COMMAND AND CONTROL IN THE DIGITAL AGE: WHY AIR MOBILITY COMMAND NEEDS ASYNCHRONOUS COMMUNICATION

GRADUATE RESEARCH PAPER

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Abstract

The purpose of this research was twofold: first, to detail a rift between how Air Mobility Command (AMC), as the air component to U.S. Transportation Command (USTRANSCOM), conducts command and control (C2) in today's relatively permissive environment and how C2 may need to be conducted in a contested environment against a peer-adversary; and second, to prescribe a method of communication suited for degraded communication in a contested environment.

Developed and refined during a period of global freedom of maneuver – a time where the United States military enjoyed the ability to move and communicate how and when it wanted – today's C2 structure is heavily reliant on centralized command, centralized operations, and decentralized execution. The primary and secondary means of communication are further reliant on synchronous communication – and thus an uninterrupted line of communication. Peer and near-peer adversaries possess the ability to disrupt communication placing both operational and tactical C2 at risk.

Tactical C2 – data collection, analysis, and decision cycle at the forward edge of execution – was analyzed for the 2021 airlift of U.S. citizens, allies, and vulnerable Afghans as part of the largest Non-combatant Evacuation Operation (NEO) in United States history. Analysis showed that a resilient, distributed, and device-agnostic system capable of protected communication both across and off the Air Force Network (AFNet) provided critical pathways in a dynamic, yet still permissive, communication environment. Furthermore, the ability to communicate synchronously and asynchronously, at the discretion and ability of end-users, within a single system has value well beyond just synchronous communication.

Acknowledgments

I would like to thank my advisor, Lieutenant Colonel Aaron Glassburner, for his direction, advisement, and mentoring through countless rounds of refinement of my research question and the associated data collection, cleaning, and analysis. I would also like to thank and recognize the team of Airmen dedicated to transforming how mobility aircrews communicate and operate in a digital world.

The Digital Aircrew Initiative team is a forward-thinking group of disruptors who found a solution to a decades long problem and did not accept no for an answer. Steps taken with today's technology will allow the training leap to future technology. I'm sure I will miss some people, but I must thank by name Majors Justin Poole, Stephen Heptig, and Christian Brechbuhl for their bullheaded determination. Additionally thank you to Lieutenant Colonel Richard Aguirre, in AMC/A3, and Mr. Ward Walker, AMC Chief Technology Officer, for your support of a fledgling team doing great work at the unit level but in need of headquarters support.

To the units willing to leap into the unknown in support of advancing how we communicate and operate, thank you. Change is rarely easy. Innovators and early adopters pave the way for the masses who follow. Thank you to the 305th and 60th Air Mobility Wing leadership for your support of this effort - specifically to the men and women of the 32d, 2d, 6th, and 9th Air Refueling Squadrons, the 21st and 22d Airlift Squadrons, and the 87th Air Base Wing Command Post. I'd also like to thank the team of Air Operations Center professionals and flight managers who were willing to charge into the unknown with us.

Lastly, and most importantly, I must thank my family for all the support and time given up in pursuit of this research. To my wife and children: you are the engine that drives me forward.

John M. Cockburn, Major, USAF

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COMMAND AND CONTROL IN THE DIGITAL AGE: WHY AIR MOBILITY COMMAND NEEDS ASYNCHRONOUS COMMUNICATION

I. Introduction

General Issue

U.S. Transportation Command (USTRANSCOM) was established in 1987 as a functional combatant command (Herrera & Kaileh, 2020). Air Mobility Command (AMC) was tasked with presenting forces to and acting with delegated operational command (OPCON) on behalf of USTRANSCOM to accomplish assigned mobility missions in the air domain. Transportation speed and global versatility make air transport a sought-after capability. Department of Defense (DoD) demand for air transportation has consistently outpaced capacity. Airlift and air refueling capacity challenges coupled with 30 years of global freedom of maneuver within a relatively uncontested domain (referencing global logistics not the "last tactical mile") led Air Force senior leaders to focus on corporate business models and strategies that strive for efficiency above all else (Brown Jr., 2020; Choate, 2020; Fasching, 2021). While the DoD must be good stewards of taxpayer money, efficiency can be the enemy of military effectiveness – especially when adversaries can influence, degrade, or possibly deny mission accomplishment (Choate, 2020).

During the period where the U.S. military enjoyed global freedom of maneuver (1950s – 2010s)[1], the mobility enterprise's efforts to increase efficiency, coupled with gaps in available and approved technologies, led Air Mobility Command to increase reliance on telephone, email, and face-to-face communication modes for passing information – with communication often initiated by aircrew (information pull). The primary means of communication were driven by

[1] One can argue that the U.S. military can still move forces and equipment to a place of its choosing, on its timeline. However, for the purposes of this paper, the period of unrestricted global freedom of maneuver ends in the mid-2010s as a result of increasing intelligence collection and efforts to negatively influence U.S. military global mobility while deliberately remaining below the threshold of armed conflict. See the literature review section on peer adversary scope (pg. 13) for more information.

ease of access and a perception that they were *good enough.* Furthermore, any perception of efficiency was viewed solely through the lens of the command and control (C2) apparatus. As technology advanced, the gap between aircrew and C2 preferred modes of communication widened. Moreover, the primary modes today are unlikely to be effective for a future conflict with a peer adversary (Fasching, 2021, pp. 55-56).

Problem Statement

AMC lacks effective technology to allow seamless two-way communication flow between tactical-edge users (dispersed or distributed operators, maintainers, and aerial porters) and more centralized C2. At the tactical level, mobility aircrew routinely operate away from both Air Force Network (AFNet) terminals and globally dispersed C2 nodes. Furthermore, the primary and secondary modes of communication require synchronous interaction between operators and C2 personnel. These issues challenge efficient communication in a permissive environment but, more importantly, risk ineffective communication in the multi-domain contested environment expected in future conflict against a near-peer or peer adversary.

Research Objectives/Hypotheses

Objective: Synthesize an understanding of the current communication and data sharing methods in use between AMC aircrew and C2 (both 618th Air Operations Center (AOC) and globally distributed nodes). Bin the methods between "approved" government solutions and commercial shadow-IT and perform descriptive statistics to illustrate relative use and usefulness. Use this gained understanding to provide data-driven recommendations to AMC for future communication mediums.

It is hypothesized that the primary mode of AOC-approved communication will be voice (telephone pre/post flight and radio/satellite phone in-flight). Additionally, in-person physical exchange of mission paperwork, downloaded from a web server then printed, is hypothesized to be the primary method of data/file sharing. The researcher anticipates finding an incongruence between how the AOC and aircrew prefer to communicate – internal to their groups and between each other.

Research Focus

This research focuses on communication and data/file exchange between the 618 AOC, or its delegated global nodes, and aircraft commanders from C-17, C-5, and KC-10 aircraft. Two scenarios are studied in this research: a case study of communication during the 2021 Afghanistan NEO, named Operation ALLIES REFUGE, and limited electronic delivery of Aircrew Departure Papers (ADPs) (a conglomerate of mission orders, ATC-filed flight plans, detailed routing and fuel planning, weather, and other pertinent mission leg information) during the 2021 calendar year.

Air Mobility Command's Digital Aircrew Initiative (DAI) team released a survey, shortly after the completion of Operation ALLIES REFUGE, which the researcher used to study the modes of communication available and preferred by aircrew, detachments, and local C2. Digital ADP delivery research focused on C-17, C-5, and KC-10 mission legs between March and November 2021. The primary analysis revolved around when in the aircrew sequence of events papers were requested by aircrew and if any corollary impact for on-time takeoffs could be found.

Investigative Questions

Question 1: What is the 618 AOC's preferred mode of communication with aircrew? Sub question: why?

Question 2: How well does the AOC's preferred mode allow for data mining, eventual machine learning and/or artificial intelligence?

Question 3: Does the AOC's preferred method require symmetric or asymmetric communication? Does it allow for both?

Question 4. How resilient, redundant, reliable, and/or distributed is the AOC's preferred mode? (Essentially will the mode remain an option while increasing along the competition continuum?)

Question 5: What is an AMC aircraft commander's preferred mode of communication with the AOC? Sub question: why?

Question 6: How well does the aircraft commander's preferred mode allow for data mining, eventual machine learning and/or artificial intelligence?

Question 7: Does the aircraft commander's preferred method require symmetric or asymmetric communication? Does it allow for both?

Question 8: How resilient, redundant, reliable, and/or distributed is the aircraft commander's preferred mode? (Essentially will the mode remain an option while increasing along the competition continuum?)

Question 9: Which mode provides the fastest two-way communication? Related questions: do any modes provide for both one-on-one and one/multi-on-multi communication? Do any modes allow for additional parties to join the communication stream after it has begun and consume/contribute information without requiring redundant transmission of previous data?

Methodology

An ex post-facto case study methodology was used to collect and analyze data on Air Force mobility aircrew communication during the 2021 Afghanistan NEO. Data was further refined using an AMC survey released to aircrew and C2 personnel who supported the operation.

Additionally, AMC adopted limited use of a digital ADP delivery method during 2021. Data was extracted directly from Mattermost, the communication system where ADP requests were made, and linked to mission data from the Global Decision Support System (GDSS). Furthermore, regression analysis was accomplished to determine any possible correlation between ADP request time and an on-time aircraft departure.

Assumptions/Limitations

The DAI survey on usage of Mattermost – an open-source coded collaboration and chat tool hosted in the government cloud environment (further explained on page 18) – during the NEO was developed internally by that team. As such the researcher had no opportunity to influence the type of questions asked or to mitigate any response or question biases. The survey was released on a volunteer basis but only within the system being studied so all respondents had some familiarity with the system, increasing the likelihood of selection bias. Survey results contained a mix of Air Force specialties and varied results, but its voluntary nature likely resulted in sampling bias.

The research originally intended to conduct linear regression of all 27,635 mission legs recorded in GDSS for 2021. The independent variable would have been relative time (in hours) that crews receive departure papers. The dependent variable would have been the relative time (in hours) of actual aircraft departure. Both variables relative times were in relation to scheduled takeoff time. The analytical goal was to describe any correlation between when an aircrew receives departure papers and when the mission departs. However, ADP receipt could not be determined for most missions – which received printed paperwork sometime during the departure sequence of events. The research would require assuming all paperwork was received on-time during the sequence of events at aircrew show time. This assumption was determined to be invalid and would have resulted in imprecise calculations being presented as definitive correlation. Additionally, a precise time for ADP receipt could not be determined for the missions which utilized Mattermost to receive electronic ADPs. System limitations, during data extraction from Mattermost, limited usable information to when a crew requested ADPs – actual receipt could not be determined. Ultimately, the researcher chose to change the variables for analysis. . Regression analysis was limited to missions which used digital ADP delivery. Aircrew ADP request time was held as the independent variable while actual takeoff time was analyzed as the dependent variable

Implications

The U.S. Air Force Chief of Staff, General C.Q. Brown Jr. (2020), clearly states the strategic imperative – "If we don't change – if we fail to adapt – we risk losing the certainty with which we have defended our national interests for decades" (p. 2). General Brown goes on to add that many of today's capabilities were developed when today's general officers first entered military service (roughly 30 years ago). Rapid Global Mobility operates today more as a team of teams than a self-sufficient naval vessel at sea. Information flow has evolved from physical interactions with analog adjustments to digital information with just-in-time updates – effectively moving towards two-way data flows. Technology has proliferated in the civilian sector and yet the DoD is woefully behind and being outpaced by strategic competitors, especially China. The U.S. military has a limited window to correct course before risking an unprecedented loss in future conflict (Brown Jr., 2020).

