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Sensors, Interpreters, Analysts: Operating the 'Electronic Barrier' during the Vietnam War

Abstract

This article examines a widely-cited case study in histories of remote, computer-mediated warfare: the US Air Force's 'electronic barrier', a system designed to detect and destroy communist truck convoys entering South Vietnam via the Ho Chi Minh Trail during the Vietnam War. Existing scholarship on the programme has foregrounded the technological novelty of the system, in particular its use of sensors, unmanned aircraft, and the computer centre from which the programme was remotely managed. This article seeks to provide an alternative perspective on the barrier by asking how human operators remained as fixtures in the system. To do so, I focus on 'embodiment' and 'tacit knowledge' through an analysis of the practices of photo interpretation and data analysis which persisted despite efforts to successively computerise the barrier. Drawing on internal reports and memoranda gathered following extensive archival research, I show how these practices were required to resolve critical, systemic problems of ambiguity and inaccuracy that could not be resolved by the computer. The effect was a constant drive for expansion in data and bombs, and the construction of a blunt and extraordinarily aggressive instrument which was instrumental in facilitating the unprecedented scale of the bombing campaign waged by the US Air Force on eastern Laos.

Keywords

Vietnam War, IGLOO WHITE, electronic barrier, automation, digital computing, Cold War

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Introduction

[[Figure 1]]

The United States was not at war with Laos in the 1960s, yet the US Air Force waged one of the biggest aerial surveillance and bombing operations of the Cold War over the jungles and valleys in the east of the country. The objective was *interdiction*: that is, to disrupt the North Vietnamese Army's supply lines that wound their way into South Vietnam via Laotian territory, and which were frequently used to shuttle materiel vital to National Liberation Front guerrilla units. These supply lines were commonly referred to by US strategists as the 'Ho Chi Minh Trail'—although it was less a 'trail' than a complex and carefully maintained infrastructure comprised of truck parks, anti-aircraft artillery, roads, bridges, and walking paths. The war waged on this infrastructure by American armed and intelligence forces incorporated numerous tactics that targeted both the landscape and the people who inhabited it. US jets on nightly sorties devastated key routes with barrages of cluster bombs, cratering roads, destroying bridges, and triggering landslides. Other aircraft dropped innumerable miniature landmines that could maim or kill porters as they walked the trails (Gatlin 1968). Other US Air Force units assigned to herbicidal operations sprayed chemicals to kill the vegetation below, poisoning the earth and water sources in the process (Clary 1971).

One of the most important elements of this interdiction programme was the so-called 'electronic barrier system'. Devised by a group of physicists known as the JASON Division, the electronic barrier was first deployed in late 1967. Over the following five years, tens of thousands of seismic and acoustic sensors were air-dropped over convoy routes, embedding in the soil to detect the seismic rumblings of truck traffic, or hanging in the jungle canopy to eavesdrop for acoustic activity. The sensor data was transmitted to an airbase in Thailand, thousands of miles away from the battlefield, at which point trained analysts observed blips of activity on their computer screens and coordinated bombing sorties to destroy suspected convoys. Crucially, they thought, the system could peer through the various obfuscatory layers—nightfall, clouds, and canopy—that had previously greatly limited American aerial reconnaissance. It came with a price tag of approximately $1 billion per year (Edwards 1997, 3).

For those reporting on Vietnam in the American news media in the early 1970s, IGLOO WHITE was a horrifying but spectacular realisation of an operational paradigm where soldiers mostly sat back and observed complex, 'rational' machines searching for and destroying the enemy (Jaubert 1972; Stanford 1975; Dickson 1976). In the scholarship on Cold War defence computing, IGLOO WHITE has been presented as an important case study emblematic of a distinctive 'cyborgian' strategic rationality (Edwards 1997) and a precursor to contemporary remote, unmanned warfare (Bousquet 2008; Shaw 2016; Elish 2017). These are fair claims: the electronic barrier employed remote autonomous devices, automatic data-processing computer systems, and unmanned aircraft with the aim of dominating a vast territory and combatting an 'enemy insurgency'.

