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Utilizing Simulated Environments to Increase Effective Communication among Distributed Teams

by

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Abstract

Effective communication is a vital ingredient for team success as poor communications could oftentimes lead to mission failure. Many organizations operate using distributed teams due to geography limitations, security concerns or a host of other reasons. Distributed teams must work together effectively while being physically apart. The Air Force Air Operations Center (AOC) functions as a distributed operations command team charged with conducting air operations that synchronize in the joint environment. This paper will go into details about an operational command and control center and the common forms of communication in use today in the AOC. The current literature will highlight how distributed teams can succeed and excel while mitigating limitations. Finally, this paper will propose a future study from which the results can evaluate the effectiveness of utilizing simulation environments on improving communication and thus mission accomplishment among distributed teams. The application to the current AOC construct will provide valuable insight into the future of war prosecution using emerging technologies.

Introduction

Communication is an integral part of command and control (C2). In operational level command and control centers, the senior commanders or decision makers may not be collocated with individuals and organizations in the decision making process. This distributed nature makes the element of effective communication methods more important. Current means of communication include video, voice, chat, email, or some combination of any of them. Each of these methods have a myriad of pros and cons. It is important to tailor the communication solution to the situation as needed.

Admiral Ellis characterized the Video Teleconferencing Capability (VTC) during Operation Allied Force as a powerful tool if properly used, because of its ability to shorten decision cycle times dramatically, to communicate a commander's intent clearly and unambiguously, and to obviate any requirement for the leading commanders to be collocated[1]. Though collocation allows stakeholders to physically see each other when communicating required decisional information, there is an inherent security risk having leading commanders collocated. Despite these high praises from Admiral Ellis, the absence of collocation of senior commanders, the highly distributed nature of the bombing effort, and an overreliance on email, VTCs, and other undocumented communication resulted in a notable lack of integration of many of the key staff elements in Allied Force[2].

Operational chat usage has become increasingly popular across the full spectrum of military operations. Chat use by the military grew rapidly during Operation Enduring Freedom and Operation Iraqi Freedom[3]. The real-time participation of concurrent users has turned the use of chat into one of the most widely used communication protocols for military C2[4]. However, there are risks associated with various chat tools and protocols. Technical risks are the most documented by organizations like the Defense Information Systems Agency (DISA). DISA concludes these risks are not limited to external risks but also internal risks such as integrity, confidentiality, availability, tactical information exchange, and situational awareness[5].

This paper will go into details about an operational command and control center and the common forms of communication in use today. The current literature will highlight how distributed teams can succeed and excel while mitigating limitations. Finally, this paper will propose a future study that can evaluate the effect of utilizing simulation environments on improving effective communication among distributed teams.

Background

During times of war or crisis, air campaigns should be planned with the basic principles of war as well as the tenets of airpower in mind. Maximizing them requires an effective planning and command function as well as a means to communicate and execute a given plan. The command structure and system that we have evolved to prosecute an air war takes the form of an Air Operation Center (AOC)[6]. The AOC is the operational-level command and control center that provides the Commander of Air Force Forces with the capability to direct and supervise the activities of assigned and attached forces and to monitor the actions of both enemy and friendly forces[7]. When there is more than one U.S. military service working in an AOC, it is called a Joint Air and Space Operations Center (JAOC). In cases of allied or coalition (multinational) operations in tandem with USAF or Joint air and space operations, the AOC is called a Combined Air and Space Operations Center (CAOC)[8]. For the purposes of this paper, we will simply refer to the different operation centers' structural forms as the AOC.

The planning processes that take place in an Air Operations Center (AOC) often include team members that are geographically distributed. Sometimes these members are located many time zones away in other parts of the world and provide necessary information for the AOC to execute its mission. To effectively plan for a mission there are different pieces of information that are needed from different sources. In a multidomain environment, this might mean getting information from weather, intel, cyber, space, etc to get an accurate picture of the environment. Currently, communication between the different and potentially geographically separated groups or members is done through some combination of voice, Microsoft Internet Relay Chat (mIRC) chat and/or email. These mediums operate on classified and unclassified networks as required for mission. When traffic is heavy or mission requires, there is a need to mointor multiple mIRC chat windows which could lead to the overlooked data or the increased workload of continuously scrolling through to make sure nothing was missed[9].