II. Literature Review

Peer Adversary Scope

The 2018 National Defense Strategy recentered the United States' defense enterprise on great power competition (Mattis). With that came a fury of senior military leaders echoing the message that global strategic competitors (i.e., China and Russia) are rapidly closing the gap between the Nation's ability to bring to bear the military as an instrument of power and their ability to counter (through deterrence, denial, or defeat). General Jacqueline Van Ovost (2020), Commander of AMC, warned that peer adversaries "spent the last thirty years studying the United States… developing the strategies and weapon arsenals specifically designed to defeat the U.S. military's operational centers of gravity and critical warfighting capabilities" (p. 1).

Originally attributed to Carl von Clausewitz, U.S. Joint Publication (JP) 5-0 (2020) defines a center of gravity as "the source of power that provides moral or physical strength, freedom of action, or will to act" (Joint Chiefs of Staff [JCS]). By identifying one's own centers of gravity, militaries determine what to protect in order to ensure freedom of maneuver. Doctrine directs dissection of centers of gravity into critical capabilities, requirements, and vulnerabilities (Eikmeier, 2004). As an Air Force key capability, Rapid Global Mobility is critical to conducting military operations (Welsh III, 2014).

The systems, policies, and procedures for command, control, and communication that enable mission execution are the Rapid Global Mobility critical vulnerabilities most relevant to this research[2]. In 2012, the Chairman of the Joint Chiefs of Staff concluded that the U.S. military's "reliance on technological superiority is a potential vulnerability that our adversaries

[2] Command, control, and communication could be considered a critical requirement, defined by JP 5-0 as an "essential condition, resource, and means for a critical capability to be fully operational." However, the researcher labeled it a critical vulnerability due to its potential deficiencies and vulnerability to attack by a peer adversary.

will seek to exploit" (Dempsey, 2012). The National Defense Strategy specifically called for a need to "prioritize developing resilient, survivable, federated networks and information ecosystems from the tactical level up to strategic planning" (Mattis, 2018).

Command and Control Structure

The tenant of *centralized control and decentralized execution* remains the foundation for command and control of air forces. Airpower theory struggled with the duality of these concepts since aircraft were first used for military purposes. Decentralized control allows freedom and speed of maneuver at the tactical level but reduces available options to the overall operational commander. Essentially the opposite is true for centralized control. Prior to 1975, Air Force doctrine referred to centralized direction and decentralized control (Hinote, 2009).

Joint Doctrine refers to "decentralized execution of centralized, overarching plans or via mission command… The level of control used will depend on the nature of the operation or task, the risk or priority of its success, and the associated comfort level of the commander." (JCS, 2017). The document advises that advanced information systems and communications may enhance the understanding of leaders up the chain of command. Of note, a since deleted warning from the 2007 edition of JP 1 states "these technological advances increase the potential for superiors, once focused solely on strategic and operational decision making, to assert themselves at the tactical level. While this will be their prerogative, decentralized execution remains a basic C2 tenet of joint operations" (Hinote, 2009).

Current Air Force doctrine updated the tenant again to "Airmen execute mission command through centralized command, distributed control, and decentralized execution" (Air Force Doctrine Publication (AFDP) 1, 2021). Responsibility and authority for planning, directing, and coordinating operations are retained with the overall commander through mission command – which will be explored in the next section. Distributed control allows for delegated responsibilities to dispersed locations or lower echelons and AFDP-1 warns that contested environments may increase this requirement. Finally, decentralized execution “promotes effectiveness and resilience at the tactical level” by delegating span of control to exploit time-sensitive opportunities in dynamic situations (AFDP-1, 2021).

Mission Command

The Prussians developed the philosophy of mission command as an effort to operate through war’s fog and friction (Ben-Shalom & Shamir, 2011). The philosophy of decentralized command was reliant on initiative, responsibility, and mutual trust (Storr, 2003). Higher echelons of command focused less on direct control of actions at the tactical level and instead delivered intent. Subordinates were then free to execute the best tactical approach to achieve the intent based on conditions of the battle space known only at their level (Ben-Shalom et al. 2011). While air mobility operated in uncontested environments slowly centralizing more of its decision making, the U.S. Army began adopting mission command in the 1980s.

General Martin Dempsey, as the Chairman of the Joint Chiefs of Staff, directed the force to embrace mission command, saying the “fight against a decentralized enemy has driven home the necessity to decentralize our capabilities and distribute our operations” (2012). The vast distances within the Indo-Pacific area of responsibility coupled with China’s growing capabilities create a speed and logistical problem set for any potential future operation within the region. Dempsey warned “decentralization will occur beyond current comfort levels and habits of practice,” noting smaller, lighter forces must have freedom of action in an increasingly uncertain, complex, and competitive environment (2012). Mission command requires understanding, intent, and trust. Commanders are responsible for clearly articulating intent – the guiding star of mission command. Understanding must flow both directions as all echelons iteratively frame and reframe the situation to co-create a common context (Dempsey, 2012).

Given that mission command is permeated through joint and service doctrine, one would expect to see it in wide use throughout the DoD. Yet, the Air Force did not add mission command to its primary doctrine until 2021 and culture change lags. A mix of societal, political, and military aversion to risk can lead to the reluctance of senior leaders to give away a level of control. The continuing relevance of mission command, when real-time information is readily available to commanders, has been called into question by some scholars (Ben-Shalom et al. 2011). If commanders are reluctant to give away control, they are potentially emboldened by the reach-in capabilities of modern systems.

Dempsey warned against these potential barriers (reluctance, culture, and commander reach-in enabled by technology) to mission command. The volume and availability of information provided by modern C2 systems can reach a point where more harm is done than good. He further cautioned "the commander can easily penetrate to the lowest level of command and take over the fight… no C2 technology has ever successfully eliminated the fog of war, but it can create the illusion of perfect clarity from a distance" (Dempsey, 2012). Technology should be used to ensure bi-directional communication and information flow but not to fight from the headquarters.

Push versus Pull Communication

Communication between C2 and tactical forces can take four forms: 1) C2 pushes information/directives down to tactical users, 2) C2 pulls information/data up, 3) Tactical users push information up, and 4) tactical users pull information down from C2. Successful military operations require all four to create the common context Dempsey referred to in the previous section. However, militaries must guard against an overreliance on C2 pushing directives down and pulling information up during tactical operations – to avoid executing from the headquarters. For the purpose of this research, pull communication refers to end-users pulling information from C2. Push communication refers to C2 pushing information, data, or intent, to users.

Push communication requires fewer interactions and ensures up-to-date information, assuming the message is received (Bhide et al., 2002). Essentially, as information is available upstream it is delivered downstream either immediately or at defined periods without being solicited. The model works extremely well for periodic and predictable engagements, especially when connection speeds are not a limiting factor (Juvva & Rajkumar, 1999). The consistency of push communication in an advantage (Besta et al., 2017). Submarines under emissions control restrictions rely on push communication to allow them to passively listen while remaining undetected (Sykora, 2006). Air mobility assets operate in environments similar to submarines more than one might assume at first glance.

Pull communication allows a user to gain information on demand. Unlike, push communication, pulling information from C2 does require a request message. The communication is typically slower than when using push techniques but can reduce potential noise or overload (Juvva & Rajkumar, 1999). Additionally pull communication can reduce bandwidth requirements and ensure a smooth experience for remote users on mobile devices or slow networks (Bhide et al., 2002).

Push and pull models have mixed advantages and disadvantages – typically in contrast with each other. A chosen model "should not sacrifice the scalability of the server (under load) or reduce the resiliency of the system to failures" (Bhide et al., 2002). Mixed models utilizing both push and pull communication are the most effective by maximizing advantages while minimizing disadvantages. Regular interval or scheduled messages, as well as urgent and emerging information, should be pushed to a client. Non-essential communication should be pulled by clients, especially when operating on limited-speed networks (Bhide et al., 2002).

Synchronous versus Asynchronous Communication

Nodes, across wireless and satellite networks, are bandwidth constraints that must be competitively allocated across users based on demand (Ganti et al., 2007). In synchronous communication sender and receiver must be time-synched and operating at the same frequency – essentially communicating in real-time, either in person or online. When users have little choice on available network connections, asynchronous communication systems provide a mitigating solution to bandwidth concerns. Asynchronous communication allows transmission and reception of information at varied, out-of-sync rates – this could be due to bandwidth capabilities or other issues competing for sender/receiver time (Juvva & Rajkumar, 1999).

Electronic mail (e-mail) is an extreme example of asynchronous communication. But out-of-synch does not necessarily equate to long wait times between messages. Technological advancements enable what some scholars have come to refer as time-critical asymmetric, or asynchronous, communication (Fernandez & Ramamritham, 2004). Modern systems, like Slack or Mattermost, allow for concurrent communication to a single or multiple users. The time between transmission and receipt are significantly reduced – often at the discretion of the receiver (White et al., 2017). Further, e-mail lacks contextual queuing, has limited scale, and insufficient search functionality; making lengthy two-way communication ineffective through email, even if sender-receiver delays are reduced.

Military global telemedicine and aeromedical evacuations suffer from the same tyranny of distance as air mobility. Synchronous telemedicine is primarily conducted through telephone or video conferencing. Since 2004, U.S. Indo-Pacific Command used Pacific Asynchronous TeleHealth (PATH) as a low-bandwidth, web-based solution to telemedicine, with a 12-hour median response time (Nettesheim et al., 2018). The above response time would not be acceptable for air mobility tactical C2, but research has shown that an over reliance on synchronous communication leads to "diversion of attention, forgetfulness, and errors" (Coiera & Tombs, 1998). This leads to fragile operations due to artificial dependencies on availability, capability, and time-sync that synchronous communication systems impose. Complex systems require loose coupling to design for anti-fragility. A single system, with associated policies, which reduces response time for asynchronous communication while simultaneously allowing synchronous may optimize the duality which existed previously: communication can be asynchronous or synchronous but never both, without switching systems.

