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14. ABSTRACT

Lessons learned from Project Perilous are used to develop a future unmanned system employment concept, that of a human analog Artificial Intelligence (AI). The function of the AI is to manage and prioritize the information flowing to and from the operator so that he or she may focus the preponderance of their attention elsewhere. The AI concept was incorporated in an operational decision game (ODG) to assess potential benefits. The ODG indicated that information processing speeds will be limited so long as humans are in the unmanned system decision making loop. The AI concept was updated to operate autonomously thereby capturing the full benefits of an AI's processing advantage over humans.

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Executive Summary

Title: Man and Machine Interaction on the Future Battlefield

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Thesis: When using manned and unmanned teaming tactics, the force best able minimize human interaction with its robotic teammates will be able to cognitively outmaneuver an otherwise equal force.

Discussion: The initial intent of this paper was to explore the viability of achieving a third offset using manned and unmanned teaming; specifically, by improving information transmission between unmanned systems and their operators, or cognitive ergonomics. The rapidly increasing number of information inputs the average service member must manage while executing their job, particularly leaders, Unmanned Systems Operators and Joint Terminal Attack Controllers, is going to eventually overwhelm the cognitive processing limits of said individuals unless the methods by which the reciprocal information flow passes from operator to unmanned system. By analyzing Project Perilous and applying the lessons learned from the initial attempts at Unmanned Aerial System (UAS) employment to contemporary systems, the initial concept of human analog Artificial Intelligence emerged. A series of decision games then tested the AI concept against a potential future conflict. The outcome of the decision games confirmed that a human analog AI could be beneficial. The decision game responses tend to focus more on the ability to swarm and conduct real-time problem solving to "overwhelm" the enemy through a coordinated massing of forces. The human analog AI concept began as an operator assistant, managing routine tasks of the drone fleet under its control. When an individual drone reached a decision point, the AI would prioritize those inputs and present it to the operator for a final decision. Through automation, the AI would handle the vast amount of information flow between an operator and a drone in the background, presenting matters requiring human input to the operator, allowing the human to allocate their attention elsewhere. The results of the wargame indicated that this process could be beneficial, but not enough so to provide an offset.

Conclusion: The initial human analog AI concept was overly narrow in scope. To achieve an offset, cognitive processing speed needs to increase without degrading the individual drone's ability to operate. Regardless of how much information the AI filtered out, as the size of the swarm increased, a backlog would appear on the operator end due to human cognitive processing limitations. Therefore, the final opinion of this paper is that a human analog AI is essential as part of future unmanned system employment but its benefits are inversely proportional to the level of human input. Creating an AI to simplify information marginalizes the AI's ability to process a virtually unlimited (technology dependent) amount of information. Correction of this deficit would create a competitive advantage, an advantage worthy of an offset.

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Introduction

The financial constriction following the conclusion of World War II significantly affected the Department of Defense's predecessor, the War Department, giving rise to a scenario where emerging competitors held a numerical advantage to U.S. forces. This changing political and military climate demanded a response, leading the U.S. military to develop the concept of an offset. An offset is a method of creating a relative combat advantage over competitors by using technology to bypass the costs associated with maintaining a numerically superior conventional force. Offsets do not last forever; eventually, a competitor's technology will adapt and evolve, necessitating revision. Additionally, offsets generally only gain traction during post-war drawdown periods, as Department of Defense budgets tend to swell during times of conflict. There have been two significant offsets to date: nuclear deterrence following World War II and the combined effects of improved Intelligence, Surveillance, and Reconnaissance (ISR) assets, to include space based systems, Global Positioning Systems (GPS), and Precision Guided Munitions (PGM) following Vietnam.[1]

As the U.S. concludes major operations in Iraq and Afghanistan, the DoD budget is again shrinking, competitor numbers are growing, and the PGM and ISR assets once considered revolutionary are now commonplace for both state and non-state actors alike; at this stage, development and application of an offset warrants consideration. Manned and Unmanned Teaming (MUM-T) has emerged as a promising platform; adopting MUM-T capabilities and tactics in the creation of an offset has strong potential. By shifting development focus from unmanned systems alone to refining the methods through which human operators interact with machines on the battlefield, MUM-T will increase cognitive processing speed, thereby allowing U.S. forces to outmaneuver the enemy, physically and mentally.

Understanding the need for an offset, it is the intent of this paper to demonstrate how focusing on the man-machine interface aspect of MUM-T will achieve a lasting competitive advantage over current political antagonists. Taking the lessons learned from a historical case and applying them to current unmanned system employment models, requirements of the future operating environment become clear. Using an operational decision game as a vetting mechanism, members of all military branches and occupational specialties refined that environmental picture into a single solidified concept depicting the future of MUM-T.

Manned and Unmanned Teaming Overview

MUM-T refers to a phenomenon where humans work in coordination with an unmanned machine or machines in the execution of a common task. Contemporary examples range from simple remote-control cars to the unmanned aerial systems (UASs) used by militaries worldwide. Today MUM-T exists in nearly every arena of contemporary society, illustrating the far reach of the technology. To mitigate ambiguity, in the context of this paper, the term MUM-Twill imply an association with militarized forces and the "manned" portion of MUM-T will refer to a combatant; in either case, whether the forces are regular or irregular is irrelevant to the definition. The "machine" in MUM-T is equally fluid in definition and will henceforth refer to a mechanical vehicle capable of self-locomotion. Under this common framework, MUM-T has been in existence since the 19th century; its presence and influence on the battlefield has gradually increased with time. However, to say that progress has been linear would be a mistake. The initial MUM-T projects conducted in the late 19th to the early 20th centuries made significant progress, both conceptually and technologically. This progress continued until the period immediately following World War II, when development stagnated and plateaued, continuing through the turn of the century. During this time, componentry improved substantially but the employment models remained essentially the same.

Within the concept of MUM-T, there are three key areas of interest: the man, the machine, and the method through which they interact. Given the relatively static evolutionary trajectory of man, the preponderance of MUM-T research focuses on the machine and the methods through which it interacts with man. In this context, the machine is approaching the apex of its capabilities. This is not to say that drones will cease to evolve, but rather drone design has caught up to manned aircraft in complexity, and technology limits both manned and unmanned vehicles equally. The exception to this rule is size reduction, where drones maintain significant advantage over manned systems. Man and machine interface on the other hand is ripe for development, especially in the field of automation. Recent progress in Artificial Intelligence (AI), augmented reality, virtual reality, and multi-sensory interfaces, are on the verge of revolutionizing MUM-T employment, effectively ending the seventy-year stagnation.

To understand the revolutionary potential of the man-machine interface as it pertains to drone usage, it is important to first understand the foundational concepts behind MUM-T. Project Perilous, one of the initial attempts at remote controlled drone employment, provides the ideal venue for that exploration. Given Perilous' rudimentary technology and rapidly evolving employment concepts, the relationship between man and machine and the challenges unique to the project are ripe for dissection. An analysis of the trajectory of Project Perilous yields the insight necessary to efficiently direct attempts at creating a MUM-T offset

Historical Review of Project Perilous

Whether in the context of the war on terror or the quadcopters used by neighborhood children, the word drone carries with it a strong sense of modernity. To some extent a falsity, this reflection is nonetheless useful in that it provides a reference point by which to explore what "drone" means. By observing contemporary Unmanned Systems, there are three distinct concepts fundamental to the technology's existence: method of human control, autonomy, and drone to human information transmission. These generally invoke visions of flight simulator joysticks, computer screens, and The Terminator movies; however, the foundational technologies behind these capabilities came into existence nearly one hundred years ago, coalescing into the modern concept of an unmanned system during the interwar period.

The ability to operate a drone would not be possible without the capacity to exercise control over the vehicle. The means of accomplishing this has evolved over the years, but the foundation lies in basic radio control. In twenty-nine years' time, the concept of radio control would evolve from an abstract concept to a weaponized system capable of guiding a remote-control vehicle to a specific target. In 1885, Nikola Tesla first demonstrated the wireless transmission of electromagnetic information.[2] Almost immediately, the Navy began to follow the development of wireless communication, not initially envisioning remote control but rather a method to communicate ship to shore over long distances.[3] Four years later, the Navy conducted the first successful long range radio communications trial.[4] To this point, electromagnetic transmission was still limited to communications, or replicating the duties traditionally accomplished with the wired telegraph. That would all change in 1898, when Nikola Tesla again broke ground by demonstrating the ability to control the movements of motorized vehicles using an adaptation of the wireless telegraph system.[5] By 1914, the concept of remote control had gained enough legitimacy that congress provided funding for a joint Army/Navy project to explore the systems capabilities.[6] Now institutionalized, the years preceding World War II would see the technology applied to nearly every aspect of Army and Navy operations as staffs everywhere attempted to integrate the new technology into their specific warfighting functions.

From inception, an operator's ability to employ a drone as adeptly as if they were present inside the vehicle has proven to be problematic. The concept of autonomy emerged as a response; developers sought to provide drones with an ever-increasing ability to conduct certain operations without human input. The first example was the gyroscopic stabilizer produced by Lawrence Sperry. Combining his father's work with gyroscopes and his own love of aviation, Lawrence Sperry would develop a system capable of managing all three axes of an aircraft without human intervention. Lawrence, fully committed to an aviation career, went to New York to join the Glenn Curtiss flying school. Here, in addition to developing his flying skills, he began to solidify the concept of a gyroscopic stabilizer. Once complete with his official pilot training in the fall of 1913, Curtiss offered Sperry the opportunity to travel to North Island, California to continue developing his autopilot. In North Island, Sperry had access to Curtiss's shop and airplanes to conduct experimentation. More importantly, Sperry also had access to the U.S. Navy, already heavily involved in Curtiss's work with the flying boat[7]. Two months later, Sperry had developed a working stabilizer that would remain relatively unchanged in basic design through his death in 1923. The Navy and the Army utilized this design through the interwar period and subsequently integrated it into nearly all aviation platforms.

In its most basic form, drone to human information transmission is an operator visually observing a craft's actions and subsequently applying the required inputs based off those observations. Though not an obsolete strategy even today, developers quickly identified that this would be insufficient as a standalone capability, hastening the integration of video transmission through television into drone use. Lagging only slightly behind radio control, the first wireless transmission of a moving object occurred in 1923 as the result of a joint public private effort between the Navy Research Laboratory and Jenkins Laboratory.[8] Four years later, testing demonstrated the ability for TV broadcasts at distances in excess of 200 miles.[9] In addition to range improvements, the quality of the picture rapidly increased as well. The first transmission conducted by NRL and Jenkins had a picture quality of 15 lines, a stark contrast to the 850 lines characteristic of the systems in operation at the end of the 1930s.[10] Between the two capabilities, TV broadcast had reached tactical relevancy and was ready for militarization by the end of the interwar period.

Radio control, autopilot, and TV are the three technologies that would form the foundational framework, allowing for the creation of the first unmanned aerial systems. The three innovations would define corresponding core concepts (method of human control, autonomy, and information transmission respectively) that continue to both define what it is to be a drone and guide future development in the field to this day. It is through the lens of the three core concepts that this paper will evaluate the evolution of unmanned systems, specifically the historical case of Project Perilous.

