AIR WAR COLLEGE

AIR UNIVERSITY

LEVERAGING ARTIFICIAL INTELLIGENCE AND AUTOMATIC TARGET RECOGNITION TO ACCELERATE DELIBERATE TARGETING

by

Gary P. Beckett, Lt Col, USAFR

A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

Advisor: Lt Gen (Ret) Allen G. Peck

31 February 2020

DISCLAIMER

The views expressed in this academic research paper are those of the author and do not reflect the official policy or position of the U.S. government, the Department of Defense, or Air University. In accordance with Air Force Instruction 51-303, it is not copyrighted, but is the property of the United States government.

Biography

Lt Col Gary P. Beckett is a student, Air War College, Maxwell Air Force Base, Alabama. A graduate of the Reserve Officer Training Corps at Florida State University, he completed Undergraduate Combat Systems Officer (CSO) Training at Naval Air Station Pensacola, Florida. Lt Col Beckett then completed the F-15E Basic Course at Seymour Johnson AFB, North Carolina followed by an operational tour and an assignment as a Formal Training Unit instructor there. Later, he served as Director of Operations of the 307th Fighter Squadron, followed by Air Command and Staff College at Maxwell Air Force Base. He then served two consecutive tours in the Pentagon as a Total Force Strategist in AF/A-5/8 and then as Deputy Division Chief, Reserve Strategy and Planning. After Washington, D.C., he served as Commander, 350th Recruiting Squadron, Joint Base McGuire-Dix-Lakehurst, New Jersey. Lieutenant Colonel Beckett holds a Master of Aeronautical Science from Embry-Riddle Aeronautical University as well as a Master of Military Operational Art and Science from Air University. He is a Senior CSO with over 1,800 hours in the F-15E and two deployments in support of Operation Iraqi Freedom and Operation Enduring Freedom.

Abstract

Evidence demonstrates the deliberate targeting cycle lagged the pace of low-end conflict in Operation Inherent Resolve (OIR). If the joint force does not identify and mitigate the factors which led to this phenomenon, then these factors will certainly be amplified in high-end conflict. This research examines deliberate targeting in OIR, identifies causal factors, and recommends improvements to ensure advantage in future conflict. To secure victory in tomorrow's war, the joint force must address the three prevailing causal factors of inadequate intelligence capacity, insufficient ISR asset availability, and redundant target vetting within the deliberate targeting cycle.

Research into Artificial Intelligence (AI) and Automatic Target Recognition (ATR) illuminates various efforts having the potential to mitigate these deliberate targeting deficiencies. For one, machine learning, data mining, and data fusion are AI capabilities which could be applied to the intelligence challenges identified in the research. In addition, autonomous systems which find, fix, identify, and track targets are ATR capabilities which could augment deliberate targeting and enhance the JADC2 of forces.

With these technologies in mind, several recommendations are offered with the overall objective of accelerating deliberate targeting through augmentation of the process with AI and ATR. These technologies have the potential to bolster intelligence capacity, improve ISR asset availability, and accelerate strike approval. In turn, these improvements could enhance JADC2 and ensure decision advantage in future conflict.

Introduction

Thomas Friedman, in his latest book, *Thank You for Being Late*, cites Moore's Law, which states that microprocessor chips double in power every two years.[1] Alarmingly, he goes on to say that this growth rate surpasses our ability to adapt.[2] And as technology accelerates, so does the warfare it enables, leaving the joint force scrambling to keep pace.

To persevere, Department of Defense (DOD) leadership must first acknowledge that future warfare will overwhelmingly be characterized by speed. The DOD must then shift defense priorities toward emerging technologies which demonstrate the potential to offer decisive advantage on the battlefield. The Air Force has already begun this process by leading an effort to accelerate our decision cycle within JADC2. This effort is fundamental to our ability to compete, deter, and win in the future against peer competitors who threaten U.S. national security.

Contesting our efforts are adversaries who have studied U.S. warfare since our sweeping victory over Iraq in Desert Storm. Some of these adversaries are already demonstrating a technological advantage in key areas such as AI. Arguably, our greatest adversary is an ascendant China, which aggressively invests in AI, believing it should be the global leader in pursuit of AI.[3] China also continues to threaten the security of U.S. partners and allies in Asia through its actions in the South China Sea, fomenting an environment of regional instability.