However, if IGLOO WHITE is to serve as an exemplar in such genealogies, then it is necessary to also look beyond the machine and scrutinise the practices, recessive though they may be, carried out by human operators. Rather than take for granted the centrality of computer technologies in the so-called 'electronic battlefield', this article asks: what ‘embodied’ practices remained as fixtures in the operation, and what role did they play in the computational, sensory, and offensive processes of the system? Drawing on US Air Force documents gathered from the National Archives and Records Administration, the Virtual Vietnam Archive, and the Defense Technical Information Center, I closely examine a collection of internal reports produced about the system during its operational deployment that describe types of interpretive and analytic work that could not be performed by machines. Focusing on these embodied, tacit operational practices, I contend that it is crucial to look beyond the spectacle of advanced technologies and problematise the myths of rationality and omniscience should we wish to understand the way such systems operationalise and authorise violence.

IGLOO WHITE and Cyborg Warfare

The existence of the Ho Chi Minh Trail was known to US intelligence analysts long before President Lyndon Johnson officially initiated the ground war in Vietnam in 1965. During the successful communist uprising against the French colonial army over a decade beforehand, some trails had been widely used by Ho Chi Minh’s army to stage key supplies and move personnel. Following the partition of Vietnam in 1954 and the end of French colonial rule in the country, American political intervention increased substantially to ‘contain’ communist influence in the region. Due in no small part to these interventions, the 1956 elections planned to lead to reunification never took place, and the presence of US intelligence and military operatives steadily built up over the rest of the decade. The Laotian trails, offering a supply and communication link between the communist-controlled North Vietnam and guerrilla forces in based in hamlets and cities across the US-backed southern state, became a focal point for American strategists intent on aggressively enforcing the partition of the country.

Military Assistance Command Vietnam (MACV), the United States' primary in-country command established in 1962, had an active interest in the trail network and compiled data on 'Viet Cong infiltration' in the early 1960s (see MACV document cited in Sturdevant 1964, 3). Between 1964 and 1966, however, there was an intensification of analysis. A succession of separate reports authored by defence analysts at various US agencies and think tanks offered what they perceived as evidence of an expansion of the Ho Chi Minh Trail. Many of these reports argued that increased investment on the part of the NVA—in economic, materiel, and personnel terms—signalled that the trail would be of growing strategic importance in the war (CIA 1964, 1965; Deitchman et al. 1966; Sturdevant 1964; Zasloff 1964).

These reports included a variety of progress metrics that supposedly quantified the NVA's use of the trail network. In order to produce such metrics, however, the authors relied on an immense intelligence gathering effort that drew on sources including aerial photography and spy networks distributed across South Vietnam's many hamlets. The ROADWATCH programme, for instance, relied on local Vietnamese civilians recording passing NVA truck traffic and reporting observations to American analysts (Schweitzer 1966). In these reports, the conditions of the roads, the categories of truck commonly seen on them, the environmental and topological features of the region, and the patterns of convoy movements became the subjects of scrutiny by teams of US intelligence operatives.

The quantity of information collected about the trails increased to an unmanageable degree by the mid-1960s. Defence researchers began to investigate the possibilities of introducing digital computers and electronic sensors to partially manage the collection and processing of intelligence on North Vietnamese Army (NVA) 'infiltration'.

The JASON Division convened in August of 1966 for their annual summer study, on this occasion to ruminate on the issue of interdiction. The resultant report, titled *Air-Supported Anti-Infiltration Barrier*, detailed a possible system that would employ computerised data-processing and remote sensors to continuously track NVA troop movements through the Laotian jungle. The proposal was met with enthusiasm by Defense Secretary Robert McNamara, and its recommendations were quickly expedited as a matter of urgency. A little over 12 months later, the system was deployed.

