Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
May 2, 2024
A Regional Conference of the Society for Industrial and Systems Engineering

Exploring Combat Training Center Data Exhaust

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Author Note: The views expressed herein are those of the authors and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

Abstract: Army Combat Training Centers (CTCs) operate a live, virtual, and constructive combat training scenario to prepare military units to execute combat operations. These robust training scenarios make CTCs rich in operational data, and the information they produce provides critical feedback to field commanders. We explore using "data exhaust" from CTCs for two functions: in-depth feedback for rotational training units and analysis of Army readiness for senior leadership. We develop an understanding of the CTC sensors and data system and map these various systems to war-fighting functions. In the process, we identify current uses of the data environment for a CTC, focusing on how information is collected, stored, and analyzed. We describe a new system being developed to make CTC data available for analysis. Using insights gained from these explorations, we recommend additional uses for existing data and additional sensors to create new CTC data streams.

Keywords: combat training centers, data-centric operations

1. Introduction & Background

While standing in the batter's box awaiting a pitch, every detail about a baseball player is judged. A scout looks at the player's stance, criticizes how he holds the bat, and even evaluates his confidence level. This method of subjective player appraisal has been replaced by data analytics, first showcased by the Oakland Athletics in 2002 in what has come to be called "Money Ball". In the same way, the US Army's Combat Training Centers (CTCs) increasingly use data-centric evaluations of units rotating through their robust scenarios. Since CTCs are the closest simulation to warfare that the Army has, the data they produce is increasingly sought after by senior leaders to evaluate readiness, tactics, combat formations, leadership, human performance, and technology. This study has informed two other studies regarding readiness directed by the Chief of Staff of the Army and by the Deputy Assistant Secretary of Defense for Force Readiness.

The primary mission of the US Army is to fight and win the nation's wars (U.S. Department of the Army, 2019). Army units prepare to execute this mission through tactical training and rehearsals. However, realistic combat environments are difficult to replicate. CTCs were established to provide a realistic large-scale training environment where units engage in simulated combat against an armed and determined opponent. Units conduct operations at a CTC as if deployed in a combat zone with minimal exceptions, the most important being that blank ammunition is used during the force-on-force phase of the training exercise.

The first CTC, the National Training Center (NTC), was founded in 1979 at Fort Irwin, California (Kemper & CA, 1996). NTC's primary mission is to provide a comprehensive training center for combat arms training and obtain data on the effectiveness of the doctrine currently being used by the Army (Kemper & CA, 1996). The second mission was not addressed until 1985 (Kemper & CA, 1996). Although it took several years to refine its training operations, NTC was considered a success, and other CTCs were established with a similar mission. In 1987, the Army established the Joint Readiness Training Center (JRTC) in Fort Johnson, Louisiana (formerly Fort Polk). In 1988, the Army established the Combat Maneuver Training Center (later renamed the Joint Multinational Readiness Center) in Hohenfels, Germany (Gebicke et al., 1999). In 2023, US Army Pacific Command (USARPAC) established the Joint Pacific Multinational Readiness Center (JPMRC) in the Indo-Pacific Region.

CTCs typically conduct eleven one-month training iterations annually, each called a "rotation." After a six-month intensive training, the rotational unit will move its personnel and equipment to the designated CTC. After installing sensors and instrumentation, the unit will enter the scenario to conduct live, virtual, and constructed simulated conflict against a determined enemy (the opposition forces or OPFOR). These opposition forces are arrayed to simulate a specific type of threat selected by senior leaders and intelligence analysts. Observers-Coach-Trainers (OCTs) adjudicate the conflict and provide periodic feedback to the rotational unit. While these combat operations unfold, the CTC collects data using a system of sensors, OCT observations and manual measurement, and other equipment such as unmanned aerial surveillance drones. The collected data is sent to the

Training Analysis and Feedback Center (TAAF), where teams of Army analysts develop dashboards for feedback. After two weeks of operations, a ceasefire is called, and a CTC conducts an after-action review (AAR) to provide feedback to the soldiers and their leaders. This AAR feedback is supported with qualitative and quantitative assessment using the data and analytics from the TAAF. Once complete, the rotational unit returns to its home station with invaluable experience, lessons learned, and a take-home package of AAR feedback. At the same time, the CTC is left with useful "data exhaust".