Communication within geographically distributed teams can often mean extending the time it takes to get a task completed while waiting to receive a response from other sources of information. The vehicle that the AOC uses to command and execute the air war is known as the Air Tasking Order (ATO). An ATO is a powerful tool that aids the Air Component Commander efficiently and effectively plan, organize and direct air operations through centralized planning. The ATO provides a breakdown of missions for a 24-hour period that includes the aircraft, call signs, times and other information needed for the Air Operations Center members to track and monitor missions.[10] The ATO process is complex by its very nature. To get an ATO from initial conceptualization to execution takes approximately 72 hours with a daily ATO release occurring every 24 hours. Within an AOC this means that up to five Air Tasking Orders (ATOs) are concurrently in development at any one time. This long timeline can often lead to information not getting where it needs to be in a timely fashion or sometimes arriving after it is no longer applicable or needed. Another aspect that may be worth considering is the increased coordination that needs to happen when you need to add or adjust missions in execution or scheduled later in the current ATO cycle[11].

A common source for all important information could help bring about a distributed collaborative, knowledge-based crisis action planning system, where both machine and human knowledge are utilized synergistically to create mission plans in a timelier fashion. The creation of a simulated environment could help the decision makers to visualize the entire operational and decisional picture in one place. Current literature and vernacular refer to this as the “operational picture” from which commanders receive consolidated information. This paper adds the term decisional because of both the planning and execution elements that simulated environments provide. This consolidation of information could help to not only facilitate more effective communication among the distributed team but could also lead to a more efficient planning process prior to and during execution.

Effectiveness of Communications in Distributed Teams

What is lost in the transfer of information when face-to-face communication is not possible? It is important to understand how the communication medium can influence group processes and outcomes and not only how the communication medium affects the timeliness of the information, but how the quality of outcomes is affected. A collocated team has many levels of potential communication from face-to-face to email and when one fails, another can be easily substituted. In a distributed environment, face-to-face communication is replaced by additional virtual tools. One way to quantify the loss of fidelity due to distributed communication is to identify a set of information exchange requirements (IER) for every communication. These IERs would encompass both the complexity, speed, security, and reliability of the information being exchanged and the various types of supporting communication media[12].

Efforts to Assist Distributed Teams, With or Without AR/VR

There are many examples of efforts to assist distributed teams. In a paper published in 2006, Greschke et al study the effectiveness of Distributed Mission Operations (DMO) systems. They reflect on the design considerations that need to be taken into account when putting together DMO systems. Some of these considerations include the number of sites, the fidelity of the connected systems, secure data and voice communications, management tools, and of course the bandwidth requirements. One important thing that they address is timing. The two organizations working on this effort are AFRL and the Swedish Defense Research Agency the fact this is an international distributed event brings up issues of latency and real time communication. Two key discoveries were made during testing. One was that the latencies involved in transoceanic connections to Europe were manageable and the second was that aside from some security issues and national security policies in various countries on the use of the Internet, the use of the Internet may one day offer a lower cost alternative for distributed networks used for unit-level ground-based training[13]. These discoveries led them to be able to expand their testing to conduct multi-entity, real-time technology experiments including laboratories in Australia, Canada, Sweden and the United Kingdom.

Though this paper focuses on the collaboration of military teams in mission planning tasks, we could explore the effectiveness of using Collaborative Virtual Environments (CVE) to foster effective teamwork with distributed teams in any task completion. A paper by Roberts et al proposes to investigate the team performance when the distributed team has a shared observation of an interactive object and share the manipulation of objects[14]. For this experiment, the main task was to build a gazebo and this task was broken into smaller sub tasks. There were also different display configurations which differed in their ability to facilitate interactions with the other participants. The team performance was measured by the time taken to complete the task and each component subtask. Evaluation of the process by the users was measured by their perception of collaboration. Since the gazebo task required collaboration at numerous points it meant that a faster user must often wait for the slower one to catch up before beginning the next step and the perception of collaboration could be affected by asymmetry between users of the different systems. Once again one of the concerns that was brought up was the network requirements and the conditions during the experiment. A key take away however, is that the level of immersion can affect the user's experience with the system and how the user's familiarity with the system can affect the time needed to complete tasks.

Understanding Conflict in Distributed Teams

The very nature of distributed teams brings about the topic of conflicts that may arise due to the potential lack of shared identity, shared context, and spontaneous communication. Hinds et al identified 4 hypotheses about the distributed teams:

1. Shared identity will moderate the relationship between geographic distribution and conflict particularly interpersonal conflict.
2. Shared context will moderate the relationship between geographic distribution and conflict particularly task conflict.
3. Spontaneous communication will be positively related to shared identity and shared context and will moderate the relationship between geographic distribution and conflict.
4. Task conflict and Interpersonal conflict will be associated with lower performance in collocated and distributed teams and will be more strongly associated with reduced performance in distributed as compared with collocated teams[15]

Conflict is inherent in team dynamics and perhaps more so in distributed teams. These hypotheses bring up some important things to consider when building distributed teams as well as some insights on how to perhaps build better distributed teams or at least increase the possibility to reducing the conflicts within the team.