The JASON's recommendations centered on a 'barrier system' comprised of remote, distributed radio and computer technologies. Arrays of sensors with built-in transmitters would be airdropped into the jungle whereupon they would 'listen' for convoy movement. On detecting activity, they would transmit to a reconnaissance aircraft in constant orbit overhead which would then relay the data in real-time to the Infiltration Surveillance Centre (ISC). This decision-making and data processing hub, staffed by a team known as Task Force Alpha (TFA) operating IBM computers, was located at an airbase in Thailand, thousands of miles away from the Ho Chi Minh Trail. From this remote location, TFA analysts could observe the live activations of the sensors on computer screens and datasheets and, at least in theory, determine the speed, the direction of travel, and size of the convoy. Having done so, they could then call in an aircraft to intensely bomb the area in question (1968, 8).

Contemporaneous articles on the barrier emphasised the new computational, quantitative logic shaping Vietnam policy. Alain Jaubert, writing in an article for *New Scientist* as President Nixon attempted to demobilise troops, described American officers 'zapping the Vietcong by computer': 'as the troops go home', he wrote, 'the computers and advanced weapons move in' (1972, 685). In the *New York Times Magazine*, Phil Stanford referred to 'giant computers' presenting technicians with 'probable targets' (1975, 1f). The journalist Paul Dickson described the barrier system as 'a manless, giant, lethal pinball machine from which no living thing can escape' (Dickson 1976). Dickson's reference to a pinball machine was not to trivialise the violence and devastating force of the system, but to highlight an apparently 'gamified' vision of war described by its operators. His analogy referred to a widely circulated quote attributed to an IGLOO WHITE technician which was originally printed in an *Armed Forces Journal* article in 1971: 'we wired the Ho Chi Minh Trail up like a drugstore pinball machine, and we plug it in every night' (cited in Gibson 2000, 396).

In scholarship on Cold War computing, IGLOO WHITE is occasionally presented as an exemplar of a cyborgian melding of human and computer, and a technological realisation of a cybernetic strategic rationality. Themes of automation, remote sensing, the computerisation of war, and premonitions of drone warfare abound in this literature. Edwards (1997, 4) opens his widely cited account of Cold War technopolitics with an enduring image of IGLOO WHITE's command and control hub: 'young soldiers' sat at computer terminals, 'faces lit weirdly by the dim electronic glow, directing the destruction of men and equipment as if playing a video game'. In his history of the drone, Shaw (2016, 87) writes that IGLOO WHITE 'commanders could feel, hear, smell, and see the enemy from hundreds of miles away, moments before they were bombed'. For Cockburn (2015), this was 'the world's first automated battlefield' and 'the precursor of the drone wars that America would fight in the twenty-first century'.

However, through close study of internal documents produced by the US military and its attendant think tanks, we can gain another perspective on the electronic barrier: this transformation of military strategy into the computational management of logistical circuits—a practice that Mirowski (2002, 177) wryly terms 'blipkrieg'—produced an enormous bureaucratic mire of form-filling, data structuring, and repetitive analytic work that produced considerable confusion and ambiguity. In IGLOO WHITE, such forms of internal organisational frictions arose in addition to the emergent forms of environmental resistances and the range of countermeasures employed by North Vietnamese soldiers to misdirect the sensors.

For James Gibson (2000), IGLOO WHITE captures the essence of what he calls 'technowar'—that is, the quantitative logic of industrial accountancy applied to the design and conduct of military strategy. As an erstwhile Ford executive and Harvard Business School graduate, McNamara's responsibility for the normalisation of technowar as a 'style' of strategic planning in the Department of Defense is assured in Gibson's account. Here, IGLOO WHITE joins other operations closely associated with McNamara, such as the 'strategic bombing' of North Vietnam, the mass surveying of the Vietnamese peasantry in the Hamlet Evaluation System (HES), and the notorious 'bodycount' policy where US marines were assigned the hazardous and grim task of counting enemies killed after a skirmish. These operations had a distinctly administrative quality, in that problems of strategic planning became synonymous with problems of information management.