Project Perilous

To understand Project Perilous, there must first be a general understanding of the allied air campaign over Europe in 1943-1944. At the beginning of 1943, the allied air forces were in a transition period. Despite a less than stellar performance in the preceding year, “the Casablanca

Conference of January 1943 sought to put the bomber offensive to the forefront of Allied strategy."[11] Through the incorporation of both precision and area bombing tactics, the Allied air forces sought to destroy the German economy and morale.[12] However, by the end of 1943, they had arguably failed to live up to expectations. This is not to say that the bombing campaign was ineffective; rather, it was not able deliver the decisive blow initially envisioned.[13] Additionally, the U.S. alone suffered unsustainable causality rates as high as 68 percent.[14] This was largely due to Germany's focus on air defense artillery to augment its dwindling fighter force; "By 1944, 33 percent of artillery production and 20 percent of ammunition was directed towards anti-aircraft activity." The combination of unmet expectations and high causality rates yielded an environment where senior leaders were primed to embrace any plan capable of reducing German morale while minimizing personnel loss.

In late 1943 and early 1944, US intelligence began to report that Germany was developing a new rocket system that could not only target London, but also potentially New York.[15] Speculation as to the overall capability of the rockets varied, but it was enough to concern British and American senior leaders.[16] Allied commanders attempted numerous bombing raids on the suspected launch sites, but due to the overwhelming air defense systems, robust construction of the structures, and the required accuracy, the raids were unsuccessful and resulted in the loss of many aircraft and personnel.[17] One launch site alone had cost the allies "an estimated 2000 men and some 450 aircraft."[18] The US Army Air Force, who had been experimenting with the concept of using remote controlled aircraft as weapons for a few years at this point determined that this would be the best solution to the aforementioned problems. In the spring of 1944, the United States established Project Perilous to facilitate the development and employment of weaponized radio controlled aircraft. Project Perilous would encompass three separate operations; Aphrodite, Anvil, and Abusive. Each operation would be based on the same basic principle; install remote controlled equipment in a war-weary bomber that was about to be decommissioned, fill it with explosives, and direct it into a target. However, the specific methods used to accomplish this differed in a few key areas from operation to operation. Therefore, each operation will be discussed individually in terms of the point of human integration, level of automation, and information transmission in addition to a basic overview to demonstrate conceptual evolution.

Operation *Aphrodite*

Operation Aphrodite was the initial, most ad hoc, and subsequently the most primitive attempt at developing a remotely piloted aircraft under the Project Perilous umbrella. Aphrodite's operating concept was straightforward; a drone B-17 would take off under the guidance of a pilot and radio operator who would later bail out once they established the aircraft on course and all required checks were complete. Overhead, a specifically configured B-17 or B-24 would act as the mother ship, carrying the drone operator in the back. The drone pilot then initiated transfer of control, at which point the drone operator would take control via radio and fly the B-17 via radio the remainder of the duration to the target. Aphrodite would launch two missions resulting in six lost drones, none of which impacted the target as desired[19]. Only one drone operated as anticipated; unfortunately, on final approach, clouds obscured the drone pilot's view resulting in an overshoot. The remaining five drones suffered a variety of equipment failures, resulting in substantial miss distances. In all, the USAAF deemed the operation a failure, grounding Aphrodite after the second mission until equipment issues could be resolved.[20]

The exercise of human control over Aphrodite drones was conceptually modest, yet physically demanding. To start, using the AZON (AZimuth ONly) system, the drone operator could affect a left or right turn, but in elevation, full down deflection was the only option, making range accuracy particularly troublesome. Through testing, it was determined that with full down deflection in the elevator, it would take *roughly* 975 feet of forward travel for a fully loaded B-17 to impact the ground given an initial airspeed of 180 knots and an above ground altitude of 300 feet[21]. Thus, it was through preplanned ground reference points that the drone operator would initiate the final attack run, leaving no ability to make any corrections once initiated. Additionally, once airborne and under control of the drone operator, the only aspect of the kill chain that the operator could influence was when and where the drone detonated, not if. This was for two reasons. First, the remote-control system was too primitive to facilitate a landing. Second, due to the method of loading and the explosives used, Torpex and Nitrostarch, there was a high probability the drone would detonate under given a crash landing regardless of whether the safe/arm system had been activated.[22] Given the mission requirement of accuracy inside of twenty feet, the Aphrodite system could not meet mission in sterile conditions, much less in combat[23].

Operation Aphrodite B-17s were fitted with two key autopilot components, the Sperry Gyroscopic Stabilizer and the automatic control equipment; ACE for short.[24] The Sperry system was a three-channel autopilot, controlling the pitch, roll, and yaw of the aircraft[25]. Once engaged, the gyroscopes internal to the system could detect any deviation on their respective access then, via servos, would send correcting signal to the appropriate aircrafts controls. Note that this autopilot system was only capable of maintaining a heading on straight and level flight; it was unable to execute a flight plan. The ACE was an altitude hold system based on a radio altimeter connected to servos that would correct in pitch to maintain a given altitude above ground[26]. When combined, the two systems could maintain a B-17 drone on heading at 300 feet above ground, the planned ingress altitude for the missions and a crucial capability given the lack of sophistication of the remote-control system. While conceptually sound and fully capable of operating as expected, the Aphrodite autopilot system was susceptible to reliability issues due to the immaturity of the technology. On multiple occasions, gyroscope or ACE malfunctions were responsible for mission failures.[27]

In terms of information transmission, Aphrodite employed a basic, utilitarian interface, leaving drone operators with a substantial information defect relative to the mission requirements. For all but one of the drones associated with Aphrodite, the only cueing available to drone operators was the unaided. The Aphrodite crews mitigated this shortfall as best as possible by painting the drone wing tops white or yellow and adding smoke generators, but it was still insufficient[28]. The most prominent issue was the weather and the tendency for clouds to break the operator's line of sight at the most inopportune times[29]. Coming in a close second was the mothership standoff distance. For the drone concept to be beneficial, the mothership was to maintain sufficient standoff to avoid the anti-aircraft flak threat. However, as the mothership moved further away from the drone, the operator would lose a proportionate amount of profile queuing, an issue that compounded the difficulty in achieving the desired 20-foot accuracy as per mission requirements. As aforementioned, there was one Aphrodite drone with additional cueing; the new technology of television. Due to the technology's infancy, the supply chain was not adequate to outfit more than one aircraft, but the impact of the addition was clear. With the addition of a TV camera in the nose of the drone and a transmitter in the tail, the Aphrodite project could demonstrate a usable signal in the mothership at distances up to thirty miles[30]. With added cueing from the TV system, the problem of cloud interference and operator proximity to the drone would be manageable. Unfortunately, the only aircraft fitted with the TV system suffered an ACE malfunction and crashed shortly after takeoff, preventing the systems validation[31].

Operation *Anvil*

After the unsuccessful Aphrodite missions, the Army sent out a request for assistance to the Navy who had been working on drone projects for several years.[32] Under the new arrangement, a small detachment of Navy personnel would take over drone development while falling under the previously established Army Airforce chain of command.[33] To acknowledge the Naval involvement, the operation was designated Anvil. In stark contrast to Aphrodite, Anvil would be using remote control equipment specifically developed for controlling aircraft, thereby greatly increasing functionality[34]. Additionally, the drone aircraft would now be a PB4Y (Naval variant of the B-24) and there would be two motherships, both Lockheed Venturas. Otherwise, Anvil was similar in design and execution to Aphrodite. Anvil would conduct two operational missions, both of which ended in failure. The first attempt concluded abruptly when the drone exploded in midair shortly after takeoff with the jump crew still aboard. On the second, all systems worked as expected. Unfortunately, the operators misinterpreted a poor TV image and guided the drone to an incorrect location. Upon impact the drone exploded, making this the first time a Perilous drone completed a flight as intended, unfortunately it was directed against the wrong target.[35]

The amount of control an operator could exert over an Anvil drone was far superior to that of Aphrodite, which was constrained because of the limited functionality of the AZON system. Its initial, sole purpose to add azimuth control to a standard freefall bomb, AZON equipment was hurriedly adapted to control an aircraft, an operation exponentially more complex. Conversely, the Anvil equipment was the result of roughly seven years of pointed development[36]. The result was a system capable of remotely manipulating a preponderance of the aircraft's systems. The left and right movement of a joystick would initiate a corresponding turn in the drone, just as in the AZON system. However, that was the extent of the similarities. The Anvil system featured two phone dials that were located adjacent to the joystick, providing control of other systems[37]. "Instead of numbers you dialed the operations you wanted the drone to perform in unmanned flight"; a system that provided control over flaps, cowl flaps, carburetor heat, incremental climb and descent, ACE on/off, smoke trail on/off, and engine power to mention a few[38,39]. Additionally, the Anvil system also included provisions to arm the system via remote control[40]. The cumulative capability of the Anvil system, while structurally primitive, was conceptually similar to what drone operators expect from modern systems. Despite the Anvil system's ability to control a drone at distances up to 70 miles, the project decided to introduce a second operator into the system[41]. Aphrodite and early Anvil operating concepts dictated a single control change, the handoff from the jump pilot to the operator prior to the jump crew exiting the aircraft. This process provided a method of troubleshooting communications issues should they arise, thereby providing the highest chance of mission success. In the name of safety, the Anvil project lead decided to add a second control change to the process. In addition to the handoff from jump crew to operator, there would be a second handoff from an enroute operator to a final guidance operator. This second handoff would be conducted in radio silence with no personnel aboard the drone to troubleshoot should issues arise, adding an unnecessary point of friction, one that proved nearly catastrophic on Anvil's second and last mission.[42]

The autopilot system used in Anvil was essentially identical to the system used in Aphrodite. The only addition was the ability of the drone to return to straight and level flight if something interrupted communications with the operator.[43] While conceptually small, this modification carried significant implications with regard to mission integrity. Given an operating altitude of 300 feet, an interruption in signal on an Aphrodite flight could result in loss of the drone depending on the flight profile preceding the loss of communication. With Anvil, a similar scenario would result in autopilot and ACE taking over, allowing the mothership an opportunity to regain control of the drone and resume the mission.

The equipment used in Anvil marked a leap forward in information transmission capabilities. Without the ability to monitor the drone's progress, the additional control capability would have been much less influential. In contrast to Aphrodite, Anvil was able to procure enough TV systems to not only ensure that there was one in the nose of each aircraft, but to also place one in the cockpit to monitor the aircraft's compass card[44]. The two cameras not only increased accuracy, but also introduced a method of operating the drone completely out of sight of the mothership, greatly increasing the probability of mission success, and ensuring safety of the motherships.

Operation *Abusive*

After a second Anvil failure, the Navy decided to cancel the project due to a combination of expense, political pressure, and a perceived lack of potential[45]. Once the Navy abandoned the project, the USAAF again took the lead, this time using remote control equipment designed by the AAF Technical Servicer Command specifically intended to control an aircraft[46]. The new project, renamed Abusive, used a system called Castor, which bore a striking resemblance to the equipment used in the Navy's Anvil project aside from a few additional electronic components. In a departure from its predecessors, the significance of Abusive did not come from technical innovation; it was in the manner of employment scheme.