Considering the actions and strategic narrative of the Chinese, it becomes evident that the pursuit of so-called "game-changing" technologies such as AI and ATR is a critical component of U.S. national security; so much so, that some pundits warn absent aggressive action, the U.S. risks losing its lead in AI.[4] If America loses the lead in these vital technologies, it may also lose the next conflict against a peer adversary. It's time to change the game.

Thesis

The deliberate targeting cycle is not responsive enough to succeed in tomorrow's conflict. To mitigate challenges in the current process, deliberate targeting should be augmented by Artificial Intelligence and Automatic Target Recognition, which may bolster intelligence capacity, improve ISR asset availability, and accelerate strike approval.

Case Study: Operation Inherent Resolve

Research Methodology

This research employed case study methodology with a single case analysis of Operation Inherent Resolve. Process tracing was accomplished through interviews with personnel having first-hand knowledge of the deliberate targeting cycle in OIR. This methodology is derived from George and Bennett's *Case Studies and Theory Development in the Social Sciences.* Five officers in the rank of lieutenant colonel to major general from the Air Force and Army were interviewed. The interviewees all had direct knowledge of the deliberate targeting cycle to varying degrees and were eyewitnesses to the process and its efficiency.

Evidence

The preponderance of evidence collected in the interviews, combined with secondary source information, validated the thesis that the deliberate targeting cycle was unresponsive in OIR, with one officer even noting "[they] could not get CENTOM approval of weaponeering for weeks."[5] In their book *Hunting the Caliphate*, Dana Pittard and Wes Bryant arrive at the same conclusion by noting that the U.S. Embassy strike cell had a "very restrictive and time-consuming process to gain airstrike approval."[6] Indeed, the inefficiency of the process required the strike cell to ultimately invent a novel process, dubbed "Planned Dynamic," which circumvented joint doctrine and resulted in strikes in as little as three hours,[7] and though all but one respondent agreed that the doctrinal deliberate targeting cycle was unresponsive, all respondents agreed that several processes are favorable candidates for augmentation by AI and ATR. Synthesizing the interview data yielded the three primary causal factors of inadequate intelligence capacity, insufficient ISR asset availability, and redundant target vetting.

Processing, exploiting, and disseminating (PED) intelligence data is a frequent limiting factor in joint targeting. For one, extensive personnel are required to PED the massive amount of intelligence which floods a Joint Operations Center. Pittard and Bryant noted this challenge in discussing the difficulty of exploiting a steady flow of intelligence, which often resulted in inaccurate information during their tenure in Iraq.[8] Interview data further confirmed this challenge as all but one respondent identified intelligence operations as a limiting factor in the targeting cycle,[i] with one officer stating that the intelligence apparatus could not keep up with the amount of data that streamed in.[9] Also, Benjamin Lambeth's draft research on OIR confirmed this assessment in citing Brent McGurk[ii], who stated that "the [primary] challenge was intelligence and target development…"[10]

Second, another officer noted that intelligence data fusion was a lacking element of the targeting cycle.[11] Lambeth's research strengthens this argument in highlighting the vast of amount of information which must be fused in the deliberate targeting process, including four to five feeds of overhead imagery, electronic communications intercepts, human intelligence, and hostile and friendly fire.[12] Pittard and Bryant also recognized this factor, noting that the "level of focus required [to coordinate this amount of information]…would probably be mind-boggling to the outside observer."[13] The strain placed on a single operator often can exceed their capacity and may result in single points of failure as humans are stretched to their cognitive limits.

Another element stretched to its limit was ISR asset availability. Pittard noted that there was a severe shortage of ISR assets available during his tenure, which impacted operations in Iraq.[14] And though Pittard deployed to Iraq before the interviewees, he was hampered by

[i] The dissenting opinion resided with an officer who supported the Battle of Mosul, the coalition's primary focus during his tenure

[ii] Presidential envoy for the global coalition against ISIS

Afghanistan's Operation Enduring Freedom in the same manner the interviewees faced competing priorities in OIR. In fact, during this phase of OIR, Iraq was priority, which then hampered operations in Syria in a similar fashion. Because of this, respondents who participated in Syrian operations agreed that there were not enough joint ISR assets available.[iii] This disproportionate allocation of ISR assets demonstrates there were indeed not enough of them available for CJTF-OIR.