As scholars have noted, these endeavours did not elucidate the war narrative for American commanders. Rather, the drive for ever-more data served mostly to contradict, confuse, and counteract American efforts in the war. Belcher's account of the HES, focusing on the embodied 'sensory' practices carried out by military advisors, helpfully elucidates how interpretive work is an enduring part of military computer systems, and indeed, how computation structures the act of interpreting (2019, 427). The broader rationality in play here is clear in Bousquet's (2008) account of the 'cyberneticisation' of the American war machine during the Cold War. Bousquet shows how McNamara's signature operations cultivated 'information pathologies' which did not clarify but rather produced 'greater uncertainty', if not 'a fictional account of the conflict' in Vietnam (97).

Internal reports on IGLOO WHITE describe a proliferation of interstitial manual tasks to bridge inter-system incompatibilities, to clarify ambiguities, and to structure data. In my inquiry below, I follow Elish's assertion that 'new technologies do not so much do away with the human but rather obscure the ways in which human labour and social relations are reconfigured' (2017, 1104). Indeed, as Caron (2020) notes, these human-machine configurations can de understood as facilitating varying degrees of 'automation' and 'autonomy'. To understand how these degrees map onto the operational violence of IGLOO WHITE, it is necessary to develop a holistic view of how the sensory technologies, institutional procedures, and tacit manual practices interlinked in the decision to bomb a particular location.

To do so here, I draw on the concept of 'tacit' and 'situated knowledges' to demonstrate the extent to which complex computer systems rely on interpretive work that makes information *computable*. Central to this discussion is an understanding of tacit knowledge as grounded in practical experience. As such, it is modulated and enframed by the institutional and technical contexts in which such practices and experiences are developed. For Donna Haraway, 'the "eyes" made available in modern technological devices shatter any idea of passive vision'—whether prosthetic or organic, they 'are active perceptual systems, building on translations and specific ways of seeing' (1991, 583). In the technoscientific rationality of 'technowar', things that were seen were committed to the record only if they could be numbered.

Indeed, questions of vision and visibility are therefore quite literally central in this case study, as the analytic gaze of the photo interpreter was one of the enduring tasks that could not be elided by machines in IGLOO WHITE. I draw on accounts of embodiment in Belcher (2019) and Wilcox (2017) to examine these questions. Wilcox, examining this point in relation to the contemporary armed drone, argues taking this approach 'disputes narratives of the sublime capabilities of technologies and, furthermore, shows such narratives as partaking in a totalizing logic that ignores the specific forms of embodiment found in drone warfare' (Wilcox 2017, 24-25). Focusing on embodiment allows us to problematise the inferred innate rationality and omniscience of computerised weapons systems, and clarify the continued roles that humans play as agents within them.

The following sections of this article will examine this through focusing on descriptions of the types of *manual* analytic work that was central to the anti-infiltration programme before and during the deployment of the electronic barrier system. These descriptions have been gathered through archival research into internal US Air Force reports and memoranda that document internally the elaboration of the barrier programme. Firstly, I discuss the interdiction programme as it functioned before IGLOO WHITE, and highlight the factors which, for the JASONs, justified the invention of the electronic barrier concept.

Limiting Conditions

The 'evidence' for many of the statements made about the scale and rhythms of the Ho Chi Minh Trail was drawn from a base material of aerial photography—images which in themselves were often ambiguous and demanding of a very particular, tacit, and therefore *manual* interpretive practice. The National Photographic Interpretation Centre (NPIC) served as the institutional home of this practice. As Biggs (2018, 174) notes, the NPIC was instrumental in the formation of military policy in Southeast Asia as aerial photography became 'a staple of presidential briefings on the "Vietnam situation"'.