Ironically, conventional bombing had neutralized the V rocket launch sites that inspired Aphrodite prior to the projects commencement.[47] The Germans maintained presence at the location to trick Allied forces into wasting valuable assets on a pointless target.[48] With high level AAF pressure to continue to invest in the project, new target sets would be needed to employ the drones against[49]. The conditions necessitated the development of a general-purpose system, capable of changing employment methods according to available target sets. The result was a system with three discrete configurations, designated Cottongrass, Corticated, and Close Support Visual Control, each with an entirely different method of integrating the operator into the drone operation. Each configuration had additional sub-phases, designed to accommodate further mission requirements. Abusive designed the Cottongrass configuration for use against large area targets in much the same manner as the German V Rockets[50]. Consequently, Cottongrass would forgo the mothership concept and rely on three different methods of ground-based control. Phase 1, the simplest method, did not involve control at all, but would rely on the autopilot to maintain heading and a timer to cut the engines at a preset interval thereby ditching the aircraft in the general vicinity of a city[51]. Phase II and III would incorporate radar azimuth cueing from which an operator could make corrections and initiate the dump command from a ground based control station[52]. The only difference between Phase II and III was an additional radar system to prevent jamming[53]. Corticated maintained the same employment principles as Aphrodite and Anvil with each phase incorporating varying levels of tracking technology[54]. Corticated used a mothership and drone team to strike “easily recognized pinpoint targets”.[55] Targets unable to be distinguished from the air prompted the design and subsequent use of Close Support Visual Control, a significant departure from previously established employment schemes.[56] Close Support Visual Control used ground-based operators in addition to the airborne ones to aid in accuracy and target acquisition. To accomplish this, a team of controllers would insert themselves in close proximity to the target. Phase I would require two controllers and Phase II would require three. The intent was to fly the drone over the objective area via a mothership, where the ground controllers would take over. In Phase I, one controller would be stationed directly in line with the final attack path to control azimuth and the second would be ideally established ninety degrees off and as far out as possible to control range[57]. Phase II would employ the same setup with an additional operator equipped with a TV screen to take over final guidance in both azimuth and range[58]. Despite the complexity of all three configurations, the foundation of modern drone employment techniques is evident.

The autonomous capabilities of Abusive's drones were essentially identical to that of Anvil therefore requiring no further discussion. Though, it should be noted that, despite supposed independent developmental efforts, the systems were so similar which highlights the technological limits of the day.

The Abusive project introduced the use of radar as an additional information path. In Cottongrass and Corticated, the operator in the ground control station and mothership each used radar[59]. By using radar, the drone operators could navigate the drone with precision regardless of visibility. In a continuing trend, the technique of following a drone via radar tracking would establish the same principals we use today with GPS tracking and moving maps, further demonstrating the clear lineage between Perilous and 21st century drones.

Cognitive Ergonomics

Technological progress along the core concept pathways in Project Perilous was indeed revolutionary, producing technologies that were individually capable. The remote-control system used by Anvil manipulated many aspects of the plane's operation. The TV and Radar systems used in Abusive provided accurate location and instrument readings in real time. The autopilot system introduced during Aphrodite’s development kept the aircraft on a set heading, altitude, and airspeed with little to no drift. Counter-intuitively, the remarkable progress seen through inception and development of Project Perilous did not lead to success. Upon review, two interrelated factors proved significant. The operator lacked sufficient situational awareness and control over the aircraft, rendering him unable to account for the aircrafts inability to accomplish the mission autonomously. Conversely, the autopilot systems in the Perilous drones lacked the sophistication required to compensate for the inadequate level of human control over the drone. In short, there was a failure in cognitive ergonomics.

Regarding the interaction of humans and machines, a sequential set of steps is necessary to achieve the desired outcome. An operator must tell a machine what to do and the machine must be able to present the operator with critical information pertaining to the execution of that task, enabling the operator to make subsequent decisions. Cognitive ergonomics is the science and the art of designing this man-machine interface in a manner that best facilitates human decision-making. In the case of drones, to include Project Perilous, cognitive ergonomics is the cumulative effects of all three of the core concept technologies and the method through which they interact with the operator. So why is cognitive ergonomics to blame for Perilous’ failure? To answer this question, one must look at each operation individually and the evolutionary progress through each operation.

Operation Aphrodite experienced six failures out of six attempts. Upon closer inspection, two distinct themes emerge; method of human control/autonomy and information transmission. Failures related to method of human control and autonomy consisted of autopilot issues, of which there were five; three ACE and two lateral. The three ACE failures include two uncontrolled climbs and one inability to dive, and the lateral failures were uncontrolled turns. To understand these failures, recall that the control system used in the Aphrodite project was the AZON system, which provided a limited amount of control over the aircraft due to the simplicity of the system. Consequently, the operators relied nearly completely on the autopilot, a system that they could not override and was unstable. The lack of foresight in designing the method of human control and the operator control panel placed an unacceptable load on the autonomy aspect of the drone’s operation. Given the technology that was available at the time, the control panel could have been fitted with an autopilot override and incremental elevation control, preventing the overburdening of the autopilot system.

The only failure related to information transmission was a loss of visual contact scenario. While on short final to the target, a small cloudbank obscured the drone from the operator. Once the drone reemerged on the backside of the cloud, it had overflown the intended dive point; however, the operator chose to initiate the dive anyway resulting in a target overshoot. Information transmission between the drone and the operator was limited to the operator visually observing the drone from the window of the mother ship. Under this construct, something as benign as a small cloud bank can prove fatal to a mission. Additionally, the Aphrodite staff only had access to one TV system, which was lost in an autopilot crash. Had this aircraft been equipped with the TV camera, the operator would have had the ability to complete the mission.

Operation Anvil experienced two failures out of two attempts. The first failure was a midair detonation of the payload, largely attributed to faulty arming panel wiring. As the drone was still under manned pilot control at the time of explosion, this is irrelevant. The second failure was another loss of visual contact scenario, virtually identical to that of Aphrodite. The only difference between the two was that the Anvil drone was equipped with a TV system, which provided a secondary method of information transmission. However, as the operator shifted from visual control to TV control of the drone as it passed through a rain cloud, the TV operator incorrectly identified the surface target and attacked the wrong location.[60] Incorporating the lessons learned from the failed Aphrodite missions, the Anvil drone was properly equipped with a TV system. However, due to poor display resolution, the drone operator was not able to properly distinguish surface targets, ultimately leading to mission failure. Again, the interface between the drone and the pilot proved to be the critical point of failure; in this example, it was due to technological immaturity, not poor design.

Under the umbrella of Abusive, there were twelve failures out of twelve attempts. Of those twelve failures, five were attributed to flak and one was attributed to icing; these are considered irrelevant. Of the remaining six failures, poor information transmission back to the operator accounts for all of them, with five lost due to a loss of visual contact situation and one lost because of poor TV picture. Learning from Aphrodite and Anvil, the Abusive drones could remotely enable and disable the autopilot as well as manually climb and dive the aircraft, eliminating the issues with human interface and overextending the capabilities of the autopilot. Additionally, Abusive added a radio beacon tracking capability and increased TV instrument monitoring to the drones in an effort to account for adverse weather. The result was a drone that was technologically capable of hitting a target with relative accuracy in a complete loss of visual contact scenario. However, given that the instrument TV feed took up one or more screens, the nose TV feed took up a screen, the radio beacon feed took up another input source, and there was an additional requirement to operate visually, there was an overwhelming amount of input sources. The potential for an operator to integrate all sources into a single useable representation of the drone's flight profile was nonexistent, causing a multiple loss of contact scenarios.

With the exception of the loss of contact scenarios, the failures experienced during Project Perilous were mechanical in nature yet unnecessarily catastrophic. Whether it be a more adequate control system with TV as in the case of Aphrodite, better resolution screens as in the case of Anvil, or the loss of contact problems experienced in Abusive, all were equally avoidable given a better integrated control station. Cognitive Ergonomics, or improving the method by which the three core concepts interact with a human operator, could have circumvented the problems that plagued Project Perilous. That is not to detract from the noteworthy technological advancements. Typically, the subsequent project addressed the preceding project's interface issues based off the lessons learned best exemplified by the adaptation of an improved control scheme in Anvil and Abusive. Nonetheless, man-machine interface did not progress enough to produce combat effective drones.

Conclusion

As stated in the Marine Corps Operating Concept: How an Expeditionary Force Operates in the 21st Century, "mastering the man-machine interface offers a revolution in military operations."[61] The method of human control and information transmission capabilities in modern day drones has advanced well beyond the processing limitations of the human operator. This has been the case since the later stages of Project Perilous, as evidenced by Abusive. Unlike Project Perilous, drones are now capable of flying an entire mission autonomously without any human input other than initial programming. Further, autonomous technology has advanced to the point where a single operator can "control" an almost unlimited number of drones simultaneously. Herein lies the issue; due to ethical concerns, completely autonomous drone operations are not palatable today for several reasons. How should the USMC strike a balance between automation and operator control/situational awareness given the constraint of human cognitive processing limitations and the restraint of maintaining a man in the loop? The answer is rooted in technological evolution with a foundation in cognitive ergonomics.

Initial Concept Development

Translating a vehicles movement through a three-dimensional world onto a two-dimensional display presents Unmanned Systems Operators (USOs) with a significant obstacle to overcome. A pilot operating an aircraft uses every available sensory input to accurately analyze the current situation. Sight provides spatial orientation and instrumentation information, hearing augments mechanical operating conditions and provides radio communications and audible system alerts, the vestibular system provides additional spatial orientation cues, touch or positional inputs contributes control feedback and control setting information, and so forth. Conversely, depending on the system, a typical USO must rely on only two sensory paths to perform the same functions, visual for display and hearing for both limited audible cueing and radio communications, if required. To date, the solution to this problem has been to rely on automation to augment human control, resulting in nondynamic movement profiles reliant on preplanned routes and autopilot, allowing the operator to focus attention on sensor operation. This is beneficial in that it allows for the operator to dedicate nearly all available cognitive processing to sensor operation which, depending on the mission, set can be ideal. However, as unmanned systems continue play an ever-increasing role on the battlefield, there will be a corresponding requirement to operate in a dynamic manner commiserate with the manned systems they are replacing, requiring a significant improvement in the current man-machine interface methodologies.

Improving unmanned system man-machine interface is a problem requiring two separate approaches, one from the operational and strategic unmanned system aspect and one from the tactical aspect. At the operational and strategic level, unmanned systems are larger in size and traditionally utilize operators whose sole job is to oversee the system. Conversely, tactical systems are significantly smaller and require individuals to assume the operator role as a duty on top of their other assignments. These different approaches to manning have important implications for how those systems interact with the operator. Operational and Strategic systems operate in a hub and spoke manner where smaller, dislocated crews oversee the launch and recovery of the system and a central control hub is responsible for the conduct of the mission whereas tactical systems rely on a single operator for all aspects of the flight and operate from mobile control stations that are typically man packable. This means that operational and strategic systems benefit from a high degree of flexibility in the man-machine interface, where tactical level systems must be small, light, and cannot completely dominate the operator's cognitive capacity, as the operator has other responsibilities.