Proposed Improvements to Command and Control (C2), Mission Planning, Battlespace Management, Etc.

Many efforts have been made to improve the command, control, planning, and management systems. In the space domain, the Space Operations Visualization Leveraging Augmented Reality (SOLAR) is currently being developed. SOLAR applies multimodal visualization and naturalistic interaction methods, including augmented reality and large shared displays, informed by a targeted work domain analysis using Cognitive Systems Engineering methods and is designed using a combination of both user-centered design and ecological interface design to unite the science of cognition with practical applications for fostering the understanding necessary for space object measurement, identification, characterization, and COA generation and evaluation that go well beyond traffic control[16].

RAND conducted a study that centered around improving Air Force command and control through enhanced agile combat support planning, execution, monitoring, and control processes. This study concluded that creating a process, clearly defined in doctrine, to specify airspace control system planning, execution, monitoring, and control supply, demand, and integrator roles including what information flows, in what format, and to whom, could lead to better integration between combat support and operations[17].

So what's next?

Based on the research collected on distributed teams, communication and efforts to assist distributed teams with and without AR/VR technology, this researcher proposes the following experiment to measure and evaluate the effectiveness of AR/VR technology to enhance communication amongst distributed teams. The following pages will outline a proposed experiment primarily geared toward the AOC construct to suggest improvements and introduction of AR/VR technology using synthetic environments to enhance communications across the distributed AOC team.

Methodology

Research Question

Would the addition of AR or VR technologies help to increase the effectiveness of communications with distributed teams?

Study Set-Up

Near peer adversaries, China and Russia are developing advanced air defenses, interceptors, surface -to-air missiles (SAMs), and radar networks to defend their airspace and push U.S. forces out of reach. They have also developed ballistic and cruise missiles along with strike aircraft to attack U.S. regional bases and naval forces while hardening their facilities to limit damage from strikes. Their efforts also include an array of mobile systems to make the U.S. targeting problem more difficult. Additionally, friendly forces must protect against cyber-attacks to disrupt planning and operations. The combination of these capabilities creates what is known as the anti-access, area-denial (A2/AD) environment. The A2/AD environment adds more complex variables to mission planning and execution especially in the air domain[18].

To help simulate AOC mission planning practices in this A2/AD environment, the proposed study will include both Red Forces (enemy) and Blue Forces (friendly) participants. The AOC personnel/participants will act as the Blue Forces. The Red Force will have a number of critical assets and the ability to fire at a target within a specific range, called the “Threat Circle”. This increased A2/AD environment, will help this experiment exercise more realistic threats faced by AOCs today and in the future. If blue aircrafts enter this threat circle, they could be shot down. Threat nodes are connected via a number of interfaces, ranging from satellite communications, IP networks and voice communications. These connections represent a vulnerability, if a system has satellite or internet based communications, they can be attacked and temporarily mitigated by Cyber or Space capabilities respectively.

The Blue Forces will be acting as an AOC. In this capacity, its role is to plan the allocation and timing of domain assets to successfully mitigate or eliminate the enemy's forces. To achieve this, AOC personnel will be split into 3 teams, each team represents a domain (Air, Space, and Cyber). Domains will be required to communicate via liaisons. The liaison should not make decisions for the team but is intended to convey the teams plan and coordinate with other liaisons. The liaison will be located with their respective team but will be able to communicate with the liaisons for the other teams. Each team will have a limited number of assets at their disposal to mitigate or destroy a target. Each of these assets will produce an effect on the Red Forces targets. Once all of the assets are used, they have no effects left to use. A platform's assets can be used at the same time across targets, and multiple platforms can use their assets on the same target at the same time in order to layer effects when necessary.