Mattermost Primer

Platform One, DoD's centralized DevSecOps team, deployed an on-premise instance of Mattermost for use by members of the software development community across the department at the onset of the COVID-19 pandemic. Mattermost is an open-source code collaboration platform available via a mobile application or web browser. Powered by availability and scalability, the platform grew significantly in usage throughout the pandemic. Because the platform is government hosted, the DoD maintains data sovereignty – a major factor in it gaining approval over other applications. Mitchell Moushon, Product Manager for the team overseeing Platform One's Mattermost, stated "before there was an official, approved chat channel, people were sharing information on Slack, Signal, and WhatsApp. While those are all encrypted, we wouldn't have been able to track them if there was a security leak" (https://mattermost.com/customers/us-department-of-defense/).

Because Mattermost is open-source coded it is highly configurable. Platform One, and to some extent Mattermost Inc., can quickly respond to customer feature needs through coding sprints or plug-ins. At the wing level, the 305th Air Mobility Wing and the 60th Air Mobility Wing pivoted heavily to Mattermost well in advance of AMC. Aircrew were drawn to it – willing to overlook its underdeveloped user interface, in comparison to slack, because they finally had a Controlled Unclassified Information (CUI) approved collaboration platform that could work natively on mobile devices and NIPR computers alike.

For this research, all references to "Mattermost" indicate the on-premise Impact Level (IL) 4 instance hosted by Platform One. Mattermost, Inc. provides the backbone platform but none of what AMC users are currently doing would be possible without hosting it in a government cloud environment.

III. Methodology

Methodology Summary

Research was conducted utilizing a mixed methodology. In 2021, following a limited test-case scenario, AMC began allowing command-wide electronic ACPs (flight plan, weather, and other mission data) delivery via Mattermost. This enabled direct delivery from AOC flight managers to aircraft Electronic Flight Bags (EFBs), a government-issued and controlled iPad. Data was extracted directly from the communication system where ACP request times (relative to scheduled/estimated takeoff time) were compared to actual takeoff time (relative to scheduled/estimated takeoff time). Regression analysis was accomplished to determine any possible correlation between crew paper request time and on-time aircraft departures.

Case studies are often used to analyze systems or events and evaluate processes. Studies help answer descriptive questions (what happened) and explanatory questions (how or why something happened). A case study was used to both describe and explain aspects of communication throughout the Afghanistan NEO. Even within AMC, the operation was very broad, and despite being a multi-agency effort, the research case was intentionally narrowed to tactical C2 between mobility aircrews (C-17 and KC-10) and C2 agents (618 AOC and distributed nodes) for airlift operations. The researcher selected this case due to it being the first known widespread instance of asynchronous communication to conduct tactical C2 within AMC. C2 communication was observed electronically in real-time and extracted ex post-facto then analyzed from the chat application Mattermost, hosted on military cloud-based infrastructure. Research focused on aircrew crew rest management, mission execution communications, and real-time sharing of lessons learned. Additionally, an AMC-released survey was used to further triangulate valid data, control for sample bias, and bolster analysis.

Data Collection

Aircraft mission data for the C-17, C-5, and KC-10 for January 1, 2021 through November 30, 2021 were extracted from GDSS through a mission ad hoc report into a Microsoft Excel file. The data extract captured administrative information like aircraft type, call sign, aircraft tail number, and mission number; mission planning data like departure and arrival airports, departure scheduled and/or estimated times, and tasked wing and squadron; and finally, mission execution data like actual departure time, delay time, delay type, delay reason, and actual land time. Approximately 28,000 mission legs were extracted.

In some cases, GDSS legs were removed from the analysis because of incomplete or inaccurate entries into the system of record. Specifically, when actual takeoff time was recorded as earlier than three hours before either scheduled or estimated takeoff the leg was removed. Scheduled takeoff times are set when the mission moves from the planning phase into execution. Any planned or unplanned changes to expected takeoff time, once in execution, adjusts the estimated departure time – while scheduled time remains unchanged. None of the airframes used in the analysis have aircrew show times, within their established sequence of events, which would allow a takeoff time more than three hours early. C-17 crew show is two hours and forty-five minutes prior to takeoff. C-5 and KC-10 aircrews show to the airfield three hours and fifteen minutes prior to takeoff. One hundred fifty-four missions were excluded due to this discrepancy, which likely resulted from an execution mission change which was not updated within GDSS.

Furthermore, 158 training or contingency missions were excluded because they took off later than the defined "on-time" takeoff windows without an assigned primary or secondary delay code. Had command and control teams properly completed their mission data capture sequence, a delay code would have been assigned. This led the researcher to conclude that the data could not be trusted, and it was excluded. Lastly, without further details to explain discrepancies between scheduled and estimated takeoff times an assumption was required to choose which time to set as the practical execution "scheduled" time. In instances where no scheduled takeoff time existed in GDSS, estimated times were used to ground the relative time calculations. Missions delayed more than 48 hours (for any reason) were recharacterized for analysis because issues like disapproved diplomatic clearances or long aircraft maintenance breaks could not be mitigated by digital ADP delivery. Figure 1 suggests that a significant majority of missions takeoff within the window between on time and six hours late.

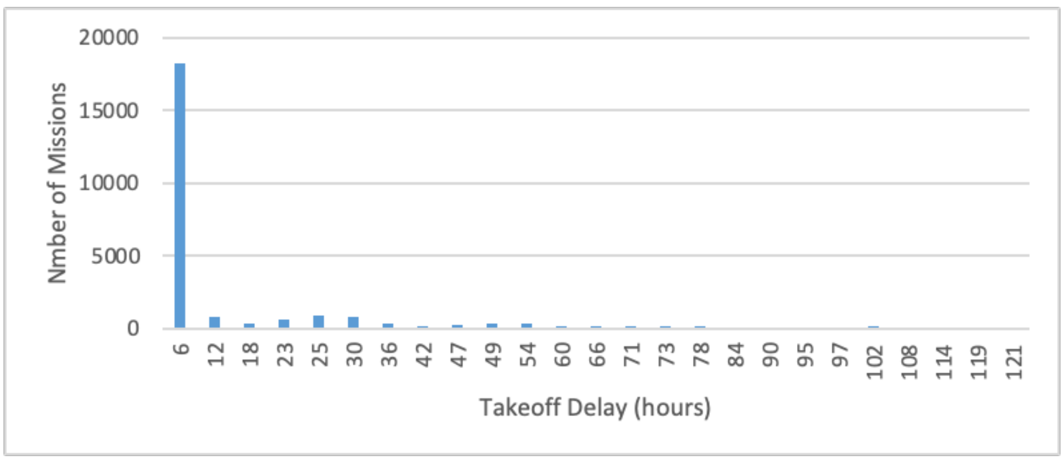

Figure 1: Departure Delay (Relative to Scheduled Takeoff Time)

Ignoring that specific bin of missions, a pattern emerges among missions with longer delays. As seen in peaks of Figure 2, after a mission is delayed past six hours it is likely to reset for 24 hours from the originally scheduled time. This reset repeats on a 24-hour cycle, at 48, 72, 96, and 120 hours, with a six-hour period after reset – if takeoff cannot occur during that six-hour window, another reset appears likely. While not specifically part of this research, the likely cause is aircrew duty time (the time period a crew is generally legal to operate an aircraft). For these reasons, when practical, once a mission delay was greater than 48 hours, the researcher reset the "on-time" baseline to any updated estimated departure time. This allowed a more realistic understanding of what was happening during execution.

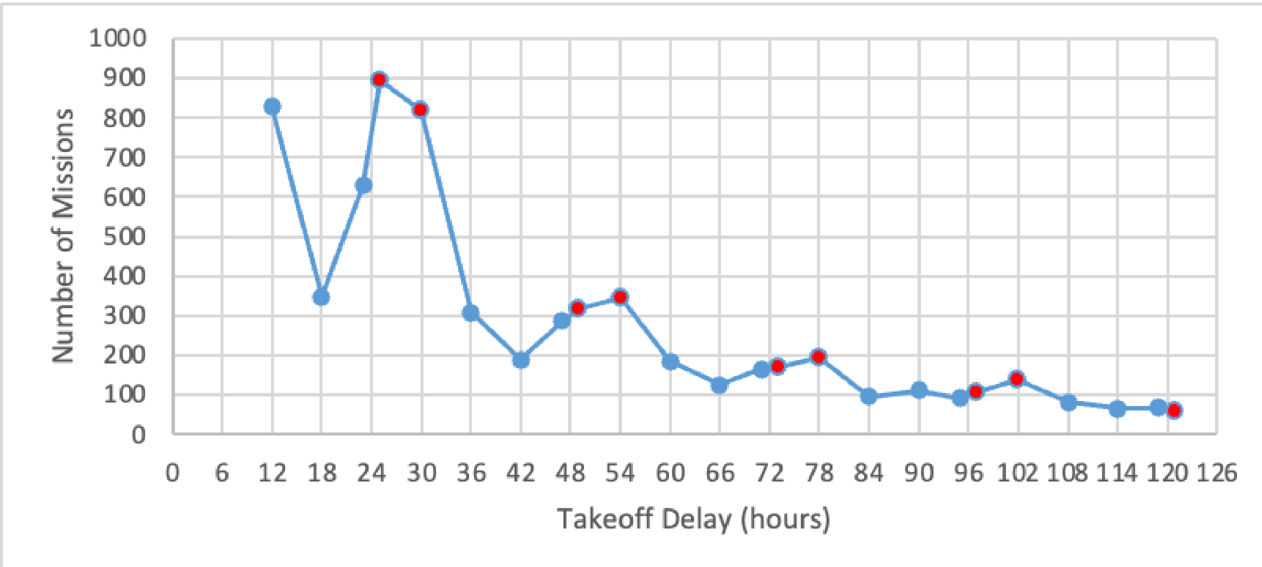

Figure 2: Six-Hour Window for Takeoff Before 24-Hour Reset

In all cases, absolute times were not used. ADP request times were recorded in relation to either scheduled or estimated departure time, as well as actual takeoff time. All times were recorded in hours rounded up to the nearest tenth of an hour. Positive time values annotate early occurrences (i.e., before scheduled/estimated/actual); whereas negative time values annotate late occurrences (i.e., after scheduled/estimated departure).

Additionally, approximately 2,600 chat entries from the primary Mattermost channel used to facilitate communication between the 618 AOC flight managers and aircrew (USAF-618AOC-MOD "10. Flight Management") were extracted as text. This data was then converted in Microsoft Excel and filtered into categories: ADP requests from crews, flight manager responses, other mission related communication, system messages, and "other." ADP requests were then linked to mission legs using request date/time, callsign, mission number, and aircraft tail number. Chat entries began in March 2021, after AMC authorized flight managers to deliver

ADPs through Mattermost on a limited basis at aircraft commander request. GDSS data was extracted in December 2021, covering January through November. Thus, the period of research analysis was March 1, 2021 through November 30, 2021. The convergence of these two datasets resulted in 1,453 unique aircraft mission legs for quantitative analysis.