A NPIC glossary published in 1966 provides some insight into the terminological and technical standards of photographic interpretation during this period. The document set out a formalised protocol to be followed by NPIC analysts when assessing the 'interpretability' of an image (NPIC 1966, 20). Interpretability was defined as the 'suitability of the imagery with respect to answering requirements on a given type of target'. An analyst could assign a particular photograph a level of interpretability that is either ‘G’ (good), ‘F’ (fair), or ‘P’ (poor) (1966, 20). The protocol stated that an assessment should account for the following ‘limiting conditions’: the grain of the film, the contrast, motion blur or maladjusted focal length, the exposure, the ground resolution of the image, the distance and angle of the lens with respect to the target object. The camera, aircraft, pilot, landscape, weather, and the development process all combined to produce the aerial photograph.

The strategic importance of the aerial perspective for US strategists resulted in a recharacterisation of the Laotian landscape in terms of whether its environmental features either permitted or denied surveillance from the air. The ‘limiting conditions’ that obstructed the pilot’s-eye-view were many, and they were frequently emphasised in intelligence reporting on the trail network. For about six months per year, the region was typically covered in dense, low-lying cloud and experienced heavy thunderstorms, with the effect of rendering aerial reconnaissance sorties either operationally risky or worthless for intelligence collection purposes (Schweitzer 1966, 6–7). In spite of the frequent orbits of reconnaissance aircraft during the dry season, obtaining verifiable intelligence from the air on the specifics of the quantity of traffic and tonnage of supplies travelling along the Ho Chi Minh Trail remained an extremely difficult task.

The efforts of US photo analysts were further complicated by deliberate tactics employed by NVA troops that anticipated the view from the air. Anti-aircraft fire from NVA artillery positions bunkered into hills around the trail was a persistent threat. Other tactics devised by NVA engineers complicated the attempts of US Air Force pilots to photograph the trail. For instance, the JASONs reported that the NVA constructed vast bamboo trellises interwoven with foliage and hung them over sections of road to mask the truck traffic moving beneath from the gaze of US reconnaissance aircraft (Deitchman et al. 1966, 21). Especially when the US reconnaissance sortie rate increased in the mid-1960s, NVA truck activity shifted mostly to nighttime operations. Trucks were equipped with radar, and drivers turned off headlights or pulled into well-camouflaged parking spots when they detected a US aircraft approaching.

In an effort to deny the NVA the natural coverage of the jungle canopy, the herbicidal programmes were extended to the Laotian jungle (ibid., 21). The environment itself was designated a target of continuous assault by the Air Force, with chemical weapons such as Agent Orange and Napalm dropped over busier routes with the intention to reduce the lush jungle to a barren, blackened landscape—one more amenable to the US military's demands for an expansive, omniscient view from the air. Between 1965 and 1969, Air Force units assigned to herbicidal operations sprayed hundreds of thousands of gallons of chemical defoliants such as Agent Orange over Laotian territory (Clary 1971, 106).

As a consequence of all these circumstantial and deliberate contingencies that hampered the intelligence-gathering process, information visualisations based on photographic analysis were almost invariably discussed in the reports in a way that drew their credibility into question. In a striking high-level admission, a CIA document sent to President Lyndon Johnson in 1965 plainly stated: 'aerial photography, limited as it is by cloud cover, darkness, and concealing tree cover, has over the past year proved of little value' (CIA 1965, 6–7). For the JASON Division, these existing limitations served as the initial justification for a new experimental system that employed electronic technologies to more rapidly detect, locate, and destroy NVA convoys.