The analysis of Project Perilous identified cognitive ergonomics, and the mastery there of, as key to maximizing the benefits of unmanned systems. There are two key observations that further frame the lessons garnered from perilous. First, as mission complexity increases, success is directly proportional to both the level of control the operator exercises over the system and the amount of feedback received from that system. Second, while an increase in human integration into unmanned system operations yields a corresponding increase in accuracy, this methodology is only beneficial prior to reaching limits of human cognitive processing, after which diminishing returns necessitates some amount of automation. As with the inverse relationship between automation and mission complexity and strategic and tactical systems, the level of human integration is competing against the operators cognitive operating limitations. However, it is through these three opposing perspectives that a single solution capable of addressing all three problems emerges: human analog artificial intelligence (AI).

The intent behind a human analog AI is to create a software set capable of incorporating available unmanned system sensors to replicate human scene interpretation and, contingent on operator preferences, either present the operator with prioritized decision points or make autonomous decisions based on learned operator tendencies and pre-established parameters. This capability would allow tactical operators to remain engaged in present-time conflict and operational and strategic level operators to expand mission capabilities into roles best filled by manned aircraft. To further define the AI concept, it should include the following specific capabilities:

1. Though human limitations require some level of automation; an AI should not operate independently but rather be able to prioritize information requirements based on importance and present the operator with a consolidated list of decision points.
2. To accommodate increased mission complexity, the AI must be able to interpret commander's intent as well as understand when it reaches a decision point.
3. The AI must be capable of learning the decision-making preferences of a given operator to minimize the input required in dynamic environments.
4. The AI system must be man portable and able to integrate with multiple different systems.
5. The AI must present decision points to the operator in a manner that allows for simultaneous localized situation analysis.

Combined, these capabilities provide a solution to the aforementioned conflicting concepts. However, without further testing, full extent of the AI's impact on operations cannot be assessed;

incorporating a human analog AI into an operational decision game will allow for an unbiased evaluation of the concept’s applicability.

Operational Decision Game

To determine the human analog AI concept’s applicability and areas in need of improvement, an Operational Decision Game (OGD) was devised to test the aforementioned capabilities. The ODG presented participants with a single scenario but two different equipment loadouts: one with unmanned systems operating under a contemporary construct (play 1) and one with systems controlled by a human analog AI (play 2). Once complete, the employment techniques used for AI assisted and contemporary scenarios were compared to identify potential benefits.

The scenario used for the ODG was based on a future aerial interdiction strike to neutralize a nuclear weapon threat. In the scenario, a carrier air wing must destroy a point target defended by a complex integrated air defense system in much the same fashion as Project Perilous. The mission utilizes unmanned systems (notional modernized X-47B) controlled by an AI employment scheme based on learned human responses. Leading up to the mission, the AI observed five years of manned carrier air wing mission training events covering multiple iterations of every wing mission essential task. Using advanced blue force tracking, the AI recorded the flight profiles of every flight within the wing and analyzed the individual mission data. With commander oversight, cumulative post mission commander analyses yielded a framework of correct and incorrect individual maneuvers and tactical decisions. The resultant database provides the AI sufficient reference points so that it can evaluate situations based on a predicted outcome and desired end state even in the absence of specific instruction.

With the scenario background established, it is important to note a key limitation; though the ODG does provide an excellent venue to test operational and strategic level concepts, the detail required to analyze tactical level operations is lacking. Specifically, how would the proposed technologies affect the small scale technical tasks associated with an unmanned system operator? This is significant, given the proposed utilization of the AI concept is largely centered on tactical level operator benefits. Therefore, the fact that this ODG focuses on big picture employment such as course of action narratives and not on how an operator would go about everyday tasks is an intentional compromise between all three levels of war. The mission set chosen, an aerial interdiction mission, provided for the widest breadth of scope possible given the constraints of the exercise.

Seven military members covering all four services and a wide variety of military occupational specialties completed the ODG. Excerpts and conceptual summaries from each respondent are as follows:

Respondent 1: Play 2

1) Central Idea: “Use deception to increase enemy cognitive load”
    a) The force best able to process and act on large amounts of information will enjoy a maneuver advantage.

2) Necessary Capability: “Robust X-47B capability with swarming”
    a) The one person per drone model that we currently use is not feasible in future conflicts because it does not provide any benefit beyond the protection of a single individual.

3) Application & Integration of Military Functions: “Intel: Decision to strike requires good awareness of IADs status”
    a) To make MUM-T an offset, individual drones in a swarm must be able to individually and collectively make decisions to

accommodate a wide variety of sensor inputs as well as communications denied environments.

Respondent 2: Play 2

1) Central Idea: “In synch with SOJ activity, X-47 (with swarm & AI capability) enter country via northern gap in IADs exploiting IADs gaps and terrain masking”
    a) Reinforces requirement for a swarm capability.
    b) Ability for swarm to analyze and react to observed indicators and react appropriately in a communication degraded environment.
    c) Includes ability to visually signal to other aircraft and react appropriately.

2) Spatial & Temporal Dimensions: “Temporal dimension synchronization to overwhelm/confuse defenses”
    a) Reinforces requirement for a swarm capability.
    b) Reinforces requirement for disposable assets.
    c) Reinforces ability for both cloud and individual based AI application.

Respondent 3: Play 2

1) Central Idea: “The key word is “overwhelm”, we need to throw so much at NK at the same time that even if they have the ordnance of capability to counter it all, there will be too much happening at the same time for human minds to account for or deal with [it] simultaneously. Once they are confused and overwhelmed to the point of paralysis, we strike with everything we have”
    a) Reinforces requirement for disposable assets.
    b) Reinforces requirement for a swarm capability.

- Respondent 4: Play 1

1) Opportunities and Threats to Achieving the desired conditions: “Threat is another country showing up with more advanced systems to help out.”
    a) Reinforces need for autonomous capability and for those systems to be able to understand mission intent and make decisions in the grey zone. Additionally, the AI system must be able to decide if it should continue given the current operating environment.

Respondent 5: Play 1

1) Problem Statement: “Density of assets and layered defense and time. If I kick out one aspect and I have time to persecute the target before they shift and/or fire.”
    a) Reinforces ability to think in the grey and adapt on the fly.
    b) Illustrates need for an AI to be able to recognize and attack time sensitive targets if it benefits the overall mission or if the benefit outweighs the degradation to the current mission.

2) Application and Integration of Military Functions: “Best if I could integrate AI IW assets (cyber, space).”
    a) Cloud based AI but maintain ability to continuously update onboard data sets to reflect the most current collections and “learned” actions so that if separated from the cloud, the individual drone would be able to continue the mission based on commander’s intent.
    b) The drone would also need to be able to preserve mission details while disconnected for future incorporation into the post mission analysis.

Respondent 6: Play 2

1) COA Narrative: “X47- Overwhelm system with targets.”
    a) Reinforces requirement for disposable assets.
    b) Reinforces requirement for swarm capability.
    c) Application and Integration of Military Functions: “Maneuver must be synched with intel assessment of responses.”
        i) Ability for AI to autonomously conduct BDA and attack again if necessary.

Respondent 7: Play 2

1) Opportunities and Threats to Achieving Desired Conditions: What if “Intel is wrong. More than one functional BM site exists…”
    a) Reinforce the requirement for autonomous TST capability.

From the seven responses, two recurring themes emerged, necessitating revision to the assumptions associated with the human analog AI. The first is that when offered, the ability to utilize swarm tactics became a critical capability in the respondents course of action. Second, when not able to swarm, the respondents placed on the ability to analyze and react to a rapidly changing environment in real time. Two additional capabilities appeared in frequently enough to warrant inclusion into the revised concept: swarming, which was generally associated with the utilization of disposable assets and the ability of an AI system to operate equally well in a collaborative environment as in an autonomous one.

Refined Concept

The initial approach to a human analog AI, henceforth referred to AP1, was based on a logical extension of the techniques used to solve the issues experienced by Project Perilous. A more capable autopilot, coupled with improved information transmission and detailed methods of human control, would result in a correspondingly accurate and capable system. However, after observing the ODG responses, it became clear that, while the capabilities described in AP1 were applicable, the approach was far too narrow in scope. MCDP-1, the Marine Corps foundational warfighting doctrine, states that "Since war is a fluid phenomenon, its conduct requires flexibility of thought. Success depends in large part on the ability to adapt—to proactively shape changing events to our advantage as well as to react quickly to constantly changing conditions."[62] To achieve this goal, AP1 relied on concise and accurate information presentation, enabling an operator to make a better decision or input choice. Here, the concept's flaw becomes evident. Even though this approach had the potential to increase capability, it emphasized the translation of information into a format digestible by the human operator limited by physical cognitive capabilities, the very phenomenon it was attempting to bypass. The result would be an increase in throughput, but the overall speed of processing would not increase so long as the man/machine interface remained human centric. Therefore, to fully achieve a wartime advantage as described by MCDP-1, the force best able minimize human interaction with its robotic teammates will be able to cognitively outmaneuver an otherwise equal force, resulting in a true offset.

The top two trends identified by the ODG, the importance of swarm tactics and the ability to rapidly analyze and react to situational inputs, best illustrate the need to shift to a machine centric AI. The ability for unmanned systems to swarm, or to collaboratively execute a central task just as manned systems would, is undeniably the future of drone use. Ethically and financially, people always have been and will continue to be a military's most valuable asset. Swarming allows for a single human operator to control multiple unmanned systems simultaneously, thereby increasing overall combat power while protecting human capital. However, the operator's capabilities will continue to influence the speed of action of the swarm's decision making cycle. To illustrate this phenomenon, envision a scenario where an unmanned system operator is controlling a swarm of twenty drones collectively tasked with identifying and targeting armed-foot mobile enemy combatants in an urban counterinsurgency scenario. Operating under an AP1 construct, the AI assisting the operator controls drone search patterns, refueling cycles, and flight profiles. Additionally, the AI will identify armed enemy combatants and prioritize them based on proximity to friendly forces and perceived threat level of the weapon system they are carrying. Once directed to target an enemy, the AI will analyze the target set to choose the correct weapon and attack geometry, based on learned commander's preferences. The operator's sole responsibility is to monitor the continuously updated priority feed which displays the real-time video overlaid on a moving map of all other enemy and friendly positions, and administer the final “fire” command for each target.

Given a relatively low intensity conflict in which there are typically only one to two simultaneous targets at any given time, the AP1 construct would be effective. Feasibly, an entire city could fall under the jurisdiction of one person, the operator. However, applying the AP1 construct to a high intensity conflict, which regularly presents many simultaneous targets, exposes significant weaknesses. Regardless of the number of display screens available to the operator, due to cognitive load, he or she could analyze few targets, and act on even less. This delay would provide most combatants the critical seconds required to break line of sight and avoid targeting. Additionally, a competent foe would quickly exploit this gap by coordinating simultaneous movements so that an operator would be unable to single out a target. Flocks of birds and schools of fish have demonstrated the effectiveness of this tactic for millions of years. Now, again envision the high intensity scenario except this time the AI controlling the swarm could target any identified enemy unless it was within 100 meters of a friendly position. Shifting to an approach where human involvement is the exception and not the standard so that the number of drones in operation is the only limit to simultaneous engagements and the speed at which each drone executes the targeting process would depend only on machine processing speed.