Finally, the AMC Digital Aircrew Initiative Team released a Mattermost usability survey immediately following Operation ALLIES REFUGE. The survey was external to this research; thus, the researcher had no opportunity to adjust questions or control for biases. However, the researcher was provided full access to the results from all 118 responses for analysis. Data collected from the survey included anonymous administrative data, system usability data, and open-ended questions, as shown in Table 1 below.

Table 1: DAI Survey Question List

Question	**Response Option**
What was your primary duty position during the NEO?	Select from options, Write-in
Had you used Mattermost prior to the NEO?	Yes, No
How likely are you to recommend Mattermost to someone in a similar role?	Not Likely at All (0) - Very Likely (10)
During the surge in operations, Mattermost had this impact on my job ability:	Enhanced, No impact, Degraded
If Mattermost didn't exist, I would most likely. communicate via:	Select from options only
Mattermost was good at:	Paragraph style fill in blank
Mattermost was bad at:	Paragraph style fill in blank
If you could tell AMC/CC one thing about Mattermost what would it be?	Paragraph style fill in blank
I used Mattermost to (use case data):	Select from options, Write-in
What was your most reliable method of communication?	Select from options, Write-in
How did you connect to Mattermost (most of the time)?	Select from options only
Any recommendations for future rules of engagement involving Mattermost?	Paragraph style fill in blank
Any requests for Mattermost developers (app or website feedback)?	Paragraph style fill in blank

IV. Analysis and Results

Impact of Electronic ADP Requests on Aircraft Departure Times

In total, 1,453 requests for electronic ADPs were linked to GDSS mission legs through the flight management channel during the nine-month window of analysis. There were likely other requests direct to local command posts as witnessed in Mattermost teams at Joint Base McGuire-Dix-Lakehurst, Travis AFB, Dover AFB, and Al Udeid Airbase; however, this research remained focused on direct digital communication between the AOC and aircrews.

Regression describes the relationship of collected data and cannot precisely predict future values. However, by solving Equation 1 for an on-time takeoff ($y = 0$) an estimate for the best time to provide ADPs was found to be 4.4 hours prior to scheduled takeoff. This presented an opportunity to look at when crews were requesting ADPs from flight management at the 618 AOC when utilizing Mattermost. To understand the impact, one must first understand the aircrew alert sequence for the airframes studied as part of this research. Standard crew alert time is three hours and forty-five minutes (3+45) prior to scheduled or estimated takeoff for the C-17 and four hours and fifteen minutes (4+15) prior for the KC-10 and C-5. Show time at a mission location (the squadron, base operations, or command post) is one hour later; 2+45 and 3+15 respectively. Allowing 20 minutes to login to an AFNet computer and GDSS, crews can print their mission paperwork for initial review between 2+25 and 2+55 prior to takeoff, well inside of the 4+25 suggested from the data to ensure an on-time takeoff. At this point, crews are gathering mission equipment, conducting a mission route, weather, and restrictions study, briefing, and finally pre-flighting the aircraft. Of note, aircrew pulldown of ADPs from GDSS remains the primary delivery method per AMC policy.

Data from Mattermost ADP requests for 618 AOC-controlled missions suggests that crews want this information well earlier than it is being received as seen in Figure 3.

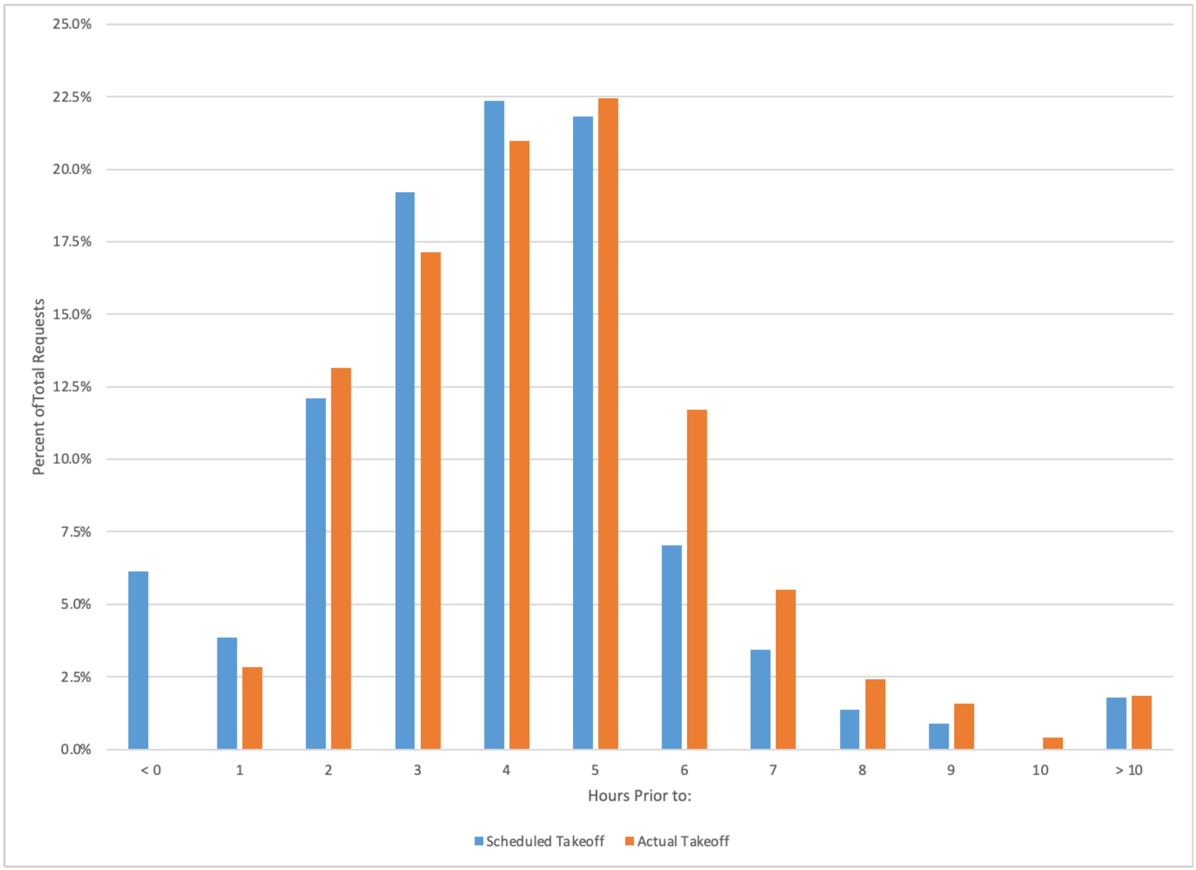

Figure 3: Crew Requested ADP Times, Relative to Scheduled and Actual Takeoff Times

For missions already in the global system, the time between aircrew alert and show is full of deadtime. Most crews are driven by bus from lodging to the operations facility and could use that downtime to study important mission and flight information, contained within ADPs, if received electronically prior to departing lodging. Asynchronous communication allows crews to address issues and otherwise utilize the "white space" during the launch sequence.

Descriptive statistics for the 1,453 instances of aircrew requested digital ADPs relative to scheduled takeoff time are shown in Table 2 below. While the mean was 3.3 hours prior to takeoff, aircrews requested ADPs four or more hours prior to scheduled takeoff 38.7% of the time when Mattermost was used. In cases with a large negative value, actual takeoff mirrored request time, plus or minus a few hours, indicating another likely reason for the significant delay – like aircraft maintenance condition, diplomatic clearance issues, or airfield and/or air traffic control restrictions.

Table 2: Descriptive Statistics for ADP Request vs Scheduled Takeoff

Statistics	Value
Mean	3.3
Standard Error	0.1
Median	3.5
Mode	2.7
Standard Deviation	4.8
Sample Variance	22.7
Kurtosis	306.0
Skewness	-12.4
Range	152.0
Minimum	-117.5
Maximum	34.5
Sum	4771.5
Count	1453.0
Confidence Level(95.0%)	0.2

Descriptive statistics for aircrew requested digital ADPs relative to actual takeoff time are shown in Table 3 below. Requests ranged from 34.9 to 0.1 hours prior to actual takeoff. Aircrews requested ADPs four or more hours prior to actual takeoff 48% of the time when Mattermost was used. Mean, median, and mode approached the 4.4 hours prior to takeoff which was predicted in earlier analysis to result in an on-time takeoff. Of note, 2.8% of ADPs requests were inside of one hour prior to takeoff when the crew would already be on the aircraft. The researcher observed that, in most cases, these were either quick-turn departures or requests for updated papers – either way these requests could not be made without electronic delivery capabilities. The researcher noted that both these extreme requests (less than 1 hour before actual takeoff and greater than 4 hours prior to takeoff) would not be possible with delivery of physical papers.

Table 3: Descriptive Statistics for ADP Request vs Actual Takeoff

Statistics	Value
Mean	4.1
Standard Error	0.1
Median	3.9
Mode	4.3
Standard Deviation	2.6
Sample Variance	6.8
Kurtosis	35.8
Skewness	4.3
Range	34.8
Minimum	0.1
Maximum	34.9
Sum	5971.5
Count	1453.0
Confidence Level(95.0%)	0.1

Simple linear regression analysis was conducted for the 1,453 linked electronic ADP requests. The independent variable was ADP request time (in hours) relative to scheduled or estimated departure time. A positive value indicated a time prior to the scheduled event, whereas a negative value indicated a time after the scheduled event. ADP request time and actual aircraft takeoff time were strongly positively correlated, ($r(1452) = .836$, $p < 0.000$) as seen in Figure 3. Furthermore, the overall regression model was statistically significant, ($R^2 = 0.699$, $F(1,1451) < 0.000$, $p < 0.000$). The regression equation was found to be

$$y = 0.7335x - 3.2449 \text{ where:}$$

X values are ADP request times relative to scheduled/estimated takeoff, in hours

Y values are actual takeoff times relative to scheduled/estimated takeoff, in hours