In response to this specific issue, one respondent noted that the scarcity of ISR assets regularly required general officers to "sit at the table" to settle disagreements over allocation,[15] while another noted that as remotely piloted aircraft (RPA) increased in demand, Hellfire missiles had to be rationed.[16] This should never have happened as CJTF-OIR was responsible for operations in Iraq and Syria and should have been resourced sufficiently to execute operations in both countries concurrently. Unfortunately, the reality of a globally-engaged joint force all but ensures there will likely never be enough ISR assets available to theatre commanders.

To ease the burden, AI and ATR systems may increase the capability and therefore the availability of these finite resources. Advanced ATR sensors, supported by AI, may compensate for shortfalls by identifying more targets than a human operator can, and doing so much faster. In turn, this could accelerate or potentially even abolish the current target vetting process, one of the identified challenges in deliberate targeting in OIR.

In the early stages of the conflict, targets were vetted by CENTCOM, nearly 7,000 miles from Baghdad, resulting in excessive strike approval delays.[17] Pittard noted this dynamic as early into his deployment he was "bombarded with anxious calls from [the] Embassy, State

[iii] Those who participated in Iraqi operations did not cite ISR asset availability as an issue as during their tenure the Battle of Mosul was underway and was designated as the priority if not explicitly by order, then implicitly through resource allocation

Department, Defense Department, [and] various intelligence agencies [who wanted]…updates and reassurances…" prior to strike approval.[18]

Exacerbating the issue was the coalition dynamic, which further delayed strike approval due to partner nation vetting requirements.[19] Pittard also noted that during his tenure the coalition was "basically at war with itself," and that the fight against ISIS was "one of the most frustrating experiences [he'd] yet had in the military."[20] In fact, one interview respondent noted that even two years after Pittard left, targets still passed through at least seven different entities during vetting.[21] Another respondent agreed that vetting was a challenge and added that the process of intelligence review, weaponeering, and collateral damage estimation (CDE) occurred multiple times by disparate entities.[22] Lambeth noted the convoluted process as well, quoting then-Major General Lofgren, stating that "each target required multiple days of coordination with interagency and the Iraqis to get approval."[23]

Interview data combined with the experience of Pittard and Bryant as well as research conducted by Lambeth confirm the thesis of this research. Although there were additional factors not mentioned in this research which degraded deliberate targeting, the causal mechanism for this case was prohibitively slow operations in Phase Two of the joint targeting cycle. Certainly, some contributing factors are beyond Joint Force Commander control, such as political objectives and ROE, but there are several elements of deliberate targeting which could be accelerated with AI and ATR.

Artificial Intelligence

Artificial Intelligence is crucial to ensuring the United States maintains a competitive advantage as we progress toward a multipolar world. This new dynamic will breed instability, which will generate conflict as actors seek greater advantage vis-à-vis one another. To ensure the U.S. maintains advantage in the future, it should aggressively pursue AI. This capability is vital as AI has demonstrated speed, flexibility, accuracy, persistence, reach, and coordinated mass in weapon systems,[24] which are all critical competencies for tomorrow's conflict. Indeed, AI is so vital that the Center for a New American Security calls for a 25-billion-dollar investment across the government, measures to stem the loss of American AI talent, and actions to prevent theft of critical AI by malign actors.[25] And the primary malign actor in this field is China, which is pursuing AI-enabled data fusion, information processing, and intelligence analysis.[26] Absent aggressive pursuit, the U.S. may lose the technology race in this field.

With the "why?" addressed, a consideration of the "what?" is necessary. Fundamentally, AI concerns machines capable of modelling the intellect typically associated with human cognition.[27] The two types of AI are Artificial General Intelligence (AGI) and Narrow AI. AGI seeks to make sense of the world and is able to match, or in some cases, outperform human ability to do so.[28] Unfortunately, the scientific community believes AGI is an unresolved technical challenge which will remain so for several years.[29] In contrast, Narrow AI operates ubiquitously, possessing the ability to execute diverse tasks such as recognizing objects and people,[30] and should be considered for augmentation of deliberate targeting, JADC2, and other applications.