In addition to shifting from a human centric AI to a machine centric AI in the overall design of the human analog AI system, the ODG identified two additional capabilities for inclusion in the overall concept. Though unintentional, the AI concept became indivisible from swarming as time went on. While not directly related to the central theme of the paper, it is important to comment on the emphasis placed on using disposable assets in an AI controlled swarm that emerged during the ODG. After the ODG, three respondents specifically used the word “overwhelm” when describing their theory of success in defeating the notional integrated air defense system (IADS) and another respondent alluded to the principle without using the specific term. In the context of this specific ODG, “overwhelming” an IADS system implies providing enough targets so that the system, regardless of complexity, cannot possibly engage all of them, thereby guaranteeing that at least one will make it to the intended target. As defensive systems advance, this tactic will become increasingly relevant in all domains, not just the air, but its success comes at the cost of sacrificing several assets to ensure overall mission success. Given the hefty price tag of current unmanned systems, this may not be viable, necessitating a change to the current quality over quantity equipping philosophy to a quantity over quality paradigm.

Using disposable assets also has implications for swarm command and control. AP1’s command control philosophy was envisioned as a cloud based system where a centrally located AI would control and collect feedback from the various unmanned systems operating under its control. However, through the course of the ODG, it became clear that conflicts against a peer threat would imply a certain amount of communications degradation, a significant hindrance to cloud based command and control systems. Therefore, individual unmanned systems operating within a drone must have the ability to operate collaboratively as well as individually, which would require each drone to possess computing poser sufficient to act just as the central AI does; something potentially at odds with the quantity over quality methodology.

Through the years, the U.S. military has sought to reduce war’s human cost through technological innovation; this paradigm is best summed as few with great equipment can outperform many with lesser equipment. However, Deputy Secretary of Defense Bob Work stated that “……the third offset strategy, or strategies, are much more than just technology.

They're about increasing the competitive advantage of our American forces and our allies over the coming decades."[63] Simply stated, methods of employment should receive an equal if not greater amount of thought that technological innovation as the DoD searches for future offsets. Additionally, MCDP-1 states that "Speed is rapidity of action. It applies to both time and space. Speed over time is tempo—the consistent ability to operate quickly. Speed over distance, or space, is the ability to move rapidly. Both forms are genuine sources of combat power."[64] Both principles highlight the outdated approach of AP1, something the ODG respondents quickly identified. By shifting AP1 to a machine centric AI concept, speed of action can generate a true competitive advantage at no additional cost.

Conclusions

Given the findings of the wargame and analysis of the refined AI concept, it would be remiss to omit any mention of the security of ethics and how it will affect the future of autonomy in MUM-T, particularly as it pertains to weaponizing autonomous systems. To start, this is by no means an attempt to solve either situation but merely intended to highlight areas that political, scientific, and religious leaders alike must address concurrently with the technological innovation if any progress is to be made. Presently, there is a well-intentioned moratorium on weaponizing autonomous systems. At the beginning of the Project Perilous case study, a reference to the Terminator Movies illustrated the contemporary perception of autonomous robots. While science fiction, it aptly characterizes a fear shared by many: what would happen if a weaponized drone using an AI went rogue? A more pertinent example, what would happen if an enemy was able to commandeer a drone's AI so that it intentionally targeted friendly forces?

Although the aforementioned dilemmas remain unresolved, they highlight an important consideration; there is an expectation that machines will be mistake free, which is both erroneous and unattainable. The standard set by humans is most certainly not free from error. In the aviation community, training crashes are not uncommon. In air, sea and land domains, instances of friendly fire are unfortunately, also not uncommon. While not acceptable and typically followed with improved processes to prevent a recurrence, there is a tacit understanding that it may, likely through a different causal chain. Surely, AI shouldn't?

A second consideration is the use of data in the development of an AI capable of executing upon commander's intent. The ODG provides an example of the potential risks through observation and recording of an entire airwing's training syllabus to "teach" an AI. In this situation, the AI recorded the performance characteristics of an entire carrier airwing's inventory of aircraft and pilots, to include the decision preferences of its leaders. If an enemy should compromise that information, the effects would be catastrophic. If administrators failed to discover the breach, the enemy would obviously have an insurmountable advantage in a direct confrontation. Furthermore, regardless of whether the breach was discovered, it would effectively render those pilots useless; introduction into combat would mean near certain death.

Even with potential ethical and security drawbacks, it would be a mistake to forgo utilizing AI to achieve a third offset. The U.S. faces enemies with disparate ethical standards. Enemies that will not hesitate to leverage an AI controlled drone swarm given the opportunity. For no other reason than ensuring that a viable counteraction exists should an enemy employ autonomous AI technology, the DoD should strive to remove humans from MUM-T decision making to the fullest extent possible. The U.S. could leverage its technological advantage to achieve fully autonomous drone operations first, creating a significant interim offset. Improved cognitive processing speed of maneuver units combined with the money saved through a reduction in personnel would put the DoD in a position to respond favorably to emerging threats, the true essence of an offset.

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[17] H. R. Everett, *Unmanned Systems of World Wars I and II* (Cambridge, MA: MIT Press, 2015), 357.

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[21] Olsen, *Aphrodite: Desperate Mission,* 46.

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[27] Everett, *Unmanned Systems of World Wars I and II*, 358.

[28] Ibid, 357.

[29] Olsen, *Aphrodite: Desperate Mission,* 53.

[30] Everett, *Unmanned Systems of World Wars I and II,* 356.

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[41] Olsen, *Aphrodite: Desperate Mission,* 260.
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[49] Everett, *Unmanned Systems of World Wars I and II,* 364.
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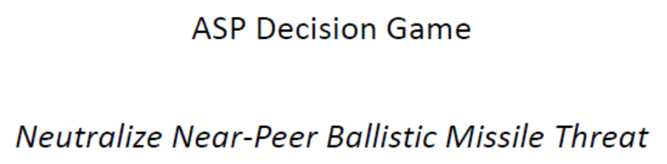
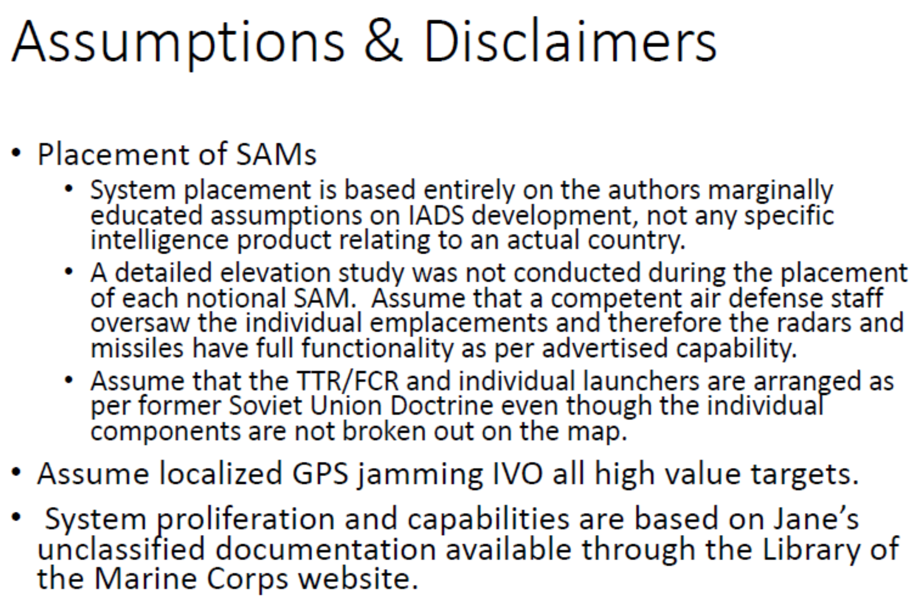
[63] Bob Work, "The Third U.S. Offset Strategy and its Implications for Partners and Allies" (speech, Willard Hotel, Washington, DC, January 28, 2015).
[64] Headquarters US Marine Corps, Warfighting, MCDP 1 (Washington, DC: Headquarters US Marine Corps, June 30, 1991), 40.

Appendix A – Counter Interconnectable Ballistic Missile Threat Current and Future