Equation 1: Regression of ADP Request Time vs. Actual Aircraft Takeoff

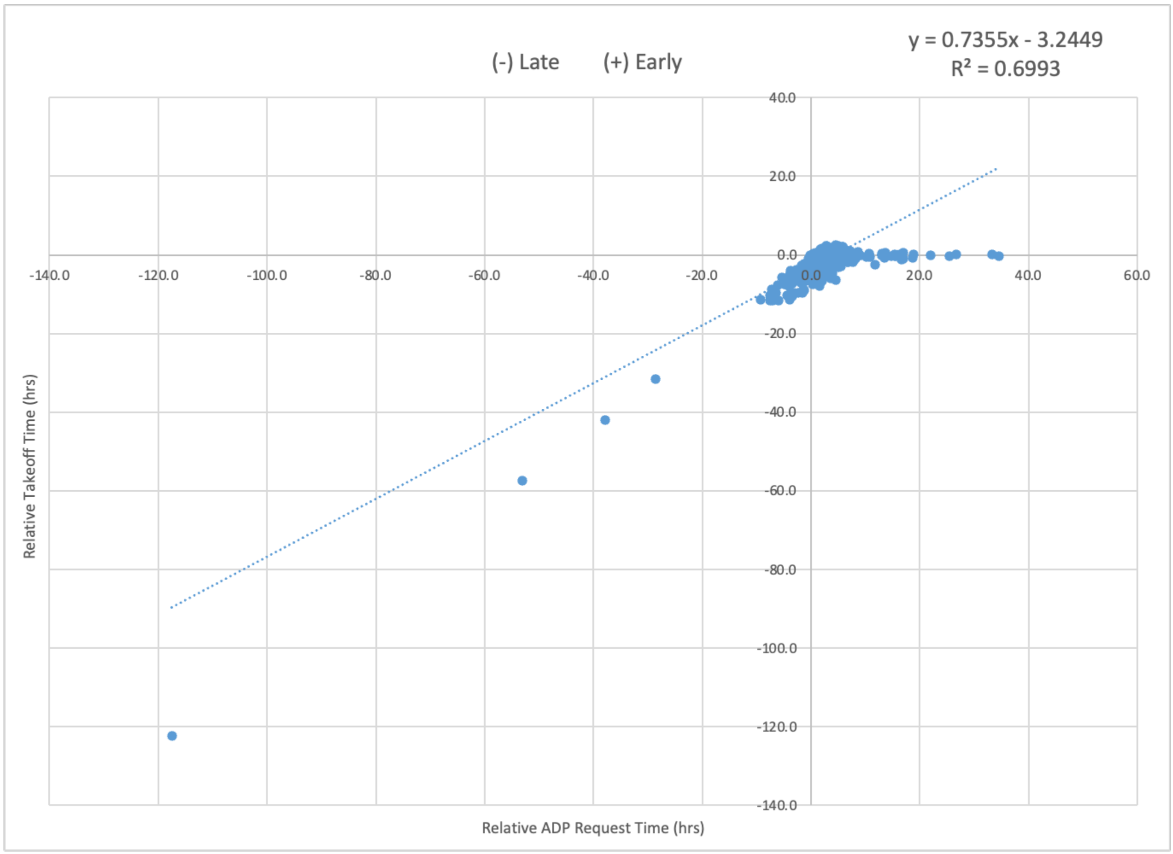

Figure 4: ADP Request Time Versus Actual Takeoff Time Relative to Scheduled Time

The model does not fit well when ADP requests occurred well in advance (greater than 6 hours) of scheduled takeoff. Flight managers do not begin building ADPs until 6 hours prior nor are they required, by AMC regulation, to publish them until 4 hours prior to takeoff. Additionally, aircraft mission timing is important. Just as AMC desires to minimize delayed takeoffs, "early" takeoffs come with operational challenges for downline entities and thus require AMC approval. Essentially, ADP requests earlier than 6 hours prior to takeoff are queued and do not influence takeoff time. To test this, regression was conducted a second time, excluding all data where aircrew requested ADPs ten or more hours prior to scheduled takeoff. This analysis showed a higher correlation ($r(1426) = .918$, $p < 0.000$) as well as explained more of the variation ($R^2 = 0.843$, $F(1,1425) < 0.000$, $p < 0.000$), as seen in Figure 4 below.

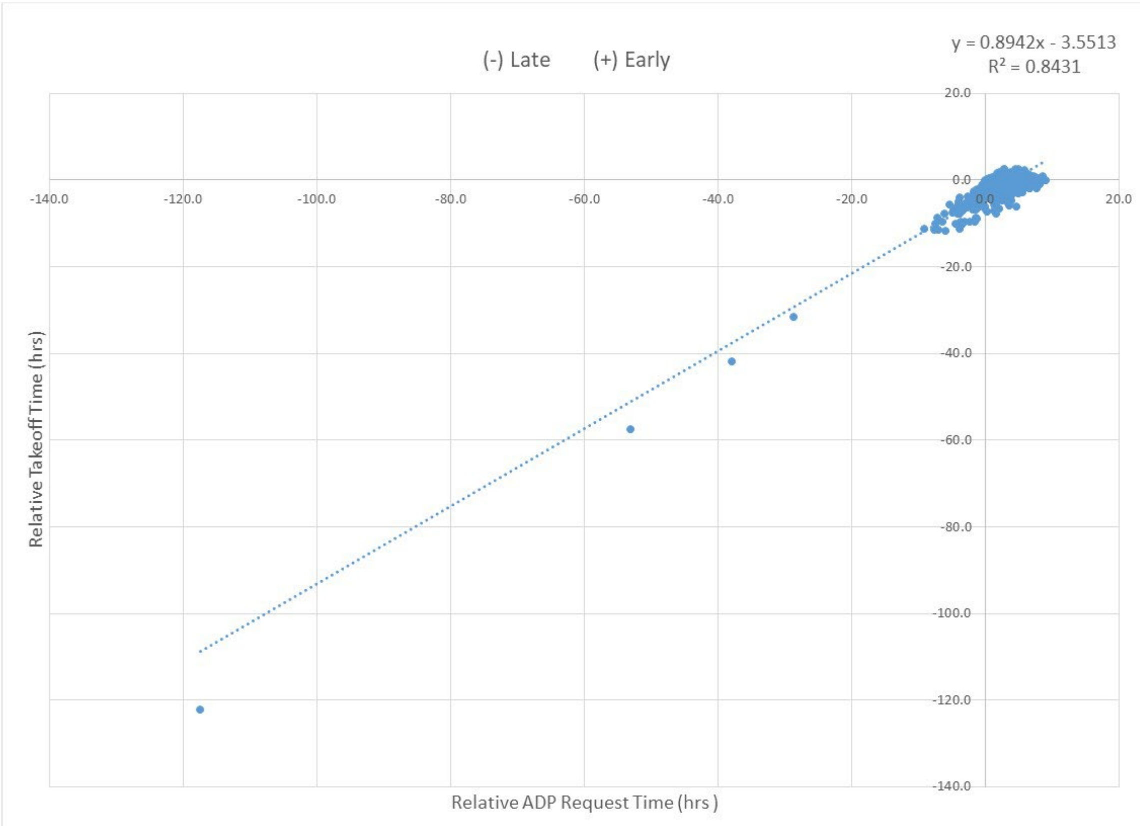

Figure 5: ADP Request Time Vs. Actual Takeoff Time, Excluding Outlier Requests

Case Study Analysis of Communications During Afghanistan NEO

The case study was limited to AMC's evacuation of personnel from Afghanistan on military aircraft, specifically the C-17 and KC-10. KC-10s operated from a detachment out of RAF Mildenhall, UK, while C-17s operated mostly out of a node at Al Udeid AB, Qatar. Evacuees were pulled out of Afghanistan and into a variety of intermediate locations before eventually making their way into the United States. While both Mildenhall and Al Udeid have a relatively permanent DoD presence and both airframes have operated out of them before, the size of the contingent and the scale of operations presented unique command, control, and communications problem sets.

KC-10 crews operating out of Mildenhall were beddown in a location without telephones and with thick walls which severely degraded native cellular service. Detachment leadership received wi-fi pucks from the local installation and rapidly setup Mattermost channels within the main 618AOC-MOD team to manage crews. Broad operational information, daily care and feeding, aircrew legal for alert, and flying schedules were all managed and communicated through Mattermost. In some instances, aircrew were even alerted through Mattermost. While not ideal, due to notification restrictions and the asynchronous nature of a chat application, this appeared to work – in part because the operation pace and structure was like the KC-10's main deployed mission. KC-10 operations, similar to the approach of the AOC for normal missions, created a single channel for limited critical communication to all crews or to initiate a request for synchronous communication between C2 and a crew in their crew-specific channel. This allowed the detachment to reduce noise and maintain an information flow that was logical. Crews had a log of all communications applicable directly to them without needing to sort out irrelevant data. This process allowed the right people to flow in and out of the right information stream as necessary. The detachment commander affirmed that "fewer passengers would have been evacuated so far by KC-10s operating out of Mildenhall if it were not for the Mattermost platform. Having our data via mobile devices while on the flight line or on crew buses has been AMAZING!!"

The researcher noted multiple issues while studying communication between the Air Mobility Command Center (AMCC) at Al Udeid and C-17 aircrews. These issues resulted in more negative feedback by aircrew as observed by the survey. Communication at Al Udeid was extremely slow. Available phone lines were often busy and many Mattermost messages went unanswered – the apparent cause seems to be poor Mattermost communication processes, a poor channel setup, and overtasked controllers which resulted in an overload of information. Crews reported it was either difficult to find pertinent information (drowned out by digital noise) or that their requests went unanswered. Overwhelmingly crews rejected the use of Mattermost as a means of alerting them – due to digital noise creating significant nuisance notifications and/or the difficultly with receiving timely notification via an asynchronous communication platform.

This is not to say that Mattermost was a failure at Al Udeid – in fact, the researcher observed, and aircrew confirmed, that Mattermost provided critical situational awareness and timely information when it went well for the crews. The AMCC chose to consolidate all communication and coordination into a single channel in a separate team. This meant that crews, who were already members of the 618AOC-MOD team required onboarding to the AMCC team to communicate. This was a cumbersome and unnecessary step. Additionally, conducting both synchronous (real-time two-way communication) and asynchronous (non-time sensitive requests) in the same channel drowned out important messages. Crews were left with two options – read every post regardless of applicability to them or risk missing critical information by only periodically checking in.

Immediately following the evacuation, the AMC Digital Aircrew Initiative team released a survey via Mattermost intended to capture aircrew, flight manager, and en route node C2 feedback. Table 4 shows the population of 118 survey respondents. As expected, aircrew and AOC personnel accounted for roughly 80% of responses. Most respondents (87%) had exposure to Mattermost prior to its use during the evacuation.

Table 4: DAI Survey Respondent Demographics

Respondant Duty Position	# of Responses	% of Total Responses
Aircrew	69	58.5%
TACC	24	20.3%
Squadron	13	11.0%
Theater C2	4	3.4%
Stage Management	4	3.4%
Installation C2	3	2.5%
Contingency Response	1	0.8%
Totals	118	

A large majority of respondents (79.5%) reported that Mattermost enhanced their ability to operate during the evacuation. Figure 6 provides a breakdown of mission enhancement responses by major respondent categories. Aircrew responses mirrored the larger majority, while AOC personnel were less likely to report that Mattermost enhanced their ability to perform their job.