One specific application of Narrow AI which should be considered within the context of deliberate targeting is autonomy, defined as the ability of a machine to execute tasks without human input.[31] An everyday example of this is a robot vacuum cleaner. Autonomous systems execute preprogrammed tasks, interacting with the environment through sensors and actuators.[32] These machines follow a basic rudiment of sense, decide, and act,[33] using software which compares observed patterns to reference ones programmed in memory.[34]

Although sense, decide, act provides a reliable foundation, Narrow AI vastly increases in capability when coupled with machine learning, which is a software approach that programs robots to learn and then teaches them.[35] The training information may be general in nature or specific to a particular field. IBM's Watson is an example application of both general and specific machine learning. After Watson amazed audiences on *Jeopardy!* with its general knowledge, it was later used to diagnose medical conditions and recommend treatment plans after digesting massive amounts of medical data.[36]

Machine learning algorithms can also classify data and find correlations to make statistical predictions about future behavior.[37] In fact, Canadian research demonstrated that machine learning correctly classified secret documents reliably to 90%,[38] while AFWERX expects AI to improve AWACS availability by 25% through predictive maintenance.[39] Furthermore, machine learning can identify anomalies in data.[40] For example, London's Cromatica camera software predicted suicides by detecting abnormalities in observable patterns of life.[41]

AI makes yet another substantial leap forward when combined with deep learning technology. Deep learning is a type of machine learning which enables systems to improve their analytical capability through data *and* experience.[42] Deep learning is well-suited for processing massive amounts of data[43] since the machine begins with simple concepts and builds increasingly complex ones.[44] One of these concepts is predictive analysis, which was demonstrated by AlphaGo, the machine famed for defeating Lee Sedol in Go in 2016.[45] The game of Go is a computationally massive problem and AlphaGo's victory demonstrated the utility of deep learning in processing, experience, and prediction. This capability could be leveraged to mitigate the challenges of intelligence analysis, where the amount of data frequently exceeds human capacity to PED it.[46]

AI also possesses the capability to fuse data more effectively than humans. Zhao et al. noted the success of AI in data fusion and decision-making augmentation in their research.[47] This key finding may alleviate the burden on the human element in PED. Stanley McChrystal cited this challenge in *Team of Teams*, alluding to a "four-foot-high mound" of intelligence data stacked and unexamined in a supply closet in Baghdad during Operation Enduring Freedom.[48] Furthermore, a Congressional Research Service report on AI touted the critical importance of AI in the overall ISR mission.[49] The report also highlighted the applicability of AI to Multi-Domain Command and Control through data-fusion.[50]

Another effort, named Project Maven, seeks to resolve some of these PED challenges by using AI and machine learning to differentiate people from objects in Unmanned Aerial Vehicle video footage. The project also seeks to overcome the problem of infoglut, which is inherent in intelligence analysis.[51] Strengthening the case for AI, the Stockholm International Peace Research Institute (SIPRI) asserts that machine learning is well-suited to ISR management, decision support systems,[52] and prediction.[53] These various efforts demonstrate that AI has the potential to accelerate deliberate targeting and ultimately, JADC2.

Automatic Target Recognition

Automatic Target Recognition (ATR) software was first invented in the 1970s and has recognized objects through pattern analysis since its inception.[54] ATR refers to the automatic or unaided capability of machines to process sensor data to locate and classify targets.[55] Aided Target Recognition (AiTR) is a type of ATR which emphasizes human-in-the-loop operations, seeking to reduce the workload on the human operator.[56] The Department of Defense should continue to research AiTR while concurrently exploring on-the-loop and out-of-the-loop ATR technologies, being careful to ensure lethal fires always remain a human decision.[57]

The intent of ATR is to detect and identify targets through data, which are typically (although not exclusively) presented as imagery.[58] These images include sensor data from Forward-looking Infrared (FLIR), Semi-Active Radar (SAR), TV camera, laser radar, and non-imaging sensors.[59] ATR systems recognize shape, height, velocity, radio frequency, and acoustic signature[60] as well as other characteristics.[61] ATR also identifies human targets,[62] multiple and group targets, specific events, light flashes, muzzle blasts, environment changes, disturbed earth, and more.[63] The latest ATR even differentiates between people walking and running.[64] In addition to identification, ATR technology performs image fusion, target tracking, and persistent surveillance.[65]

Automatic Target Recognition has been used by the military for decades in various applications. A 2017 SIPRI report cited 154 military-fielded ATR systems, of which 50 were decision aids, 24 were command and control, and 56 collected and processed information.[66] Many of these ATR systems are found in weaponry such as the Royal Air Force's Brimstone missile, which is capable of identifying, tracking, and striking vehicles autonomously.[67] Other advanced ATR weapon systems that can detect, identify, track, select, and attack targets include the Dutch Goal Keeper, multi-national Phalanx, and Israeli Iron Dome.[68] Since these systems are capable of finding and discriminating specific targets, they could have decisive impact on future deliberate targeting as the DOD increasingly incorporates them into sensing and strike platforms.[69]