CTCs accomplish their primary mission by providing units with the training facility, live/virtual/constructive scenarios, opposition forces, and OCTs to evaluate and provide assessment and feedback. The CTC secondary mission is to provide data to training units and senior leaders (Diano, 2007). Training units use CTC data to improve their tactics and skills. Senior leaders also evaluate Army readiness with CTC data. While the leaders and OCT teams at the respective CTC locations have learned to expertly use data to improve training through their After Action Review (AAR) process, there may be untapped usefulness for data outside the scenario. How can the Army answer questions of readiness, maintenance, logistics, human performance, and acquisition from the data "exhaust" of the CTC's?

At the request of operational leaders, our team's primary focus is on extracting additional insight from existing data produced at the Combat Training Centers. Our second focus is to explore additional insights that could be available for Army leaders with additional data collection efforts (additional sensors or processes). We will answer this by analyzing and mapping the current CTC system of people, organizations, sensors, and processes. We will also conduct a limited exploration of existing instrumentation system (IS) data from NTC. This data is rather large (5-7 TB per rotation, 50-70 TB per year) and has historically not been made available. The U.S. Army Combat Capabilities Development Command (known as DEVCOM) is making this data available through a secure hybrid cloud, through which our multi-year effort will access the data.

2. Related Work

John Mashey popularized the term "big data" at the turn of the twenty-first century while working in this seemingly limitless digital landscape (Diebold, 2012). Defined as a collection of structured, unstructured, and semi-structured data that is huge, complex, and growing, big data provides organizations with more detailed analytics than traditional data (Russom et al., 2011). Meta Platforms manages content sharing among Instagram's 1.4 billion users. By facilitating human interaction and sharing on a sensored technology device, Instagram provides value to its customers who in turn create data that is valuable for Meta's core advertising revenue. The core functions could be tracking the number of content uploads per minute or gauging the number of likes achieved by content from various categories (Agostini, Gianturco, & Mechant, 2022). Like Meta or Google, Army Combat Training Centers understand the value of data and are working to modify their technological systems infrastructure to take advantage of it (McLamb, COMMAND, & STUDIES, 2003).

Multiple past efforts have used quantitative and qualitative data from CTCs to evaluate Army tactics, organization, or technology. Several recent research efforts have focused on the pivot from training for counter-insurgency to training for large-scale combat operations (Diano, 2007; Doyle & Coombs, 2018) at the CTCs. Past research efforts have evaluated small unit performance at the CTCs (Lawrence, 1992), combined or joint operations (Barks & SCHOOL, 2009), logistical and combat service support (April, Stednick, & Christian, n.d.), and human performance (Dyer et al., 1992). Each of these was made possible by some level of access to CTC data.

3. Understanding CTC Systems and Data

Our approach involved stakeholder analysis, systems mapping, and initial data exploration of instrumentation data. With a general understanding of the four Combat Training Centers of the program's modern era, we began to elicit stakeholder analysis to understand the current sensors, data, and data products within CTCs. We held conversations with independent researchers interested in the effectiveness of current Army readiness measures, Observer-Controller-Trainers (OCTs) at the National Training Center (NTC), and key leaders at the Joint Readiness Training Center (JRTC). These conversations stressed the role of Combat Training Centers (CTCs) as the Army's premier training opportunity while also serving as the best means to evaluate units. These CTCs culminate with After-Action-Reviews (AARs) highlighting what did and did not go well in simulated combat. These AARs are heavily supported by data collected manually by OCTs and in depth fire and maneuver data recorded by the instrumentation system.