A Proposal for an 'Air-Supported Anti-Infiltration Barrier'

In terms that downplay the gravity of the proposition, the possibility of initiating a full-scale ground invasion of Laos to seize control of the roadways was said by the JASONS to be 'constrained' by political considerations:

> Everything we do must satisfy the *principle of deniability*, to give the Soviet Union the opportunity to close its eyes to our operations. This is in the hope that some vestige of the 1962 Geneva Agreements will remain as a convenience to both parties, preferable to an escalation of ground war into Laos. (ibid., 25–26, emphasis mine)

Despite the aggressive operations conducted by US forces over Laotian territory during the preceding years—including intense herbicidal and bombing campaigns—the Americans had never 'officially admitted the air or ground reconnaissance operations in all their scope', nor had the North Vietnamese 'publicly admitted their infiltration operations in Laos' (ibid., 26). According to the JASON Division, the possibility of using sensors as a discreet, distributed intelligence gathering source would allow for a 'cost-effective' increase in surveillance while also counting as an apparently justifiable incursion on Laotian sovereignty (ibid., 52–54). The proposition that devastating aerial bombardment and the seeding of what was ultimately thousands of sensors and innumerable mines might 'satisfy the principle of deniability'—whereas, on the other hand, ground personnel would not—is expressive of some American strategists' adherence to a stratified logic of the battlefields of Southeast Asia. For them, the war on the ground could be fundamentally shaped and effectively controlled from a 'safe'—and as they saw it, a politically immaterial—vertical distance.

To sustain the barrier, the JASONs anticipated that a vast coordinated effort in aerial-logistics would be required—one estimated to cost about $800 million annually. For the anti-vehicular system alone, they estimated that 800 sensors, 6500 'SADEYE' cluster bombs, and 5 million gravel mines would be 'sown' over the Ho Chi Minh trail every month (ibid., 46). The requirement for such immense quantities of ordnance was in part due to the design of the barrier system, whose contradictory logic meant that it would destroy itself: the mass-bombing of any section of road following a sensor activation would have the likely effect of destroying other sensors and mines in the area, and consequently, sensors and minefields would have to be continuously 'reseeded' by US Air Force pilots (ibid., 13). This maintenance cycle of seed and self-destruct was built in to the system concept.

Furthermore, the anti-infiltration barrier envisaged by the JASON Division would not function through the precision targeting of detected activity. For instance, the JASONs estimated—correctly as it turned out—that the process of airdropping sensors into the jungle was likely to result in errors in logging their location (ibid., 32). Given that the sensors were designed to be dropped in 'strings' of four or five in sequence to detect *local* activity along routes, having a systematic record of where they landed partially determined the accuracy of sensor data. The JASONs knew that this accuracy could not be guaranteed. In its absence, a flash of presence detected by a sensor would not trigger an expeditious pinpoint interception, but a devastating broad attack (ibid.).

Although the JASONs envisaged possibilities to computerise the interpretation of sensor data with 'information processing' and 'pattern recognition' techniques, they also made it clear that a substantial amount of manual practices would still be required to support the barrier system (ibid., 53). Foremost among these activities was the enduring problem of aerial photographic capture and interpretation. They wrote that 'daily or weekly' photo-reconnaissance over the barrier area, amounting to some 2500 square miles, was 'essential' and that the resultant imagery had to be interpreted 'immediately' in order to build up intelligence of the shifting geographies of the trail. Actualising this would require

> a single U-2 [spy plane] for weekly operation, and a crew of about 10 photo interpreters. The latter must be of first-quality, well trained, and familiar with their assigned terrain areas. This is likely to be one of the most difficult requirements to meet in the entire system. (ibid., 44)

For the JASONs, the use of sensors could not serve as reliable intelligence gatherers on their own. Rather, the sensors would further compound the need for additional manual analytic work to confirm whether sensor activations actually signalled truck presence, or whether they were 'noisy' activations triggered by weather, animals, or electrical faults. Far from simply automating the bombing of enemy convoys, the JASONs thus expected that the proposed barrier system would introduce further interpretative demands in order to trace the range of countermeasures introduced by the NVA, discern new routes for sensor 'seeding', and assess the damage following bombing sorties. Amidst a broader effort to industrialise aspects of the interdiction programme over the following years, photo and data analysis—with their tacit interpretive processes—proved to be one of the prime tasks that could not be delegated to a machine.