Recent developments in ATR include multispectral and hyperspectral imaging detection. Multispectral and hyperspectral images are generated by recording electromagnetic radiation. Applied Research, LLC recognized that these systems are particularly well-suited to detecting targets from aircraft and spacecraft.[70] They patented a system which vastly reduced the time required to classify multispectral and hyperspectral images and promised real-time target detection,[71] a capability which could be used to accelerate deliberate targeting in future conflict.

Another technology with continued applicability to future conflict is SAR mapping. This technology is continuously evolving and is widely employed by Joint Force operators across multiple different weapon systems. Currently, SAR mapping mostly relies on the highly-trained skill of operators interpreting the generated images. To be sure, these warfighters identify targets in seconds now, but that pace will be too slow for next generation warfare, where machines will identify targets in nanoseconds. The joint force should investigate emerging technologies in this field such as SAR ATR.

The standard sequence of SAR ATR consists of the three stages of detection, discrimination, and classification.[72] This sequence timing was accelerated by Hidetoshi Furukawa in 2018 using a proposed Convolutional Neural Network[iv] dubbed “Verification Support Network”, which exhibited 99.55% accuracy in classification of a 2,420-image dataset.[73] Furukawa’s research demonstrated that ATR is quite well-suited to the challenge of target

[iv] Deep learning network which can differentiate objects in images

detection and identification, and further should be considered for augmenting deliberate targeting and JADC2.

The success of these systems shows promise for accelerating deliberate targeting. The Department of Defense should expand its research and development of these key technologies and develop tactics, techniques, and procedures to incorporate them into JADC2. Systems which can detect and identify targets instantaneously, transmit encrypted data, and then fuse it are vital to maintaining advantage in future conflict.

AFWIC

This research advocates the Department of Defense invest in Artificial Intelligence and Automatic Target Recognition. Thus far, no specific organization is identified as lead agency. The Air Force has an organization called the Air Force Warfighting Integration Capability (AFWIC), which is well-suited to this task. AFWIC could take the lead on many recommendations cited in this research and further develop these technologies for implementation across the DOD.

AFWIC was created by Secretary Wilson and General Goldfein to examine the Air Force's "diverse warfighting portfolio and drive enterprise-wide solutions to complex issues…[and] to rapidly identify key areas for investment in new capabilities that build the foundation for a Joint Force that is able to conduct true multi-domain operations, even in the most difficult scenarios."[74] AFWIC's mission is to "drive enterprise-wide integration and future force design…[and] develop total force, multi-domain operating concepts…"[75] According to General Goldfein, this organization is the "lead for integrating and designing a blueprint of a future Air Force."[76]

The stated mission and vision of AFWIC make the organization an ideal fit for leading the Joint Force in the pursuit of these game-changing technologies. In fact, AFWIC already has established JADC2 and AI Cross-Functional Teams (CFT).[77] These teams should lead the DOD into next-generation warfare by accelerating deliberate targeting with AI and ATR. To that end, some specific recommendations for AFWIC are offered below.

Recommendations

The Air Force should prioritize research, development, testing, policy and doctrine, funding, and implementation of AI and ATR for deliberate targeting and ultimately, JADC2.

Research

- The Air Force should prioritize AFWIC and fill its remaining billets by summer of 2021. Graduating Senior Development Education and Intermediate Development Education students should be a priority for hiring. AFWIC should also increase Active Guard Reserve (AGR) and Military Personnel Appropriations (MPA) tours for Air Force Reserve and Air National Guard Airmen to bolster capacity and leverage the unique technical civilian skillsets of the Total Force in the areas of AI, ATR, and machine learning.[v]
- AFWIC should partner with major defense laboratories including, but not limited to, the Air Force Research Laboratory, Sandia National Laboratories, Los Alamos National Laboratory, Defense Innovation Unit Experimental, Kessel Run, DARPA, and any emerging DOD software laboratories to determine which AI and ATR technologies are best suited for testing and development.[vi]
- AFWIC should partner with industry to determine which AI and ATR technologies are best suited to the Air Force's needs and acquire technologies which exceed the capability of those developed by DOD's national laboratories.
- AFWIC should partner with academic institutions and leverage the AI CFT to determine which AI and ATR technologies are best suited to the Air Force's needs.