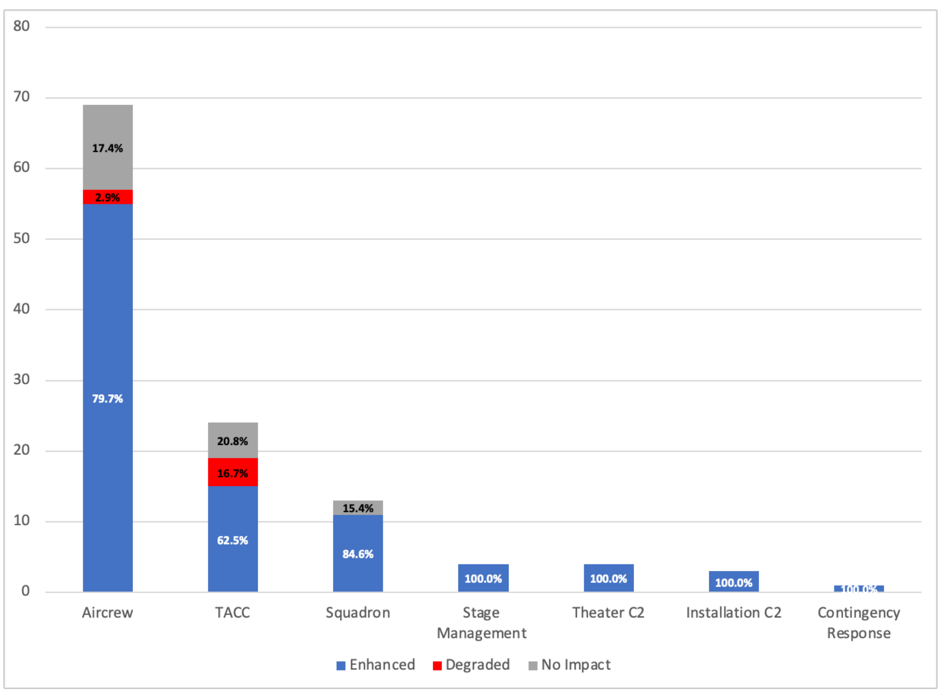

Figure 6: How Did Mattermost Impact Job Performance, By Response Category

As indicated by Figure 7, most respondents (93%) would recommend the application to others (responses between 10-6), while only 0.8% were highly unlikely to recommend Mattermost (responses between 2-0). Additionally, 58.5% of respondents indicated they were very likely to recommend Mattermost to others (responses between 10-9). The mean likelihood response was an 8.5, with a median response of 9, and a mode of 10. Mattermost appears to be highly recommended as a form of CUI-compliant mobile communication between C2 and aircrew.

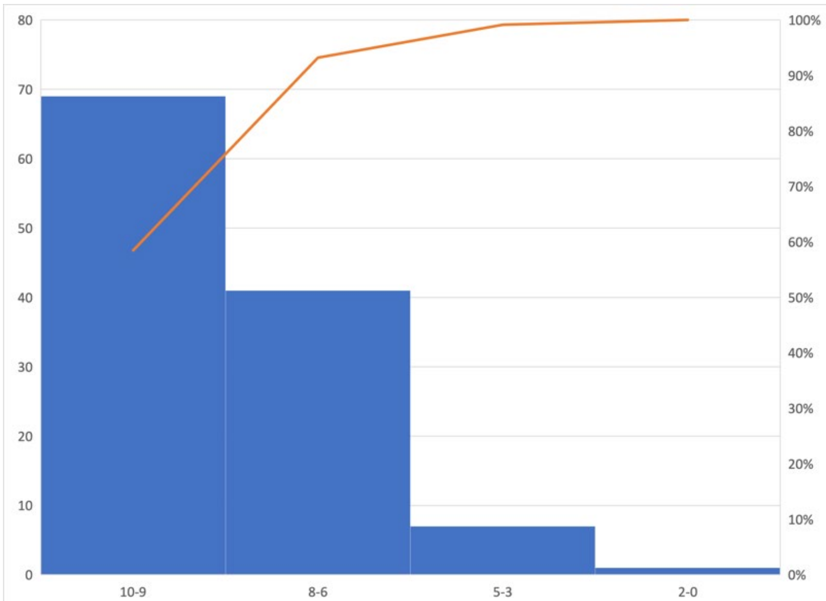

Figure 7: Likelihood to Recommend Mattermost to Others

Without Mattermost, most people indicated they would use a less secure means of communicating mission information, as seen in Figure 8. The survey did not ask respondents if they understood acceptable means of communicating CUI, but it appears that most will choose access to information over protection of information – if a choice must be made. In short, respondents indicated that they viewed current methods hinder protected mobile and digital communication and file transfer for users beyond the edge of the AFNet. Table 5 lists responses

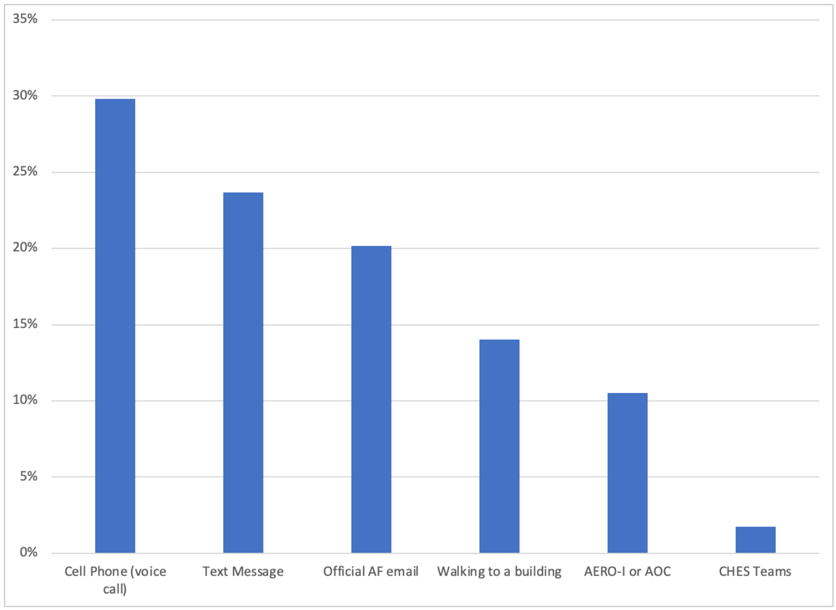

Figure 8: Without Mattermost, How Would You Communicate?

by position and communication medium. Over 50% of all respondents, and 64% of aircrew, indicated a cellphone (via voice or text message) would be their primary means of communicating without Mattermost. Beyond cellular communication, 20% of aircrew said they would physically walk to a building to communicate. No aircrew would use Microsoft Teams, offered by DoD's licensure of Office 365 at Impact Level 5, due to limited access to NIPR terminals during the launch sequence. Flight managers would use Air Force email (50%) or AERO-I/ACARS (29.2%). The survey did not allow participants to write-in answers; thus, it is missing the unapproved, non-protected means of communication the researcher has witnessed and are found later in the survey (i.e., WhatsApp, Slack, GroupMe, or Facebook Messenger).

Table 5: Communication Medium by Position, Without Mattermost as an Option

	Cell Phone (voice call)	Text Message	Official AF email	Walking to a building	AERO-I or AOC	CHES Teams	Blank	Totals by position
Aircrew	27	17	7	14	3	0	1	69
Squadron	2	6	2	2	0	1	0	13
TACC	1	1	12	0	7	0	3	24
Stage Management	0	2	1	0	1	0	0	4
Contingency Response	0	1	0	0	0	0	0	1
Installation C2	1	0	0	0	1	1	0	3
Theater C2	3	0	1	0	0	0	0	4
Totals by Category	34	27	23	16	12	2	4	118

When asked for their most reliable mode of communication during the NEO, respondents were able to choose from a list or write-in an answer. When respondents could provide their own modes of communication a few honestly provided unapproved communication apps. As hypothesized, Table 6 shows that Mattermost and telephone (cellular and landline) calls accounted for 73% of all respondents, relatively evenly at 34.7% and 38.1% respectively. GDSS, text message, and email were the next most reliable means of communication, at 6.8%, 5.1%, and 5.1% respectively. Aircrew found telephone calls followed by Mattermost to be most reliable at 49.3% and 21.7% respectively. Open-ended feedback questions indicate that internet connectivity, responsiveness from C2 entities, and attention-grabbing notifications were the main reasons. Aircrew were also the primary users of radios, telephones, GDSS, text messages, and Slack/WhatsApp with greater than 60% of the responses for each of these modes, despite being only 58% of all respondents. Essentially, aircrew crave situational awareness and will use any means to gain it – hindered primarily by operating beyond the bounds of traditional AFNet communications.

Table 6: Most Reliable Mode of Communication, By Position

	Aircrew	Squadron	TACC	Stage Management	Contingency Response	Installation C2	Theater C2	Totals By Comm Mode
Phone (cell or landline)	34	0	9	1	1	0	0	45
Mattermost	15	10	7	3	0	2	4	41
GDSS	5	0	2	0	0	1	0	8
Email	2	1	3	0	0	0	0	6
Text Message	4	2	0	0	0	0	0	6
ACARS	0	0	3	0	0	0	0	3
Radio	3	0	0	0	0	0	0	3
Blank	3	0	0	0	0	0	0	3
Slack/WhatsApp	2	0	0	0	0	0	0	2
All Had Their Place	1	0	0	0	0	0	0	1
Totals By Position	69	13	24	4	1	3	4	118

Mattermost was the most evenly spread form of communication across the various positions; of those who found it most reliable 36.6% were aircrew, 24.4% were squadron operations personnel, 22% were en route stage or C2 personnel, and 17% were AOC personnel. AOC personnel found reliability in the phone (37.5%), then Mattermost (29.2%), and ACARS or email (both at 12.5%). In fact, AOC personnel accounted for all respondents who found ACARS most reliable and half of those who found email most reliable. Open-ended feedback questions tended to show that AOC "reliability" was more a measure of familiarity with a specific communication mode and attention-grabbing notifications than the internet connectivity issues remote users, like aircrew, were having.