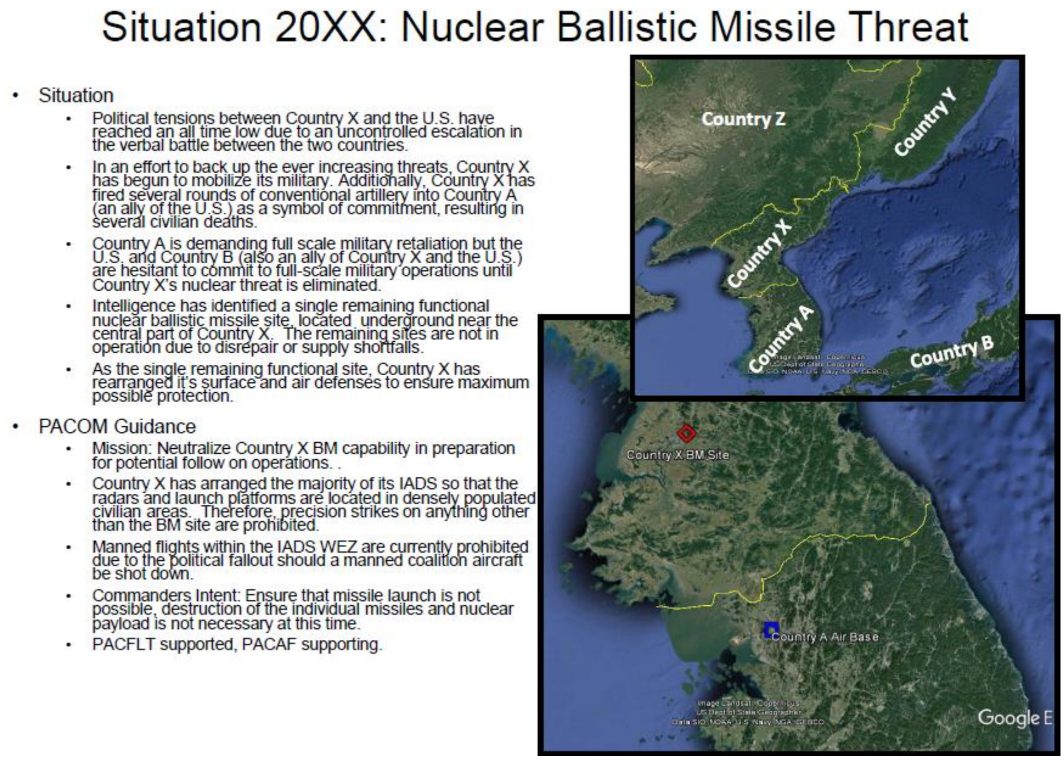
ASP Decision Game

Neutralize Near-Peer Ballistic Missile Threat



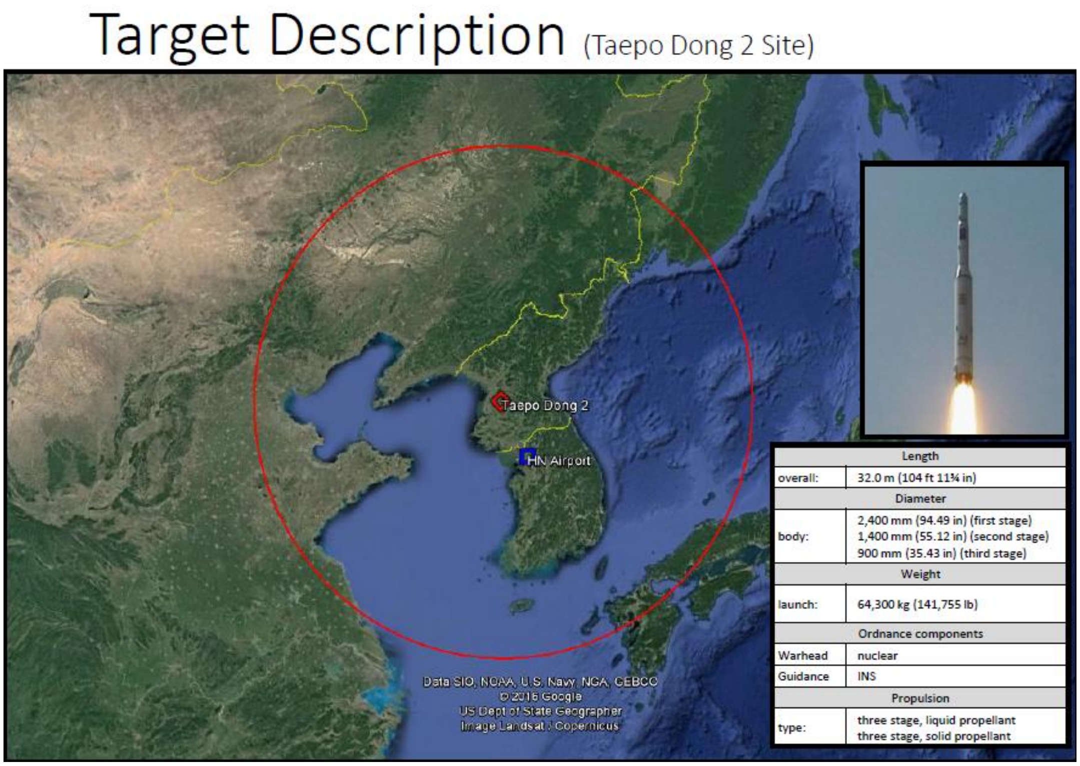
Assumptions & Disclaimers

- Placement of SAMs
  - System placement is based entirely on the authors marginally educated assumptions on IADS development, not any specific intelligence product relating to an actual country.
  - A detailed elevation study was not conducted during the placement of each notional SAM. Assume that a competent air defense staff oversaw the individual emplacements and therefore the radars and missiles have full functionality as per advertised capability.
  - Assume that the TTR/FCR and individual launchers are arranged as per former Soviet Union Doctrine even though the individual components are not broken out on the map.
- Assume localized GPS jamming IVO all high value targets.
- System proliferation and capabilities are based on Jane’s unclassified documentation available through the Library of the Marine Corps website.



Situation 20XX: Nuclear Ballistic Missile Threat

- Situation
  - Political tensions between Country X and the U.S. have reached an all time low due to an uncontrolled escalation in the verbal battle between the two countries.
  - In an effort to back up the ever increasing threats, Country X has begun to mobilize its military. Additionally, Country X has fired several rounds of conventional artillery into Country A (an ally of the U.S.) as a symbol of commitment, resulting in several civilian deaths.
  - Country A is demanding full scale military retaliation but the U.S. and Country B (also an ally of Country X and the U.S.) are hesitant to commit to full-scale military operations until Country X's nuclear threat is eliminated.
  - Intelligence has identified a single remaining functional nuclear ballistic missile site, located underground near the central part of Country X. The remaining sites are not in operation due to disrepair or supply shortfalls.
  - As the single remaining functional site, Country X has rearranged it's surface and air defenses to ensure maximum possible protection.
- PACOM Guidance
  - Mission: Neutralize Country X BM capability in preparation for potential follow on operations. .
  - Country X has arranged the majority of its IADS so that the radars and launch platforms are located in densely populated civilian areas. Therefore, precision strikes on anything other than the BM site are prohibited.
  - Manned flights within the IADS WEZ are currently prohibited due to the political fallout should a manned coalition aircraft be shot down.
  - Commanders Intent: Ensure that missile launch is not possible, destruction of the individual missiles and nuclear payload is not necessary at this time.
  - PACFLT supported, PACAF supporting.



Target Description (Taepo Dong 2 Site)

Length	
overall:	32.0 m (104 ft 11¾ in)
Diameter	
body:	2,400 mm (94.49 in) (first stage) 1,400 mm (55.12 in) (second stage) 900 mm (35.43 in) (third stage)
Weight	
launch:	64,300 kg (141,755 lb)
Ordnance components	
Warhead	nuclear
Guidance	INS
Propulsion	
type:	three stage, liquid propellant three stage, solid propellant

Target Description (Taepo Dong 2 Site)

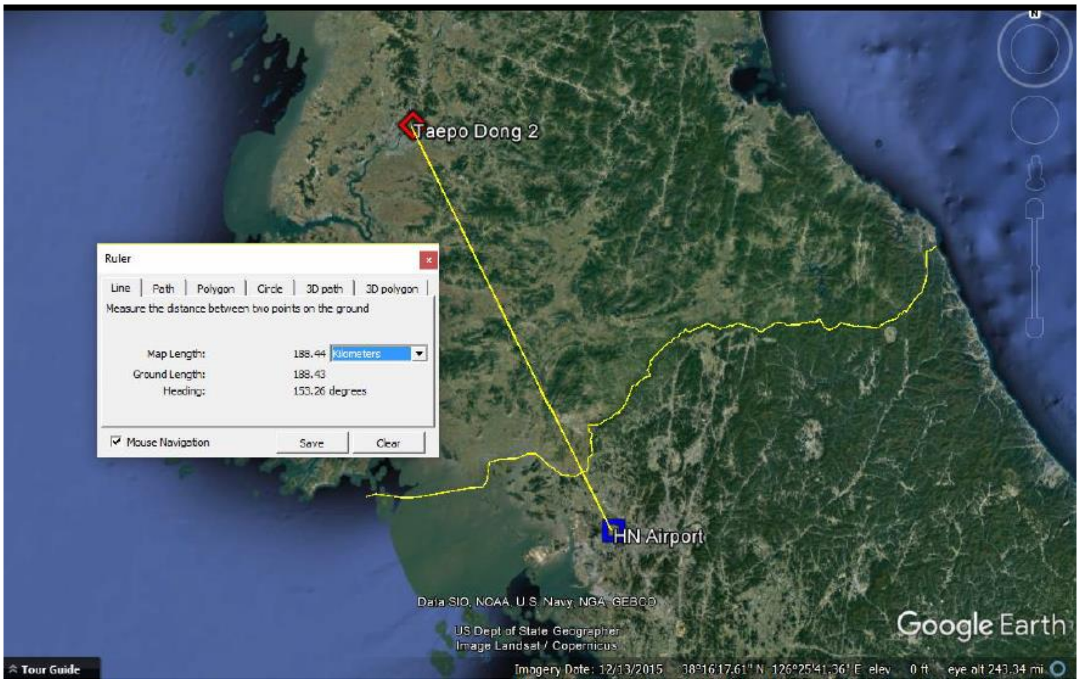
Staff and Security Force Barracks (Control facility is located in a bunker two stories under these buildings)

22 Feet

35 Feet

Concrete Silo Cover (est. 10' thick)

Target Description (Taepo Dong 2 Site)



Ruler

Line | Path | Polygon | Circle | 3D path | 3D polygon

Measure the distance between two points on the ground

Map Length: 188.44 Kilometers

Ground Length: 188.43

Heading: 153.26 degrees

☑ Mouse Navigation

Imagery Date: 12/13/2015 38°16'17.61" N 126°25'41.36" E elev 0 ft eye alt 243.34 mi

IADS Overview

- Country X operates in excess of 50 ground-control intercept and early-warning radar facilities, which provide overlapping coverage of the entire country, particularly along the southern border and on the west coast. However, coverage along the northern borderis lighter than elsewhere. In the mountainous, central area of the country, there are gaps in low-altitude coverage, particularly below 300 m (1,000 ft) because of terrain masking. An automated air defense command-and-control system, which will allow greater precision in monitoring and shorten operational response times, has been under development for several years.
- An unknown number of early-warning radar sites utilize underground facilities from which the radars are elevated on hydraulic lifts for operation and then lowered again for protection and maintenance. There are several important early warning radar bases located on mountain peaks in the southern half of the country. Since the mid-1990s, Country X has made modest progress in deploying modernized radars and EW equipment. Among the items introduced to service are GPS and AWACS radar jammers as well as updated P-10 'Knife Rest' and P-14 'Tall King' early-warning radars.
- In addition to radars, Country X Air Force, or the intelligence services, operate a number of electronic intelligence (ELINT) systems that are targeted against elements of the U.S. and coalition partners in the area. Older systems are believed to include: 'Box Brick', 'Brick Round', 'Brick Square', 'Dry Rack', 'Fix Eight', 'Fix 24', and 'Hat Rack'. During the late-1980s through the mid-1990s, the Country Y operated a Soft Ball ELINT system in Country X. No reliable information is available concerning newer ELINT systems.

- Jane's

Air Defense Systems

Air Defense Command

- SA-2F x 30
- Pechora-M x 8
- S-200V x 4
- HQ-9 or S-300 x UNK*

Army

- HN-5A x 500*
- SA-6 x UNK*
- SA-11 x UNK*
- SA-7a x 4500*
- SA-13 x UNK*
- SA-14 x UNK*
- SA-16 x 1500*
- SA-18 x UNK*
- FIM-92A x UNK*