[v] Although outside the scope of this research, there exists a corresponding human capital element of talent management to this challenge which may require attention.

[vi] Although outside the scope of this research, there exists a corresponding resourcing element to this challenge which may also require attention.

- AFWIC should designate a cell responsible for coordination with each partner in defense, industry, and academia.

Development

- The JADC2 CFT, AI CFT, and Army Futures and Concepts should collectively devise an implementation plan for AI and ATR augmentation of JADC2.
- AFWIC should foster a shared vision for JADC2 with the other services. Each service's futures element should be a key partner in the development of AI and ATR. AFWIC should designate LNO billets for sister services.

Testing

- AI and ATR should be tested at the Shadow Operations Center using a risk-driven concept of operations (CONOP). During low-risk operations, the human should operate in-the-loop. Medium-risk operations should transition to human-on-the-loop and high-risk operations progress to human-out-of-the-loop. Although there is currently no inclination for lethal fires execution without human approval, testing the capability should occur in the event future warfare requires it. These tests should also focus on building trust in AI and ATR systems. The JADC2 CFT should lead this effort.
- ATR systems should train on available friendly and adversary datasets across the Joint Force. ATR should be tested by employing them on RPA and UAV platforms in exercises such as Red Flag or Weapons School integration phase.

Policy and Doctrine

- Air Force Doctrine Document Annex 3-30, JPUB 3-30, JPUB 3-60, and all AOC associated Tactics, Techniques, and Procedures manuals should reflect AI /ATR best practices as appropriate, upon Full Operational Capability (FOC) of these systems.
- The Air Force should modify current or pioneer new doctrine which specifically addresses JADC2 of non-conventional paramilitary proxy forces.[vii]
- The Air Force should adopt Planned Dynamic as a third type of targeting and document the process in JPUB 3-60 once proven it is viable.

Funding

- AFWIC should champion AI and ATR in the Program Objective Memorandum.
- AFWIC should champion AI and ATR for the Joint Force and collaborate with sister service elements, ensuring a unified voice in programming them into the President's Budget.

Implementation

- These capabilities are urgently needed in *high-end* conflict. Once Initial Operational Capability is achieved, AI and ATR should be fielded in PACOM as a test bed for further refinement using a human-in-the-loop CONOP to establish FOC.

[vii] This is a secondary recommendation derived from research interviews. Although this recommendation did not fit the narrative of this body of research, it remains relevant in the author's opinion.

Conclusion

The current deliberate targeting cycle lags the pace of modern warfare. The targeting cycle operates at the speed of the doctrinal battle rhythm and will fail to execute inside the adversary's decision cycle in high-end conflict. The Joint Force must accelerate deliberate targeting and by proxy, its own decision cycle, through investment in Artificial Intelligence and Automatic Target Recognition. These technologies should be researched, developed, tested, and implemented through a strong partnership across the Joint Force and with our defense national laboratories, industry, and academia. AFWIC, the JADC2 CFT, and AI CFT should lead the Joint Force in developing, resourcing, and implementing AI and ATR in deliberate targeting and JADC2.

The Airpower Research Task Force was tasked to derive "quick wins" from Operation Inherent Resolve. The first quick win is to validate the AI and ATR targeting capability claims in this research through training exercises such as Red Flag or Weapons School integration phase. If AI and ATR prove they can accelerate deliberate targeting as suggested, then these capabilities should complete formally for resources in the Planning, Programming, Budgeting, and Execution cycle. Upon increased trust, they can later be considered for wider application in JADC2. This first quick win will take the initial steps toward leveraging Artificial Intelligence and Automatic Target Recognition to accelerate deliberate targeting.

Appendix – Case Study Interview Questions

What was your job and title during OIR and how does it relate to the Joint Targeting Cycle?

Overall, how effective was the JTC in achieving strategic objectives of campaign?

How efficient was it?

To the best of your knowledge how well was Phase 1 of the JTC executed?

Phase 2, 3, 4, 5, 6?

Any steps that weren't executed according to doctrinal recommendations?

Where were the bottlenecks in the JTC?

Was *specifically* the deliberate targeting process slower than doctrinal recommendations?