The primary instrumentation used by the CTCs combines MILES infrared lasers that simulate lethal direct fires and instrumentation that generates the positional information for dismounted soldiers, vehicles, and aerial platforms. This system produces a complex game of "laser tag" as demonstrated in Figure 1. This instrumentation system records the time and specific actions for most fire and maneuver actions within the combat scenario. The instrumentation systems record the number and success of fires and associated casualty rates. It records all maneuvers and allows the OCTs to replay an engagement during

AARs. MILES gear and the instrumentation system are the bedrock of operational data analysis. While MILES gear tracks the damage inflicted between opponents, the instrumentation system collects location data on training units. As discussed above, this instrumentation system typically produces 5-7 TB of data per 2-week rotation. When paired together, analysts achieve a thorough understanding of operations and can create products that greatly enhance the effectiveness of AARs. This data can also be very beneficial for longitudinal analysis of the Army if archived and made available with the appropriate security measures, which is what DEVCOM is currently working on and which our team hopes to access in the future.

In addition to this robust instrumentation, the CTCs also collect data through various sensors on unmanned aerial systems (UAS), combat cameras (for example, capturing images of poor camouflage), electronic spectrum sensing, and voice communications capture (of radio transmissions). The Training Analysis and Feedback Center (TAAF) collected and processed this data to give commanders and OCTs AAR-ready products to support immediate feedback and instruction.

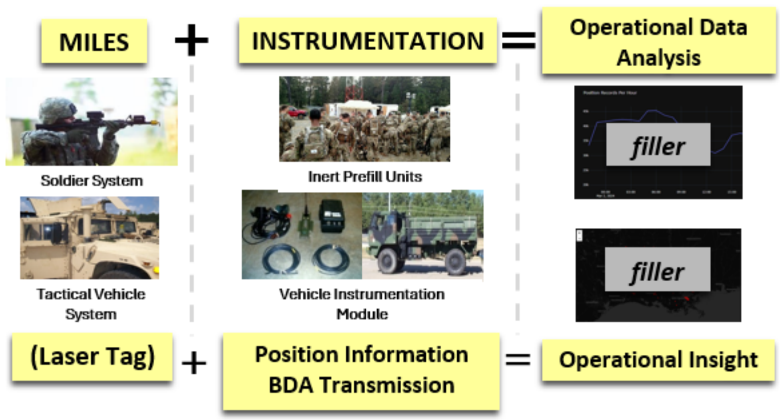

Figure 1: CTC sensors within data collection system contribute to operational data analysis.

These systems create data that we call "data exhaust", meaning it was passively collected. In addition to the passively collected data, each OCT team observes and collects data in what we refer to as "Green Book Data" (OCTs often collect this data in Army-issued green notebooks). The CTC leadership drives the data collection for OCTs to focus on desired training objectives. For example, OCTs may collect the time a command takes to move its command post or the number of vehicles per day that were not operational. Our study aims to maximize the use of the "data exhaust" (passive data) without adding additional collection burden on the OCTs to collect "Green Book" data.

4. Nascent Combat Training Center Data Environment

Data is created as units rotate through the Army's CTCs to participate in live/virtual/constructive combat. The instrumentation system tracks soldier fire and maneuver as discussed above. While current data collection efforts are focused on providing high-quality feedback to the rotational units, other Army organizations are increasingly looking to use CTC data to answer senior leader questions. As seen in Figure 2, various other Army organizations could use this data to understand readiness, modernization, acquisition, logistics, and agility. Conducting longitudinal research on these topics requires well-documented data from many different CTC rotations.

The TAAF data centers have limited space for data storage. The instrumentation system produces 5-10 terabytes of data per rotation. This data is temporarily stored on-site for several additional rotations, at which point this data is deleted (data storage length varies between the four CTCs). Storing this data in a long-term storage repository would allow longitudinal tactics, equipment, and readiness studies. The DEVCOM Army Research Lab (ARL) is building a hybrid cloud repository for the CTC data. This repository will allow approved researchers to gain access to CTC data to answer validated questions. The ARL repository will prevent the export or leakage of CTC data while providing researchers the necessary tools to explore this valuable data. Our research team is one of the first research teams to request access to the data. We are hoping to gain access in early April.