The largest barrier to communication in a global environment appeared to be access to the medium. For voice communications, aircrew either need to physically be at a DSN landline, be issued a government cellphone with a worldwide plan, or rely on their personal cellphone plan. Additionally, telephones are a form of synchronous communication, requiring all parties to be present at the same time. No one can join the information stream late without requiring information to be repeated. Mattermost usage during the contingency proved no different concerning connectivity issues. As seen in Table 7, 70% of all respondents used commercial internet of some sort, wi-fi or cellular hotspot, as their primary means to connect to Mattermost. A larger majority (94%) of aircrew used an internet connection other than AFNet – 39.1% used commercially available wi-fi (at lodging or base operations), 8.7% used a unit-issued hotspot device, while an alarming 46.4% were reliant on a hotspot from their personal cellphone's data plan. By contrast, 79% of AOC personnel connected via NIPR AFNet, accounting for 61% of all NIPR connections to Mattermost. Bridging AFNet users with edge-users operating beyond the boundary of traditional military networks proved a major advantage and capability of Mattermost.

Table 7: How Users Connected to Mattermost

	Aircrew	Squadron	TACC	Stage Management	Contingency Response	Installation C2	Theater C2	Totals By Connection Type
Personal hotspot	32	2	0	1	1	0	0	36
Commercial Internet / CAFnet	27	6	5	2	0	1	0	41
NIPR	1	4	19	1	0	2	4	31
Issued hotspot	6	0	0	0	0	0	0	6
Blank	3	1	0	0	0	0	0	4
Totals by Position	69	13	24	4	1	3	4	118

Survey participants were then asked to select all use cases they found for Mattermost. Users could also write in a response if they thought of a use case not listed. As indicated in Figure 9, the digital transfer of ADPs was the largest use case (selected by 82% of respondents); however, more than half of all respondents also indicated they used Mattermost to maintain overall situational awareness and/or pass time-sensitive and non-time-sensitive information. Mattermost was used by 24.6% of respondents to pass information to C2 when phone lines were busy – a benefit of asynchronous communication. Additionally, 38% of respondents indicated they used Mattermost to avoid passing sensitive information via telephone voice or text, for security reasons – indicating that given the option to pass information securely they will. This is significant when coupled with the conclusion that forced to choose between information sharing and information protection, aircrew will choose sharing.

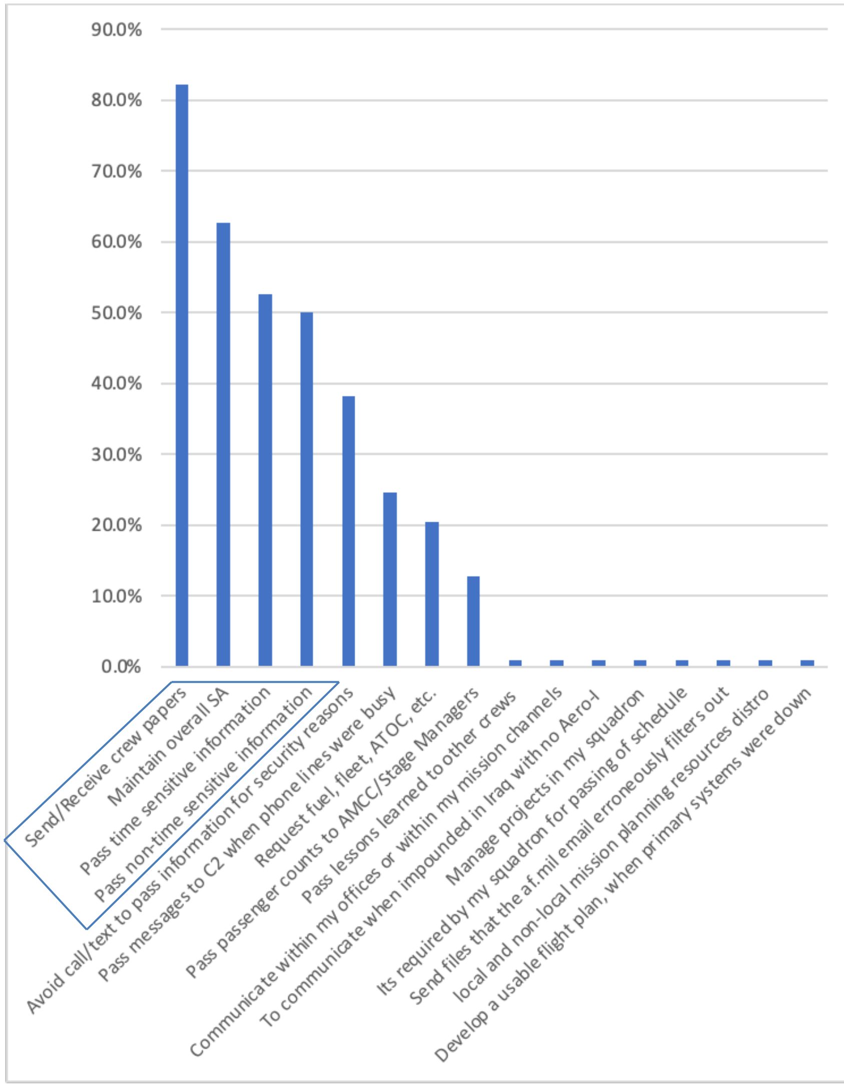

Figure 9: User Reported Use Cases for Mattermost

Finally, the survey asked three open-ended questions: What was Mattermost good at? What was Mattermost bad at? If you could tell the AMC Commander one thing about Mattermost, what would that be? These questions had no leading responses and were fill in the blank, in paragraph format with no character limit. The researcher used an open-source code word cloud generator, created by Jason Davies, to distill common themes from the comments, presented in Figures 10-12 below.

When asked what Mattermost was good at, 84.7% of survey participants responded. Major themes are indicated in Figure 10 and include: quickly and securely delivering crew papers, information, communication, and situational awareness. Further review of responses in line with these themes found that respondents appreciated a resilient and persistent application that provided CUI-compliant mobile communications, effectively bridging the gap between AFNet connected personnel in the AOC and aircrew operating on or beyond the network's traditional edge.

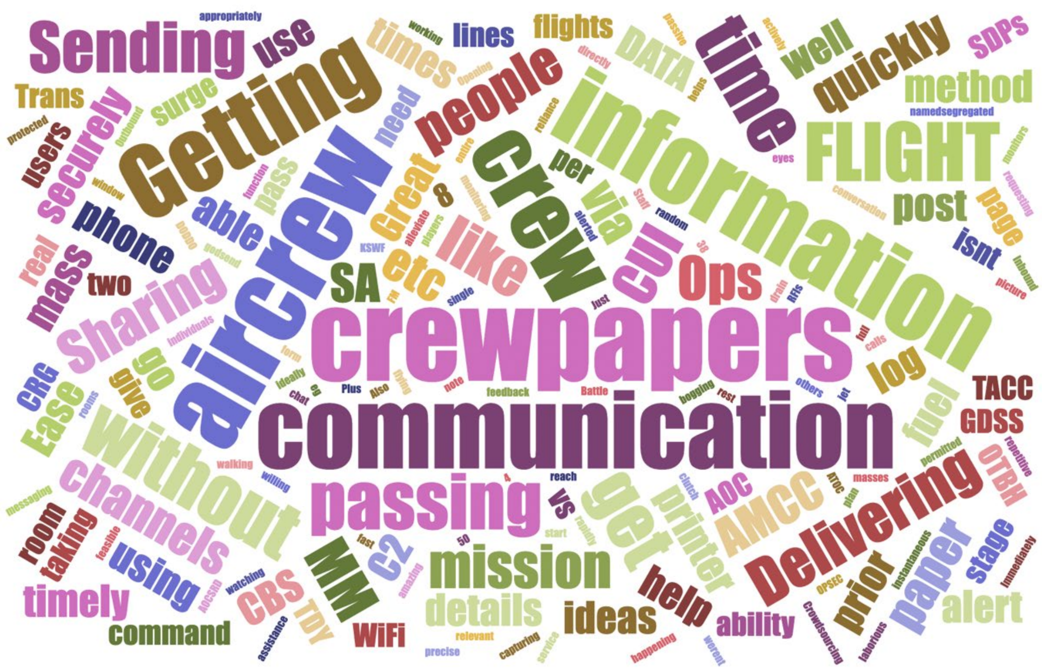

Figure 10: Mattermost Was Good At, WordCloud

When asked what Mattermost was bad at, 72% of survey participants responded. Major themes are indicated in Figure 11 and include: notifications, alerting aircrew to fly, nothing, and getting a response. Additional analysis of responses also found a concern with work/life balance and always being connected – which the researcher independently noticed during the review of NEO communications. There is a fine balance between being able to connect with anyone at any time and overusing that ability – which could create a large imbalance or lead to burnout.

Figure 11: Mattermost Was Bad At, WordCloud

When given the opportunity to tell the AMC Commander one thing about Mattermost, 84% of survey participants responded. Major themes are indicated in Figure 12 and include: Mattermost is a reliable tool, make it the primary method of ACP delivery, mandate its use, and fund the system. There appeared to be mixed opinions regarding the AMC Flight Crew Information File (FCIF) and Concept of Operations (CONOPS) which govern Mattermost usage and interaction between aircrew and C2 agencies, specifically the 618 AOC. Aircrew desire reliable digital access to ADPs on their issued EFBs – they are less concerned if ADP delivery is automatic, sent by AOC flight managers, or en route C2 personnel at AMC nodes within the Global Air Mobility Support System. Flight managers appeared split into a few groups (the size of which this research was not able to determine): some flight managers dislike the system, others find it easier than other methods of electronic delivery but do not feel that electronic ADP should be standard across all missions, some feel that the FCIF and CONOPS should be strictly enforced, while the last group feels the FCIF handcuffs them and would like to see wider usage of Mattermost.

Figure 12: What Would You Tell AMC/CC About Mattermost, WordCloud

Investigative Questions Answered

Question 1: What is the 618 AOC's preferred mode of communication with aircrew? Sub question: why? 62% of AOC personnel indicated that Mattermost enhanced their job performance, while 17% indicated that it degraded performance. Without Mattermost, AOC personnel are likely to seek communication via email, AERO-I, or the telephone. Open-ended survey questions showed that "reliability" for AOC personnel may have been correlated to system familiarity and notifications. System notifications in Mattermost were viewed negatively, as compared to telephone ringers, by flight managers. Additionally, there appear to be two main groups: those who desire the ability to use Mattermost for more than the FCIF-allowed purposes (i.e., general communication and collaboration with aircrews) and those who feel ADP retrieval is an aircrew task (i.e., they should not be delivering papers unless at remote locations).

Question 2: How well does the AOC's preferred mode allow for data mining, eventual machine learning, and/or artificial intelligence? Following communication streams via email is extremely difficult. As for telephone communication, while artificial intelligence's ability to synthesize, translate, and act upon voice data is improving, synthesizing text is an easier and cheaper task. The technology required to glean information and utilize artificial intelligence to make decisions from digital text will develop faster and be available at scale more cheaply than that required for voice analysis. The results of this research indicate that current AOC methods of communication are less prepared to make use of machine learning and artificial intelligence.