If so, what do you think caused the DT process to be slow?

Was the DT process executed according to doctrinal recommendations?

About how long did it take to get targets approved?

What contributed to or caused that timing?

How well did the PED process flow? Was it timely?

Why or why not?

What do you think could be done to improve the PED process?

Is there anything you think that could be automated in the JTC?

Is there any role that you think AI could play in the JTC?

Is there any role that you think Automatic Target Recognition could play in the JTC?

Any additional recommendations for CSAF for the JTC based on your experience?

Notes

[1] Thomas L. Friedman, *Thank You for Being Late* (New York: Picador, 2016), 38.
[2] Friedman, *Late*, 32-33.
[3] Gregory C. Allen, *Understanding China's AI Strategy: Clues to Chinese Strategic Thinking on Artificial Intelligence and National Security* (Washington, DC: Center for a New American Security, 2019), 4-5.
[4] Martijn Rasser, Megan Lamberth, Ainikki Riikonen, Chelsea Guo, Michael Horowitz, and Paul Scharre, *The American AI Century: A Blueprint for Action* (Washington, DC: Center for a New American Security, 2019), 7.
[5] Maj Gen Andrew A. Croft (Deputy Commanding General – Air, Combined Joint Forces Land Component Command – Operation Inherent Resolve and Deputy Director, Joint Air Component Coordination Element, Combined Joint Task Force – Operation Inherent Resolve), interview by the author, December 19, 2019.
[6] Dana J.H. Pittard and Wes J. Bryant, *Hunting the Caliphate: America's War on ISIS and the Dawn of the Strike Cell*, New York: Post Hill Press, 2019, 145.
[7] Croft, interview.
[8] Pittard and Bryant, *Hunting the Caliphate*, 189.
[9] Maj Gen Chad P. Franks (Deputy Commander for Operations and Intelligence, Combined Joint Task Force – Operation Inherent Resolve and Commander, Ninth Air Expeditionary Task Force – Levant), interview by the author, November 20, 2019.
[10] Benjamin S. Lambeth, "America's Air War on ISIS: A Diagnostic Assessment," working draft, July 15, 2019, 181.
[11] Croft, interview.
[12] Lambeth, "Air War on ISIS," 82-86.
[13] Pittard and Bryant, *Hunting the Caliphate*, 172.
[14] Pittard and Bryant, *Hunting the Caliphate*, 112.
[15] LTC Matthew J. Gomlak (Special Operations Joint Task Force – Operation Inherent Resolve J3), interview by the author, January 8, 2020.
[16] Franks, interview.
[17] COL Shanon J. Mosakowski (Fire Support Coordinator and Chief of Lethal Fires, Combined Joint Task Force – Operation Inherent Resolve), interview by the author, January 8, 2020.
[18] Pittard and Bryant, *Hunting the Caliphate*, 114.
[19] Mosakowski, interview.
[20] Pittard and Bryant, *Hunting the Caliphate*, 97.
[21] Mosakowski, interview.
[22] COL Thomas R. Bolen (Division Fire Support Coordination and Commander, First Infantry Division, Combined Joint Task Force – Operation Inherent Resolve), interview by the author, January 9, 2020.
[23] Lambeth, "Air War on ISIS," 181.
[24] Vincent Boulainn and Maaike Verbruggen, *Mapping the Development of Autonomy in Weapon Systems* (Solna, Sweden: Stockholm International Peace Research Institute, 2017), 61-63.
[25] Rasser et al., *A Blueprint for Action*, 4-5.
[26] Elsa B. Kania, *Battlefield Singularity: Artificial Intelligence, Military Revolution, and China's Future Military Power* (Washington, DC: Center for a New American Security, 2017), 21.

