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Big data grows daily, leaving an increasingly larger digital thumb print. Billions of hours and terabytes of information is left unexploited, with even more millions being generated in near-real to real time. A study of the RAF’s use of OR at Bomber Command in WWII examines use of the scientific method applied to assess failures and successes of targeting operations. Swapping the WWII battlefield for the vast, ever growing irregular battlefield of big data, an initial concept was designed using a MUM-T approach to the find and fix portions of the targeting process. DoD must develop current capabilities to address implications for future war as opposed to only funding new capabilities addressing what we think war will look like.

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MASTER OF MILITARY STUDIES

TITLE:

OPERATIONAL RESEARCH IN THE ROYAL AIRFORCE DURING WORLD WAR II AND HOW IT CAN BE APPLIED TO BIG DATA IN FUTURE WAR

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
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Executive Summary

Title: Operational Research in the Royal Air Force During World War II and how it can be Applied to Big Data in Future Wars

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Thesis: Operational research techniques can be applied to current technology to enable precise targeting utilizing the growing amount of big data in any environment.

Discussion: This project was to imagine what future warfare could look like through the examination of a historical study which helped shape an initial concept for a future capability. A study of the Royal Air Force's use of operational research at Bomber Command in WWII examined the effects of the scientific method being applied to assess failures and successes of targeting operations. From the results of this analysis Operational Researchers were able to provide objective recommendations to increase effectiveness of equipment use, training of pilots and target identifiers, and ultimately decrease casualty rates over the period of four years. Ultimately, by the end of the war, through reiterative research, evaluation, and analysis, Operational Research increased the RAF's targeting accuracy and lethality and decreased casualty rates without requesting new technology. Swapping the WWII battlefield of urban and suburban Europe for the vast, ever growing irregular battlefield of big data, an initial concept was designed using a MUM-T approach to the find and fix portions of the targeting process. Specifically, the initial concept, Needle Finder, takes into consideration six current programs being researched and tested by DARPA and couples social media scraping and AI analysis of CCTV to assist the intelligence analyst in developing targets. Results of the decision game enhanced the concept by adding AI and machine learning to all aspects of big data analysis from social media, CCTV, PFD's and FMV. Analysis from AI and machine learning then tips and cues analysts for further development, action, or dismissal. This refined concept is then combined with three other author's concepts to create an overarching urban environment concept addressing the Intelligence, Maneuver, Logistics, and Protection warfighting functions.

Conclusion: The Needle Finder Concept is one that could easily be developed and employed from technologies and concepts that exist today. Its utility can be seen at all levels of combat from tactical to strategic. Future war is most often thought of as occurring in mega cities of massive urban scale with millions of people. Currently, with the number of mobile devices owned outnumbering the number of homes with access to internet, videos, pictures, Facebook posts, snaps, tweets, blogs, etc. will clog and possibly overwhelm the battlefield and warfighter making targeting more difficult and requiring different tools for analysis. The DoD's third offset strategy portends the military must do more with less but still gain and maintain the tactical, operational, and strategic advantage in an ever-increasing technological world. MUM-T in the form of AI to provide analytical support will provide the DoD with the capability to do just that: more refined, detailed analysis of HVI targets, buildings, groups etc. with less manpower and assets on the ground. The DoD must encourage development of current capabilities to address current problems that have implications for future war as opposed to only funding capabilities that might address what we think war will look like.

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Introduction

While the distinct turning point of World War II (WWII) was the entrance of the United States into the conflict at Pearl Harbor, England managed to have a sizable impact on German operations both up to the entrance of the US and after. A large part of England's success can be credited to their ability to consistently update and reform their tactics, techniques and procedures across all branches of the military as the enemy moved and evolved on the battlefield, in the water, and for the specific case study of this paper, in the air. Operations research teams were employed throughout the British military during WWII to improve effects and operations with available means, perhaps most successfully in the Royal Air Force (RAF).

While bombing was not new to the RAF in WWII, it was still a fresh enough concept technologically and tactically speaking that presented a problem when facing the Germans: how to penetrate enemy defenses, navigate to the prescribed target, effectively bomb the target, and then return to base.[1] Initial tactics, techniques, and procedures of the Royal Air Force produced highly inaccurate results on the ground, many times missing a target completely, coupled with a high casualty rate. The British Air Ministry, having seen positive results from operations research teams in both Submarine Command and Air Defense Command, established their own operations research team to help improve effectiveness, accuracy, and casualty rates. These research teams used the scientific method to objectively provide recommendations on changes to tactics and techniques employed using currently fielded and available equipment and technology.

By studying the use of operation research teams in the Royal Air Force for strategic bombing, this paper highlights the vast improvements made in a short span of time without the acquisition process to obtain new capabilities to address an enemy on an evolving battlefield. Emphasis in the analysis of the historical case is placed on the targeting aspect of the intelligence warfighting function, specifically the find and fix portion of the targeting cycle on the evolving battlefield of big data.

Analysis of the case study then goes on to highlight the importance of the use of operational research to better utilize existing technology as well as provide plausible application to current technologies the Defense Advances Research Projects Agency (DARPA) is working on that address characteristics of the future operating environment as outlined in the Army Operating Concept. From the analysis and initial concept of big data analysis to find and fix portion an enemy, an operational decision game evaluates its employment and effectiveness. Results of the game are then used to further develop and refine the concept. Finally, the refined concept is combined in overarching warfighting function focused concept for operations in an urban environment.

Manned and Unmanned Teaming

From hot air balloon surveillance in the American Civil War to the MQ-1 Predator unmanned aerial vehicle (UAV), militaries consistently seek to gain and maintain a technological advantage over an adversary. Manned and unmanned teaming (MUM-T) is not a new concept to militaries around the world. Militaries are consistently developing new ways to see further, loiter longer, and project power faster. From 1945 until just recently, the US has enjoyed a strategic, operational, and tactical advantage over its allies and adversaries, an offset of power, that acts as a deterrent to military engagement. Over the past ten years, both allies and adversaries of the United States have made large strides in technological capabilities. There is an increasing possibility that an adversary is able to use tactics and technology against the US in a manner that would inhibit and effective response.[2]

To counter an ever increasingly capable adversary, the Department of Defense developed the Third Offset Strategy as an effort to maximize the capabilities of a smaller US military by coupling it with advanced technology. [3] The Third Offset looks to deter adversaries from engaging and if they do, provide units with "autonomous and semi-autonomous operational capabilities [that] may increase lethality, improve protection, and extend …a units' reach." [4] The United States Army and Marine Corps see the DoD's strategy specifically as a way to employ manned and unmanned teaming (MUM-T) with advanced technologies to support the future force.

Advanced technologies range on a spectrum from fully autonomous strike or reconnaissance capabilities to artificial intelligence and machine learning that enhance an analyst's or operator's capabilities. Despite where on the spectrum a technology lies, the main goal is to enhance or advance not only the physical offset, but also the cognitive advantage, increasing effectiveness while maintaining minimal manpower and decreasing casualty rates. Currently, the military often finds itself in reactionary mode to adversaries who use basic technology to attack the US or to get "lost" in the cloud of big data knowing the limitations of US military capabilities and systems. It is within this big data cloud the United States military may gain the greatest cognitive advantage allowing to find and fix the enemy. Through analysis of the use of Operational Research in World War II, this paper attempts to identify a possible avenue to closing the gap on future war manned-manned teaming in a way to find, fix, and finish our adversaries more efficiently with less risk to troops all using data readily available today.

Historical Review of Operational Research in the Royal Air Force in WWII

In 1830, Carl Von Clausewitz proposed that the nature of war never changes. War is war, always consisting of three things: emotion (the people), the reason (government), and chance (the military).[5] His idea of the nature of war is timeless; even today, 187 years later, war still consists of the same trinity. However, the way war is fought has changed vastly. The way war is waged today has morphed, even as recently as the past ten years, consistently adapting to the advances of the times which currently means the vast increase in information and data that is produced daily.

Technology and its subsequent data, considered menial and now part of everyday life, was big news or did not even exist a decade ago. Ten years ago, full motion video from a drone was considered a military grade or Silicon Valley type of capability. Today anyone can pick up a drone that streams full motion video and still capture capabilities that can be instantly uploaded to the internet via a Bluetooth connection. Facebook was just beginning to grow and twitter had just been created; social media was new and exciting and merely a way to keep in touch with old friends. Now every facet of life is inundated by social media, with many using these platforms as an outreach to start social movements, conduct e-commerce, and conduct governmental business. Digital cameras and video cameras were the best way to capture life's special moments on a small SD card and upload them to your hard drive; now every moment can be instantaneously captured, edited, and uploaded or distributed with a smart phone. To check our heart rate, we had to know where to find our pulse and manually count the beats as we watch a clock; now there are devises that can monitor and track this information and tell you how your VO2 max has changed over the past month. These things are data that is now instantly available to anyone who knows what they are looking for.

Every day, the amount of data produced increases, flooding the world with vast amounts of information at every second. Big data may be exciting and wonderful, but it has not changed the nature of war. It has however, forever altered the battlefield on which the military traverses. The question becomes how is big data employed in a meaningful manner for and by the military?

Using the scientific process, operational research (OR) examines and analyzes different aspects of a problem through a scientific process with the goal of streamlining, enhancing, and/or fixing an issue. OR is the scientific study of consequences by the examination of all "factors, variables, and constraints so that is possible to discern why things happen as they do and what can be done to change outputs and thereby solve problems."[6] Keys to successful employment of OR are:

- the use of the scientific process to cut down on personal, professional, and/or institutional bias
- to have individuals with a vested interest in outcomes present to help interpret outcomes in terms relevant to the project.

Every year the Department of Defense (DoD) attempts to anticipate future requirements for the way war will be waged. The department spends countless man-hours dedicated to envisioning future wars in order to identify requirements for upgrades on current warfighting systems or identifying a requirement gap which can only be fulfilled with new or improved warfighting systems. This gap analysis requirements process is not new to the DoD or to any military organization in any other country. As far back as pre-World War II, countries have looked at past wars to try to identify future needs. Unfortunately, the outcome is still often strikingly similar: the mark is missed. In 1937 B.H. Liddell-Hart (a prominent military thinker at the time), wrote a memorandum to the Secretary of State for War that can be applied even today:

> [t]he more one examines the course of past wars the more one is impressed by the frequency with which military policy and preparations have taken the wrong turning…The way that decisions are reached on questions of strategy, tactics, organization, etc., is lamentably unscientific. It is due in part to the difficulty of

> developing a truly critical habit of mind under the conditions of military subordination, and in part the lack of any staff organ devoted to research…The task ought to be given to a body of officers who can devote their whole time to exploring the data on record, collecting it from outside, and working out the conclusion in a free atmosphere…It is also very desirable that they should be supplemented by a permanent nucleus consisting of some first-rate University men who have been trained in the processes of scientific enquiry. [7]

The idea of scientists working with the military was not completely new then and old news today, with the use of big research corporations such as the Rand Arroyo Center, but the capacity in which Liddell-Hart's ideas became most effective was in the establishment and success of small teams of scientists conducting OR with the within the Royal Air Force (RAF) during World War II. The military has successfully used OR to evaluate existing capabilities, such as radar or bombing planes, to make recommendations for better, possibly more efficient, use. Even today, the use of OR may enable the DoD to employ OR methodology to big data processing techniques with the aim of enhancing intelligence collection and targeting processes.