Question 3: Does the AOC's preferred method require symmetric or asymmetric communication? Does it allow for both? Telephone communication requires synchronous communication. Email allows for asynchronous, although at reduced effectiveness compared to modern collaboration tools. Except for Mattermost, no observed communications tools allowed for both synchronous and asynchronous communication.

Question 4. How resilient, redundant, reliable, and/or distributed is the AOC's preferred mode? (Essentially will the mode remain an option while increasing along the competition continuum?) The results of this research indicate that the AOC's preferred mode is telephone communication, which can easily be denied, disrupted, or intercepted. Because the communication requires both parties to be available at the same time, an adversary need only attack one party to completely deny the communication. Additionally distributed AOC operations would be extremely difficult for aircrew should the AOC need to execute a continuity of operations plan. If AOC personnel were to physically disperse, aircrew would struggle to determine which number to call. Finally, the majority of the communication methods in use are unprotected, unencrypted communications (i.e. cell phones, landline telephones, ACARS, AERO-I.)

Question 5: What is an AMC aircraft commander's preferred mode of communication with the AOC? Sub question: why? Aircrew do not prefer Microsoft Teams, email, or AERO-I mostly due to accessibility and effectiveness. Cellular communication was their most reliable method, and most preferred if Mattermost is not available. Open-ended responses indicated that aircrew perception of Mattermost reliability was heavily influenced by unanswered requests to theater and AOC C2. As indicated by job performance enhancement and likelihood to recommend, aircrew want Mattermost – however, effective communication requires multiple parties.

Question 6: How well does the aircraft commander's preferred mode allow for data mining, eventual machine learning, and/or artificial intelligence? See the answer to question two above for the voice communication methods. Because Mattermost is deployed within the DoD Platform One ecosystem it is possible to share data with other mission applications, as required. This allows an Airmen to develop an IL-4 aircrew scheduling tool which can automatically export a scheduled crew to a mission channel in the 618 AOC's team in Mattermost. Furthermore, the Strategic Requirements Division of the AOC is exploring the possibility of using machine learning and artificial intelligence to scan the Mattermost information stream in an effort to sense, make sense, and prioritize requirements (requests for information or needed decisions) to provide C2 in a deliberate order.

Question 7: Does the aircraft commander's preferred method require symmetric or asymmetric communication? Does it allow for both? Mattermost is traditionally an asynchronous communication tool; however, it allows for parties to transition to synchronous communication when necessary, and time allows. This allows all parties to provide non-time-sensitive information asynchronously and then transition to real-time communication when necessary.

Question 8: How resilient, redundant, reliable, and/or distributed is the aircraft commander's preferred mode? (Essentially will the mode remain an option while increasing along the competition continuum?) Because Mattermost is government-cloud hosted and built on Kubernetes it is extremely resilient. Communication can persist as long as the user has a data connection of any kind. Additionally, IL-4 authentication is available on mobile devices without PKI CAC certificates. Further, as seen during the NEO, the system is scalable and expansive. Platform One personnel were able to increase available bandwidth to support a large increase in use during the evacuation.

Question 9: Which mode provides the fastest two-way communication? Related questions: do any modes provide for both one-on-one and one/multi-on-multi communication? Do any modes allow for additional parties to join the communication stream after it has begun and consume/contribute information without requiring redundant transmission of previous data? The telephone remains the fasted form of communication due to its persistent auditory notification – a ringing phone is harder to miss than a Mattermost message popup notification. Traditionally, telephone calls are limited to one-on-one communication. Conference calling is available but limited and would require information to be repeated after determining the need for a conference. Mattermost allows users to flow in or out of an information stream on demand. Additionally, because message history is available upon joining repeating information is not required every time a party joins the communication.

V. Conclusions and Recommendations

Conclusions of Research

AMC users crave connectivity. Initially, this may appear to run counter to the doctrine of mission command. However, mission command requires intent, understanding, and trust. The Afghanistan NEO was replete with successful examples of aircraft commanders making tactical decisions informed by commander's intent. A persistent and resilient collaboration platform, like Mattermost, enhances understanding. Asynchronous communication allows for a flow of information that can be received and responded to during periods of connectivity. In a permissive environment, these may be the periods of "white space" during the launch sequence. In a contested environment, it could be any time an aircrew finds a data connection (commercial or military network). Despite craving connectivity, AMC teams operate at or beyond the traditional edge of AFNet. Mattermost found success, in part, because of its ubiquitous accessibility across devices and internet connections. Remote users can access on mobile devices (i.e., cellphones or EFBs) and communicate synchronously or asynchronously with C2 at government workstations connected to NIPR. Without an approved secure solution, users have demonstrated that they will use other unapproved, albeit typically encrypted, platforms. Aircrew want information access and protection but have demonstrated they will choose access over protection if a choice must be made.

Mattermost is not a panacea. There will likely be a future solution that provides more capability and better integration than Mattermost. However, Mattermost is today's solution and can train the force for tomorrow. The DoD sensed a need for leap-ahead technology as early as the 2018 National Defense Strategy. Air Force Chief of Staff, Gen C.Q. Brown Jr., narrowed that focus for the Air Force in his Accelerate Change or Lose call to action. Advancement is not made by waiting for leap-ahead technology to be invented. Often change is iterative. Technological change is as much cultural as it is technology dependent. If AMC waits for tomorrow's solution to shift culture, it will require a multi-year effort to then shift culture and train the force before any new advancement can reach its potential. Mattermost adoption and expansion will assist the digital cultural transformation for air mobility. Concepts like beyond-line-of-sight (BLOS) tactical data link (TDL) and Joint All-Domain Command and Control (JADC2) are the future. However, efforts can be made in the present to secure today's communication – use of IL 4 Mattermost does not move backward from IL 6 (classified) or IL 5 (National Security Services CUI) communication, it moves communication up from IL 2 (publicly releasable information) systems to an appropriately secured platform.

In a contested environment, synchronous may not be the best means of communication. Likely periods and places of degraded or disrupted communication will deny sender and receiver link up. In synchronous communication, if that link cannot be made (i.e., both sender and receiver are unable to link or not available at the same time) the message is lost. BLOS TDL is very likely the future of on-aircraft communications, enabling the concepts of JADC2. However, a ubiquitous platform like IL 6 Mattermost could operate on that data connection. Efforts today on IL 4 Mattermost will provide a trained force that has developed good communication practices and procedures.

Mattermost provides its greatest capability to the force by blending synchronous and asynchronous communication in a single platform, which provides a single source of truth data stream. Aircrew, C2, and support personnel can flow in and out of the information stream as necessary without requiring information to be repeated. Dedicated asynchronous channels draw appropriate attention across a wide span of users to a specific issue that can be discussed in a crew or mission-specific channel. This second channel (unique to each mission) allows either asynchronous or synchronous communication dependent on the situation and availability of all parties without creating information overload and noise – as experienced by C-17 crews during the Afghanistan NEO.

Mattermost can provide AMC with much more than digital ADP delivery – which currently appears to be the sole focus. Its asynchronous communication capabilities are underutilized. Time spent on phone calls repeating information to multiple sections on the execution floor of the AOC could be collapsed into chat streams within mission channels on Mattermost. Duty officers, flight managers, and decision-makers (like waiver authorities) could flow in and out of channels as required. Consuming the available past communication stream to quickly gain situational awareness, provide assistance and then leave the chat. As an approved DoD communication platform, all posts are stored to comply with FOIA requirements. This provides a unique machine learning and artificial intelligence capability that a small team within the AOC Strategic Requirements Division has begun exploring.

The resilient and distributed nature of a platform like Mattermost increases mission velocity and safety while securing communication and file sharing at the appropriate impact level. Today, the AOC coordinates with aircrew in a first-come, first-served order as established without priority by telephone switchboards. Furthermore, requests are limited to the available phone lines – if all lines are busy or the call goes unanswered, aircrew must wait and attempt to communicate synchronously later. The currently centralized operation of C2 runs counter to the doctrinally stated central tenant of airpower. Disruption of a C2 Center (like an AOC) would wreak havoc on telephone communications between distributed aircrews and a newly distributed C2 apparatus. C2 personnel could decentralize to overcome the disruption (innocent or adversary-caused) but aircrew would have almost no way to know what telephone numbers to call to reestablish communication. Mattermost, at IL 4, bridges the gap between remote users and command and control personnel – truly enabling centralized control, distributed operations, and decentralized execution.

Overreliance on voice communication introduces increased opportunity and likelihood of open-source intercept. Many of the communication modes used to enable aircrew-C2 information sharing are unsecure. As seen in the Russia-Ukraine conflict, telephone voice and text message communication can easily be intercepted and triangulated, resulting in targeted strikes. Technology is rapidly evolving to the point where AI will be able to auto-transcribe all intercepts – to sense and make sense of what is being communicated, by whom, where, and when.

In a not-so-distant future, an unlimited number of requests could be received via asynchronous chat via a system like Mattermost. These inputs could then be filtered and prioritized by machine learning-enabled artificial intelligence – providing AOC personnel with an intentional order to respond via their limited resources. Additionally, efforts are underway to link Mattermost and GDSS to automate ADP delivery to crew-specific channels via mission number. All of these efforts aim to securely improve understanding and awareness between AMC's warfighters and those who enable them.

Recommendations for Action

- Fund Platform One Mattermost at the Major Command level to provide sustained access to mobility forces. Seek programmed funding to continue the development and use of this communication tool.
- Continue to develop other data connections and end-user applications to integrate

mobility requirements across micro-services (i.e., automated ADP delivery from GDSS to Mattermost mission channel, integrated use of Puckboard Scheduling, Puckboard Logging, and Mattermost.

- As hardware proliferation allows, consider funding an IL-6 (Secret) Mattermost instance. This would provide secure chat on a proven and user-familiar collaboration suite.
- Expand Mattermost interactions between aircrew and C2 beyond electronic file delivery. The system easily provides electronic ADP delivery but is capable of much more – single-source data stream where users can flow in or out of the information stream as required without duplicating message traffic. A single system that allows both synchronous and asynchronous communication (based on user needs and availability) is undervalued.
- Explore artificial intelligence and machine learning capabilities to understand, prioritize, and sort Mattermost requests for information or decisions. This would provide purpose-driven priority instead of first-come, first-served interactions between tactical users and C2.

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14. ABSTRACT
Research addressed communication between Mobility Air Force aircrew and command and control (C2) elements. Provides qualitative analysis of electronic communication via asynchronous collaboration tool Mattermost - hosted by DoD's Platform One. Further provides quantitative analysis of the relationship between aircrew departure paper request time and aircraft departure, relative to scheduled takeoff time. Research concluded that electronic delivery of aircrew departure papers provides earlier access to mission information which positively affects on-time departure rates. Asynchronous modes provide benefits to reliable, redundant, and distributed communication not available to synchronous modes, like telephones.

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