Small unmanned aerial vehicles with line of sight in the company fire support team

by

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Abstract

Nations have attempted to use Unmanned Aerial Vehicles (UAVs) on the battlefield since at least the First World War (Imperial War Museum, n.d.). However, the Russia-Ukraine War was the first war that saw widespread usage of the broad range of technologies that fall under the title Unmanned Aerial Systems (UAS). Both sides have used sophisticated multi-layered Unmanned Aerial Systems to engage targets with direct and indirect fires (CNA, 2023). It is undeniable that UAVs have significantly impacted the war, and other nations, including the United States, have become painfully aware that they are behind the curve in integrating UAS into every level of their militaries. Given the widespread usage of UAS in modern large-scale combat operations to detect artillery targets and increase fire mission processing speeds, the United States Army should integrate small UAVs (sUAVs) into company Fire Support Teams to increase their effectiveness in order to defeat near-peer adversaries. While the impact of UAVs is undeniable, it is still unknown exactly how much they improve the effectiveness of company-level Fire Support Teams.

Since artillery is such a core element of the Russian Way of War, artillery units were early adopters of UAVs in the Russia-Ukraine War (Cranny-Evans, 2023). The advantage of being able to observe targets far forward of the front line without needing to put troops within eyesight of the target is immense. Still, it is unknown exactly how much more effective these units are with UAVs. The purpose of this research would be to determine what improvements are made in the key performance indicators of a Company Fire Support Team when a small UAS is integrated into its operations. The key performance indicators to be measured are observable area, target detection, and fire mission processing.

A quantitative study with an experimental between-participant posttest-only control-group design was conducted to test these indicators. Eight Forward Observer teams composed of Kansas State University Reserve Training Officer Corps (ROTC) Cadets were separated into two groups. The control group was given basic fire support tools and occupied an observation post (OP). From that OP, each team had 10 minutes to identify as many targets as possible and process fire missions on them while maintaining Line of Sight with the UAV and the targets. Data on the key performance indicators were then compared to the data collected from the experiment group. The experiment group performed the same operation as the control group; except they were provided with a small UAV. Once the data was collected and analyzed, it was possible to begin to determine exactly how much the effectiveness of a company fire support team increased when a small UAV was integrated into its operations. This research did not examine the following factors: how the generated fire missions would be handled at the battalion level or above, the effects of large UAVs on the battlefield, how the current EW domain would affect the UAVs in question, or how fires planning would be affected by the introduction of UAVs at the company level.

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Dedication

I am dedicating this thesis to the following:

My Lord and Savior, Jesus Christ

My wife, Anna Brantley

My children, JL and Allyssa Brantley

My parents, Jason and Danitta Brantley

My in-laws, Mike and Karen Corl

Thank you all so much for your support while I was in Graduate School.

Chapter 1 - Introduction

The United States Army has been attempting to use Unmanned Aerial Systems (UASs) in combat since the First World War (Imperial War Museum, n.d.). Since that first radio-control fixed-wing plane, designed to counter German dirigible airships, UASs have become integral parts of many countries' warfighting efforts. Over three dozen countries now have armed UASs in their arsenals (Bergen et al., 2020). With the proliferation of cheap, off-the-shelf UASs, almost all countries now have UASs used for intelligence, surveillance, and reconnaissance (ISR) (Bergen et al., 2020). While the concept of UASs is nothing new, the rapid evolution in their technology has radically changed the battlespace. There is no better example of this than the Russia-Ukraine War. Both sides of the conflict have integrated UASs into every echelon of their forces, especially at the lowest levels. The Russians, for instance, will often have three UAS networks in the air during an operation: one to scan for and monitor artillery pieces, the second to scan for targets and enemy forces in the close fight, and the third to accompany their maneuver forces (CNA, 2023). The increasing number and level of integration of UASs on the battlefield make them an issue no military can ignore.

The Department of Defense (DOD) breaks down UASs into groups. These groups are differentiated based on weight, altitude, and speed, with the smallest UAVs being Group One and the largest being Group Five (Department of the Army, 2023). See Figure 1 for the exact specifications of each group. Groups One and Two are classified as small UAS, while groups Three through Five are large UAS. While these groups help us understand UAS capabilities, it is essential to know that any UAS can be used to destroy or defeat most targets (Department of the Army, 2023). For instance, a group one UAS can destroy a Russian T-90 battle tank by dropping a well-placed mortar down an open access hatch (Detsch, 2024). The US Army currently has

UASs at all echelons but not at every warfighting function (Drones, 2024). The six warfighting functions are command and control, movement and maneuver, intelligence, fires, sustainment, and protection (Department of the Army, 2022). The warfighting functions provide a framework for the common critical capabilities available to commanders and staff at all echelons and levels of war (Department of the Army, 2022).

One notable omission is that the US Army does not have a small UAS for Company Fire Support Teams (FISTs). According to The Department of the Army's Training Publication "Observed Fires" (2017), also known as ATP 3-09.30 or simply the .30, a company FIST's mission is to integrate fires for the supported commander. The FIST does this by planning, coordinating, and observing all fires, including artillery, mortars, naval surface fires, army attack aviation (attack helicopters), and close air support (Department of the Army, 2017). In other words, they are the eyes of the commanders to shape the battlefield with all available fires assets. The Russia-Ukraine War has shown in the real world that UASs assist fire supporters in accomplishing all their tasks. The Reconnaissance Strike and Fires Complexes, Russia's targeting systems, primarily comprise UASs to locate and destroy indirect fire targets (CNA, 2023). Whether those targets are deep behind enemy lines and destroyed with missile artillery or destroyed with mortars in the current firefight on the front line, they are almost always observed with UASs (CNA, 2023). Given this widespread usage of UAS in modern large-scale combat operations to detect artillery targets and increase fire mission processing speeds at the lowest levels, the United States Army must integrate small UAS into Company Fire Support Teams to increase their lethality in order to defeat near-peer adversaries.

Group	Weight (lbs)	Speed (knots)	Normal Operating Altitudes (ft)	Notes	Threat & COTS Examples	US Examples
Group 1: micro/mini UAS	0-20	<100	<1,200 AGL	Generally, Generally, hand-launched commercial off-the-shelf, radio-controlled platforms. They have limited ranges and small payload capabilities. They offer real-time video. Operated within the user's line of sight, they offer real-time video. Operated within the line of sight of the user	DJI MAVIC, Enterprise Dual	RQ-11 Raven
Group 2: small tactical	21-55	101-250	<3,500 AGL	Small airframes with low radar cross sections provide medium range and endurance. Launched from unimproved areas with a small number of people involved. Requires line of sight to the ground control station.	SKY-09Ps	Scan Eagle
Group 3: Tactical	56-1,320	101-250	< FL 180	Similar to Groups 1 and 2, UAS requires a larger logistical footprint. Range and endurance vary significantly among platforms	Shahed	RQ-7B Shadow
Group 4: Strategic or theater	>1,320	Any speed	> FL 180	Relatively large systems operated at medium to high altitudes. This group has extended range and endurance capabilities. Usually, it requires a runway for launch and recovery.	Forpost	MQ-1C Gray Eagle MQ-1A/B Predator
Group 5: Strategic	>1,320	Any Speed	> FL 180	Operates at medium to high altitudes and has the greatest range, endurance, and airspeed. Requires a sizeable logistical footprint like that of manned aircraft and has a suite of optics for targeting and weaponry for engagements	Wing Long II	RQ-4 Global Hawk MQ-9 Reaper

AGL – above ground level COTS – Commercial-off-the-shelf DJI – Da-Jiange Innovations FL – Flight Level	Ft – Feet Kts – Knots Lbs – Pounds MQ – American military drone	RQ – Reconnaissance unmanned aircraft system UAS – Unmanned aircraft system

Figure 1.1 Counter-Unmanned Aircraft Systems, 2023

The advantages of allocating small UASs to company Fire Support Teams seem apparent. As the eyes of the commander, they must see as much of the battlefield as possible; a small UAS would give that to them in spades. They also need to positively identify targets and process fire missions to achieve the desired effects on these targets. Again, a UAS with the proper optics would seem to provide this. The Russia-Ukraine War has undoubtedly demonstrated that these assumptions work in practice. However, what has not been demonstrated is how much the key performance indicators of a Fire Support Team improve with the use of UASs. The purpose of this research is to determine what improvements are made in the observable area, target detection, and fire mission processing when a small UAS is integrated into a Company Fire Support Team while keeping the UAS and targets in direct line of sight. This information will give commanders and staff of the US Army a better understanding of what small UASs bring to the fight when used by a company FIST.

This research did not examine the broader effects of these UASs on the battlefield. This research was restricted to the company level; planning or coordinating their use at the battalion level and above was not considered. This research used a group 1 UAV as classified by the DOD, and the participants kept the UAV withing line of sight and the targets within line of sight. This research also did not consider electronic warfare (EW) or other counter-UAS (C-UAS) systems used by the US or other militaries. C-UAS is a rapidly developing domain within militaries across the globe, and including their use in this study would render it out of date within months and would be prohibitively expensive to enact.

Chapter 2 - Literature Review

According to The North Atlantic Treaty Organization (NATO), the assumed decisive factor for success in battle is having an information advantage (Nobert, 2023). An information advantage allows commanders to make quick and accurate decisions before the enemy can organize against their actions. Unmanned Aerial Vehicles have long been one of many avenues for gaining that advantage. Since their development in the 19^{th} century, they have been mainly designed for military use (Ahmad et al., 2024).