While OR can be applied to any problem the generates enough data to collect, analyze, and make recommendations from, the practice is perhaps best showcased by the British RAF during World War II. Liddell-Hart's 1937 recommendations were ironically foretelling in 1937 as the British Royal Air Force first employed their Operational Research Section (ORS) in 1939. Great Britain was facing the German Luftwaffe, or fighter command, which proved to be extremely effective. The RAF had no time to add to their defensive capabilities so, instead employed the ORS to apply the scientific process to the impending problem. "Rapidly, these men examined radar performance, the assignment of targets, the system of warning, the stationing of fighters and antiaircraft guns and their co-ordination with radar," which led to many discoveries of weaknesses in British radar defense that were resolved based on recommendations from the group. [8]

In 1941, based on the success of the two previously established ORS's located at the Anti-Aircraft Command and the Costal Command (radar and U-boat defenses), one of the most successful operational research sections was established in the RAF's Bomber Command. The ORS became one of the most influential military instruments during the war. From 1941, until the end of the war in 1945, the ORS for Bomber Command would make British bombing operations more accurate, more lethal, and safer for the pilots flying the missions.

Operational Research in the RAF Bomber Command

When the War began in 1939, Bomber Command tactics were almost exclusively focused on precision bombing, targeting "specific industrial targets" with the goals of:

- crippling Germany's ability to outfit the war
- destroying the will of the people. [9]

By 1941 it was painfully clear to the RAF and Great Britain that precision targeting was a disappointment. Ironically, precision bombing, as executed, was found to be highly inaccurate: "less than one third of the strike force was navigating to within five miles of the target," and in addition to the inaccuracy, RAF casualty and injury rates were significant. [10] The British Air Ministry quickly authorized and created a Bomber Command ORS working for the Senior Air Staff Officer, equivalent to Army Headquarters Chief of Staff. The ORS was tasked to rectify the abysmal success rate of bombing and to figure out how to reduce pilot mortality rates.

Once established, the Bomber Command ORS began by establishing the definition of success for the section. Dr. Basil G. Dickens, the well qualified and by name appointed head of the ORS, articulated the ORS's primary aim was to "study the success of operations in terms of percentage of aircraft dispatched which bombed the target and make recommendations" to improve the rate. [11] He then went on to emphasize that the governing factors were tactics, equipment, and training.[12] Obtaining the necessary data for analysis from thousands of aircraft sorties would be a continuous process that proved difficult due to the constant rotation of bombing missions that was occurring regularly. Data collected to develop a "time histogram of the raid" included "target attacked; bombs dropped on target; time, height, heading, and air speed at release; what was in the bomb site; and bomb aimer's and pilot's reports," which would allow for the development of a "time histogram of the raid." [13] In addition to these mainly quantitative factors, cameras were installed in all bomber planes to help determine location of the aircraft when bombs dropped and to "pinpoint bomb bursts," all in an effort to identify the location where bombs were actually released.[14] Taking all of these factors into consideration, the ORS began to make recommendations almost immediately.

By December 1941, Dickins and his staff had completed their initial analysis of these data. From this data, the ORS identified two challenges crucial to overcoming the lack of accuracy bombers had:

(1) pilots were having trouble navigating to the correct target

(2) once at a target (correct or not) bombers were having trouble finding where to aim. [15]

Both challenges were incredibly important to overcome for the RAF. Missing targets altogether was a waste of ammunition, time, and a waste of resources- both material and human. Correcting inaccurate aiming, would allow for successful strategic bombing strikes and reinforce or propel success on the ground. The researchers believed that both issues could be addressed through the use of a pre-existing navigation system called Gee. Gee used a "series of ground transmitter signals [that] would be received by an aircraft and displayed…as position lines… [and] a special map," on which navigators would be able to identify a plane's position almost immediately. [16] It had an accuracy rating of between .5-5miles and a range between 300-400 miles. Based on the identified potential, the ORS recommended to Bomber Command leadership a series of experiments to test the capabilities of Gee as well as multiple alternate uses of the system.

In December 1941, ORS received the go ahead from command to conduct the experiments with the guidance to ensure experiments were set up to mirror similar operational distances and ranges to those being flown in Germany. The first two flights were conducted prior to Christmas with the results coming as a discouraging gift on 23 December. The initially prescribe technique of using one pilot as the navigator and the other as the bomb releaser was not a viable option. And to make matters worse "it was not possible to determine position over the target area less than two miles' precision." [17] With poor results from this technique, it was back to experimentation to try and find another solution with Gee. This time two ideas were developed by members of the ORS and the Air Ministry: (1) "blind bombing" conducted by Gee equipped aircraft, and (2) Gee equipped aircraft guiding non-Gee equipped bombing aircraft, and either mark the target with flares or incendiaries. [18]

With two new experiments, it was back to the test flights for ORS in February of 1942. Blind bombing techniques were quickly proven as inadequate thus reinforcing the idea that visual recognition was necessary for successful runs. [19] Target illumination by Gee aircraft on the other hand proved highly viable using a technique named 'Shaker.' Using this technique, an attack consisted of three stages or waves:

- first, Gee-equipped planes that would illuminate the target with flares

- second, Gee-equipped planes would then mark the target with incendiaries
- third, bomber planes would fly over and exploit the target with high explosives.[20] [21]

Despite successful experiments in February, Bomber Command leadership requested additional tests to further validate the area bombing technique using Gee. The Shaker technique was employed in March of 1942 against the Renault Works in Paris and was deemed a fantastic success. [22] Unfortunately, follow on raids during, March and April, using the same technique did not enjoy the same successes.

Following each raid ORS collected the prescribed data points and conducted analysis to identify shortcomings and possible reasons for inefficient results using the new area bombing Shaker technique. In addition to the prescribed data points, weather effects on the raids was also considered. The analysis determined that haze played a significant factor in unsuccessful raids, regardless of the amount of illumination, and that the maximum effective range for target identification on dark cloudless nights was 13,000 feet. [23] Specific conclusions such as these played an important role in the planning, evaluating, and expectations for future bombing raids and ultimately increased the effects of Bomber Command, though not as much as expected. The analysis also led to recommendations for the formation of a force specifically designed for and dedicated to target finding, known as the Pathfinder Force (PFF). [24] The Gee Shaker technique was used successfully from March until August 1942, approximately six months (as initially assessed), before the Germans figured out a way to jam the systems.

While target-finding and aiming were indeed large challenges to initially face and overcome, they were not the only ones. In addition to these issues, the RAF faced an ever evolving and increasingly dangerous enemy in the German air defense. As British raids became more effective, more were conducted, but the current size of the raid force created an easy target for German defenses leaving RAF bombers vulnerable to increased human and mechanical losses. To counter this challenge, ORS recommended bombing en masse, using concentrated, large forces. Strength in numbers, it was reasoned, would overwhelm German air defenses while simultaneously increasing the probability of a successful RAF bombing attack with fewer losses.

Although this common-sense approach was rooted in ORS disciplined, mathematical analysis, RAF command's initial response to the concentrated bombing technique focused on increased aircraft collisions and percentages of loss. Dickens and his team spent countless hours analyzing the data points to produce the probability of a collision. This analysis indicated that the probability of collision was no more than a half percent risk while the chances of being shot down was three to four percent risk (still less than concentrated raids). [25] By May of 1942, ORS research concluded that there was a definite correlation "between concentration (both in time and space) and losses. As concentration increased, losses dropped, particularly when the moon was down." [26] ORS Recommendations for raids with at least fifty aircraft per hour on nights with low illumination and at least eighty aircraft on nights with good illumination were sent to the Air Ministry in June. [27] This technique not only diminished RAF losses, it also contributed to RAF objectives of diminishing German civilian support and morale for the war. The concentration technique was adopted and used in June 1942 and losses due to enemy air defense were reduced.

Not long after the issue of concentration was worked out, the Germans figured out how to jam the Gee system making the Shaker technique less effective. From August- December 1942, the RAF made do with the equipment and techniques available to them. It was until mid-December 1942 through January1943 that the RAF received new systems and technology that could be employed to enhance accuracy.

Oboe, a new precision navigator system, was introduced in December. H2S, "an on-board ground mapping radar," was introduced in January. [28] In addition to the navigation systems, two new aircraft were introduced for use by the RAF: the Mosquito, a high-altitude aircraft, and the Lancaster using new target indicators dropped by the Path Finding Force (PFF). [29] With the debut of these systems, the data available to the ORS from multiple battles was used to evaluate, analyze, and recommend the most effective way to employ the new systems.

Oboe, the new precision navigation system, relied on two ground stations to speak to one aircraft: one handled navigation, while the other would signal the location in which bombs should be dropped.[30] H2S was a radar attached to an aircraft, giving it much further range than the 500k of both Gee or Oboe. Throughout the first four months of 1942 the RAF used both Oboe and H2S to conduct bombing raids throughout Germany. After each one of the raids, ORS retrieved the prescribed data for analysis and began to compared the bombing accuracy using both systems. In April, ORS released a report detailing that "when using Oboe for ground marking, [success] was three times better than predicted [thirty-five percent attack within three miles of aiming point], but by comparison H2S ground marking had not met expectations [sixteen to nineteen percent within three miles of aiming point]. [31]

H2S was not a complete failure though. While ORS found it lacking as a ground marking system, there was potential seen in using the same system in a sky marking capacity. During the raid on Berlin in March of 1943, Bomber Command employed a timed run (from a landmark) technique for the first time. [32] This technique called for following a short distance of fixed time and bearing prior to bomb release. It is important to note that this specific technique was prescribe and approved by Bomber Command Commander in Charge (CinC), not ORS (while an ORS is an important tool, it should not completely replace the experience of operators).

Analysis of the raid proved that the timed run technique was ineffective: pilots bombed a concentration of target indicator illuminators despite them being outside of the estimated time of arrival for the target. [33] Despite the issues, Dickens believed in the utility of the timed run and directed the ORS to continue analysis on how to better employ the technique and the H2S. ORS analysis indicated that inadequate planning of the timed raid was the major contributing factor to poor execution. ORS recommended more detailed and in-depth command wide planning to facilitate proper placement of target indicating illuminators in accordance with the prescribed place and time indicated in the plan. [34] Poor planning at the command level to ensure effective use of the timed run technique, proper placement of H2S illuminators, and successful bombing of the target. As a result, H2S remained a useful tool for Bomber command throughout the war. In 1944 ORS recommended turning on H2S only when in range of the target to combat bomber loss. [35] This is an excellent example of how ORS worked continuously analyzing outcomes to meet the ultimate goals set forth by the RAF.

While bombing techniques were being evaluated and altered based on ORS recommendations, pilot and aircraft loss rate were still an issue. Determining loss causes was a difficult project due to the mission of bomber command. For every raid conducted, a small percentage of aircraft and pilots did not make it back, but not always for the same reason. Some pilots fell prey to the German air defenses, while others suffered flak or debris damage, but due to engine fires, ultimately did not make it home. Late in 1942 it seemed as though the majority of losses were being taken the Lancaster aircraft, as opposed to the Mark I and Mark III. ORS assessed the raids involving all three aircraft and initially concluded that the seemingly high number of Lancaster losses was due to an increased number missions flown involving only the Lancaster aircraft. [36] While the conclusion might appear obvious to planning staffs, the fog of war and high operational tempo made such simple conclusions difficult. The obvious only became so after disciplined and rigorous analytic effort by the ORS.

Despite the ORS Lancaster revolution, aircraft losses remained a pressing command issue. In 1943 a new system, named Window, was introduced to the RAF and Bomber Command. Window was "the name given to strips of aluminum foil of precise length dropped from aircraft to confuse enemy ground radar," a simple yet effective technique that the RAF had been saving to use, knowing that it would not be long until the Germans began using it too. [37] Dicken's and his section provided Bomber Command, a study that showed the probability of bomber casualties being reduced by one third. [38] Bomber Command immediately put Window to use in the Battle of Hamburg. The results of the raid on Hamburg were resounding: aircraft interceptions 8.4%, a four percent drop since the previous month before the use of Window; attacks 3.2%, a 1.3% drop; and finally, only 4.9% flack damage to aircraft, a ten percent decrease. [39]

By early 1944, the effectiveness of H2S, Oboe, and Window had been thoroughly analyzed and documented by ORS. Yet the day-to-day continued to vary. Some raids produced excellent results both in effectiveness on the ground and in terms of low loss rates while still others saw a regression of effectiveness and higher loss rates. What then was the common denominator? Command leadership once again turned to ORS for help in identifying the problem. This time the scientists looked at bombing accuracy inconsistencies, specifically at how target indicator characteristics, such as flash and color, in relation to atmospheric conditions such as smoke, fog, haze, etc. may have played a role in lack of accuracy on target. [40] Based on the review of numerous pilot logs linked with missed target reports and interviews with bomb aimers, it was determined that both pilots and aimers had trouble visibly distinguishing the target indicator. More importantly, it became painfully apparent that many of the crews did not understand how the pathfinding system (H2S) worked in general. [41] Such basic misunderstanding explained both poor employment of the tool in general as well as inconsistencies.