We assess this as one of the CTCs' largest opportunities to improve data usage, as data offers valuable insights over time. During its time in storage, the data is currently used in two ways: 1) It is sent to the TAAF Data Center, where data is used to create After-Action-Review (AAR) ready products for OCTs to use in training and instructing units. 2 It is shared with adjacent Army organizations through the nascent ARL hybrid cloud, where it is used to answer other Army questions of interest.

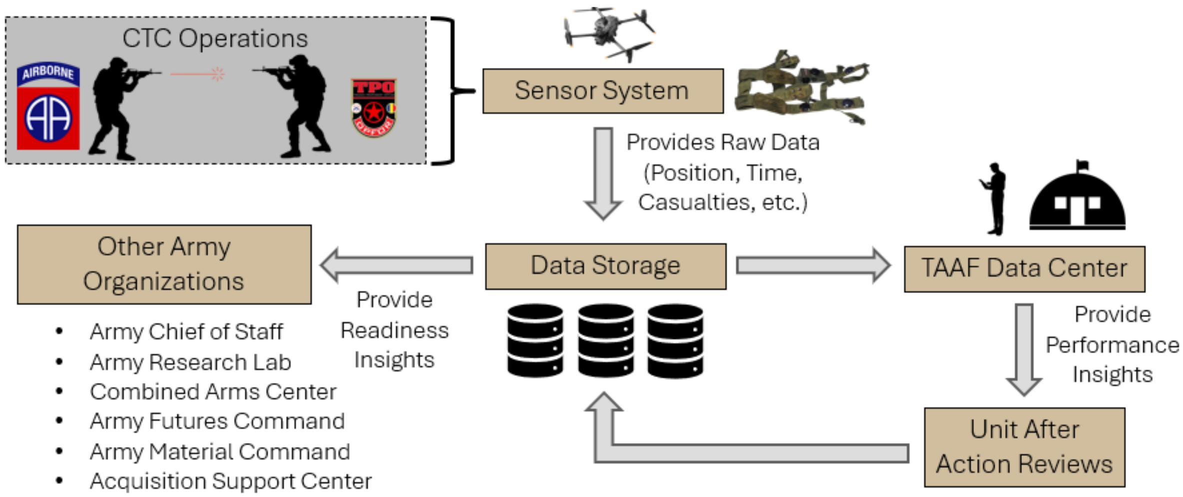

Figure 2: CTC Data Flow and Utilization

5. Mapping Systems and Data to Warfighting Functions

Current CTC data collection can be organized by warfighting functions, as displayed in Figure 3. Current CTC data collection occurs through the following means: The Sleep Analysis (Oura) Ring is a ring soldiers and leaders wear to monitor their sleep while in the CTC environment. It allows OCTs to monitor the amount and quality of sleep to help units understand sleep's impact on unit performance. CTCs currently use voice traffic monitoring to record radio transmission, offering insight into a unit's effectiveness of Command and Control. CTCs possess CESNA planes with cameras capable of capturing CTC rotations from the skies in real-time. Grey Eagle UAS can also gather intelligence and images without being manned by CTC staff. Combat photographers further supplement these sources of overhead photos with on-the-ground images. LOGSTATs provide a current status of on-hand and forecasted consumption of critical classes of supply (food, ammunition, fuel, etc). The PERSTAT provides the current status of all personnel (authorized, assigned, on-hand, killed, wounded, etc). The NEST EW system keeps track of specific electronic signatures. With a large focus on cyberspace in the multi-domain operations of today, this data allows units to understand the importance of minimizing or masking electromagnetic signatures. CTCs utilize Q50 Radar Data to capture an enemy's ability to track and monitor shots fired from artillery and indirect fire. This data enables units to understand the impacts of firing their artillery on enemy intelligence and counter-fire. The CTC Instrumentation System is the set of systems and gear soldiers wear while training in the CTCs to track location, movement, and shots being fired and received. The final method of data collection is notes taken by OCTs. Referred to as "Green Book Data," this data often focuses on training objectives and observations. How well a unit communicates, the effectiveness of leaders, and casualty adjudication not done through the Instrumentation System are all examples of what this data may look like.