History of UASs

UASs were first used in the mid-19th century when hot air balloons were employed for military reconnaissance (Ahmad et al., 2024). This practice continued for some time and evolved, leading to early forward observers (FO) using balloons to direct artillery fire in the First World War (Morgan, 1960). Other unconventional tactics were also experimented with in the early 20^{th} century. In 1903, cameras were strapped to pigeons' breasts for aerial reconnaissance by the Bavarian Pigeon Corps (Ahmad et al., 2024). The first quadcopters, a vehicle with four rotors to control flight, were developed during this same time (Darack, 2017). These were manned vehicles but are the predecessors of the popular quadcopters dominating today's small UAS commercial market. These earliest UASs all had a similar mission of gathering intelligence and conducting reconnaissance (Ahmad et al., 2024). These early examples show that trying to put eyes in the sky for observers is nothing new. So, when small UASs became easily available, with good cameras, using them to direct fire was a natural extension of the past.

The US Army’s first UAS was developed in 1917 and was known as the Kettering Bug, which is seen as the precursor to modern cruise missiles (Ahmad et al., 2024). The Kettering Bug

Figure 2.1 LaRock, K. (n.d.) Kettering Aerial Torpedo "Bug". [Photograph]. National Museum of the Unites States Air Force. Dayton, OH, United States.

was launched from a dolly and portable track like many fixed-wing medium-sized UASs today. Once launched, the UAS would be guided toward its target using pneumatic and electrical systems for a preset length of time. Once that time was reached, it shed its wings and dived towards the earth, and its 180-pound explosive payload would detonate on impact. The Bug never saw combat; less than 50 were built before the armistice ended the First World War (National Museum of the United States Air Force, n.d.). However, the basic idea of strapping explosives to a fixed wing aircraft to deliver them to a target is still used today. For example, on April 13th, 2024 Iran fired 170 UASs, along with ballistic and cruise missiles, at Isreal. Among the UASs where Shahed 136's which are Iranian made have the same basic design as the Bug (Terajuma, 2024).

Figure 2.2 Horton, W. (n.d.). Winston Churchill standing with DH 82B Queen Bee. [Photograph]. Imperial War Museum. London, UK.

During the inter-war period, many radio-controlled aircraft were developed as targets for anti-air gunnery (Imperial War Museum, n.d.). During this time, it is believed that the slang word "drone," meaning UAS, was first used. The word was inspired by the name of the DH 82B Queen Bee, developed by Great Britain for target practice (Ahmad et al., 2024). The US military also created the radio-controlled aircraft Radioplane-OQ2. It was designed for artillery spotting, showing the deep roots that many modern tactics are not as new as many believe them to be (Ahmad et al., 2024). During World War II, the Germans also made developments in UAS technology. The V-1 Flying bomb was the first UAS and missile propelled by a jet engine (Ahmad et al., 2024).

After the Second War, attention was put back on aerial reconnaissance. The US Air Force began developing the Lockheed D-21 and Ryan Model 147 (Ahamd, 2024). These UASs show a massive step forward in technology. The D-21 was designed to conduct high-speed, high-altitude strategic reconnaissance. Its D-21B model was capable of speeds of over Mach 3, with a range of 3,000 miles and a max altitude of 95,000 feet (National Museum of the United States Air Force, n.d.). The D-21 went on four flights over communist China during the Cold War under the code name "Senior Bowl," but the missions were ultimately unsuccessful.

Figure 2.3 U.S. Air Force. (n.d.). Lockheed D-21B. [Photograph]. National Museum of the United Sates Air Force. Dayton, OH, United States.

The 1990s and 2000s saw significant growth in using UASs for military purposes. While UASs from the previous decades saw thousands of hours of use, several systems, such as General Atomics' Predator, Northrop's Global Hawk, and Boeing's Scan Eagle, have accumulated hundreds of thousands of operating hours (Ahamd, 2024). These increased operational hours are explained in two parts. One is simply the improvement of the technology; as UASs become more capable, they are used more. The

Figure 2.4 U.S. Air Force. (n.d.) MQ1-B Predator landing. [Photograph]. United States Air Force.

second reason is the Global War on Terror. From 2010 through 2020, the United States undertook over 14,000 UAS strikes in Afghanistan, Pakistan, Somalia, and Yemen (Rollins, 2023).

Also, during the 1990s, the first unmanned quadcopters were being developed (Darack, 2017). In 1999, the Draganflyer Quad Helicopter was released and quickly became popular among UAS researchers; it also had moderate public recognition because of its appearance in the movie *Inspector Gadget* (Darack, 2017). From there, it was only a matter of time and innovation before more complex systems were released. The first commercially successful quadcopter was released in 2010 by the French company Parrot. Their AR.Drone was also the first quadcopter controlled solely by Wi-Fi (Darack, 2017). In April 2015, 3D Robotics released their Solo Quadcopter, the first to allow professional video by attaching a GoPro camera (Darack, 2017). Shortly after, DJI released their very popular Phantom 4 UAS, which can track an object on the ground using machine learning.

Non-state armed actors quickly grabbed these quadcopters and other small UAS for their purposes. They have used them in a wide range of activities such as attacks against, and incursions into, vulnerable targets, including critical infrastructure or public places; for intelligence, surveillance, and reconnaissance; for targeting support; and for smuggling (United National Office of Counter-Terrorism, 2023). In 2020 alone, 65 terror attacks using UASs were recorded, a sharp increase since the early 2000s (United National Office of Counter-Terrorism, 2023). The UN estimates that 65 armed non-state groups now have armed and unarmed UASs. This shows that while state militaries have a much longer history of using UASs, non-state actors, since their resources are restricted, are using these emerging technologies and adapting them much more quickly than state actors.

The Russia-Ukraine War

However, these non-state actors with their UASs have not come close to the ubiquity and sophistication of the Russian and Ukrainian militaries. To understand the tactics and strategies of Ukrainian and Russian UASs, understanding their way of war is necessary. The animosity between the countries has deep roots. Vladimir Putin, and by extension, the Kremlin in Moscow, sees the independence of Ukraine as a form of Western aggression and a piece of the "anti-Russia" agenda of the West (Mankoff, 2022). He has long believed that Ukraine, Belarus, and Russia should be united under one government since they all share a cultural and linguistic origin in the Kyivan Rus commonwealth. They were also united under the Grand Princedom of Moscow and the Soviet Union before its fall in 1991 (Mankoff, 2022). While this view is often bewildering to Westerners, it is a standard view in the elite circles of Russia (Mankoff, 2022).

In Putin's speech on February 21st, 2022, Putin used the reasoning above to justify his upcoming invasion of Ukraine (Mankoff, 2022). It was a nearly unanimous consensus of strategists at the time that the war would be swift and Ukraine, or at least the eastern parts of the country, would fall to Russia (Nobert, 2023). However, thanks to a relatively new sense of patriotic identity and an immense influx of weapons and training from the West, Ukraine held back the invasion and has since been at war with Russia (Nobert, 2023).

The Russian and Ukrainian ways of war are similar, thanks to their shared history. For this study, both country's militaries will be categorized under the Russian way of war. While Ukraine has learned a great deal from its Western allies, which has been one of the critical factors in their success so far, their central framework for war is still, in essence, "Russian" and the central pillar in the Russian way of war is artillery (Cranny-Evans, 2023). A common expression to signify the difference between Western militaries and Russian militaries is

“Western forces fire [artillery] to maneuver, Russian forces maneuver to fire [artillery]” (words in brackets were added for clarity) (Cranny-Evans, 2023). At the beginning of the war, Russian doctrine dictated that for every Battalion Tactical Group (BTG), a battalion of artillery was to be attached (Cranny-Evans, 2023). Most BTGs consist of 700-800 soldiers capable of raids, envelopments, and flanking maneuvers, and are the Russian system's lowest level of combined arms formation (Bartles & Grau, 2022). The attached battalions can vary in size and composition. However, they typically consist of two cannon batteries and a rocket company, providing immediate fire support in the close and deep fight (Reynolds, 2023).

The typical American maneuver-artillery relationship is to have a battalion of howitzers attached to a brigade combat team (Department of the Army, 2016). A typical Brigade will have four to six thousand soldiers, while the attached artillery battalion will have three batteries of six howitzers each (Cranny-Evans, 2023). This disparity of soldiers per supporting howitzer shows that artillery is Russia’s primary form of lethality in deep battles and close ones (Cranny-Evans, 2023). This paradigm of war can also be seen in the number of shells that each side of the Russia-Ukraine war lobbed at the start of the war. It is estimated that between 12,000 and 38,000 artillery rounds were fired daily (Reynolds, 2023). However, as the war dragged on, ammunition shortages forced both sides to change tactics (Reynolds, 2023). While both sides of the war had used UASs since the start of the war, they began using them in the most sophisticated ways as the ammunition shortage deepened.