[27] Vincent Boulainn, *The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk* (Solna, Sweden: Stockholm International Peace Research Institute, 2019), 13.
[28] Boulainn, *AI on Strategic Stability*, 13.
[29] Boulainn, *AI on Strategic Stability*, 13-14.
[30] Boulainn, *AI on Strategic Stability*, 14.
[31] Boulainn, *AI on Strategic Stability*, 14.
[32] Boulainn, *AI on Strategic Stability*, 21.
[33] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 10.
[34] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 8.
[35] Boulainn, *AI on Strategic Stability*, 15.
[36] Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (New York: W. W. Norton & Company, 2014), 92.
[37] Boulainn, *AI on Strategic Stability*, 18.
[38] Gregory Scott Gaudet, Maj, "Multi-Level Security Information Sharing – A New Framework for the Digital Age" (Professional Studies Paper, Air University, 2018), 12.
[39] "AFWERX Partners With Cutting Edge AI Company to Transform Aircraft Maintenance," AFWERX, accessed December 20, 2019, https://www.afwerx.af.mil/stories/predictive-maintenance.html
[40] Boulainn, *AI on Strategic Stability*, 19.
[41] Jane Wakefield, "Surveillance Cameras to Predict Behaviour," *BBC News*, May 1, 2002, http://news.bbc.co.uk/2/hi/sci/tech/1953770.stm.
[42] Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning* (Cambridge, MA: MIT Press, 2016), 8.
[43] Goodfellow, Bengio, and Courville, *Deep Learning*, 25.
[44] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 16.
[45] Kania, *Battlefield Singularity*, 15.
[46] Kania, *Battlefield Singularity*, 27.
[47] Guangzhe Zhao, Aiguo Chen, Guangxi Lu, and Wei Liu, "Data Fusion Algorithm Based on Fuzzy Sets and D-S Theory of Evidence," *Tsinghua Science and Technology*, vol. 25, no. 1 (February 2020): 13.
[48] Stanley McChrystal, General, Tantum Collins, David Silverman, and Chris Fussell, *Team of Teams: New Rules of Engagement for a Complex World* (New York, NY: Penguin Publishing Group, 2015), 120.
[49] Kelley M. Sayler, *Artificial Intelligence and National Security* (Washington, DC: Congressional Research Service, 2019), 10.
[50] Sayler, *AI and National Security*, 12.
[51] Courtney Weinbaum and John N.T. Shanahan, "Intelligence in a Data-Driven Age," *Joint Forces Quarterly,* 3rd Quarter 2018, 6.
[52] Boulainn, *AI on Strategic Stability*, 36.
[53] Boulainn, *AI on Strategic Stability*, 54.
[54] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 24.
[55] Bruce J. Schachter, *Automatic Target Recognition* (Bellingham, WA: SPIE Press, March 8, 2018), 1.
[56] Schachter, *Automatic Target Recognition*, 1.

[57] Julian E. Barnes, "Air Force Aims to Deploy a New Battlefield Weapon: Faster Communications," *New York Times*, December 8, 2019.
[58] J.G. Verly, R.L. Delanoy, and D.E. Dudgeon, "Machine Intelligence Technology for Automatic Target Recognition," *The Lincoln Laboratory Journal*, vo. 2, no. 2, 1989, 277.
[59] Dan E. Dudgeon and Richard T. Lacoss, "An Overview of Automatic Target Recognition," *The Lincoln Laboratory Journal*, vo. 6, no. 1, 1993, 3.
[60] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 25.
[61] Interview with research team from Los Alamos National Laboratories, September 11, 2019.
[62] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 24.
[63] Schachter, *Automatic Target Recognition*, 8.
[64] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 28.
[65] Schachter, *Automatic Target Recognition*, 2.
[66] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 26.
[67] Brimstone," ThinkDefence, accessed December 24, 2019, https://www.thinkdefence.co.uk/uk-complex-weapons/brimstone/
[68] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 36.
[69] Boulainn and Verbruggen, *Autonomy in Weapon Systems*, 37.
[70] Applied Research, LLC, "Automatic Target Recognition System With Online Learning Capability," Rockville, MD, 2018.
[71] Applied Research, LLC, "Automatic Target Recognition" 2018.
[72] Hidetoshi Furukawa, *Deep Learning for End-to-End Automatic Target Recognition for Synthetic Aperture Radar Imagery*, Toshiba Infrastructure Systems & Solutions Corporation, 2018, 1.
[73] Hidetoshi Furukawa, *Deep Learning ATR for SAR Imagery*, 1.
[74] "Air Force Warfighting Integration Capability: About Us," Department of the Air Force, accessed March 26, 2020, https://www.afwic.af.mil/About-Us.
[75] "Air Force Warfighting Integration Capability: About Us."
[76] "Air Force Warfighting Integration Capability: About Us."
[77] "Air Force Warfighting Integration Capability: Cross-Functional Teams," Department of the Air Force, accessed March 26, 2020, https://www.afwic.af.mil/Cross-Functional-Teams.