Based on these conclusions, ORS provided several recommendations. First, a basic training product was developed that described how the pathfinder system worked and how it was best employed. This training was disseminated to the air crews for immediate remedial training. Next, ORS recommended that current bombers have their color vision retested and future bombers be subjected to performance tests to assess their ability to discern and identify target indicators in poor visual conditions. [42] Finally, ORS recommended that "all crew members be given a full-scale practical demonstration of [target indicators] from the air before going on ops," to demonstrate proper technique and use of the system. [43]

Command leadership quickly implemented the recommendations and requested further study of bombing errors. Subsequent ORS analytic efforts resulted in follow-on recommendations for general bomb aiming training, night vision training, and even medic remedial training in the definitions and understanding of normal and "defective-safe" color vision.[44] Each of these follow-on recommendations was soon put into practice across bomber command and as training increased and color vision was revaluated, target indicator accuracy began to increase. Scientists and trainers worked side by side to fundamentally alter the way crews were selected and trained, providing change not only in the immediate future, but for long term as well.

Mid-1944 through the end of the war in 1945 saw little down turn in the problems ORS was to evaluate and provide recommendations for. Bomber Command never achieved one hundred percent accuracy with zero losses, nor did they come close. Over the course of the five years which ORS provided support to Bomber Command, they would increase efficiency, accuracy, and decrease loss rates extensively, forever changing the way war would be fought in the future. The comprehensive scientific approach the researches applied to every problem that arose provided Bomber Command with comprehensive, unbiased, and (most times) well-tested recommendations and solutions that enhanced capabilities to enable mission success. Without the help of ORS, the overwhelming success of RAF Strategic Bombing may not have been achieved.

Analysis

Initial analysis of Strategic Bombing in thein the RAF during WWII indicates that the two most applicable warfighting functions that may benefit from application of OR and big data techniques are Intelligence and Fires (specifically the targeting aspect), through the lens of a current targeting process:

- find—identifying targets as targets to be prosecuted
- fix— "determine the location of the potential target…"
- for engagement—
- finish— "action taken against the target." [45]

In first looking through the lens of the Intelligence Warfighting function, finding targets, per the Joint publication definition, was not an issue for bombers nor the ORS. Targets were identified and decided upon by the Air Ministry based on the overall objective of striking industrial targets to target the morale of German civilians.

Fixing the target that was identified as one of the preliminary, and enduring, issues that ORS would assess throughout the war. The ORS was able to objectively look at the problems at hand: trouble navigating to the proper target as well as the trouble aiming at the target, and quickly identify possible solutions. Gee, Oboe, and H2S were all navigation aid and aiming systems that were employed by the RAF, and each of these systems capabilities and effectiveness were evaluated and assessed by ORS. Each one of the systems was recommended for use in a different manner than initially intended to fix the enemy for engagement.

Through objective evaluations, assessments, and experiments the OR scientists helped the RAF quickly adapt with the tools at hand. The recommendations were never that a system was useless and new technology should be procured. Today, when a problem is identified, often times the military looks immediately to contractors who have a financial interest in the success of the equipment. Instead of looking at alternative ways to employ a piece of equipment, a requirement is identified and the DOTMLPF process begins again, often taking years to push through. Use of an unbiased operational research team would provide solutions in a timelier manner.

While the ORS evaluated objective data to help improve the pilot and aimers ability to be successful, one aspect that was not evaluated was the intelligence that was provided to the pilots prior to each raid. The Intelligence Warfighting Function encompasses the understanding of the enemy, the terrain, and civil considerations. These three items are key to fixing, or determining the location, of any target. It is quite possible that the only information regarding the target that a pilot and aimer were given were grid coordinates, a basic and generic description of the target, and a map reconnaissance to aid base terrain association off of for a night raid.

Fixing a target requires much more information to ensure accuracy. If there are numerous rivers in the target area with industrial buildings near them and pilots and aimers are using the river as terrain association to identify the industrial building target near it, there is great potential for inaccuracy. So, while one of the key benefits of operational research is post mission objective evaluation of empirical data, it is important to ensure key pieces of information identified in post mission analysis are not overlooked in pre-mission briefings.

Though it may seem easy to separate fixing and finishing by definition, they are both so closely intertwined that it is almost impossible to effectively achieve one without the other. Fixing the enemy proved to be a large obstacle that the RAF continuously improved upon that directly influenced their ability to finish or act against the target. One of the most efficient changes that ORS recommended during the war was the change from precision bombing to area bombing. If the ultimate endstate was the target morale of the German people, then the change from a few planes dropping bombs over a few runs to hundreds of planes dropping hundreds of bombs in a few runs would indeed be the most effective with the added benefit of decreasing the number of losses inflicted upon themselves.

Had the ORS not been given the task to evaluate loss the RAF and strategic bombing may not have had the impact that it did on the war. Bomber Command leadership believed that area bombing would lead to increased losses due to collision, but through the objective and unbiased evaluation of empirical data, they were able to clearly proved the exact opposite, a less than half percent chance of loss by collision and a decreased percent of loss due to enemy fire.

Operational research provided recommendations and solutions for immediate problems at hand during conflict. There was not time to develop new technology nor was there the money for it either-- while plenty of funding exists during wartime, it is usually earmarked for supplying more current inventory supplies. The Royal Air Force had so far reached the point of inaccuracy that if the ORS had not been established Bomber Command may not have become one of the most effective and necessary pieces to Britain's resistance and defeat of Germany. The

American Military is quickly approaching a similar crossroads when it comes to big data proliferation on the modern battlefield.

The Army Operating Concept: Win in a Complex World, outlines five characteristics of the future battlefield. Three of the five tie directly to big data flooding the environment at rates previously unseen or unacknowledged:

- "increased velocity and momentum of human interaction and events
- potential for over match (of our capabilities by our adversaries)
- demographics and operations among populations, in cities, and in complex terrain." [46]

Each one of these characteristics requires the ability to process vast amounts of data quickly and turn it into actionable intelligence in which operations can be conducted against be they lethal, non-lethal, force protection, etc. Fortunately for the military, technology already exists with the capabilities to sort and process big data; it would benefit the military then, to employ operational research to identify best practices in order to achieve optimal results. A closer look at each characteristic may help further illustrate the possibilities.

The first characteristic practically lends itself to the need for big data processing: "increased velocity and momentum of human interaction." [47] Social media and the ability to connect instantaneously with at least one if not more than one device provides immediate access to information sources. With immediate access to information and other people, interaction is driven exponentially faster either deliberately or inadvertently. Social media posts these days are either driven to incite actions or to "inform" or "let off steam" which, often, can inadvertently lead to action, and most times not in a positive manner. A perfect example lies in the aftermath of the 2016 Presidential Election. Information and disinformation flooded the internet and social media daily throughout the campaign and even more so following the inauguration. Within twenty-four hours of President Trumps inauguration there was a massive women's movement march that took place across in multiple cities across the country, each one advertised and propagated mainly through social media. Social media and the internet are now regularly used as mobilization tools by organizations, both for peaceful movements and violence both locally and internationally.

The military needs to take advantage of preexisting tools such as Key Hole or AgoraPulse, both social media analytic tools, and through the help of operational research develop best techniques to apply them in Iraq or Syria in the attempt to anticipate and get ahead of the next ISIS attack. Getting inside the enemy's decision making cycle would provide a strategic advantage for United States.

The second characteristic of the future operational overmatch concerns current capabilities. The United States has long enjoyed an advantage over every country in the world when it comes to equipment and training. With the increased amount of and access to information as outlined above, along with the US's snail-paced acquisition process overmatch is only a matter of time.

As initially identified in this study, the military must continuously plan and resource for the future enemy, but as that is being done, the current enemy is discovering ways to defeat and counteract current equipment and technology. In order to maintain our overmatch the military must "combine technologies and integrate efforts across multiple domains to present enemies with multiple dilemmas." [48] OR facilitates that task. In order to combine efforts across multiple domains it will take an objective, unbiased approach to evaluate what current capabilities are and where the gaps lie that must be overcome. Once identified, OR techniques can be used to evaluate existing technology and recommend solutions for the identified gaps.

Finally, the last characteristic of the future operating environment outlined by the Army is “demographics and operations among populations, in cities, and in complex terrain.” [49] With the population of the world ever growing it is safe to say the US will most likely continuously find themselves fighting future battles among complex terrain such as cities. Adversaries of the US are well aware of the rules of engagement that govern how Soldiers, Sailors, Airmen, and Marines conduct operations in and amongst population centers, slowing them down in order to ensure minimal collateral damage.

Terrorists, insurgents, and other hostile actors will use civilian population centers to their advantage degrading the military’s ability to find, fix, and finish threats. It is key then, for our military to understand the environment in which they operate and use big data resources to gain a more coherent operating picture and to use the data to maximize operation opportunity. Currently, in large cities across the globe, there are many different types of feeds that monitor every day activities for law and order purposes. The creative use of OR combine with big data resources could be used to help fix specific targets or target areas so as to eliminate or severely degrade collateral damage as loss to US forces.

<u>Case Study Conclusion</u>

Through the study of OR in the RAF Strategic Bombing Campaign during World War II and the Army’s future operating concept, the Clausewitzean idea that the nature of war never changes has been a consistent theme. War consists of the government, the military, and the people: it did in World War II and it will in any future operating environment the United States may find itself in. While the nature of war remains immutable, the character of war remains in flux. In 1949, it was the in the cities, skies, and oceans of Europe, in 2006 it was in the cities, desserts, mountains, valley's and cellular networks of Iraq and Afghanistan, and in 2025 it will be the cities, skies, cellular networks, social media, and cyber battlefields of who knows what country.

While we may not know who the United States will face or what military equipment will be present, we do know that in order to be successful the US will need to maintain current overmatch in capabilities, will need to be able to thrive in the social media, immediate connectivity realm, and will need to be able to operate quickly and efficiently in complex urban environments that encompass all of these things.

Currently, the United States is downsizing the military and previous funding that had been dedicated to equipping and modernizing capabilities leaving the services to 'do more with less.' Leaders and operators struggle with this reality on a daily basis. As has been demonstrated through this case study the use of Operational Research to further identify problems unseen and recommend solutions through the modification of existing technology and capabilities will help ensure US overmatch is maintained and in any war, anywhere, anytime.

Operational Decision Game

If the Royal Airforce was able to successfully and quickly alter tactics, techniques, and procedures and training with current or emerging equipment/technology to stay one step ahead of the adversary while becoming more accurate and efficient in finding, fixing, and finishing targets, the United States should engage a similar construct to the new battlefield of big data. Currently the Defense Advanced Research Projects Agency (DARPA) has at least six different concepts in different stages of development addressing artificial intelligence (AI), machine learning, anomaly detection, communication with computers, exploration and filtering of text, and strategic communication via social media analysis. Use of these emerging capabilities with basic capabilities preexisting currently such as social media analytical tools could quickly turn the tables of advantage for whomever employs them better, faster when sorting and analyzing big data.