Sync Charts like the one in Figure 1 will be provided. They should be filled collaboratively by the liaisons during the scenarios of the experiment. The targets are listed along the left side of the chart in the same order as the printed Commander's intent sheet. They are generalized with just the priority number listed. The timeline for each scenario is along the top of the sync chart. For each target, effects can be chosen during each time block. The blocks of the spreadsheet can be set as A, C, or S for Air effects, Cyber effects, and Space effects respectively. The effects will last for 3 hours with the exception of Air. The Red Force threat will have to be mitigated before Air can fly into it because the Red Forces will launch instantly upon detection of the Blue Forces. The goal is for the three domain teams to successfully allocate the timing of domain assets to successfully mitigate or eliminate the Red Forces throughout the timeline of the exercise.

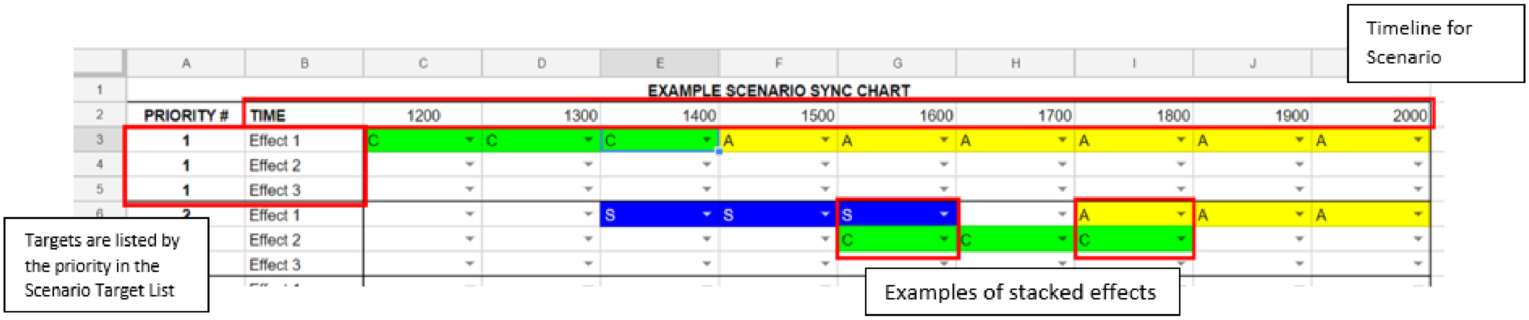

Figure 1: Sync Chart

Approach to Answering Research Question

To determine if the addition of AR or VR technologies could help increase the effectiveness of communication with distributed teams this study will compare the communication in a team without the addition of these technologies against the communication of a team that has those technologies available to them. Several variables can be modified to monitor the effects of the communication. Table 1 shows the kinds of conditions that will be tested during the study. For the purposes of this study the audio components consist of the ability to use speakers and/or microphone, while the visual components consists of the ability to use augmented reality visuals and/or chat.

Evaluation Criteria for Determining Change in Effective Communication

In a normal AOC, communication between distributed teams is done through voice or chat. In order to evaluate if the addition of AR technologies produces a change in the effectiveness of the communication within the team, the conditions of the study will go through all the possible combinations of having or not having audio and visual means of communication. The control case will be one with no audio and no visual. This will help set a baseline for the speed and ability of the team to complete the task of filling out the sync chart and successfully disabling the red forces. The case with normal conditions will be one where audio is available as well as some chat capabilities. The baseline along with the "normal" case will be compared against the performance of the teams with added AR visuals to determine the change in the communication of the teams.

Conditions of the Study		
AR1	audio	no visual
AR2	no audio	visual
AR3	audio	visual
AR4	no audio	no visual

Table 1: Study Conditions

Limitations of the Study

Simulated vs Real AOC

When planning to simulate an AOC it is important to understand that all AOCs are different, and indeed that each conflict fought by a given AOC will be different. The simulated AOC will be a controlled environment where the planning process happens according to a set guide for the planning process. In actuality, any documentation on the planning process is often seen as ad hoc or contradictory. Any number of planning or execution problems could occur within the planning and execution cycle that cause things to be added or deleted from the plan. Operational and tactical flexibility is necessary to deal with events such as late breaking intelligence, changing enemy events, or the bottlenecking of information. Throughout literature it is repeatedly mentioned how annotated times are notional and how flexible the process must be to meet the needs of each individual conflict.

Classification of Information

One of the greatest limiting factors is the classification of information and data security. In a multi-domain environment, the information needed to effectively plan a mission may have different levels of classification. The unique security classification of military information makes it challenging to have a singular simulation environment that aggregates all of the pertinent information in a single location or display. In order to model these systems, sensitive information about what can be done and how would be needed.