Use of UASs in the War in Ukraine

The Russia-Ukraine war is the first large-scale conflict in which both sides employ robust UAS-ISR complexes (Halem, 2023). Since before the war, Russia has integrated UASs into its ISR system (CNA, 2023). However, since Russia expected this to be a relatively short war, they were slow in innovating their system (CNA, 2023). They began the war with what they called the Reconnaissance Strike Complex (RSC) and the Reconnaissance Fire Complex (RFC). The complexes consisted of several sensors and platforms that increase the accuracy and lethality of their artillery, along with supplying real-time battlespace awareness (CNA, 2023). The RSC and RFC increased the lethality of their artillery by improving their target acquisition. The UASs identified enemy artillery, command posts, communications centers, strongholds, troop concentrations, and training camps for target acquisition. They were also used to identify and adjust rounds for counter-battery fire (CNA, 2023). All these tasks were performed by type three, four, and five UASs (CNA, 2023). So, while UAS played a major role in the early fighting they were not the small UAS which is the focus of this study. Most of these UASs developed before the war were classified as ISR UASs, and the development of combat UASs lagged considerably for Russia (CNA, 2023).

Ukraine, meanwhile, entered the war with very few UASs (CNA, 2023). However, with the help of Western allies, cheap off-the-shelf UASs, and internal production, the Ukrainians quickly caught up with Russia (Axe, 2024). It is estimated that in early 2024, more than 50,000 UASs were produced a month in Ukraine (Axe, 2024). Most of which were small first-person-view UASs (FPVs) that carry a small payload. Still, the Ukrainians devised tactics, techniques, and procedures to maximize their effectiveness (Axe, 2024). For instance, the Ukrainians employ FPVs as part of a two-man team. One is flying an ISR UAS, often a DJI Phantom or something similar, to identify targets. Once they have locked onto a target, the FPV, which has a much shorter flying time, often only 5-8 minutes once loaded with munitions, will take off and fly directly to the target before detonation (Axe, 2023). The Ukrainians also use FPVs to reduce the number of shells they fire by coordinating FPVs with artillery. The Ukrainians will fire a volley of artillery at a target, and then once disorganized troops and vehicles begin to flee, the FVPs will fly in to attack them. This has reduced the amount of artillery shells needed to produce the same desired effects by half (Axe, 2023). These tactics, are not what is to be studied here, but they show how flexible UASs can be on the battlefield.

As mentioned above, small drones' flexibility is why they quickly became the most sought-after platforms in the war (CNA, 2023). They are also much more likely to avoid detection by enemy radar and EW because of their small size (CNA, 2023). Ukrainians often simply ram Russian UASs out of the air with their UASs because it is the simplest and most cost-effective option (CNA, 2023). However, even with all the new tactics being developed for small UASs, their primary purpose remains to be ISR assets to assist in artillery fire.

The most significant difference in how the two countries use their small UASs is their integration into each echelon. The Russian small UASs are used at battalion and below, while the Ukrainians broadcast the real-time data for their small UASs to a higher command and control level (CNA, 2023). Integrating this information flow at a higher level allows the decision-makers to approve fire missions faster, translating into rounds on target faster than the Russians.

United States Army and UASs

Since the First World War, the US military has continued to innovate and produce more sophisticated UASs. Today, they have an impressive lineup of UASs ranging from the type 1 Raven, which is 5 pounds, backpack portable, and can loiter for eighty minutes, all the way up to a type 5 RQ-4 Global Hawk, the largest operational UAS the US military uses at the time of this study (Drones, 2024). However, the Raven is currently being phased out of service (Congressional Research Service, 2024). To replace it the Army has decided to use the RQ-28, which was a small quad copter and was distributed to specialty units (Helfrich, 2022). However, the Army stopped production of the RQ-28 and is now fielding the X10D Quad copter from Skydio (Skudio, 2025). These and other change reflect The Department of Defense allocating over 80 million dollars to procuring, researching, and developing UASs in the Fiscal Year 2025 (congressional Research Service, 2024). The US Army knows they are falling behind in UAS technology and tactics on the world stage. However,

Figure 2.5 Miller, M. (April, 2025). ***Army accelerates fielding of advanced sUAS.*** **[Photograph]. Defense Visual Information Distribution Service.**

the US Army has not mentioned allocating the new multirotor UASs to company-level Fire Support Teams specifically.

To see why allocating UASs to the Fire Support Teams is crucial to the success of the Army in large-scale combat operations (LSCO), the role and tasks of the Company Fire Support Team must first be understood.

The Forward Observer and The Fire Support Team

In the United States military history, artillery was originally a direct-fire weapon system. Howitzers would be rolled up close to or on the front lines of a battle, where they would fire on the enemy (Morgan, 1960). The person directing the fire was the battery's commanding officer, who stood directly next to or behind the firing line (Morgan, 1960). It was not until the American Civil War that someone not at the firing line directed the cannons (Morgan, 1960). At the battle of Norfolk in 1862, the Confederates held Norfolk, and the Union army had to defeat them before they could march towards Richmond. To allow the infantry to maneuver, the Confederate cannons on the mainland needed to be destroyed. The Union howitzers could shoot far enough to destroy them, but they could not see the enemy guns from their position at Fort Monroe. When the time came to mount their offensive, Major Myer, a Signal Officer, boarded a steam tugboat with a small team. His team proceeded to a point where they could observe the fire of the guns, and the shelling began. As each shell fell, its effects and the adjustments needed were transmitted to the battery by flag signals from the tugboat (Morgan, 1960). This was the first time the role of the Forward Observer was used in combat.

It was not until the First World War that Forward Observers became the standard operating procedure for directing artillery fire (Morgan, 1960). At the beginning of the war, both sides still used old tactics that used artillery on or near the front lines. They quickly discovered that artillery crews were no match for automatic rifle fire and that if howitzers got too close to the front lines, they would quickly be captured and used by the enemy (Morgan, 1960). It was in 1916 that the Forward Observer was officially recognized in doctrine (Morgan, 1960). From there, the role continued to develop into what we have today.

Currently, the US Army employs Forward Observers at maneuver platoons. A Forward Observer, along with his Radio Telephone operator (RTO), is the primary fire support representative for the platoon leader (Department of the Army, 2017). The FOs are a part of the Company Fire Support Team (FIST), which consists of a Company Fire Support Officer (FSO), a Company Fire Support Sergeant, and one to three Forward Observer teams (Department of the Army, 2017). The Mission of the Company Fire Support Team, according to the Department of the Army's Training Publication "Observed Fires" (2017), is "… to integrate fires for the supported commander." It goes on to say that to accomplish this mission, there are seven key tasks that they must perform. They are Fire Support Planning, Fire Support Coordination, Target Location and Calls for Indirect Fire, Battlefield Information Reporting, Observing Close Air Support, Observing Army Attack Aviation, and Observing Naval Surface Fire Support (Department of the Army, 2017).

For the purposes of this study, three of these tasks need explanation: Target Location, Calls for Indirect Fire, and Battlefield Information Reporting. Target location and calls for fire consist of the FIST finding the required targets, acquiring an accurate location of the target, and processing a fire mission, which is the request sent to higher headquarters for artillery or other fires assets to fire on the target (Department of the Army, 2017). Battlefield Information Reporting consists of the FIST relaying accurate information to the relevant command and control node. The FIST will compile a list of everything they see and report it to both the commander of the maneuver company they are supporting and to the fires cell at battalion. In this task, they act as the eyes of the maneuver commander and the artillery (Department of the Army, 2017).

A Company FIST's key tasks directly relate to how well they can see. This is why they are often forward of the front lines and on the greatest elevation they can find while remaining hidden. They must see as much of the battlefield as possible to be maximally effective (Department of the Army, 2017). This is why the absence of a small UAS in the Company FIST is such a glaring deficiency. A small ISR UAS would significantly increase the amount of the battlefield that they can see. It would also increase target location accuracy thanks to GPS and other sensors that most UASs come equipped with, along with the second vantage point if they can see he target from the ground. While it is certain that small UASs do help in artillery target detection and destruction, how much they improve the key performance indicators has not been studied before this report.

Chapter 3 - Methodology

The war in Russia and Ukraine has demonstrated practically that small UASs can change the battlefield. When paired with other sensors like radar and EW assets, they have been shown to decrease counter battery times to as little as two minutes (Guest, 2024), while average artillery engagements have been reduced to 3-5 minutes (Reynolds, 2023). However, these improvements have been due to the entire system of the reconnaissance strike complex of Russia and Ukraine. It is impossible to isolate the improvements made by integrating small UAS so the US military can best allocate money and research to improve their fires system. So, the question remains: How much will key performance indicators improve if the United States Army integrates small UAS into its Company Fire Support Teams?

Experiment Design

A quantitative study with an experimental between-participant posttest-only control-group design was devised to answer the above question. Christensen et al. (2015) categorize this type of test as a strong experiment design, and Glenn et al. (2013) showed how a posttest-only design better reflects real world results. A short explanation of the experiment will be given, and the rest of the chapter will go through the reasoning for selecting the design, the participants, the measurement techniques, the data collection techniques, why the data is valid, why the experiment is internally and externally valid, and the control measures used.

The Experiment

A quantitative study with a between-participant posttest-only control group experimental design was conducted to test whether the US Army should integrate sUAS into its Company Fire Support Teams. An off-the-shelf UAS, a DJI Mavic 2 Zoom, was given to four of the eight Fire Support Teams, along with the basic fire support equipment of binoculars, a map, and a compass.

To see which key performance indicators improved, they were compared to four Fire Support Teams with only the basic tools. Each team consisted of a Forward Observer and a Radio Transmission Operator. The key performance indicators measured were observable area, target detection, and fire mission processing. Each of these had its own measure of effectiveness. The observable area was measured in square kilometers. Target detection was measured by the number of targets positively identified with a target location error of less than 250 meters. Target location error is the difference between the location supplied by the team and the actual target location. Lastly, fire mission processing was measured by the time from target identification to a fire mission being transmitted. One team at a time was taken to the training area with multiple targets in the target area. They were given their mission to establish an observation point (OP) at a given location, identify as many targets as possible, and process fire missions on them in 15 minutes. The results were then collected and compared to see which indicators, if any, improved.