Design

Premised on this basic concept, an operational decision game (ODG) was designed to see how respondents might employ current big data exploitation capabilities in a combat situation. Working with another student testing a separate concept, the author co-designed a game set in the complex urban environment of a modern-day Kiev, Ukraine where insurgents have begun to wreak havoc on the city following the presidential assignation. While the initial big data concept could be used anywhere, a data rich environment of a large city with proximity to other large cities was imperative to ensure the honest opportunity for employment of the big data tools.

Two different games were distributed to provide a control group ODG. The control group game was set in the same environment where the respondents only had available to them assets currently resident in an Army Brigade Combat Team. The second ODG offered the respondents two new future concepts to use in their planning and execution, one being the big data concept title.

Respondents were given four different "tool kits" to process specific types of big data: social media, personal fitness devices, closed caption television (CCTV), and smart devices. Initially, all toolkits provided the ability to view and monitor data feeds from the sources. Only two of the four were equipped with additional analytic capabilities. The social media toolkit could automatically search for common themes and messages, flag key individuals/influencers, and notify analysts. The CCTV toolkit provided artificial intelligence (AI) with the ability to predict locations of protests and riots prior to full blown execution. Minimal guidance was given to respondents to allow for maximum interpretation, creativity, and employment of the concept.

Analysis

Sixteen operational decision games were distributed, six "control group" games and six future concept games. Of the sixteen ODGs distributed only the six future concept games were completed and returned. None of the control group ODGs were returned therefore, hindering any ability to provide comparison and contrast between responses. Response to the operational decision game varied in length and completion. While most provided full text answers with course of action sketch and/or narrative, some provided solely minimal text.

Overall response to the decision game reinforced the desire for a big data analysis capability. Without any prompting in within the game, four out of the six respondents utilized the concept in an intelligence, surveillance, and reconnaissance (ISR) role for the targeting process to "provide targeting information to forces for capture/kill [of] insurgents and detect /destroy IEDs and drones."[50] While not specifically stated, "providing targeting information" insinuates that the tool kits would first have to be used to both find and fix a target prior to any ability to provide targetable information.

While the data scraping concept received overwhelming reinforcement from the ODG's, two respondents provided comments that helped further refine the initial concept. Respondent 3 recognized the vast amount of data that would be pulled in and detailed that analysts would be needed to verify and establish targets and priorities.[51] With three of the four toolkits merely pulling in data for viewing, it would take multiple analysts to sort and provide initial analysis of the raw data. This realization led to a more holistic AI approach to the concept. Respondent 1 recognized the inherent capability the concept would have but questioned where the capability toolset would reside in the organization, triggering further analysis.

Future Concept - Technology for Urban Terrain

Created by: Majors Rachell Baca, Zachary Iiams, Jonathan Peterson, and Alexandra Plunkett

From the siege of Carthage in the Third Punic War to the current battle for Raqqa, wars have been fought in cities throughout history. Cities present militaries a multitude of challenges that are not present in open terrain, yet urbanization is expected to increase to the point that sixty percent of the world's population will live in cities by 2035.[52] As William Roseanau highlights in his article "Every Room is a New Battle: The Lessons of Modern Urban Warfare," open terrain, in contrast to urban terrain allows "maneuver and the virtually unrestricted use of firepower […] where tall buildings, narrow streets, noncombatants, and other obstacles are few or non-existent."[53] The characteristics that make the urban environment challenging for US forces, provide the enemy excellent terrain where they can exercise an asymmetric advantage. As a result, the Marine Corps Operating Concept (MOC) emphasizes that "operations in urban areas are the most likely to occur and the most dangerous."[54] Further, the MOC emphasizes the Marine Corps must "Exploit man-machine interface and manned-unmanned teaming (MUM-T) to overcome challenges in urban terrain."[55] To this end, the Technology for Urban Terrain is a four system solution taking advantage of advances in the man-machine interface and MUM-T to close gaps across multiple warfighting functions and increase US military success in the urban environment.

The systems that comprise the Technology for Urban Terrain together contribute to the warfighting functions (WFF) of intelligence, fires, logistics, force protection, and maneuver. First, the big data, machine learning/artificial intelligence (AI) analysis tool, called Needle

Finder, contributes to the intelligence WFF by providing added support to the intelligence analyst already on the ground. This big data tool enhances any analyst's ability to better and more quickly "facilitate understanding the enemy, terrain, and civil considerations."[56] It also enables enhanced support to the targeting process by providing more in-depth, holistic analysis of situations, places, and people during the find and fix portion of the targeting process. Big data machine learning/AI assisted analysis will provide analysts the ability to sift through massive amounts of data ranging from full motion video, to social media, to smart home data quickly to help develop and provide better situational awareness as well as develop pattern of life within a given geographical location. Enhanced analysis capabilities will lead to more accurate, precise targeting, increasing both our kinetic and non-kinetic effectiveness while decreasing collateral damage and overburdening units and assets.

The second system is a drone system that contributes to maneuver, fires, force protection, logistics, and intelligence WFF. The Drone Squad (DS) is a scalable system composed of a single system at the squad level that can be integrated into a drone swarm option to provide support to multiple echelons of command. The DS can also be customized by mission because of the different payloads the DS can carry. Payloads can vary from a direct fire capability, target acquisition capability, intelligence support capability, and a chemical, biological, radiological, and nuclear detection capability. The DS provides a multitude of mission support functions to the squad level and higher echelons. In support of maneuver, the DS can gain an advantageous reconnaissance position that enables US and coalition forces to quickly maneuver on the enemy. The DS can engage the enemy via the support packages and force enemy movement, and support US and coalition forces control of an area by increasing the distance a force can control by reducing the limitation of blocked line of sight due to terrain. In support of the fires WFF the DS can maneuver through or over terrain ahead of any US or coalition force to provide a position to request indirect fires that prevents US or coalition forces from exposing their position to enemy direct or indirect fire. The DS small signature will allow the DS to remain in place to observe the effects of indirect fire missions. In support of the force protection WFF the DS can enhance the defensive measures US or coalition forces are using in support of operations, and assist in the identification and location of friendly forces across the battlefield. The DS can also support logistical or combat operations by being able to move ahead of forces around dead space to identify obstacles or threats. Lastly, in support of the intelligence WFF the DS is a fast method for lower echelons of command to collect data in the operating environment and then provide threat assessments or targeting identification to US or coalition forces on the ground.

The third system is the optionally manned and armed logistics vehicle (OMALV) and primarily supports the logistics WFF. However, the system contributes directly to both maneuver and force protection in sustaining combat power. This system is an unmanned ground vehicle (UGV) platform that provides manned, autonomous, and tele-operated tactical-level motor transport operations. Moreover, OMALV offers the ability to scale the composition of convoys with up to five unmanned vehicles to every manned vehicle. This manned and unmanned scalability allows convoys the ability to task-organize to the threat environment. Additionally, the OMALV is armed with a stabilized weapon system capable of autonomous and tele-operated fire controls. A day and night optic provide for precision fires during all hours. Each OMALV is able to act as a wingman in a leader-follower manner to provide mutually supporting fires while convoys make their way along a route. Finally, the Drone Squad is able to integrate with the OMALV for ISR support and application of indirect and direct fire systems.

The fourth system is the Active Denial System (ADS), which is a non-lethal counter-personnel system that contributes to the fires and force protection warfighting functions. In terms of fires, the ADS produces non-lethal precision effects from a variable standoff range. The ADS affects human targets and the energy that the system emits causes the targets to move out of a specific area. This system reduces collateral damage that might otherwise occur from lethal fires in an urban environment. The ADS fires will mostly support close operations and can be used in fires in support of decisive operations, shaping operations, or sustaining operations depending on the commander's purpose. Likewise, the ADS will provide protection to US and coalition forces by enhancing survivability and effectiveness of friendly forces. Since the ADS repels people at a certain radius, it will minimize mobs in the vicinity of US forces and create a standoff distance that makes threats from enemy weapons less effective.

The Technology for Urban Terrain future concept incorporates four new systems that will benefit US and coalition forces in the urban environment. This concept will describe the following four systems: Needle Finder, Drone Squad, OMALV, and the ADS. For each system in the Technology for Urban Terrain future concept, this paper will provide a problem statement and a hypothesis for how the system proposes to solve the problem. Next, this paper will present a capability description, concept of employment, and measures of success for each future system that the concept proposes. Finally, this paper will provide system tradeoffs and recommend areas for future research.

Needle Finder- Big Data Machine Learning/Artificial Intelligence (AI) Analysis

Problem Statement: The world has gone digital and the amount of big data that each person and organization produces daily continues to increase leaving an even bigger digital thumbprint. Billions of hours and terabytes of information is left unanalyzed and unexploited, with even more millions being generated in near-real to real time. The United States military must figure out how to harness and analyze big data quickly, and increasingly, with less people.

Hypothesis: If the government uses an operational research approach to existing artificial intelligence (AI), analytical software, and programs then the capability required by the military will be available for employment in less time than it would take to procure new programs.

Capability Description:

Needle Finder is a program that sifts through available historical and current data, and has the AI to analyze the data within the means of a unit mission set. The Defense Advanced Research Projects Agency (DARPA) is currently researching six programs that focus on the development and use of AI for analysis and prediction as well as programs to provide analysis and recommendation for action against critical influencers through social media. The Department of Defense (DoD) will purchase access to large repositories of data such as Closed Circuit Television (CCTV) of urban areas, personal fitness devices, smart home devices, and all social media platforms. Needle Finder will use the data the DoD purchases and its repository of full motion video, imagery, and measures and signatures data to sift through for analysis when an analyst prompts it to assist in finding and fixing targets. Analysts will be able to run multiple queries based on mission sets simultaneously. The program will then sift through all of the data available, historic and real-near real time and provide predicative analysis to the analyst as recommendations to possible human and material targets, pattern of life tracks, locations for attacks, protests, or gatherings, etc. The analyst will either accept, decline, or flag to continue monitoring. Through the analysis and approval process the artificial intelligence learns patterns and links between physical and human networks and continues to provide recommendations.

Concept of Employment:

The DoD will purchase access to large repositories of data such as personal fitness devices, smart home devices, social media platforms, and CCTV footage in the area where forces are deployed. Needle Finder will access all of these repositories as well as all full motion video and raw data in the DoD repository, and will process data using a cloud interface on any computer. This capability will be resident at the Army Brigade or equivalent and higher Intelligence Section (S/G2), specifically to the analysts who are responsible for fusion of information and intelligence.

Intelligence analysts will input the unit mission set and nest it with higher headquarters's mission to enable boundary analysis, which will enhance the find and fix portion of the targeting process and force protection. The analyst sets the mission geographical boundaries to narrow the initial data sift and analysis. Once the program identifies a person, place, or thing of interest it will then automatically widen its aperture to find links and connections both in and outside of boundary or prescribed data sets. Artificial Intelligence will then provide basic analysis of the targets identified, i.e. analysis of imagery highlighting change detection on the roof of a possible combatant. It will also then identify the individual who owns the building providing social network handles and an initial social media scrape of the individual's accounts. All of this information and analysis will be flagged for the intelligence analyst to confirm or deny the target for further analysis and monitoring or not.

Measures of Success:

The most important measure of success for this concept is the amount of time it takes to cycle through the targeting process: find, fix, and finish. Upon entrance into a theater it may take months for a unit to fully develop and understand the operating environment, and only then can targets be engaged. Success would enable this understanding of the operating environment and key players within it in a matter of weeks instead of months. Success depends on the US forces's ability to more rapidly and holistically understand the problem and commit fewer assets, but with greater fidelity of the situation, resulting in more effective results quicker.