Information Flows

Beginning in the early 1960s, a series of reports published under the banner of Project CHECO—'Contemporary Historical Examination of Current Operations'—sought to provide 'timely and analytical studies of USAF combat operations' in Southeast Asia (Shields 1971, ii). The barrier programme was the subject of repeated examination and review in Project CHECO's catalogue of reports, featuring as the primary subject of increasingly detailed and lengthy documents by Gatlin (1968), Caine (1970), and Shields (1971).

Documenting the first phase of the barrier programme, Gatlin's 1968 CHECO report describes the Laotian jungle's transformation into an open testing ground where various configurations of sensors, mines, bombs, and communications procedures were trialled and assessed. Successive CHECO reports on IGLOO WHITE describe further elaborations, explaining the technical functionality of the data-processing equipment (Shields 1971, 105-110); and documenting operational progress through extensive arrays of explicatory documentation, including annotated maps and photographs, information-flow diagrams, tables, and time-series charts (Caine 1970). These three CHECO reports offer perspectives on the barrier which outline an array of deep-set tensions between, on the one hand, the perceived need to produce more information about the trail, and on the other, the capabilities of the whole assemblage to coherently manage, process, and coordinate this information at the requisite speed.

[[Figure 2]]

Gatlin's (1968) report renders the electronic barrier system as a distinctly cybernetic information flow diagram, a large feedback loop that encompassed the distribution sensors which produced the coordinates for strikes, to the attack of targets and re-seeding of sensors. According to this diagram, 'information flow' is not only conceptualised as the bi-directional transmission of signals across the radio links between discrete boxes representing the crews and technical devices in the various aircraft and command stations, but also includes the vibrations and sounds of the trucks and personnel on the trail and also visual observations from reconnaissance planes. Personnel seen by the pilot of a reconnaissance aircraft (OV-1B) constituted *visual information*, which was then transmitted back to the TACS as *audio information* providing target confirmation ('TGT CONF'); personnel also triggered explosions by stepping on button bombs (BB), generating *'acoustic signals'* which subsequently 'activated' the local sensors (1968, 8). In later iterations of the system, a number of these components were replaced or further developed to '[enhance] the effectiveness of existing procedures and automate previously manual operations' (Shields 1971, 8).

Notably, this 'enhancement' included the introduction of the PAVE EAGLE, a modified aircraft intended to be remotely piloted and fly orbital in NULLO (No Live Operator Aboard) mode. The drone could then assist in flying orbital patterns above areas with extensive anti-aircraft installations, relaying sensor data via radio link from the trail to the ISC in Thailand. In a contradiction that is perhaps exemplary of IGLOO WHITE more broadly, these 'remotely piloted' drones were typically 'manned' due to recurrent technical problems with the aircraft (ibid., 70–75).

A vital element of the barrier system was the team of Target Assessment Officers (TAOs) based at the ISC. In the first phase of IGLOO WHITE, a team of four TAOs worked an eight-hour shift, every five minutes of which 'a new computer printout was dropped onto each of their tables by an airman messenger' (Gatlin 1968, 18). It was not a simple case of reading instructions from these sheets: they had to be interpreted and scrutinised by TAOs specially trained to distinguish between activations representing the signature patterns of an enemy convoy from those which signified so-called 'random activity'. 'Exploding ordnance, gunfire, animals, thunderstorm activity, or simply the hyperactivity of the sensor itself' were recorded on these sheets, and as such, a skilled, rapid assessment of the printouts had to be performed at a rate set to the invariable five-minute rhythm of their production (ibid.). The TAOs were trained at Eglin Air Force Base in Florida before being assigned to Task Force Alpha at the ISC, but Gatlin explains that a knowledge developed through experience of the sensors' technical function and their surrounding landscapes was required to perform their duties:

> It was desirable that each Target Assessment Officer get to know intimately such things as the peculiar characteristics of the terrain, the weather, the road and trail network, the kinds of potential spurious activations, and the individual sensor performance of each of the strings and modules in his area of responsibility. (ibid., 19–20)