Expanded Explanation of the Experiment

A between-participants posttest-only control group design was primarily chosen to control for internal validity threats. The typical internal validity threats are history, maturation, instrumentation, testing, regression artifact, attrition, selection, additive/interactive effects, and other unknown errors (Christensen et al., 2015). This design controlled these threats by having a control group and randomly assigning the participants to either the experimental group or the control group (Christensen et al., 2015). Controlling these variables and threats ensured that any observed difference between the groups could be attributed to introducing the independent variable, in this case, the integration of the small UAS.

The between-participant posttest-only control group design does have one significant weakness. The assurance of equivalence of the groups is not guaranteed (Christensen et al., 2015). Randomly assigning participants to the two groups does help with equivalence, but without the presence of a pretest, it cannot be tested for. This problem is even more prevalent when the participant group is small (less than 30), which was the case for this study (Christensen et al., 2015). However, this study also included matching along with the randomization technique to increase the probability of reaching equivalence between the groups.

Other confounding variables were also threats to internal validity specific to this test. One was the weather during the separate iterations of the test. Weather conditions considerably impact visibility, and a reduction in visibility would significantly alter the measurements taken. The test was conducted over the span of roughly 4 hours with no appreciable changes in weather conditions. Eliminating weather as a variable to consider.

To ensure that the scenario in the experiment was valid, content-based evidence was collected. Content-related evidence is based on the judgment of relevant experts on whether the test adequately represented what the researcher was trying to test for (Christensen et al., 2015). In this case, the methodology was presented to three Field Artillery Officers in the United States Army: Captain Joseph Kinsey, Major Koochel, and Colonel Shawn Miller. All have a combined experience of over 50 years in Field Artillery and have held positions ranging from Fire Support Officer to Field Artillery Brigade Commander. For the remainder of this paper, COL Miller, MAJ Koochel, and CPT Kinsey will be referred to as “the experts.” The research design was presented to the experts, and they were asked three questions pulled from Christensen, Johnson, and Turner’s *Research Methods, design, and Analysis twelfth edition Global edition* (2015):

1. Do the key performance indicators represent what the research attempts to measure?
2. Do the selected key performance indicators underrepresent what the researcher is attempting to measure?

3. Do any key performance indicators represent something other than what the researcher is trying to measure?

The full responses can be seen in Appendix A, however, a summary of the expert's responses, along with the mitigating actions taken, is shown below:

1. Do the key performance indicators represent what the research attempts to measure?
    a. The experts all agreed that the key performance indicators chosen are accurate indicators for Fire Support Effectiveness.
2. Do the selected key performance indicators underrepresent what the researcher is attempting to measure?
    a. The experts had two major concerns when it came to underrepresenting what the research is attempting to measure. Firstly, the average observer-target distance (OT distance) needed to be considered. If the OT distance did not accurately represent what an average company or platoon might expect to see in a large scale combat operation the results would be less useful, because it is expected that as your OT distance increases the target location error will also increase. To mitigate this the average OT distance was added in the analysis of the data for each group. This will allow leaders to recognize If the average OT distance is greater in the experiment group or control group. It will also allow leaders to gauge what the expected target location error would be at different distances. Secondly, they pointed out that this research was attempting to measure was not lethality as was originally written, but more precisely Fire Support Effectiveness. This shift in wording was made throughout this research to be more precise.

3. Do any key performance indicators represent something other than what the researcher is trying to measure?
    a. The experts were unanimous in their agreement that the key performance indicators did not represent something other than what the researcher is trying to measure.

Another threat to construct validity is the disruption effect. Participants in a study typically perform worse when something disrupts their routine (Christensen et al., 2015). In this study, the participants were in their third year of the Army's Reserve Officer Training Corps (ROTC) at Kansas State University and had received practically no training on using a small UAS in their operations. To mitigate the disruption effect, an experienced UAS pilot from the Kansas State University Department of Unmanned Aircraft Systems was used. The pilot was instructed not to assist the participants except for piloting the UAV where the participants directed him to. By using a pilot, the participants were able to focus solely on their fire support tasks but also had all the advantages of the live UAV video footage without being burdened by operating a new technology.

Figure 3.1 ***Video Feed from UAS During Experiment***

Participants

The participants of this study were selected by convenience. Convenience sampling is a nonprobability sampling method where the participants are selected based on convenience rather than randomly selected from the population (Christensen et al., 2015). All the participants in this study came from the ROTC program at Kansas State University. In the ROTC program, all of the Cadets received several blocks of instruction on Call For Fire and Fire Support Operations. The participants also received a refresher block of instruction from the Kansas State University ROTC instructors two days before the experiment was conducted.

Since convenience sampling is not the preferred method of selecting participants, the results of this study cannot be generalized to all Fire Support Teams across the US Army. To make such a generalization, more studies like this one will need to be conducted with other participants (Christensen et al., 2015). One advantage to using the Cadets at Kansas State University is that their experience levels were very similar. The only confounding variables were Cadets with prior service to ROTC. To control this variable, the prior service Cadets were assigned to a group using matching. To match the prior service Cadets, they were listed in descending order according to their years of prior service. The Cadet with the most prior service was assigned to team one. The Cadet with the second most prior service was assigned to team two. This process continued until all of the prior service cadets were assigned to a numbered team.

Once the Prior service Cadets were taken care of, the non-prior service cadets were randomly assigned to teams. The random assignments will be conducted according to the method prescribed by Christenson, Johnson, and Turner in *Research Methods, Design, and Analysis, twelfth edition, Global Edition* (2015). The Cadets were assigned a number by sorting their last names alphabetically. The cadets were then assigned a number by numbering the first Cadet in the list with one, the next Cadet two, and so on and so forth. The Cadets were then assigned to teams randomly by using a random number generator. A random number was generated and the

Cadet associated with that number was assigned to team one. Another number was generated, and that Cadet was assigned to group two. This process continued until all eight teams were full of two Cadets each.

The teams with prior service Cadets were then matched into the experiment and control groups. Team one will, which had the Cadet with the most prior service, was assigned to the control group. Team two, which had the Cadet with the second most service, was assigned to the experiment group. The rest of the teams with prior service Cadets were assigned alternating down the list between the control and experiment groups. Once all of the teams with prior service had been assigned a team, the teams without a prior service cadet were randomly assigned to the experiment or control groups. The remaining groups were assigned by generating a random number between the first team without a prior service Cadet and eight using Random.org. The first number to be generated will go to the opposite group that the last prior service team was assigned to. For example, if the last team with a prior service Cadet was assigned to the control group, then the randomly generated team was assigned to the experiment group or vice versa. The next randomly generated team was assigned to the other group. This process continued until all of the teams were assigned to a group.

Dependent Variables

The dependent variables to be measured in this study are observable area, target detection, and fire mission processing times. A variety of techniques were used to measure these variables accurately. The observable area of the Fire Support Team was measured by taking the area given by the box delineated by the most north target positively identified, most west target positively identified, most east target positively identified, and the observation point. This area was calculated by taking the military grided reference system (MGRS) grids for the most east target and subtracting the grid from the most west target. This yielded the distance between the two targets in meters. The same was done for the furthest target north and the observation point. The two distances were then multiplied to give the area square meters. This was a ratio measurement, which is the highest form of measurement, meaning that it is fully quantitative, includes rank ordering and equal intervals, and has an absolute zero point (Christensen et al., 2015). The reliability of this measurement will be ensured by using interrater reliability, meaning that if all the experiment teams have a similar observable area, it can be assumed that the measurement method was reliable (Christensen et al., 2015).

Target Detection was measured by recording the number of correctly identified targets within the allowed time frame. For a target to count, it had to be positively identified, meaning a target description was given, and the location acquired by the team had to be within 250 meters of the actual target. 250 meters was chosen because it is the standard used for target location in the Fire Support rectification process (Department of the Army, 2020). The teams received a list of the types of targets they were to locate during their mission brief; if their target matched one of the targets on the list and was within 250 meters of the actual location, then it counted. Again, this was a ratio measurement, and interrater reliability confirmed the reliability.

Lastly, fire mission processing time was measured. The fire missions were verbally given to the researchers on the OP during the experiment. The time for each fire mission started once the Cadets confirmed that a target was identified. The time stopped once they said the last of the three transmissions of a standard US Army call for fire. An example of a call for fire and the explanation of its parts can be seen in figure 3.1, which is from the multi-service tactics, techniques, and procedures for joint application of firepower (Air Land Sea Space Application Center, 2023). The exact format is not essential for this study. However, all participants used this standard format so consistency could be achieved, and the measurements remained valid. Again, this was a ratio measurement, but test-retest reliability was used to ensure reliability. Test-retest reliability refers to the consistency of scores over time (Christensen et al., 2015). Since each team was measured multiple times on fire mission processing time, we could see if the results remain consistent over these iterations. It was expected that time will decrease as each team continues through the test as they get more comfortable with the test.