Tradeoffs:

US forces must make tradeoffs in its development of big data analysis tool. First and foremost is the initial access to the data. DoD will have to purchase access to many data services that would provide information such as personal fitness devices and smart home devices etc. While DoD could utilize a small portion of its budget to purchase such data, the overall Defense budget is fluid from year-to-year and dedication to such a program may require shifting focus and funds. Second, the organization recording and archiving CCTV footage may only archive data for a limited amount of time. Additionally, as individuals and organizations move to recording and storing data on cloud networks, the DoD's reliance on networks will become essential. The DoD's preparation prior to entering a new theater will become and remain essential to gaining and maintaining the digital initiative. Understanding the network infrastructure and digital footprint of the countries the DoD is focused on as well as requesting and purchasing the proper data feeds will be crucial.

Areas for Future Research:

Once the Needle Finder is fielded and providing support to the intelligence analyst additional research and development could further develop support possibilities of the technology. First, further development of AI and machine learning could lead to future "less man-in-the-loop" target discretion and analysis, providing and executing recommendations for target engagement. Flagging targets as important non-kinetic (think Information Operations or capture targets), kinetic targets (think kill/destroy), or engagement areas would enable faster planning cycles, greater fidelity and discretion of asset engagement, and limit collateral damage. Second, future research and development might focus on AI's ability to calculate more accurate second and third order effects outcomes based on method of target engagement. This would provide the man-in-the-loop greater fidelity of effects on the ground allowing for more accurate follow-on planning and actions. While this development would further AI, it will never fully replace the manned-unmanned team of machine, analyst, and operator.

Drone Squad

Problem Statement: Dense urban terrain (DUT) provides the enemy multiple opportunities for forces to maneuver undetected and gain an advantageous firing position due to limited ISR assets.

Hypothesis: The Drone Squad provides, beginning at the squad level, an intelligence, surveillance, and reconnaissance (ISR) capability with mission swappable pods that enhances the forces ability to conduct missions.

Capability Description:

The DS is a small drone system at the squad level that provides local ISR to the squad and has swappable mission modules that leaders can choose to employ based on mission requirement. As mission requirements change the individual drone can be linked to other drones to form the DS. In the DS set up, the drones can be linked together to move and maneuver as a separate force with different mission pods as required to accomplish any assigned mission.

Concept of Employment:

A squad could use an individual drone for local ISR to provide time and distance of nearby enemy so leaders can determine threats and risk to force. The drone will allow the operator to look ahead, see around dead spots, or lead into confined areas to determine risk. For example, an infantry squad leader could send a drone into a house first to identify if there are any hostile forces inside or a vehicle commander could use a drone ahead of his vehicle or convoy, around a blind spot, or into an intersection to determine if the route is visually clear of threats. Depending on the mission pod the drone is carrying, if the drone discovers a threat, the operator could engage the threat with the drone directly, call for indirect fire, maintain observation, or track the threat.

If the commander requires multiple drones to cover an area, he could employ them using the DS concept. A platoon leader would be able to employ four drones in a DS and Company Commander could employ as many as 12 drones in a Company level DS. A Battalion commander and higher would be able capitalize on the number of operational drones to design mission specific DS. Operating using the DS concept allows the commander a quick response to a critical situation, such as target development, support to troops in contact, or personnel recovery. If the commander requires target development he could task the DS to fly a reconnaissance mission to identify routes, to determine target location based on biometric scanning, or to fly a repetitive pattern to determine pattern of life. The commander could respond to a troops-in-contact situation by employing the DS to provide a faster ISR asset response, indirect fires capability, or to maneuver on the enemy force. Due to the DS scalable size, the DS could support personnel recovery efforts by providing a wide search area, using biometric scanning mission pods to identify personnel involved, tracking the missing personnel, or providing fire support until recovery. The DS concept provides leaders a low cost and responsive ISR asset for quickly evolving battlefields.

Measures of Success:

The two measures of success for the DS are reduced collateral damage and increased situational awareness at the squad level. A squad would need to assess the reduction in collateral damage during actual combat situations due to the difficulty of fires clearance, operator training, and target identification. It would also be useful for evaluators to assess collateral damage at military training centers before the DS is used in combat. A squad can assess its increase in situational awareness during home station training and during training at a military training center. The unit's willingness to train with the DS from the individual level and higher is the most significant factor in whether the squad will see an increase in situational awareness.

Tradeoffs:

The drone or the DS would still require an operator, reduced flight time, and payload size. The operator can set the drone or DS to operate semi-autonomously, but the DS will still require an operator to verify targets for engagement, load mission plans, pilot the drone if wanted, and provide maintenance. The operator still requires training to operate the drone, however, since the drones are based off of current market systems, units could leverage the knowledge base of personnel who already know how to pilot drones and create a unit training plan. Additionally, the DS utilizes commercial-off-the-shelf drones, whose flight time is limited to battery life. Current drone systems have approximately thirty to forty minutes of flight time. Therefore, the leader would need to take battery constraints into consideration for ISR planning, or ground units would need to carry additional batteries to keep the drone operational.[57] Finally, the drones have a limited payload capacity. Considering recent evidence, criminal organizations that use drones to deliver drugs into prisons have been limited to the weight of a hand gun, which is approximately three pounds.[58]

Areas for Future Research:

Although current commercial drones can avoid obstacles and track targets, there are still areas to improve the DS capability. First, the mission pods are based on multiple commercial-off-the-shelf drone systems, such as facial recognition, land survey, and CBRNE detection drones.[59] Mission pods need to be designed to fit the size, weight, and power constraints of the drones. Second, to use the DS concept, each drone needs an easy-to-use swarm software program that would allow fast linking and processing power distribution to allow for data management. Third, the DS would require integration with or access to a database to pull information. This information could range from biometric, vehicle, or weapon identification information. Fourth, while current drone systems do have onboard maneuvering capability, the DS requires additional research and development on artificial intelligence to maneuver against a target so that the drone can utilize additional drones, cover, and concealment. Fifth, to be as functional as possible, the drone requires longer battery life and additional payload capacity, while retaining a small deployable design. Lastly, to assist in mechanized or motorized operations, the DS could benefit from a vehicle mounted launching and charging station.

Optionally Manned and Armed Logistics Vehicles (OMALV)

Problem Statement: In both the open and urban environment, traditional ground transportation vehicles in the logistics community are not currently configured or equipped to meet the force protection demands and distributed environment described within the Marine Corps Operating Concept.

Hypothesis: The employment of optionally manned armed logistics vehicles will minimize friendly casualties by keeping personnel out of harm's way, increase convoy force protection, extend sustainment requirements for distributed maneuver forces, and re-allocate manpower to other high demand force structure requirements.

Capability Description:

The optionally manned and armed logistics vehicle (OMALV) is an unmanned ground vehicle (UGV) able to provide tactical-level ground transportation lift and internal convoy security. The OMALV is either operated as a traditional ground logistics vehicle with a human driver and internal crew or operated autonomously in a leader-follower fashion linked with a manned command vehicle. When an OMALV is not manned, the unmanned vehicle is able to navigate autonomously or by inputs from the associated command vehicle. The ratio of manned versus unmanned vehicles in planning convoy operations is one to five. The OMALV weapon system is tele-operated or autonomous and outfitted with a stabilized crew-served weapon ranging from a M240G, Mk-19, .50-cal machine gun or up to a 30mm chain gun. Additionally, the turret system would put the gunner inside the vehicle and out of harm's way by configuring the stabilized weapon system with day and night optics and engagement controller. The manned command vehicle is able to monitor up to five unmanned vehicles and network their associated weapon systems into the convoy's force protection and fires plan. Unmanned OMALVs act as wingmen during convoy operations and provide mutually supporting fires along the convoy's route either by autonomous or tele-operated operation.

Concept of Employment:

The OMALV is an armed logistics vehicle primarily employed to conduct resupply convoys and long-haul movements of supplies, bulk liquids, and military containers via motorized transportation. The OMALV system offers the capability to operate convoys at an increased rate in any given twenty-four-hour cycle with a reduced footprint of personnel. Employing OMALVs is scalable from motor transportation platoon sized missions to a Transportation Support Battalion during Marine Expeditionary Force sized missions. The lethality of a stabilized gun system able to operate day or night provides the type of precision fires that make convoy operations “hard targets” in all environments. When engaging enemy threats, the weapon system is able to provide accurate rounds on target at the maximum effective range of the respective weapon system. Additionally, the Drone Squad could integrate with the OMALV to provide an ISR platform for convoy operations. Drone Squads would provide convoy commanders route reconnaissance information, guardian angel over-watch during road marches, and the ability to call for indirect fire or air support when the DS detects enemy threats.

Other areas the OMALV system has potential supporting are offensive and defensive operations. During offensive operations, unmanned OMALVs could provide the firepower required to conduct a reconnaissance mission or act as a vanguard when able to minimize human risk factors. The OMALVs ability to network internal fires and stream video from the vehicle’s day and night optics provide valuable intel from the ground level. Unmanned OMALVs offer new means to reduce friendly casualties such as executing bounding over-watch in complex urban terrain for manned units following in trace, executing route clearance missions along main supply routes (MSR), and all the way up to conducting movement-to-contact operations in locating and relaying enemy locations. For defensive operations, OMALVs could be employed in a defensive picket-line to overwatch difficult terrain with reduced line of sight using an economy of force or set into security post duties much like a sentry in a guard post within a Forward Operating Base.

Measures of Success:

There are four areas for measuring the success of this system: increase the lethality of convoys operations in a twenty-four hour period, increase throughput of convoy operations in a twenty-four hour period, decrease manpower requirements for conducting convoys, and reduce the requirement for maneuver forces to protect logistics units. Providing precision fires to convoys turns previously perceived "soft targets" into "hard targets" to attack. The increased lethality of convoy's force protection and internal security should reduce the demand for maneuver elements embedding in resupply convoy missions or patrolling MSRs. Reducing the need to man every vehicle provides the ability to generate more convoys per day and allows force structure to move to other high demand manpower fields. Success in these four areas may reduce friendly causalities by not exposing unnecessary personnel into harm's way.

Tradeoffs:

Several tradeoffs exist with reducing manned requirements in convoy operations. First, motor transportation (MT) personnel do more than just drive vehicles from location to location. Often, MT personnel maintain and prepare every vehicle for convoys, then load and offload supplies to their customer. There may be a tradeoff to continue to do similar activities with fewer MT personnel which may impact the current MT organization. Secondly, the cognitive load of an individual will greatly vary when monitoring unmanned OMALVs in a garrison versus combat environment. Studies will need to research the correct balance of manned versus unmanned vehicles in convoy operations. Third, enemy threats will look for ways to deny the use of unmanned technologies by means of jamming, spoofing, or creating complex environments difficult for machines to comprehend. As OMALVs are presented with new situations and environments, the OMALV will be required to have an ability to upload shared information along the system enterprise. Fourth, as new technologies for the OMALV emerge, the new force structure will be required to maintain and operate the new system. It may be necessary to reduce MT operators at the cost of creating new requirements for more mechanics, armory and optics personnel, communicators, or other military occupational specialties. Finally, the tolerance for losing gear is not well received within military ranks, even if it is due to a combat loss. How will this approach to gear accountability change as units become less risk averse with employing unmanned vehicles in high risk situations?

Areas for Future Research:

Proven technologies for driving unmanned vehicles in extreme environments exists but the pairing of employing UGVs and autonomous weapon systems does not exist. First, in decreasing the man-in-the-loop and human cognitive load, research and development will need to address the combination of both autonomous UGVs and weapons systems. Operators of this system in a combat environment will quickly reach a tipping point of being over saturated with situational information and internal convoy task management. Research should focus on reducing tele-operated functions to the maximum extent possible to decrease the manpower requirement for conducting convoy operations. Second, vehicles breaking down or getting stuck is a common occurrence. Research will need to address unmanned recovery vehicles to remove the requirement of recovery operations currently being a manned mission. Finally, research should investigate new efficiencies in loading and unloading vehicles to address the manpower gap created by fewer MT personnel. The task to load and unload a convoy is time consuming and research will need to focus on more efficient container and storage systems and the best way to reduce friction in the delivery of supplies.

