions are highly relevant in context and timing. This position paper proposes that understanding the trust humans have for AI teammates is not solely based on the interactions humans have with AI teammates, as those interactions only total a small amount compared to all interactions in real-world teaming environments. Instead, research should turn towards the inclusion of all human-human relationships and inter-team relationships to understand the variety of ways in which a human's trust can change. Specifically, this paper predicts that significant changes to a human teammate's trust for an AI teammate can come from interactions with other teammates and teams that utilize a similar AI teammate, which this paper refers to as trust contagion. Researching and understanding this spread should be conducted in an environment designed to

represent the future of human-AI teamwork, meaning future research should focus on context relevance, the inclusion of multiple HATs, and the use of real AI teammates. Thus, answering these research questions will contribute to an understanding of trust that is both actionable and relevant to real-world HATs. In answering these challenges, the advancement and integration of three important research domains can be brought about: 1) effective human-AI teaming; 2) the development and maintenance of trust within a HAT; and 3) the development and maintenance of trust within organizational initiatives that utilize human-AI teaming.

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