Table 6. Grid or Laser Grid Mission
Observer: "________________ **this is** ________________,   (FDC's call sign) (observer's call sign)   **(adjust fire, fire for effect), over."**   **"Grid** ________________________, **over."**   (minimum 6 digits)   Target Description: " __________________ ."   (target description, size, activity)   Method of engagement (optional): ____________   Method of fire and control (optional): ______________________ **"Over."**
Note: The observer announces a "laser grid" mission in the warning order. Send the target grid to a greater level of accuracy (8 or 10 digits, depending on observation post location accuracy). In an adjust fire mission, send corrections in the form of a grid to the burst location and announce, "burst grid".
Message to Observer
Adjustments
End of Mission
Legend: FDC—fire direction center

Figure 3.2 Air Land Sea Space Application Center. (2023, November). JFire: Multi-Service Tactics, Techniques, and Procedures for Joint Application of Firepower.

Analysis

Once data collection was complete, a descriptive statistical analysis was conducted. The statistics calculated were prescribed by Christenson, Johnson, and Turner in *Research Methods, Design, and Analysis, twelfth edition, Global Edition* (2015). The calculations began with finding the mean of each dependent variable for the control and experimental groups using the following formula.

$$\bar{\mathbf{X}} = \frac{\sum X}{n}$$

Where $\bar{X}$ is the sample mean, $\sum X$ is the sum of all of the data points for either group, and n is the number of data points.

Once the averages were found, the standard deviation was also calculated. The standard deviation was used later in the analysis when comparing the means. The following formula was used to find the standard deviation.

$$SD = \sqrt{\frac{\sum(X - \bar{X})^2}{n}}$$

Where SD is the standard deviation, X is each of the data points in the group being examined, $\bar{X}$ is the mean of the group being examined, and n is the number of data points in each group.

When the necessary descriptive statistics were complete, inferential statistics began. However, before inferential stastics could be calculated a null and alternative hypothesis was needed. For this study, the null hypothesis was that there was no difference between the means group with basic fire support equipment and the group with the small UAS across each dependent variable. The alternative hypothesis was that there was a difference between the two groups.

Null hypothesis $H_0: \mu_b = \mu_{uas}$

Alternative hypothesis $H_0: \mu_b \neq \mu_{uas}$

To accomplish this for each dependent variable, three tests were conducted: one for the observable area, one for the target identification, and one for the fire mission processing times.

Since the experiment had a categorical independent variable and a quantitative dependent variable, a one-way analysis of variance (ANOVA) was used (Christensen et al., 2015). The ANOVA test was used to see if the difference between the two groups was statistically significant (Christensen et al., 2015). Microsoft Excel was used to calculate the results of the tests, with an alpha level of .05. The alpha level is the point at which the researchers would conclude that the observed value of the sample statistic was sufficiently rare under the assumption of a true null hypothesis (Christensen et al., 2015). In other words, setting the alpha level at .05 means that the researchers had a 5% chance of incorrectly rejecting the null hypothesis.

Once the tests were run, the values obtained had to be examined. An ANOVA test was run using a right-skewed distribution known as the f distribution. The most important values to consider in Excel's results are the F value and the p value. The F value compared the difference between the groups. If the groups have a large difference, the F value will be large; if the difference is small, the F value will tend toward one (Christensen et al., 2015). The p value, also known as the probability value, indicates the proportion of the area in the sampling distribution that lies at or beyond the value of the test statistic. Thus, a very small p-value provides evidence to reject the null hypothesis. Since the alpha level for this test will be set at 0.05, any p-value smaller than 0.05 will result in the researchers rejecting the null hypothesis.

If the alternative hypothesis is true, given the careful design of the experiment to mitigate known and unknown confounding variables, it can be assumed that the difference in the two groups is attributable to the small UAS. However, this only answers half of the questions this study aims to answer. It is still unknown how much the integration of the small UAS helped the experimental group. Two tests will be conducted to find these values.

Firstly, an unstandardized examination of the differences between the groups was conducted. This was done by taking the averages for each variable for the experimental group and subtracting the averages from the control group. This gave a raw value for each variable, showing how many more square kilometers were observed, how many more targets were detected, and how much faster the mission processing times were on average. These raw values were then converted into a percentage for ease of understanding.

Secondly, a standardized examination of the differences between the groups was conducted. Cohen's d is a popular choice for measuring the difference between means of groups, so it was used in this study (Christensen et al., 2015). Cohen's d is known as an effect size indicator, meaning it is a standardized measure of the magnitude of difference between means. The results from running this test gave the number of standard deviations one group is away from the other (Christensen et al., 2015). It was calculated by subtracting the means of the two groups and dividing it by the standard deviation of the control group (Christensen et al., 2015).

$$d = \frac{M_1 - M_2}{SD}$$

Where M_1 is the mean of the experimental group, M_2 is the mean of the control group, and SD is the standard deviation. When finding Cohen's d, a result of 0.2 or less is considered small, 0.2 to 0.5 is considered medium, and 0.8 and up is considered large.

Chapter 4 - Analysis

On May 2nd, 2025, the Cadets of Kansas State University ROTC went up to Bluemont Scenic and conducted the experiment. The weather was perfect for flying, with excellent visibility during the duration of the experiment, which can be seen in from the historical weather data in Table 1.

However, no statistically significant difference was found in any of the dependent variables. There are several factors that may have led to this beyond the independent variable of adding a UAV. This chapter will go on to detail the factors that affected the results when discussing each dependent variable. However, one overarching factor was the participants' reluctance to use the UAV. During the experiment, the experimental group was still in line of sight of the targets. The Cadets often found it easier to just use the basic tools of Fire Support rather than the drone. This will be expanded upon more in the next chapter, but it is important to keep in mind while reviewing the results.

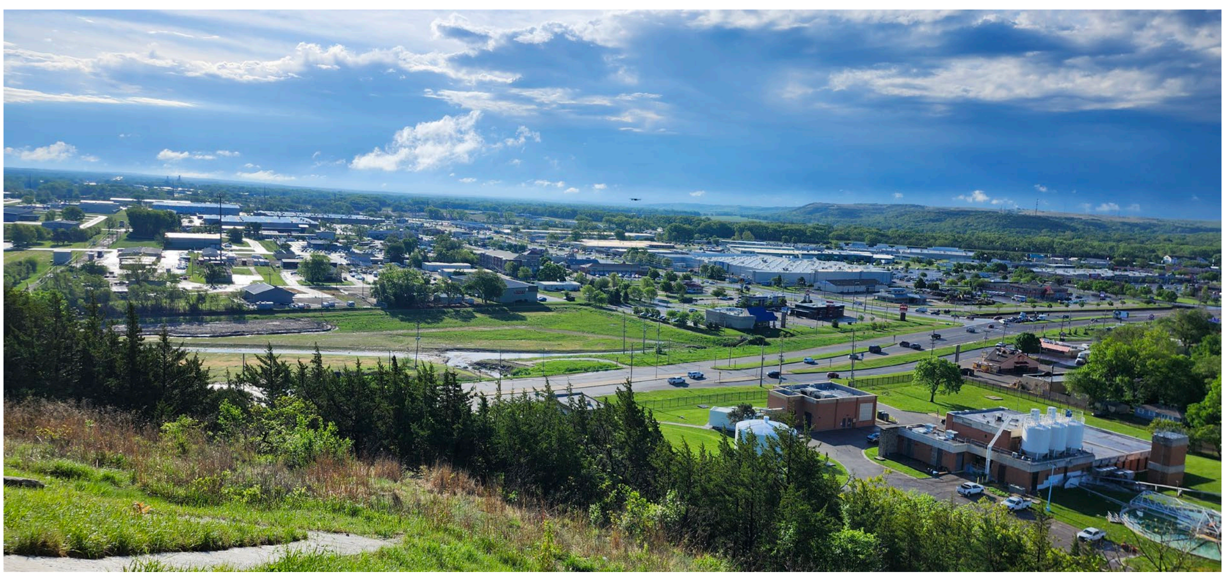

Figure 4.1 ***View from Bluemont Scenic Overlook on the Day of the Experiment***

Fri, May 2	Conditions		Comfort				
Time	Temp	Weather	Wind	Direction	Humidity	Barometer	Visibility
8:52 AM	56 °F	Sunny.	7 mph	S	84%	29.96 "Hg	10 mi
9:17 AM	56 °F	Partly sunny.	6 mph	ESE	77%	29.97 "Hg	10 mi
9:36 AM	56 °F	Partly sunny.	7 mph	SE	77%	29.96 "Hg	10 mi
9:52 AM	57 °F	Broken clouds.	7 mph	SE	74%	29.96 "Hg	10 mi
10:10 AM	58 °F	Broken clouds.	7 mph	ESE	72%	29.96 "Hg	10 mi
10:30 AM	59 °F	Partly sunny.	8 mph	ESE	69%	29.97 "Hg	10 mi
10:52 AM	60 °F	Scattered clouds.	8 mph	ESE	62%	29.96 "Hg	10 mi
11:52 AM	59 °F	Broken clouds.	3 mph	S	64%	29.96 "Hg	10 mi
12:52 PM	63 °F	Broken clouds.	3 mph	S	52%	29.96 "Hg	10 mi

Table 1 Weather Underground. (2025, May 2). ***Manhattan, KS Weather History.***

Results

As mentioned in the previous chapter, the raw data were analyzed in reference to three dependent variables: observable area, target detection, and fire mission processing times. Table 1 has the analyzed data that will be interpreted.