Active Denial System (ADS)

Problem Statement: In the urban environment, the rules of engagement (ROE) either limit traditional fires or allow them, but traditional fires cause significant collateral damage; accomplishing the mission while minimizing friendly casualties and collateral damage requires new fires technology.

Hypothesis: The non-lethal active denial system (ADS) provides a counter-personnel capability that will reduce damage to the environment, decrease civilian and friendly casualties, and allow forces to clear areas faster to enable freedom of maneuver.

Capability Description:

The ADS is a non-lethal weapon that provides a counter-personnel capability by using directed millimeter wave energy. The millimeter wave energy thermally stimulates nerves on the surface of the skin instinctively causing a person to move. [60] In the development of the system, researchers tested the system on over 13,000 volunteers and found that within seconds, reflexes caused the volunteers to move out of the beam to avoid the sensation on their skin.[61] This effect is the "repel effect" and causes humans to close their eyes, turn their heads or bodies, and move out of the beam.[62] The system has multiple built in safeguards including short shot duration, a scope for the operator to see the entire beam path, and hardware and software to adjust the beam path to adapt for environmental conditions.[63] Together rigorous testing, demonstrations, studies, independent reviews, and legal reviews proved the ADS technology effective in a relevant environment.

The DoD could integrate the ADS into multiple weapon systems depending on the intent for use. Currently, the maximum range of the ADS is 1,000 meters; however, shorter standoff ranges are possible. Due to the variation in standoff ranges, the ADS could be integrated into fixed-winged platforms, helicopters, larger UAVs, ground vehicles, and maritime vessels. The power that the system requires varies with the standoff range and depends on the generation of ADS technology. A solid-state ADS technology, currently in development, will allow for a smaller form-factor with a lighter power supply that will be man-transportable and could be useful for dismounted infantry.

<u>Concept of Employment</u>:

The ADS is a counter-personnel weapon to use as a tool in the escalation of force. Specifically, the ADS should be a standard part of operations for crowd control, convoy and patrol protection, and checkpoint security. The ADS fills the gap between "shout and shoot" by providing a non-lethal weapon that gives a standoff range, but that the target cannot ignore or overlook. To incorporate the ADS into the rules of escalation of force, the military member would give the threat a verbal warning, then a visual warning using a device like a flag or light, and then employ the ADS prior to the use of lethal force. In this situation, the weapon would likely be mounted on a ground vehicle, including the OMALV, or be man-transportable by the individual. The DoD may also decide to integrate the ADS on fixed and rotary wing platforms that are providing fire support for ground forces, or use the ADS as an alternative to lethal force in close coordination with ground forces. Crew on-board a ground vehicle or aircraft could fire the system, or an operator in the rear could fire it using a low latency camera. Either way, the operator in the ground vehicle, aircraft, or rear will receive the same image through the boresight of the weapon.

Incorporating this non-lethal weapon into the inventory provides the Joint Force Commander (JFC) additional options and provide benefits for US forces in the urban environment. According to Joint Publication 3-06, *Joint Urban Operations*, "When civilians and hostile forces are intermingled, non-lethal weapons will provide the JFC a broader range of capabilities intended to significantly reduce undesired injuries to civilians and damage to infrastructure." In addition to providing positive effects for the population of urban environments, there are benefits of using the ADS to US forces. For example, an ADS can provide friendly forces an alternative to clear angry mobs to a distance that reduces the threat of weapons against friendly forces and provides room for maneuver. There may also be a psychological benefit for US forces. Journalist David Brooks as quoted in *ARMY Magazine*, describes a scenario where insurgents use women and children in attacks against US forces causing US forces to engage, "soldiers and Marines feel a totalistic black stain on themselves because of an innocent child's face, killed in a firefight. The self-condemnation can be crippling."[64] In this same situation, the ADS would allow US forces to use non-lethal force.

Measures of Success:

The three most important measures of success for this system are reducing civilian casualties, friendly casualties, and collateral damage. An optimal decrease in these parameters is difficult to forecast since it is largely dependent on the character of the war. For example, if US forces are largely conducting air support, one might observe different results from an ADS than if ground and air forces were both heavily involved in an urban conflict. That said, a possible place to start measuring whether the ADS is successful is to look for a greater than twenty percent reduction of civilian casualties and collateral damage, and a greater than ten percent reduction in friendly casualties. Success in these measures may also increase support and trust of the local and US populace.

Tradeoffs:

There are several potential tradeoffs inherent with the ADS technology. First, the weapon could be affected by weather and atmospherics. An ADS integrated into an aircraft or ground vehicle may not be useful in inclement weather, including sand and dust storms. Similarly, the maritime boundary layer could reduce the intensity of the beam. In these cases, the user may not have the weapon available to him or the weapon may require additional power to achieve the same intensity on the target. Additionally, integrating the ADS into systems with limited size, weight, and power (SWAP) tolerances may cause operators to choose using the ADS technology instead of another sensor. For example, the MQ-9 currently does not have the SWAP to integrate an ADS, but it might be possible to integrate if the operator chose to temporarily remove and replace another sensor for missions when the ADS would be more useful. To prepare for these situations, it would be useful for the ADS to employ open system architecture and interface so it can be "plug-and-play" into existing combat systems. Finally, as with all non-lethal weapons, the ADS may not be useful in accomplishing the specific goals of the operator and the situation may escalate to a lethal engagement.

Areas for Future Research:

While multiple technology demonstrations proved ADS technology works, additional research could increase its capability even further, particularly as the ADS integrates into other systems and platforms. First, the research and development community must continue to invest in batteries that provide sufficient power in the smallest form factor possible. Second, while initial deployment of this weapon will have a man-in-the-loop, future research should be dedicated to more autonomous employment to take the load off of task saturated operators. Third, because of vibration and atmosphere that the directed energy beam will encounter when on an aircraft or ground vehicle in motion, research should improve beam stabilization. This will ensure the beam has sufficient intensity when it hits the target and reduce jitter of the beam on the target. Finally, a spiral development program could incorporate a counter-fire capability to protect ground vehicles and aircraft against rocket-propelled grenades and guided munitions.

Conclusion

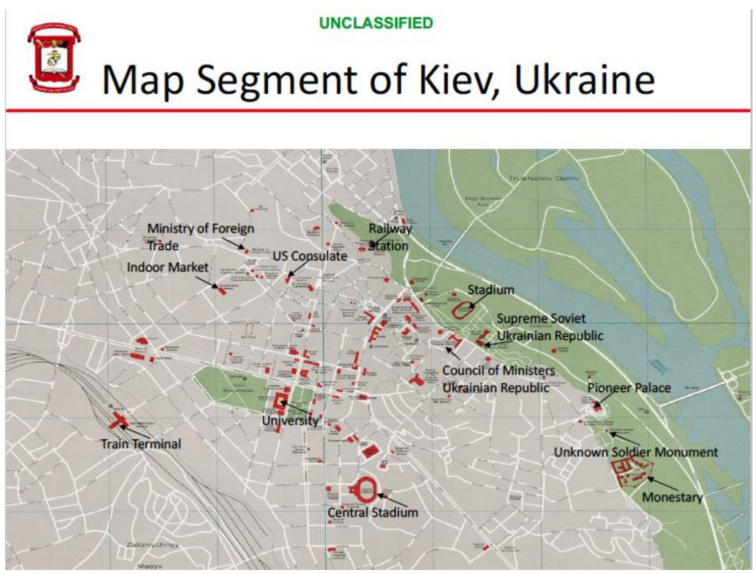
The four systems that comprise the Technology for Urban Terrain close current gaps across five warfighting functions in urban environments. These systems will contribute to the successes of US forces by allowing them to rely on machines to reduce cognitive load, protect friendly forces, prevent civilian casualties, and minimize collateral damage. Each system can be utilized individually or work together to achieve synergistic effects. The Needle Finder uses big data analytics to combine open source and classified data to provide better situational awareness from all available methods in an area of operations. The Drone Squad contributes to the WFF of maneuver, fires, force protection, logistics, and intelligence, and is a scalable and modular solution that adapts to the unique needs of a squad-level unit. The OMALV is a manned, autonomous, and tele-operated tactical-level motor transport system enhancing logistics, protection, fires, and maneuver in both urban and open terrain. Finally, the ADS is a non-lethal fires solution that provides protection to friendly forces by creating a standoff range between threats and the ADS system. Together, these four systems seek to reduce the asymmetric advantage the enemy has operating in the dangerous and com

Conclusion

The nature of war never changes, only the manner in which it is fought consistently evolves. Using what was available to them, operational research teams working with the RAF were able to address the evolving nature of the enemy and battlefield. The success of the strategic bombing campaign was not placed on the acquisitions process of developing new technology to address a what at first look to be a gap in capability. Instead, researchers applied a scientific model to evaluate the targeting process as a whole from training and manning to tactics and equipment to provide objective recommendations to leaders for improvements on operations.

Current DoD strategy is focused on what future war will look like and how the United States can continue to maintain the current, yet shrinking, offset advantage. It does not take much imagination to see how the battlefield has evolved with a growing big data domain and how that domain will quickly continue to grow and further change the way in which war is fought. The DoD needs to begin addressing the offset now, but does not have the funding or time to dedicate to expensive new autonomous and semi-autonomous systems to be employed in ten to fifteen years. Fortunately, there are already initial technologies and capabilities available the DoD can leverage with the use of operational research to learn how to effectively employ them against current problem sets across the globe.

Appendix A- Operational Decision Game in Kiev, Ukraine with Future Concepts



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Information Environment

- Kiev is a modern city with 3G/4G/LTE networks, just about everyone owns, uses, and accesses the internet via a mobile device. Personal computers proliferate the country as well, with at least 1 personal computer in every household.
  - Social Media is primary means of communication for people under the age of 35.
  - Much like the US, most people have/wear personal fitness devices (PFDs) that monitor HR and pace count at a minimum.
- In addition to Internet, 8 out of 10 households utilize some sort of smart TV device such as appleTV or the Amazon Firestick.
- 7 out of 10 households also now have smart devices controlling their thermostats, lighting, locks, etc. Many have also made the switch to other smart devices like refrigerators.
- As with much of Europe, Ukraine has installed CCTV around the city to keep a watchful eye on its citizens in a hope to deter crime. Citizens have come accustomed to the cameras and no longer ay much attention to them.

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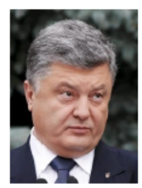
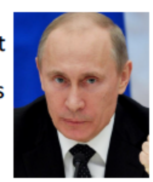
Road to War 2020



- The situation in Kiev has deteriorated quickly since the assassination of President Poroshanko which is largely speculated to have been in response to his continued push for political, economic, and judicial reforms; and the recent reinvigoration of attempting to join the EU.
- Since then, there has been an insurgency noticeably growing while the interim government works to replace Poroshanko.
- The US is currently transitioning to a new administration, but has been called upon by NATO to help suppress the unrest, squash insurgency, and aid Ukraine in the election process for the new government.
- While it cannot be proven, it is believed that Russia either conducted or supported the assassination of Poroshanko. Since the assassination, Russia has remained quiet in regards to the death, but has openly spoken of its opposition to the Ukraine joining the EU and its desire to eventually, one day, re-claim wh is rightfully theirs



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Current Situation

- Social Unrest among Locals who are worried that the government may return to a Pro-Russian state as well as though who are vocalizing the desire for a Pro-Russian government
- Protests among students both for and against joining the EU
- Assassination attempts on interim government leaders
- IED's and bombs found and detonated IVO government facilities and security forces in the area
- Recent sightings of non-governmental or media associated drones conducting surveillance of bridge crossings and areas that are highly populated throughout the day.