The introduction of augmented and virtual reality systems presents another security concern in that these systems have to manage information that may be classified or sensitive. AR/VR system designers would have to learn how to turn on and off the collection of AR/VR sensor data, and how to selectively classify it. For example, data from a combat engagement may need to be restricted, but data about geographical features, locations of infrastructure, etc. may be useful for less sensitive data services. A system that does not classify all sensor data in a bulk manner may increase the system's utility. Furthermore, these systems will have to deal with the challenging issues of securing data-at-rest and the potential loss or compromise of these devices by being able to effectively erase sensitive data if it falls into the wrong hands[19].

Simulation Environment to Display Different Sources of Information

Most battlefield management systems provided automated reporting and standardized geographical overlays to help present a common operating picture (COP) to tactical and operational level units. They are meant to aid targeting and decision-making cycles. AR/VR systems can leverage their data repositories while simultaneously providing real-time inputs during combat operations. Access to this information should make combat forces more effective and more efficient at closing with and defeating an adversary[20]. There is a delicate balance, however, with finding out the right level of information should be displayed. The use of simulation environments could help to provide combat forces with situational awareness about the operating area but the potential for information overload is also very possible. Decision makers need to be provided the appropriate level of information needed to plan and make decisions regarding the employment of tactical forces as well as monitor the operational factors of space, time, and force.

While the appropriate level of information is important, it is also worth noting that there is a difficulty in displaying certain sources of information. In the multi domain command and control structures of the future, the challenge will be finding a way to display the effects from the different domains onto the same display. For example, the simulation environments will need to have the ability to integrate information from land, air, sea, cyber and space sources of information to generate a common operating picture and be able to share this picture through various battlefield management systems.

Conclusion

Summary

AR/VR technology has the potential to be a game changer within the current AOC construct or even provide data for a new air war prosecution construct to enhance communication. Using it could create an effective way to reach the same goals but in a better, more efficient and potentially more timely and cost effective manner. The study proposed in this paper could help identify which form of technology, AR or VR, would best enhance communication in the AOC. Perhaps the answer is a delicate mixture of both technologies in a synthetic environment which gives decision makers a clearer operational decision picture when operating the AOC.

Time Savings

More efficient communication means faster communication. If faster communication shortens the decision loop, then commanders are able to make more decisions with more information saving time and ultimately resources. As stated earlier the timeline for the ATO cycle is 72 hours with long lead-times leading to information not getting to where it needs to get to when it needs to get there. The planning, coordinating, allocating, tasking, executing and assessing that need to happen in order to accomplish the objectives means that the various divisions that are responsible for strategy, plans, operations, air mobility and intelligence who are likely not collocated will need to communicate in the most efficient manner. If augmented reality solutions can help facilitate more effective communication then the necessary answers will come more quickly giving the operational level commander more time to provide inputs to the joint fight.

Cost Savings

AR/VR technology is becoming more affordable as new breakthroughs and technological advances widen the application space for these technologies. AR and VR have increased usage across the academia, industry, civil and military spectrums across the globe. Once the security concerns are addressed, the cost benefits of less deployment travel or simply no deployment travel for AOC personnel could reduce the overall expense of waging war. If individuals could serve on the distributed teams from their home station and still have the co-presence afforded through AR/VR technologies, this will increase every military members quality of life being able to "deploy" from home station.

Logistics Issues

Network connectivity as well as security issues are a constant concern. Data link, bandwidth, and latency are all factors that could impact the ability of the augmented reality systems to perform. This is especially true in remote locations at the edge of the battlefield. Forward deployed tactical networks will need to be able to support the amount of data that will need to be pushed and pulled across systems. Even if the connectivity issues are addressed the AR/VR tech would have to go through rigorous processes in order to be cleared for use in secure environments. The connections amongst the distributed teams will have to be secure wireless links with the appropriate connectivity for real time communication. These limiting factors must be addressed in order to reap the full benefits of these technologies.

Recommendations

There are already several groups within the Air Force Research Lab (AFRL) performing research in human performance as well as the many areas of augmented and virtual reality. AFRL should perform the study as they have the facilities, staff and personnel to conduct the study proposed in this paper. The team members performing the study should travel to the different AOCs to get a feel for operations and how the ATO cycle works in real-time in order to properly simulate the AOC environment for this experiment. The results could be a game changer. There are several companies currently developing tabletop map displays both with and without augmented reality that may be a viable solution to help decision makers view the operational picture. It is important for the research team to assess which AR/VR technologies would provide the best results with respect to increased effective communication in distributed teams and if those results show that AR/VR is the best solution to increasing that effective communication.

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