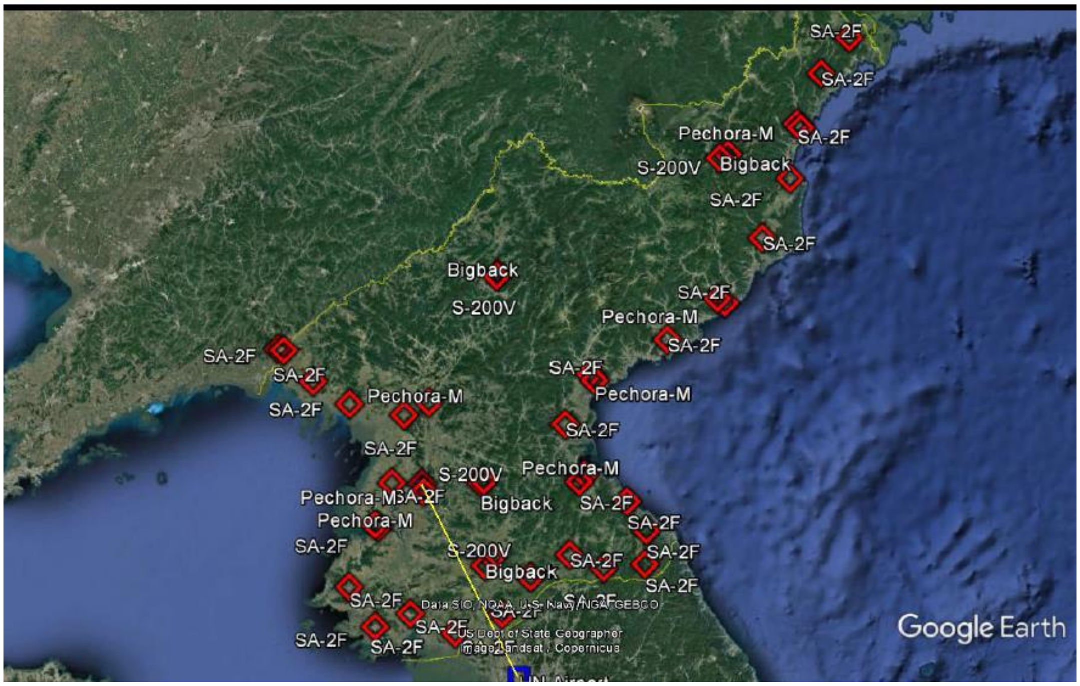
*Mobile, location UNK

ADA

- •14.5 mm (Single) ZPU-1 x UNK
- •14.5 mm (Twin) ZPU-2 x UNK
- •14.5 mm (Quad) ZPU-4 x UNK
- •14.5 mm M1983 x UNK (VTT 323 some fitted with AT-3 and man portable SAMs tracked chassis fitted with radar-controlled ZPU-4 system which is manufactured in North Korea)
- •14.5 mm (Quad) M1984 x UNK
- •14.5 mm (Single) M38/46 DShK x UNK
- •23 mm (Twin) ZU-23-2 x 1,500
- •23 mm (Quad) ZSU-23-4 x >48
- •23 mm (Twin) M1992 x UNK
- •30 mm M1990 x UNK
- •30 mm M1992 x UNK
- •37 mm (Twin) M1992 x UNK
- •37 mm (Single) M1939 1,000 x UNK
- •37 mm (Twin) Type-65 x UNK
- •37 mm (Twin) Type-74 x UNK
- •57 mm M1985 x UNK
- •57 mm (Twin) ZSU-57-2 x 250
- •57 mm (Single) S-60 x 600
- •85 mm (Single) KS-12 x 400 (With Fire Can radar)
- •100 mm (Single) KS-19 x UNK (Ex-Kazakhstan with four SON-9 fire-control radars)

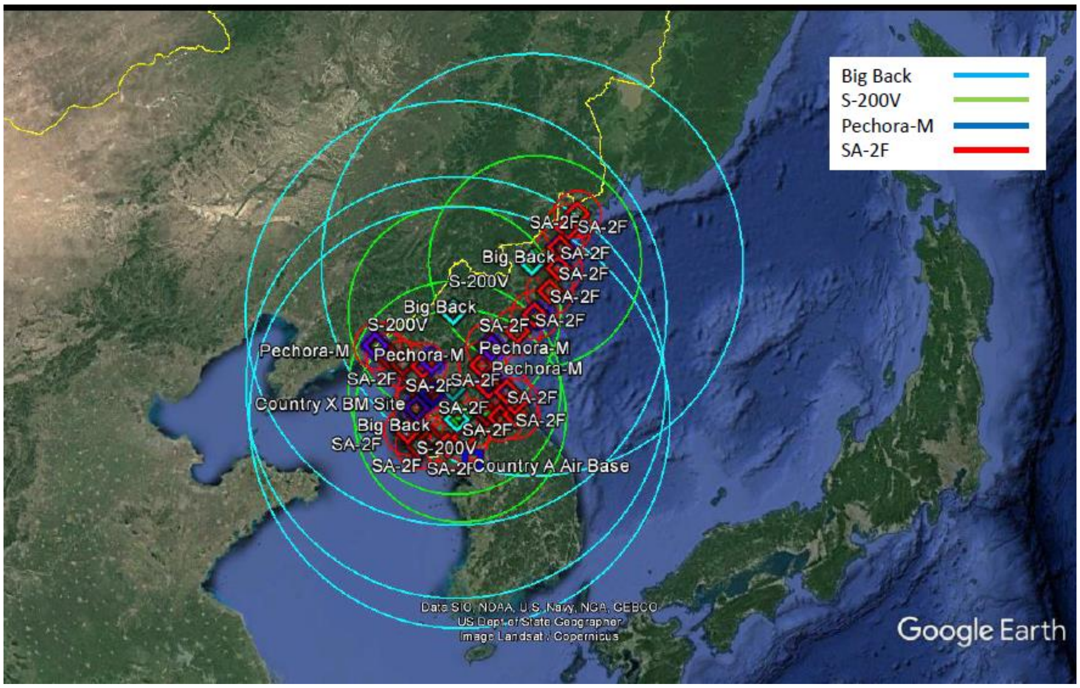
*Assumption is that, though mobile and individual locations are not known, the ADA is arranged so as to augment the SAM defenses with layered and reactive artillery cover.

IADS Overview



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
Image Landsat / Copernicus

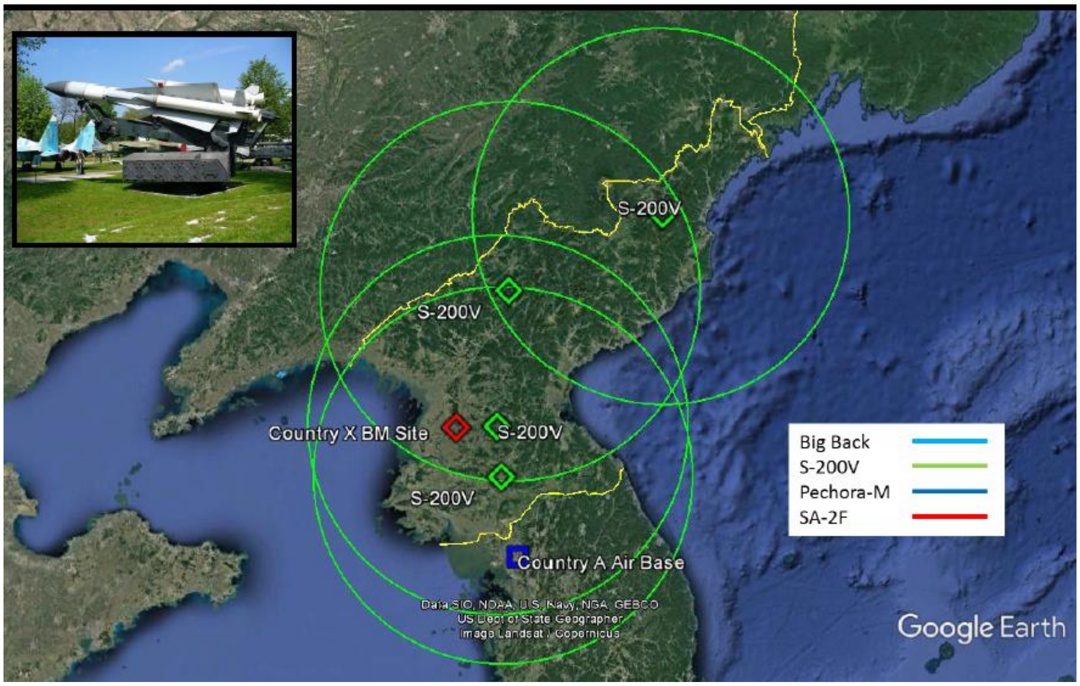
IADS Overview



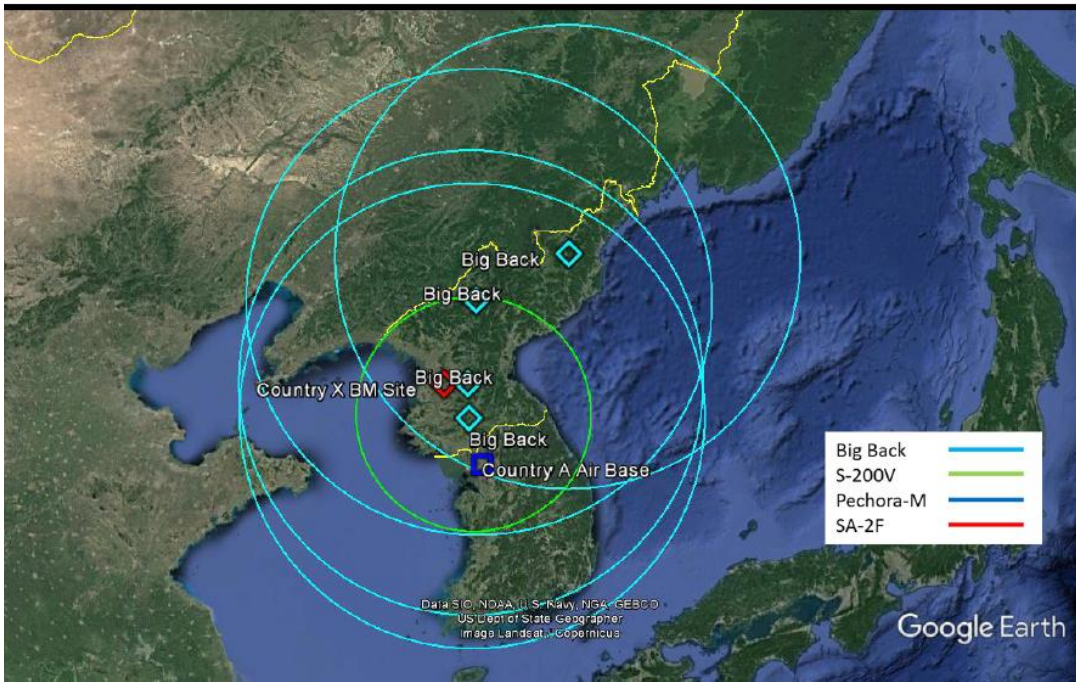
SA-2F Overview

Pechora-M Overview

S-200V Overview



EW Overview



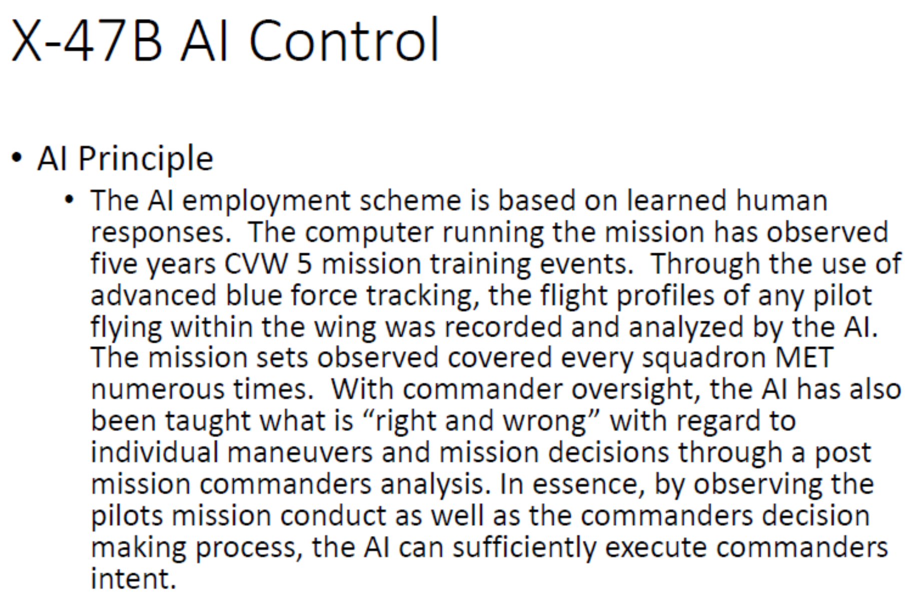
JTF Composition (You) Play 1

- AEF
  - 1 x MQ-1 Squadron (Country A)
  - 1 x MQ-9 Squadron (Country A)
  - 1 x E-8C JSTARs (Country B)
  - 1 x EC-130H Compass Call (CONUS)
  - 1 x RC-135 Rivet Joint (CONUS)
  - 1 x KC-10A Extender Squadron (Country B)
- Maritime
  - 7th Fleet (Afloat)
    - Carrier Strike Group 5
      - 1 x CVN
        - CVW-5
          - Four VFA Squadrons
          - One VAQ Squadron (EA-18G Growlers)
          - One VAW Squadron
          - One HSC Squadron
          - One HSM Squadron
          - Det (4) Operational X-47Bs (Conventional Control)
      - 2 x Destroyer (DDG)
      - 1 x Guided Missile Cruiser (CG)
      - 1 x SSGN (154 cruise missile complement)