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Enemy and Equipment

- The insurgency blends easily into the Local population wearing street clothes and participating in daily activities.
- Have the ability to initiate and exacerbate protests and riots within the city in as little as 2 hours
- There are assessed to be around 40-50 insurgents being supplied and funded by the Russian government within Kiev proper.
- Equipment includes
  - Class 1 drones- linked to smart phones with video/photograph capability
  - AK 47's and RPG's
  - Homemade bombs/IEDs

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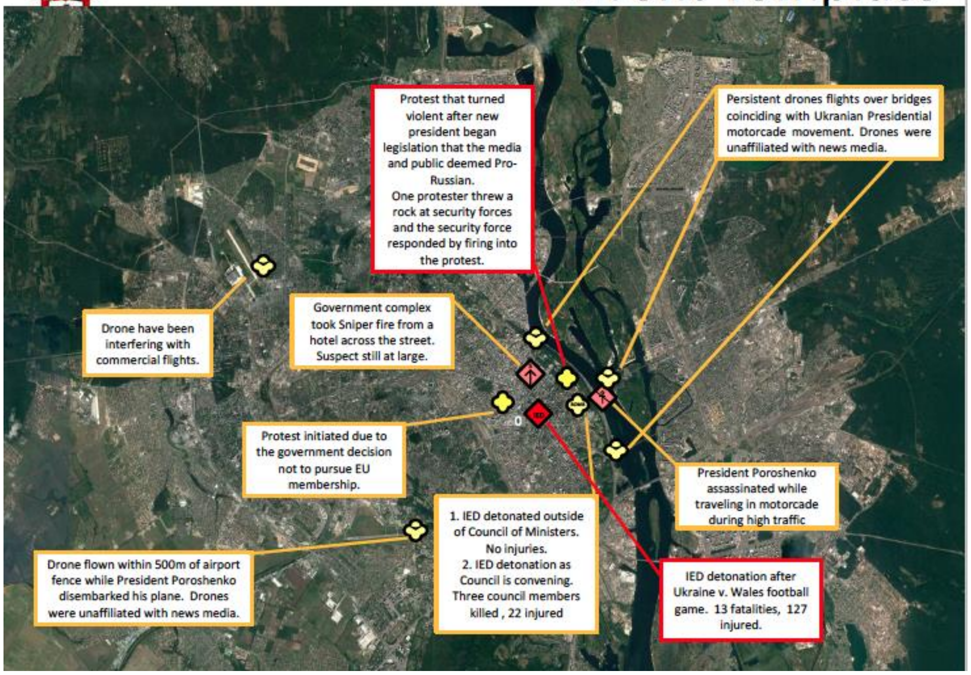
Event Template



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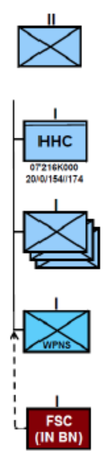
Friendly Composition

- 2/2 Infantry Battalion, 3rd Infantry Brigade Combat Team, 10th MTN DIV is fully mission capable.
  - 1 Headquarters and Headquarters Company,
  - 3 Rifle Companies
  - 1 Heavy Weapons Company
  - 1 Forward Support Company
- For full unit composition reference slide 14-20.
- 2/2 Infantry has been augmented with 108 HWWV for mounted operations



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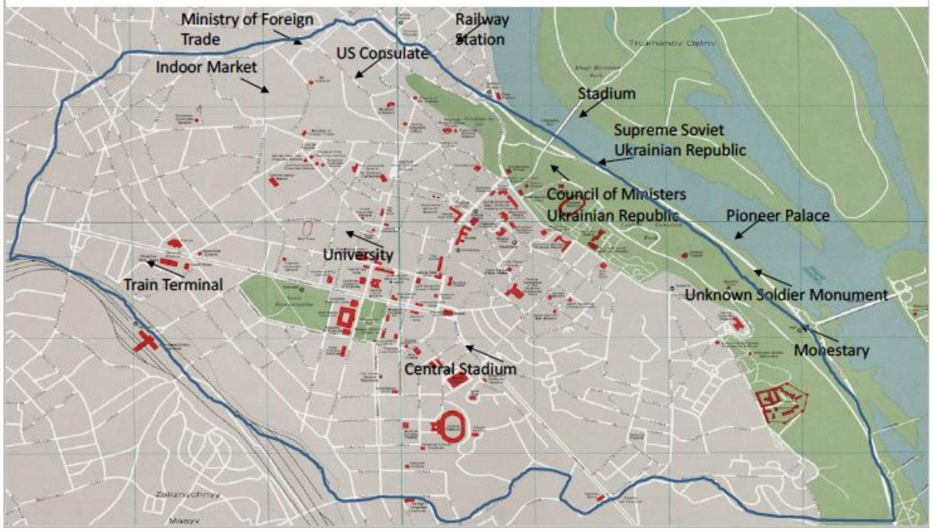
2/2 Infantry Area of Operations



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3rd Infantry Brigade Combat Team, 10th MTN DIV Commander's Guidance

- Insurgents in Kiev destroyed or reintegrated into the populace
- Set Conditions to transition security of Kiev to Ukranian security forces
- Prepare for Follow-on Operations

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Future Concept 1: Data Scraping

- Social Media Scraping Tool Kit
  - Scrapes ALL social media: Facebook, Twitter, Vimeo, Trip Advisor, Blogger, Yelp, MyFitnessPal, Garmin etc. searching for common themes and messages, flags key individuals/influencers and notifies analysts.
  - Analysts approve or disapprove the person of interest for further/follow on observation or collection
- Personal Fitness Device Tool Kit
  - Ability to view all information from PFD's within a Geo tagged area near real time.
    - Heart rate, activities completed, handle name, challenges joined/completed etc
- Smart Device Tool Kit
  - Ability to view all smart home devices within a geo tagged area real time and history up to
- CCTV Tool Kit
  - Access to CCTV across the country with AI that has the ability to predict locations of protests and riots prior to full blown execution

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Future Concept 2: Drone Squad

- Each squad or vehicle section Infantry has been issue one drone that is a part of the Drone Squad.
- Can be human controlled or autonomous
- Each drone has a one 1080P HD camera installed
- Each drone can be outfitted with one of the following pods:
  - Survey- Route Reconnaissance
  - Explosive charge
  - CBRNE Detection module
  - Target designator – Laser range finder and target GPS position
  - 9mm firearm pod – 15 rounds
  - Facial Recognition pod
  - Retransmission/Relay
  - Network Reconnaissance / Penetration
- Can operate up to 4 miles away from controller (Line of Site)
- Can fly up to 40 miles per hour
- Vehicle platforms have a recharging station
- 30 min flight time
- Battery can be changed during patrols
- 1 hour battery recharge time
- Individual Drone use
  - Drone can be set to a lead mode to fly a determined distance ahead of the squad to fly a predetermined route with the Infantry squad or maintain a distance a head of controller based on Friendly identification
  - The pod selected for the mission will determine patrol capability.
  - Based on the pod selected the pod can pull/push relevant data from information systems and databases to assist the squad.
  - The drone can be set to return to operator or fly to a predetermined points.
- Drone Squad Configuration
  - The drone squad pod load can be adjusted to suit the mission.
  - A drone is set a lead and is maneuvered by an operator or set on a pre-planned mission.
  - Drone squad is a living link system that allows for fault tolerance, if the lead drone loses contact, the drones will attempt to re-establish link and continue mission.
  - Drones can be outfitted with different communication pods to allow the drone squad to communicate on different frequency bands.

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Problem Framing

Problem Statement (incl. list of key facts and assumptions):

Tensions Between Current Conditions and Desired Conditions:

Elements that Must Change to Achieve the Desired Conditions:

Opportunities and Threats to Achieving the Desired Conditions:

Limitations:

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COA Graphic and Narrative

COA GRAPHIC OR TYPED DESCRIPTION

MISSION:

INTENT:
(purpose, method, desired condition)

CONCEPT:
(incl. key tasks by phase)

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Theory of Victory

Synopsis of your Central Idea

Necessary Capabilities

Application & Integration of Military Functions

Spatial & Temporal Dimensions

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Anything Else?

- Please include any questions, comments, or additional details about employment of future concepts here:

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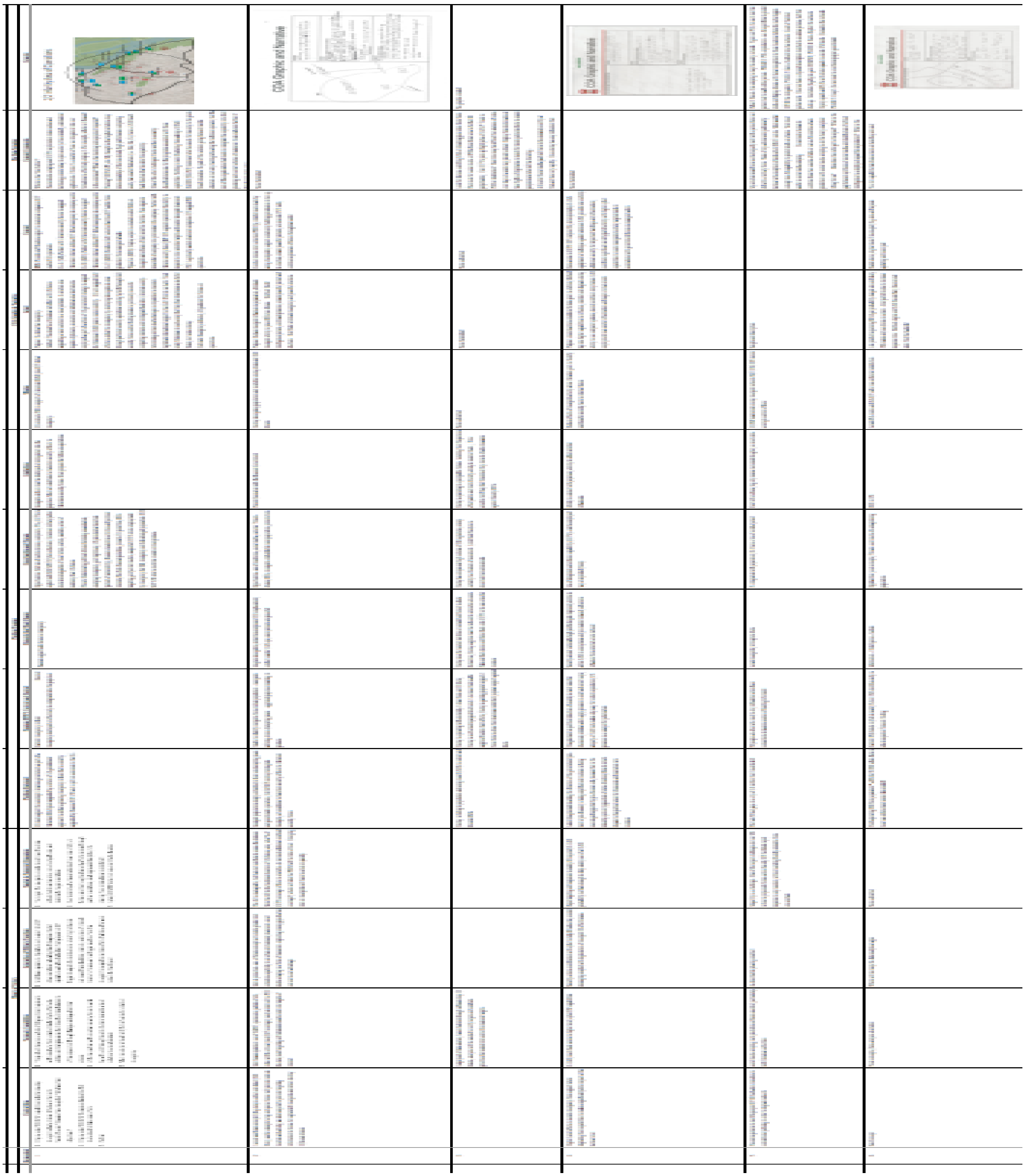
Appendix B- Table of Respondent Solutions to Kiev, Ukraine Future Concept Decision Game



Notes

[1] Randall T. Wakelam, *The Science of Bombing: Operational Research in RAF Bomber Command,* (Toronto, Canada: University of Toronto Press Inc),
[2] TRADOC Pamphlet 525-3-1, Army Operating Concept: Win in a Complex World, (2013), 11
[3] Mackenzie Eaglen, What is the Third Offset Strategy?, Real Clear Defense, February 16, 2016, http://www.realcleardefense.com/articles/2016/02/16/what_is_the_third_offset_strategy_109034.html
[4] TRADOC Pamphlet 525-3-1, Army Operating Concept: Win in a Complex World, (2013), 15
[5] Carl Von Clausewitz. *On* War. ed. and trans. Michael Howard and Peter Paret (Princeton: Princeton University Press, 1984), 89
[6] Randall T. Wakelam, *The Science of Bombing: Operational Research in RAF Bomber Command,* (Toronto, Canada: University of Toronto Press Inc), 24
[7] Joseph F. McCloskey, "The Beginning of Operations Research: 1934-1941," *Operations Research* 35, no. 1 (1987), 147, http://www.jstor.org.lomc.idm.oclc.org/stable/170920.
[8] Donald Mitchell, "Military Operations Research," *Marine Corps Gazette (Pre-1994)* 41 (2), 47, https://search proquest-com.lomc.idm.oclc.org/docview/206334873?accountid=14746.