We assess data from the Android TAK phones already being integrated into CTCs to be immensely valuable in further assessing a unit's movement and maneuver at CTCs. These Androids would, as they are being given to every soldier of a rotation in the proposed state of their integration, offer further insight into soldier fitness and ability to sustain movement and maneuver with further additions of fitness technology such as Fitbits, Garmin Smartwatches, etc. Additionally, we assess the CTCs ability to capture overhead images as critical to offering units AAR worthy products on a given unit's movement and maneuver. Expanding the current overhead imaging system to include persistent UAS would give units unabridged feedback and access to information on maneuver. This information could include a unit's ability to stay hidden en route to objectives, adherence to movement formations, light-discipline, and individual soldier discipline only being captured periodically in the current state of CTC operations. This overhead imaging could be supplemented by our third proposed means of capturing additional data exhaust from CTCs, trail cameras. While combat photographers supplement overhead imaging with an on-the-ground perspective, we assess trail cameras as a means of capturing more on-the-ground imaging more consistently. In their proposed state of being embedded into large trees and triggered by movement, these cameras would offer imaging similar to commercial deer hunting. These cameras could be placed near areas often used as objectives (CTC dependant) or avenues units often used to maneuver.

ISBN: 97819384962-4-0

	Command & Control	Movement & Maneuver	Protection	Intelligence	Sustainment	Fires
Current Sensors						
Sleep Analysis (Oura)	X					
Voice Traffic Monitoring	X	X	X	X	X	X
Cesna Cameras		X	X	X	X	X
LOGSTAT	X				X	X
PERSTAT	X	X	X	X	X	
Combat Photographers		X	X	X		X
Grey Eagle UAS		X	X	X		X
NEST EW Signatures	X		X			
Q50 Radar Data	X					X
Instrumentation System	X	X	X	X		X
CTC OCTs	X	X	X	X	X	X
Proposed Additional Sensors:						
Android TAK	X	X		X	X	X
Persitent UAS		X	X	X	X	X
Trail Cameras		X	X	X	X	

Figure 3: Current CTC Data Exhaust Collection by War Fighting Function.

A system of these cameras would also supplement OCT Green Book data by allowing OCTs to pull examples of subjective data, such as how well units utilize cover and concealment, communicate under fire, and more. In addition to supporting AARs, overhead and horizontal imagery data could be used to develop machine vision algorithms for detecting tactical objects and maneuvers.

6. Additional Lines of Effort

The rich data exhaust discussed above could be used for several efforts beyond the immediate feedback given to rotational units through the after-action review process. Our team spent some time considering some of the following use cases and discussing them with stakeholders and other research teams:

- Readiness: Does CTC performance correlate to readiness reporting? If not, why?
- Acquisition: What are relevant and realistic requirements for future acquisition efforts?
- Cyber: What techniques are able to adequately conceal command post electronic signatures?
- Intelligence: Can large volumes of overhead and horizontal imagery enable better machine vision object detection for ISR platforms?
- Communication: Could correlating transcribed radio traffic to performance illuminate best practices for communication?
- Logistics: Can logistics data lead to better logistic prediction methods or algorithms?
- Simulation: Can the Army use instrumentation system data to build more realistic combat models and simulations?

7. Future Work & Conclusion

The US Army's Combat Training Centers are invaluable for creating realistic large-scale combat training environments. The use of live, virtual, and constructive environments enables a flexible environment that can adapt to create a variety of scenarios to challenge rotational units. This environment produces valuable data exhaust that is currently being expertly used to provide feedback to rotational units. With nascent efforts between the Army Research Lab and the respective CTCs, the longitudinal data from historical CTC rotations could be available long-term in a hybrid cloud for a myriad of critical military research and inquiry. This data is available to approved researchers with validated questions. As one of the first research teams to evaluate this data, we aim to explore data quality with an initial analysis of the temporal intensity of fire and maneuver. Providing an accessible secure environment to make longitudinal CTC data available will provide incredible value to various lines of effort. In particular, the correlation of CTC data with readiness data may challenge decades of thought on how to measure readiness in the US Army.

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