Dependant variables		Average	Standard Deviation	Δ of Averages	Δ as %	Cohen's d	P Value
Observable Area (Km^2)	Control	0.72	0.33	0.07	9.34%	0.20	0.78
	Experiment	0.79	0.34				
Target Detection (#)	Control	6	5.89	1.25	20.83%	-0.21	0.73
	Experiment	5	3.50				
Fire Mission Processing Time (s)	Control	58	50.28	20.53	0.36	.41	0.11
	Experiment	78	51.66				

Table 2 Analyzed Results of the Experiment

Observable Area

The observable area of the control and experiment groups respectively, were 0.72 KM^2 and 0.79 KM^2 . While this is a 9.34% difference, the standard deviation was .33, which leads to a very wide bell curve. Meaning that the p-value was 0.78. which is well below the 0.95 required to deem the difference statistically significant.

There are several factors that the researcher believes led to this result. One being that the Cadets had a very target-rich environment. This was, however, by design. The Cadets had a very limited time frame in which they could participate in the experiment. The experiment had to be conducted during their scheduled lab section of their class. So, only two hours were available to get all teams through the experiment. This left only 15 minutes for each team to find targets. If there were relatively few targets, the Cadets would have only found one or two targets, leading to sparse data to analyze. Since there were many easily identifiable targets, the Cadets did not need to look far and wide to fill their 15 minutes. This is further evidenced by the fact that 65% of the targets were found by multiple groups.

Target Detection

For a target to count for this experiment, two requirements needed to be met. First was that the target matched what was given on the high-value target list. Second was that the target location error, the distance from the location passed during the Call for Fire and the actual location of the target, must be less than 250 meters. In total, 61% of all the targets were within both of those requirements. One team, in fact, had no Targets within the 250-meter limit. This led again to a high standard deviation, which led to a p-value of 0.73, meaning that there was no statistical difference between the control and experimental group. The wide range of ability levels in the Cadets on call for fire was no doubt the culprit of the high standard deviation.

Fire Mission Processing Time

The story of fire mission processing times is much like target detection and the observable area. There was no statistical difference between the control and experimental groups. The reason for this is likely the high standard deviation. This is again attributable to the Cadets' inexperience with Call for Fire. The longest fire mission processing time in the control group was 217 seconds, while the shortest was 17 seconds. Their inexperience is further evidenced by the fact that all of the team's fire mission processing times trended down as the experiment progressed. Meaning that each team's longest time was their first Call for fire, and the times got shorter, sometimes significantly shorter, the more missions they called. For instance, the last time recorded for the team with the longest time of 216 seconds was just 36 seconds. This wide range in times led to the lowest p-value of any of the dependent variables, only 0.11.

Chapter 5 - Conclusion

Discussion

While there was no statistical difference between the control and experimental group, the results still give us two important pieces of information about using a sUAS in a Company Fire Support Team. Firstly, a UAV is not terribly useful in a target-rich close fight without changes in tactics, techniques and procedures. Second, a UAV does not degrade the key performance indicators of a Company Fire support team, even one with very little experience. These two points of information are good news for the Army. As the US Army transitions from a counterinsurgency (COIN) fight to large-scale combat operations (LSCO) both points will become very useful to know.

As the Army moves to organize and fight LSCO, fighting "in depth" becomes increasingly important. Fighting in depth is a military concept first put forward by the Soviet Brigade Commander Georgii Amoliovich Isserson in his 1937 book *The Evolution of Operational Art.* On page 55, he states, "A modern operation is an operation in depth. It must be planned for the entire depth, and it must be prepared to overcome the entire defensive depth. Moreover, it must be anticipated that the intensity of resistance within this depth tends to increase and grow denser from front to rear." In simpler terms, he means that just breaking through a front line in modern conflict is not enough. We must be able to destroy an enemy on the front line and then continue the initiative and fight towards the enemy's rear. However, to do this effectively, the Army must be able to neutralize the enemy's deep defenses, like artillery and air defenses. This has been exactly what Russia and Ukraine have used their UASs for. So the fact that this experiment found that UAVs are not more effective in a target-rich close fight still leaves the opportunity for increases in the performance indicators in a deep fight.

The fact that adding a UAV to a company's fire support team did not degrade any of the KPIs is also very significant. This means that with little training, the U.S. Army can add UAVs to their fire support teams and not see a dip in effectiveness. While more research is needed to find the actual advantages of adding the UAV, we can rest assured that it will at least not hurt effectiveness in the scenario fabricated for this experiment.

Recommendations

Further research to discover the advantages of a UAV integrated into a Company Fire Support Team is still needed. If a researcher decides to further investigate this topic, several recommendations can be made.

Experiment Design

Firstly, the design of this experiment could be altered to better test the dependent variables. One such change would be to move the experiment group out of the line of sight of the targets. The participants in the experimental group of this study had to be consistently reminded to use the UAV that was available to them. The participants often found it easier and more expedient to just use the basic fire support tools that they had. Moving them to an area where they no longer had a line of sight would force them to use the UAV. This does come with more logistical complications, however. For instance, Title 14 of the Code of Federal Regulations, Part 107.31 restricts small UAV flights to line of sight only. Meaning that the pilot must be able to see the aircraft at all times. So, communications between the pilot and the teams become more complicated, and it restricts the distance that the pilot can fly to find targets.

Despite the complications in experiment logistics, this change would be needed to accurately test for the dependent variables.

Another change to the experiment design would be to restrict the number of targets and to make them harder to find. The target-rich environment of this study led the participants to finding many of the same targets within a small area. If there were fewer and more dispersed targets, the participants would have had to look further and wider for targets, leading to better results for the observable area and target detection. However, if another study had too few targets, this could also hurt the experiment. If there are too few targets, then the observable area dependent variable could be essentially pre-determined because of the relatively few targets to find.

Related to this last point, the time frame of the experiment is critical. In this experiment, time was very condensed. Each team only had 15 minutes to find targets and call missions on them. This was due to the time constraints of their lab sections. If they had been given more time, they likely would have found more targets in a wider area, leading to better results.

Participants

The KSU ROTC Cadets used for this experiment did a fantastic job. For their level, they exceeded all expectations. However, their lack of experience in Call for Fire led to a high standard deviation in several of the dependent variables. If this research were to be replicated using qualified Fire Supporters would be preferable. Using qualified Fire Supporters would likely reduce the standard deviation of the Target Detection and Fire Mission Processing variables, leading to better results and analysis. Additionally, simply having more participants would reduce the standard deviation. The small sample size was a known constraint going into the experiment, but future researchers should strive to get a sample size of 30 teams or more if possible.

Research Needed

Finding the quantifiable advantages of UAS on the battlefield will be critical to guide decision makers in the army on where and how to integrate them into the force. This research was aimed at the key performance indicators of a Company Fire Support Team and hence excluded many of the possible advantages of UASs at high echelons and in different war-fighting functions. Further research will be needed in all of the war-fighting functions to find the particular advantages that a sUAS can bring to their fight.

As for Fire Support, possible advantages that were outside the scope of this research would include battlefield tracking, counter-battery fire, reconnaissance, selection of observation points (RSOP), and observing deep targets. Observing targets that are beyond line of sight would be the most natural extension of this research. By simply moving the experiment behind a hill or wall and forcing them to rely on the UAS would adequately test for this. All other further research will need specific experiments that try to emulate the current battlefield to find the possible advantages of using sUAS to increase effectiveness.

Conclusion

While there was no statistical differences in any of the dependent variables, this study still showed that adding a small unmanned aerial vehicle did not degrade any of the key performance indicators of a Company Fire Support team. This leaves the opportunity for other research to be conducted to find what the advantages of a sUAS does bring to the fight. These possible advantages include observing deep targets, RSOP, and others. This research also showed that a small UAS in a target-rich close fight with tight timelines does not add a significant advantage. These two insights can be added to the growing body of information from academia and the current battlefields to help guide decision makers within the U.S. Army on where and how to integrate sUAVs in the force.

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Appendix A - Operations Order

Copy of copies
KSU ROTC
MANHATTAN, KS
28APR2025

OPORD 25-001 (Operation Fire Support UAS)

(U) References:

(a)(U) Maps and Charts:

(1) (U) Fort Riley, KS

(2) (U) Fire Support UAS ConOp

(b) (U) Other references: ATP 3-09.30 Observed Fires

(U) Time Zone Used Throughout the OPLAN/OPORD: CST

(U) Task Organization:

MS-3/KSU ROTC

1. (U) Situation.

(a) (U) Area of Interest. Manhattan, KS

(b) (U) Area of Operations. Bluemont Scenic Overlook (Wild Cat)

(1) (U) Terrain. Manhattan, KS consists of rolling hills, steep bluffs, densely wooded areas, urban areas, busy roads, valleys, creeks, dirt paths with rocks, roots and foliage, and small retaining ponds. The Bluemont Scenic Overlook is on top of a hill, 361 meters above sea level with steep sides and drop offs. There are improved and unimproved paths running throughout the area.

(2) (U) Weather.

(a) (U) Manhattan, KS

Date	High	Low	Chance of Precip.	BMNT	Sun Rise	Sun Set	EENT
May	68	44	6%	0530	0628	2019	2125

(b) (U) Expanded weather. Scattered showers and thunderstorms possible.

(c) (U) Enemy Forces. N/A

(d) (U) Friendly Forces. N/A

(1) (U) Higher Headquarters' Mission and Intent.

(a) (U) Higher Headquarters Two Levels Up.

1. (U) Mission. N/A

2. (U) Intent. N/A

(b) (U) Higher Headquarters.