[9] M. Kirby and R. Capey, The Area Bombing of Germany in World War II: An Operational Research Perspective." *The Journal of the Operational Research Society* 48, no. 7 (1997), 663
[10] *Ibid*, 663
[11] Randall T. Wakelam, *The Science of Bombing: Operational Research in RAF Bomber Command,* (Toronto, Canada: University of Toronto Press Inc), 49
[12] *Ibid*, 49
[13] *Ibid*, 50
[14] *Ibid*, 51
[15] *Ibid*, 59
[16] *Ibid*, 59
[17] *Ibid*, 60
[18] *Ibid*, 61
[19] M. Kirby and R Kapey, The Area Bombing of Germany in World War II: An Operational Research Perspective." *The Journal of the Operational Research Society* 48, no. 7 (1997), 667
[20] Randall T. Wakelam, *The Science of Bombing: Operational Research in RAF Bomber Command,* (Toronto, Canada: University of Toronto Press Inc), 62
[21] Randall T. Wakelam, "Boffins at Bomber Command: The Role of Operational Research in Decision Making." *Air Power History* 52 (4), 21 https://search-proquest-com.lomc.idm.oclc.org/docview/219748113?accountid=14746.

[22] *Ibid*, 69
[23] *Ibid*, 70
[24] *Ibid*, 76
[25] *Ibid*, 81
[26] *Ibid*, 82
[27] *Ibid*, 82
[28] *Ibid*, 101
[29] *Ibid*, 102
[30] Joseph F. McCloskey, "British Operational Research in World War II." *Operations Research* 35, no. 3 (1987), 458, http://www.jstor.org.lomc.idm.oclc.org/stable/170548.

[31] Randall T. Wakelam, *The Science of Bombing: Operational Research in RAF Bomber Command,* (Toronto, Canada: University of Toronto Press Inc), 120-121
[32] *Ibid*, 121
[33] *Ibid*, 121
[34] *ibid*, 122
[35] Joseph F. McCloskey, "British Operational Research in World War II." *Operations Research* 35, no. 3 (1987), 459, http://www.jstor.org.lomc.idm.oclc.org/stable/170548.

[36] Randall T. Wakelam, *The Science of Bombing: Operational Research in RAF Bomber Command*, (Toronto, Canada: University of Toronto Press Inc), 130
[37] Joseph F. McCloskey, "British Operational Research in World War II." *Operations Research* 35, no. 3 (1987), 459, http://www.jstor.org.lomc.idm.oclc.org/stable/170548.

[38] *Ibid*, 459
[39] *Ibid*,144
[40] *Ibid*, 160
[41] *Ibid*, 161
[42] *Ibid*, 161
[43] *Ibid*, 161
[44] *Ibid*, 163
[45] Joint Publication 3-60, Joint Targeting, (2013), II-25 & II-29
[46] TRADOC Pamphlet 525-3-1, Army Operating Concept: Win in a Complex World, (2013) 11-12
[47] *Ibid*, 11
[48] *Ibid*, 11
[49] *Ibid*, 12
[50] Operational Decision Game in Kiev, Ukraine, Future Concept, Respondent 2, Field Grade Officer, March 16, 2017.
[51] Operational Decision Game in Kiev, Ukraine, Future Concept, Respondent 3, Field Grade Officer, March 16, 2017.
[52] Joint Chiefs of Staff, *Joint Operating Environment* 2035, (Washington D.C., July 2016), 11.
[53] William Rosenau, *Every Room is a New Battle: The Lessons of Modern Urban Warfare,* (Studies in Conflict and Terrorism: 20:4, Jan 2008), 371-372.
[54] United States Marine Corps, *Marine Corps Operating Concept* (Washington DC, September, 2016), 21.
[55] *Ibid*.
[56] Headquarters United States Army, *ADRP 3-0: Operations*, (Washington D.C. November 2016), 5-4
[57] DJI, *DJI Phantom* 4, http://store.dji.com/product/phantom-4-pro?gclid=CLLpybGhn9MCFdSPswodEmUDWQ#/?_k=jpp73o, accessed 4 April 2017.
[58] Milmo, Cahal, *Drone Operated by Criminal Gangs used to Deliver Drugs, Mobile Phones, and Potential Firearms to Prisoners, Admit Senior Officials*, Independent, September 16, 2015, http://www.independent.co.uk/news/ uk/crime/drones-operated-by-criminal-gangs-used-to-deliver-drugs-mobile-phones-and-potentially-firearms-to-10504154.html.
[59] Sensefly, *Sensefly Drone,* https://www.sensefly.com/home.html, accessed April, 12, 2017.
Roame, *Flying Selfies,* https://myroam-e.com/ accessed April 12, 2017.
FlyCam UAV, *Cypher 6,* http://www.flycamuav.com/aerial-radiation-detection/, accessed April 12, 2016.
[60] Ben Lagasca, Susan Levine, and Brian Long, "Combat or Collateral Damage: New Technology Offers Urban Ops Advantage," *ARMY Magazine*, August 2015, 28, http://jnlwp.defense.gov/Portals/50/Documents/ Resources/ Publications/Journal_Articles/New_Technology_Offers_Urban_Ops_Advantage.pdf.
[61] US Department of Defense, "Active Denial System FAQs," (Joint Non-Lethal Weapons Program, Washington D.C.), http://jnlwp.defense.gov/About/Frequently-Asked-Questions/Active-Denial-System-FAQs.
[62] Lagasca, Levine, and Long, "Combat or Collateral Damage: New Technology Offers Urban Ops Advantage," 28.
[63] US Department of Defense, "Active Denial System FAQs."
[64] Lagasca, Levine, and Long, "Combat or Collateral Damage: New Technology Offers Urban Ops Advantage," 29.

Bibliography

Army Doctrine Publication. Unified Land Operations. ADP 3-0. Washington, D.C. October 10, 2011.

Bevan, Ronald W. "Trends in Operational Research." *Operations Research* 6, no. 3 (1958): 441 47. http://www.jstor.org.lomc.idm.oclc.org/stable/167031.

Blackett, P. M. S. "Operational Research." *Operational Research Quarterly (1950-1952)* 1, no. 1 (1950): 3-6.

Christopherson, Derman, and E. C. Baughan. "Reminiscences of Operational Research in World War II by Some of Its Practitioners: II." *The Journal of the Operational Research Society* 43, no. 6 (1992): 569-77.

Clausewitz, Carl Von. *On War*. ed. and trans. Michael Howard and Peter Paret. Princeton: Princeton University Press. 1984.

DJI, *DJI Phantom* 4, http://store.dji.com/product/phantom-4-pro?gclid=CLLpybGhn9MCFdSPswodEmUDWQ# /?_k=jpp73o, accessed 4 April 2017.

Eaglen, Mackenzie. “What is the Third Offset Strategy?.” Real Clear Defense. February 16, 2016. http://www.realcleardefense.com/articles/2016/02/16/what_is_the_third_offset_strategy_109034.html

FlyCam UAV. *Cypher 6.* http://www.flycamuav.com/aerial-radiation-detection/. accessed April 12, 2016.

Joint Chiefs of Staff. Joint Operating Environment 2035. Washington D.C., July 2016. http://dtic.mil/doctrine/concepts/joe/joe_2035_july16.pdf.

Joint Chiefs of Staff. Joint Targeting. Joint Publication 3-60. Washington, D.C. January 31, 2013.

Kirby, M., and R. Capey. "The Area Bombing of Germany in World War II: An Operational Research Perspective." *The Journal of the Operational Research Society* 48, no. 7 (1997): 661-77.

Lagasca, Ben, Susan Levine, and Brian Long. “Combat or Collateral Damage: New Technology Offers Urban Ops Advantage.” ARMY Magazine. August 2015. http://jnlwp.defense.gov/Portals/50/Documents/ Resources/ Publications/Journal_Articles/New_Technology_Offers_Urban_Ops_Advantage.pdf.

McCloskey, Joseph F. "The Beginnings of Operations Research: 1934-1941." *Operations Research* 35, no. 1 (1987): 143-52. http://www.jstor.org.lomc.idm.oclc.org/stable/170920.

McCloskey, Joseph F. "British Operational Research in World War II." *Operations Research* 35, no. 3 (1987): 453-70. http://www.jstor.org.lomc.idm.oclc.org/stable/170548.

Milmo, Cahal, *Drone Operated by Criminal Gangs used to Deliver Drugs, Mobile Phones, and Potential Firearms to Prisoners. Admit Senior Officials*. Independent. September 16, 2015. http://www.independent.co.uk/news/ uk/crime/drones-operated-by-criminal-gangs-used-to-deliver-drugs-mobile-phones-and-potentially-firearms-to-10504154.html.

Mitchell, Donald W. 1957. "MILITARY OPERATIONS RESEARCH." *Marine Corps Gazette (Pre-1994)* 41 (2): 47-51. https://search-proquest-com.lomc.idm.oclc.org/docview/206334873?accountid=14746.

Rosenau, William. Every Room is a New Battle: The Lessons of Modern Urban Warfare. Studies in Conflict and Terrorism: 20:4, Jan 2008, 371– 394.

Sensefly, *Sensefly Drone*, https://www.sensefly.com/home.html. accessed April. 12, 2017. Roame, *Flying Selfies.* https://myroam-e.com/ accessed April 12, 2017.

United States Army Training and Doctrine Command. The U.S. Army Training Concept: Win in a Complex World. TRADOC Pamphlet 525-3-1. October 31, 2014.

United States Marine Corps. *Marine Corps Operating Concept* (Washington DC. September, 2016)

United States Department of Defense. “Active Denial System FAQs.” Joint Non-Lethal Weapons Program. Washington D.C. http://jnlwp.defense.gov/About/Frequently-Asked-Questions/Active-Denial-System-FAQs.

Wakelam, Randall. 2005. "Boffins at Bomber Command: The Role of Operational Research in Decision Making." *Air Power History* 52 (4): 16-23. https://search-proquest-com.lomc.idm.oclc.org/docview/219748113?accountid=14746.

Wakelam, Randall T. *The Science of Bombing: Operational Research in RAF Bomber Command.* Toronto, Canada: University of Toronto Press Inc., 2009.