JTF Composition (You) Play 2 Future

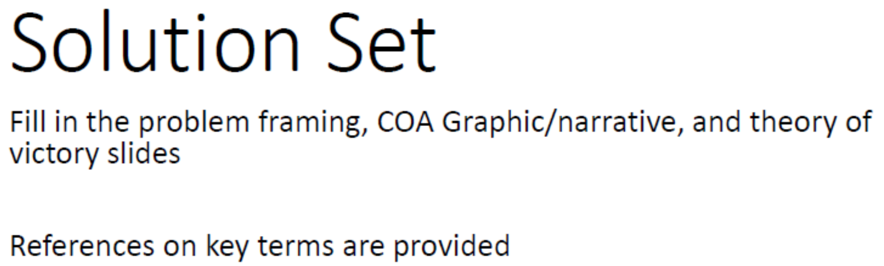
- AEF
  - 1 x MQ-1 Squadron (Country A)
  - 1 x MQ-9 Squadron (Country A)
  - 1 x E-8C JSTARs (Country B)
  - 1 x EC-130H Compass Call (CONUS)
  - 1 x RC-135 Rivet Joint (CONUS)
  - 1 x KC-10A Extender Squadron (Country B)
- Maritime
  - 7th Fleet
    - Carrier Strike Group 5
      - 1 x CVN
        - CVW-5
          - Four VFA Squadrons
          - One VAQ Squadron (EA-18G Growlers)
          - One VAW Squadron
          - One HSC Squadron
          - One HSM Squadron
          - Det (4) Operational X-47Bs
            - **Swarm controlled by AI***
      - 2 x Destroyer (DDG)
      - 1 x Guided Missile Cruiser (CG)
      - 1 x SSGN (154 cruise missile complement)

*See following page for details



X-47B AI Control

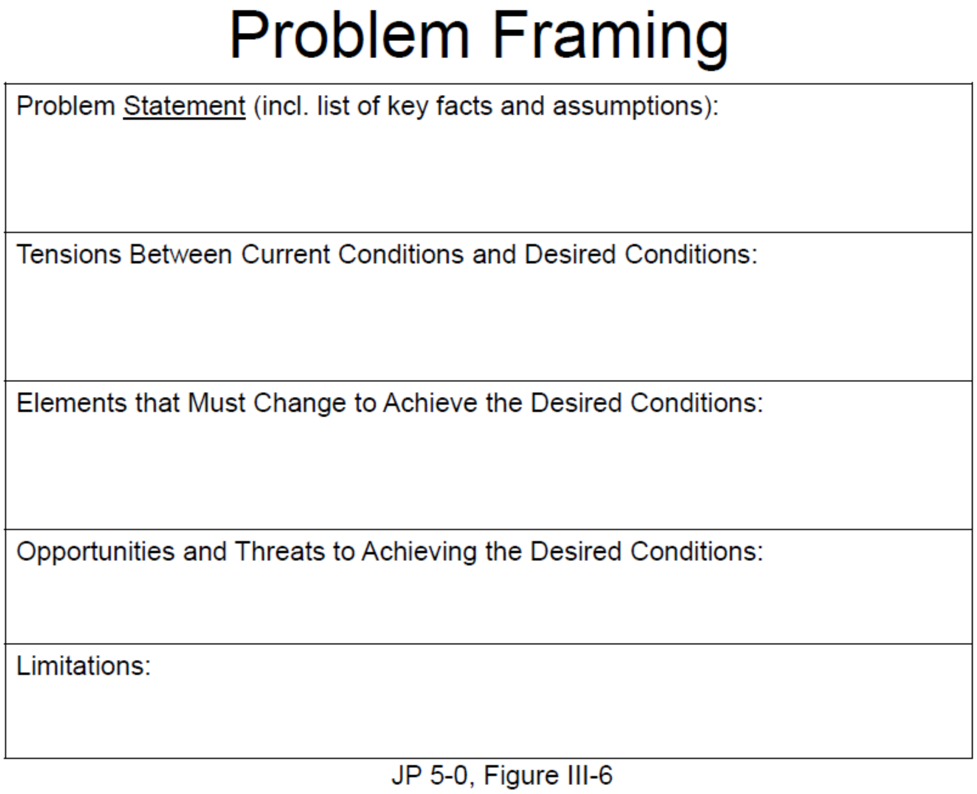
- AI Principle
  - The AI employment scheme is based on learned human responses. The computer running the mission has observed five years CVW 5 mission training events. Through the use of advanced blue force tracking, the flight profiles of any pilot flying within the wing was recorded and analyzed by the AI. The mission sets observed covered every squadron MET numerous times. With commander oversight, the AI has also been taught what is “right and wrong” with regard to individual maneuvers and mission decisions through a post mission commanders analysis. In essence, by observing the pilots mission conduct as well as the commanders decision making process, the AI can sufficiently execute commanders intent.



Solution Set

Fill in the problem framing, COA Graphic/narrative, and theory of victory slides

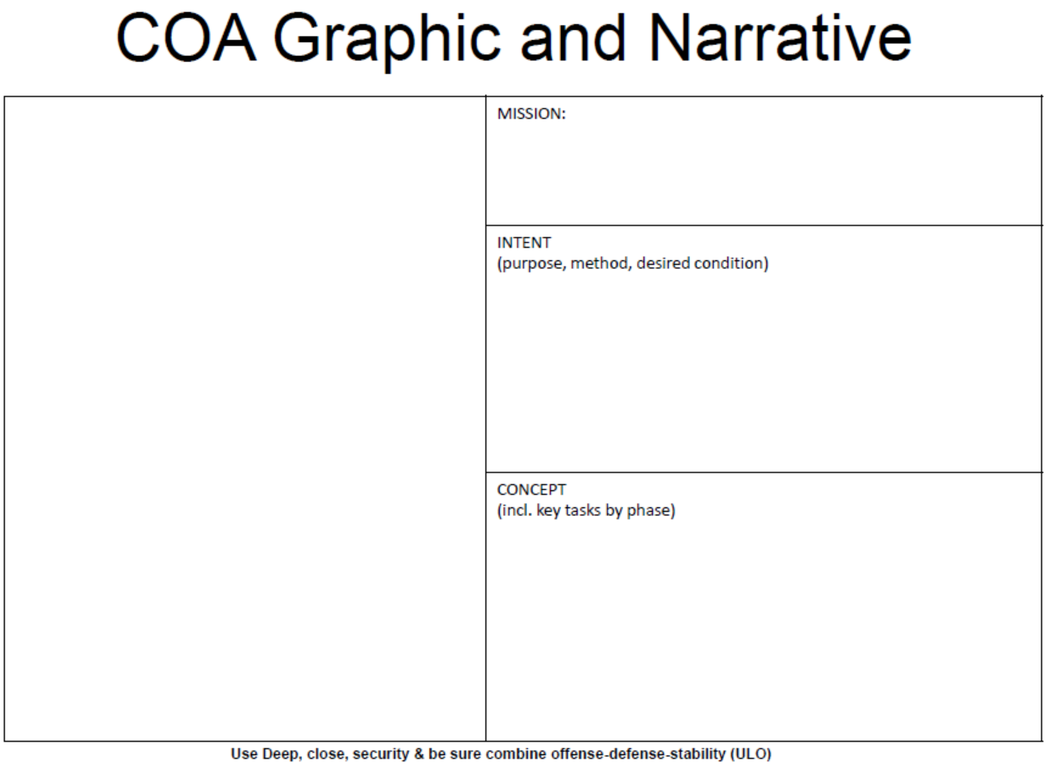
References on key terms are provided



Problem Framing

Problem <u>Statement</u> (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:

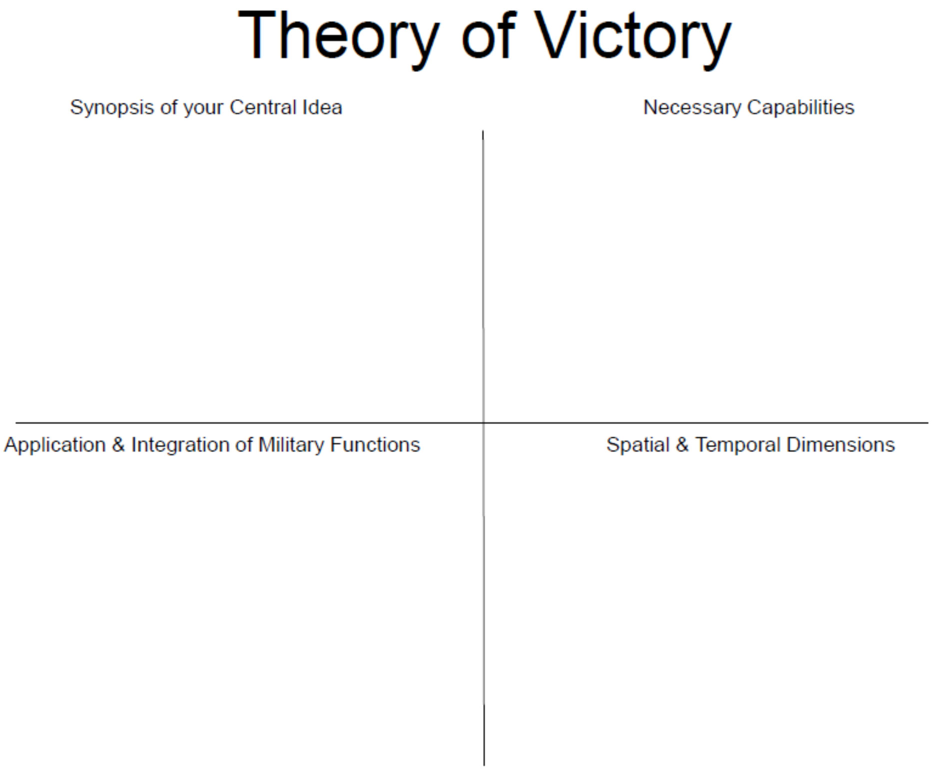
JP 5-0, Figure III-6



COA Graphic and Narrative

	MISSION:
	INTENT (purpose, method, desired condition)
	CONCEPT (incl. key tasks by phase)

Use Deep, close, security & be sure combine offense-defense-stability (ULO)



Theory of Victory

Synopsis of your Central Idea	Necessary Capabilities
Application & Integration of Military Functions	Spatial & Temporal Dimensions

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