1. (U) Mission. N/A

2. (U) Intent. N/A

2. (U) Mission. KSU ROTC Cadets establish OP Bluemont at 14S QJ 103 409 NLT 0840 and conduct fire missions until 1120 with a small UAS IOT determine what improvements are made to the key performance indicators of a Company Fire Support Team.

3. (U) Execution.

(a) (U) Initial Commander's Intent.

(1) (U) Purpose. To determine what improvements are made in the key performance indicators of a Company Fire Support Team when a small UAS is integrated into their operations. The key performance indicators are observable area, target detection, and fire mission processing.

(2) (U) Key Tasks:

(a) (U) Establish OP at Bluemont Scenic Overlook (14S QJ 103 409) (1200 Bluemont Scenic Dr, Manhattan, KS 66502) NLT 0835.

(b) (U) Form control and experiment groups.

(c) (U) Execute fire missions from both groups.

(d) (U) Gather fire mission data.

(3) (U) End state: KSU Cadets effectively train Call for Fire and the required data is gathered.

(b) (U) Concept of Operations. This operation is conducted in three phases, Phase I (Planning and Preparation), Phase II (Execution), and Phase III (Consolidation and Reorganization).

(1) (U) Phase I: Planning and Preparation. This phase begins with the receipt of this order. Cadet leadership conducts PCCs/PCIs, ensuring cadets have all required items from the packing list (Enclosure 1). Cadets review Call for Fire in classroom setting and in self-study. Cadets are randomly assigned to FO teams and then to the control or experiment group. This phase ends with the rendezvous at the Bluemont Scenic Overlook parking lot (14S QJ 103 409) at 020830MAY2025.

(2) (U) Phase II: Execution. Phase II is divided into two parts, Phase II A and Phase II B. The two parts correspond to the two one-hour lab sections.

(a) (U) Phase II A begins when the Cadets assigned to the first lab section arrive at the rendezvous at the Bluemont Scenic Overlook parking lot (14S QJ 103 409) NLT 020830MAY2025. During this phase, 2 FO teams at a time will go out to the lookout: one control team and one experiment team. The FO teams will then have 15 minutes to execute as many fire missions as possible on targets that match the HVTL supplied to them. All fire missions will pass through the BN FSE (CPT Brantley and CPT Koehn). After 15 minutes, the next two teams will cycle through the training. Phase II A will end when all teams assigned to the first lab section have completed the training or until 0920, whichever occurs first.

(b) (U) Phase II B begins when the Cadets assigned to the second lab section arrive at the rendezvous at the Bluemont Scenic Overlook parking lot (14S QJ 103 409) NLT 021030MAY2025. The second lab section will conduct operations in the same way as Phase II A. Phase II B will end when all teams asassigned tohe second lab section have completed the training or until 1120, whichever occurs first.

(3) (U) Phase III: Consolidation and Recovery. Phase III begins when all Cadets have completed the training or until 1120, whichever occurs first. During this phase, a police call of the area will be conducted, all Cadets will be released, and the data collected will be stored. Phase III ends at 021700MAY2025

(c) (U) Scheme of Movement and Maneuver.

(1) (U) Phase I: Planning and Preparation. Phase I begins upon the receipt of this order. During this phase KSU Cadets, the UAS Pilot, and CPT Brantley move to the Bluemont Scenic Overlook parking lot (14S QJ 103 409) IOT rendezvous NLT 020830MAY2025. This phase ends at the rendezvous.

(2) (U) Phase II Execution. Phase II is divided into two parts, Phase II A and Phase II B. The two parts correspond to the two one-hour lab sections.

(a) (U) Phase II A begins at the rendezvous at the Bluemont Scenic Overlook parking lot (14S QJ 103 409) NLT 020830MAY2025. During this phase, 2 FO teams at a time will go out onto the lookout, one control team and one experiment team. All other Cadets will remain in the parking lot so as not to get an advantage. When the teams get to the lookout, they will be given a HVTL and will begin conducting fire missions. Upon receiving the HVTL, the FO teams will have 15 minutes to conduct as many fire missions as possible. When an FO team spots a target, they pass the code phase "Target Identified" to the BN FSE and then generate their call for fire. The control FO Team will use the basic fire support equipment (compass, binoculars, map, and protractor). The experiment group will use the basic fire support equipment and have a Maverick Pro 2 UAS with a camera and pilot at their disposal. The Pilot will not help with fire mission processing or target identification. They will only take instructions from the FO team on where to fly the UAV. CPT Brantley and CPT Koehn will act as the BN FSE, receiving all fire missions and recording the relevant data. After a team completes their 15 minutes, they will give the HVTL back to CPT Brantley or CPT Koehn and will go to the parking lot and direct the next team to the lookout. Phase II A will end when all teams assigned to the first lab section have completed the training or until 0920, whichever occurs first.

(b) (U) Phase II B begins when the Cadets assigned to the second lab section arrive at the rendezvous at the Bluemont Scenic Overlook parking lot (14S QJ 103 409) NLT 021030MAY2025. The second lab section will conduct operations in the same way as Phase II A. Phase II B will end when all teams assigned to the second lab section have completed the training or until 1120, whichever occurs first.

(3) (U) Phase III: Consolidation and Recovery. Phase III begins when all Cadets have completed the training or until 1120, whichever occurs first. During this phase, cadets will be released back to their leadership positions. All Cadets, the UAS Pilot and Cadre will be move back to their HORs or place of work.

(d) (U) Scheme of Mobility/Countermobility. N/A

(e) (U) Scheme of Battlefield Obscuration. N/A

(f) (U) Scheme of Reconnaissance and Surveillance. N/A

(g) (U) Scheme of Intelligence. N/A

(h) (U) Scheme of Fires.

(1) KSU Cadets have Artillery Priority of Fire throughout the duration of this mission. All Fire missions will be passed through the BN FSE.

(i) (U) Tasks to Subordinate Units. N/A

(j) (U) Coordinating Instructions.

(1) (U) Commander's Critical Information Requirements/Serious Incident Reports.

(a) (U) Any injury/illness requiring hospitalization.

(b) (U) Any loss of sensitive items.

(2) (U) Other Coordinating Instructions.

(a) (U) Ensure all personnel conducting this training bring a water source

4. (U) Sustainment.

(a) (U) Logistics.

(1) (U) Class I.

(a) (U) Water: two cases of water will be located in CPT Brantley's POV.

(b) (U) Chow. N/A

(c) (U) Lodging. N/A

(2) (U) Class II. Uniform ACU

(3) (U) Class III – IX. N/A

5. (U) Command and Signal.

(a) (U) CPT Brantley Contact information.
(a) Mobile number. 573-842-8366
(b) E-mail. Jason.t.brantley3.mil@army.mil

ACKNOWLEDGE:

JASON T. BRANTLEY
CPT
FSO

ENCL:
Packing List and required equipment

Packing List

Packing List

Water source

Binoculars

Fort Riley 1:50000 MGRS map

Compass

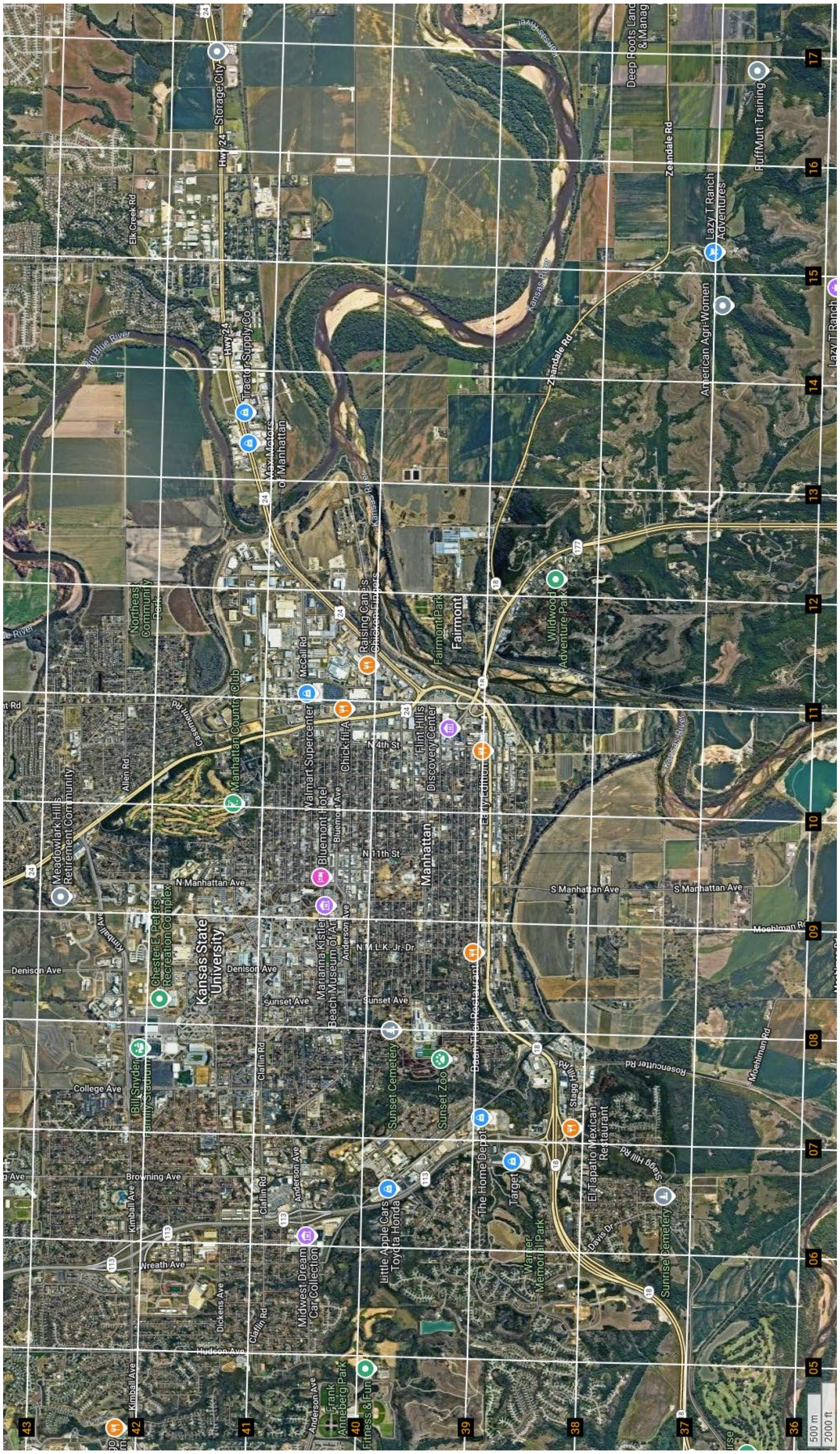
Map Markers

Protractor

Note book

pen/pencil

Appendix B - Map Used in Experiment



Appendix C - Informed Consent Form

KANSAS STATE UNIVERSITY

University Research Compliance Office

Institutional Review Board (IRB)

Informed Consent Template Form

comply@k-state.edu | 785-532-3224

PROJECT TITLE:

Small Unmanned Aerial Vehicles in The Company Fire Support Team

PROJECT APPROVAL DATE:	04/01/25	**PROJECT EXPIRATION DATE:**	05/30/25	**LENGTH OF STUDY:**	1 hour

PRINCIPAL INVESTIGATOR:	Dr. Michael Pritchard
Co-PRINCIPAL INVESTIGATOR:	Jason Brantley

CONTACT DETAILS FOR PROBLEMS/QUESTIONS:	(573)-842-8366 or JT2@ksu.edu for Jason Brantley mjp001@ksu.edu for Dr. Pritchard
IRB CHAIR CONTACT INFORMATION:	Lisa Rubin, Chair, Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224, rubin@ksu.edu; Brad Woods, Associate Vice President for Research Compliance, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, (785) 532-3224, comply@ksu.edu
PROJECT SPONSOR:	Kansas State University

PURPOSE OF THE RESEARCH:

This research aims to inform US Army leaders on how much they can expect their Fire Support Teams effectiveness to increase if they integrate a small UAS.

PROCEDURES OR METHODS TO BE USED:

You will be assigned a partner, and your team will be assigned to one of two groups. The control group will be given basic fire support tools (a compass, map, and binoculars). The experiment group will be given a small UAV, piloted by a trained pilot provided by KSU's Unmanned Ariel System program, in addition to the basic tools. You will then be instructed to identify as many targets as possible, and process simulated fire missions on them. Data will be collected to determine your observable area, fire mission processing time, and target detection. Your data will then be compared and analyzed to find the improvements made in the said key performance indicators when a small UAS is integrated.

RISKS OR DISCOMFORTS ANTICIPATED:

A small UAV will be used during this research. A trained pilot will be operating the UAV, and no participants will be allowed to operate it. You will stay clear of the UAV and will take all instructions from the pilot.

BENEFITS ANTICPATED:

Additional Call for Fire Training.

EXTENT OF CONFIDENTIALITY:

Your name will not be recorded for this study. You will be assigned a number and all data collected will be tied to that number.
The information or biospecimens that will be collected as part of this research could be used for future research studies or distributed to other investigators for future research studies without additional informed consent.

IS COMPENSATION OR MEDICAL TREATMENT AVAILABLE IF INJURY OCCURS? ☐ Yes ☒ No

Terms of participation: I understand this project is research, and that my participation is voluntary. I also understand that if I decide to participate in this study, I may withdraw my consent at any time, and stop participating at any time without explanation, penalty, or loss of benefits, or academic standing to which I may otherwise be entitled.

I verify that my signature below indicates that I have read and understand this consent form, and willingly agree to participate in this study under the terms described, and that my signature acknowledges that I have received a signed and dated copy of this consent form.

(Remember that it is a requirement for the P.I. to maintain a signed and dated copy of the same consent form signed and kept by the participant).

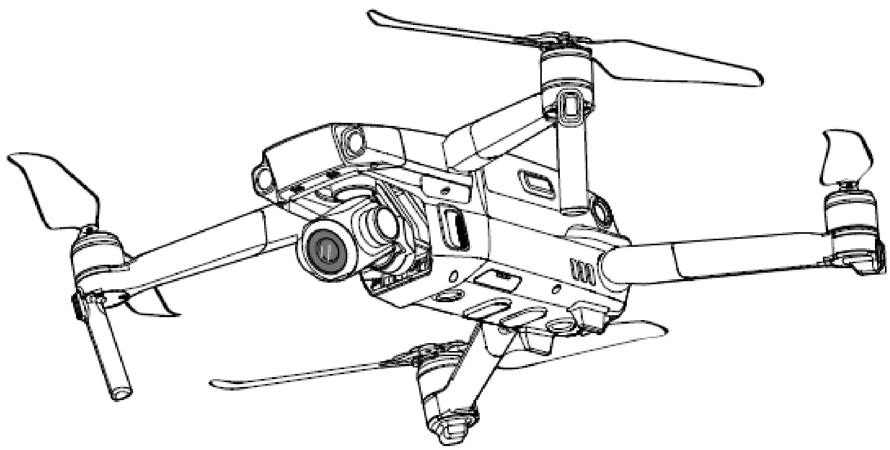
PARTICIPANT NAME:			
PARTICIPANT SIGNATURE:		**DATE:**	
WITNESS TO SIGNATURE: (PROJECT STAFF)		**DATE:**	

Appendix D - DJI Mavic 2 Zoom Specification Sheet

MAVIC 2 ZOOM

Quick Start Guide

V1.0



dji

Specifications

• Aircraft

Weight	905 g
Max Speed	44.7 mph (72 kph) in Sport mode without wind
Max Service Ceiling Above Sea Level	19685 ft (6000 m)
Operating Temperature	14° to 104° F (-10° to 40° C)
GNSS	GPS + GLONASS
Operating Frequency	2.4-2.4835 GHz; 5.725-5.850 GHz
Transmitter Power (EIRP)	2.4 GHz FCC: ≤26 dBm; CE/MIC: ≤20 dBm; SRRC: ≤20 dBm 5.8 GHz FCC: ≤26 dBm; CE: ≤14 dBm; SRRC: ≤26 dBm

• Gimbal

Controllable Range	Pitch: -90° to +30°

• Camera

Sensor	1/2.3" CMOS; Effective pixels: 12M
Lens	FOV: approx. 83° (24 mm), approx. 48° (48 mm) 35 mm format equivalent: 24-48 mm Aperture: f/2.8 (24 mm) - f/3.8 (48 mm) Focus: 0.5 m to ∞
ISO Range	Video: 100-3200 Photo: 100-1600 (auto); 100-3200 (manual)
Electronic Shutter Speed	8-1/8000 s
Max Image Size	4000×3000
Still Photography Modes	Single shot Burst shooting: 3/5/7 frames Auto Exposure Bracketing (AEB): 3/5 bracketed frames at 0.7 EV Bias Interval
Video Recording Modes	4K Ultra HD: 3840×2160 24/25/30p 2.7K: 2688×1512 24/25/30/48/50/60p FHD: 1920×1080 24/25/30/48/50/60/120p
Video Storage Bitrate	100 Mbps
Photo	JPEG, DNG (RAW)
Video	MP4, MOV (MPEG-4 AVC/H.264, HEVC)
Supported SD Cards	microSD Max Capacity: 128 GB (UHS-I Speed Grade 3 rating required)

• Remote Controller

Operating Frequency	2.4-2.4835 GHz; 5.725-5.850 GHz
Max Transmission Distance (Unobstructed and free of interference)	FCC: 5 mi (8 km); CE/MIC: 3.1 mi (5 km); SRRC: 3.1 mi (5 km)
Operating Temperature	32° to 104° F (0° to 40° C)
Battery	3950mAh @ 3.83V

Transmitter Power (EIRP)	2.4 GHz FCC: ≤26 dBm; CE/MIC: ≤20 dBm; SRRC: ≤20 dBm 5.8 GHz FCC: ≤26 dBm; CE: ≤14 dBm; SRRC: ≤26 dBm
Operating Voltage	1800mA @ 3.83V (when charging the mobile device)
Supported Mobile Device Size	Thickness supported: 6.5 - 8.5 mm, Max length: 160 mm Supported USB port types: Lightning, Micro USB (Type-B) USB-C

• Charger

Voltage	17.6±0.1 V
Rated Power	60 W

• Intelligent Flight Battery

Capacity	3850 mAh
Voltage	17.6 V (max) 15.4 V (typical)
Battery Type	LiPo 4S
Energy	59.29 Wh
Net Weight	Approx. 297 g
Charging Temperature Range	41° to 104° F (5° to 40° C)
Max Charging Power	80 W

For more information, read the User Manual:
http://www.dji.com/mavic-2

※ This content is subject to change without prior notice.