IGLOO WHITE's TAOs were not just passive overseers observing a largely automatic process. A sensor activation did not immediately and undeniably signify the presence of trucks or personnel, nor did it initialise an irrevocable chain of events that culminated in the associated region being bombed. Rather, it required the TAO to actively analyse the rows and columns over time, awaiting a certain threshold at which point the analyst could see the signature pattern of a truck in the streams of numbers. Then, they had to decide whether to formally designate it as an enemy convoy—referred to as a 'mover'—and assign a strike aircraft to bomb the area. TAOs charged with the assessment of sensor data were required to actively *interpret* it, to extract from the numerical sequences a location, trajectory, size, and speed of travel that could be used to designate a strike point.

The abovementioned inaccuracies in the sensor seeding process introduced a correlative set of ambiguities in the printouts. A sensor whose position was logged incorrectly could then distort the calculated data about a given convoy's movements. The sensor data thus had to be read against the technical and environmental contingencies embedded in the operational deployment of the barrier system alongside the countermeasures deployed by NVA forces to subvert the sensor readings. To account for such uncertainties, attack zones were expansive: strike aircraft dropped cluster bombs 'cover[ing] an area 3000 feet long and 1100 feet on either side of the target' (ibid., 18).

[[Figure 3]]

In later phases of IGLOO WHITE, these printouts became more sophisticated, but the necessity of interpreting the data persisted. The above tables pictured in Figure 3, titled CONFIRM sheets (COiNcidence Filtering Intelligence Reporting Medium), were included in the appendices of the final CHECO report on IGLOO WHITE and give an insight into how activation patterns were 'read' by an analyst. The header and footer of each sheet contained metadata pertaining to each sensor, including among other things, the ID number of the string, the distance between it and the previous sensor in the string, and the type of sensor. The bottom row of numbers in the footer denoted the assumed 'reliability' code for each sensor, indicating how much confidence the analyst should have in the data it reported. For example, sensors coded '1' were of 'unknown reliability'; '4' meant 'weather, aircraft, or random activations only'; '5' was for 'hyperactive sensors'; and '9' signified that the sensor 'activates for more than 95 per cent of truck sequences' (Shields 1971, 107–8).

The sheet is annotated with identified examples of 'typical sensor activation patterns', displaying the difference between heading of convoys, numbers of trucks, and very localised activity triggering a single sensor (ibid., 109). There are two other points worth remarking on here: firstly, the pattern generated by a 'hyperactive sensor' emitting a stream of noise—an interruption of the otherwise ordered tempero-spatialisation of detected activity; and secondly, the square block of intense activity labelled firstly 'aircraft' and then below 'ordnance'. This pattern signified the cluster bombing of a nearby trail; should the sensors' data stream suddenly go blank, it might suggest that the sensors themselves had been destroyed in the explosions.

In the latter years of IGLOO WHITE, analysts at the ISC also used a system referred to as COLOSSYS—Coordinated LORAN Sensor Strike System. LORAN (Lock/Range Navigation) referred to a radio-guidance system prevalently used by the US Air Force in bombing sorties during the Vietnam War, and in theory was also capable of directing the aircraft to automatically release sensors and ordnance at specific coordinates (ibid., 4). The COLOSSYS rendered sensor activations on computer monitors as a glowing white shape called 'the worm', which moved 'down the map at a rate equal to the computed target speed' so that the analyst could '"see" the movement of the truck' (Caine 1970, 17). The 'worm' display automatically calculated estimated times of arrival at various nearby target locations.

The COLOSSYS system automated aspects of the target assessment process, although it still relied on substantial manual analysis and tacit knowledge of both the technical apparatuses and their environmental contexts. Suspect patterns for instance were passed over to a radio operator with the expertise necessary to conduct an audio assessment of signals transmitted by nearby acoustic sensors, matching the waveforms with the signature characteristics of truck engines (ibid., 21). If it was determined to be a 'mover' (convoy), 'a touch of a light pen to the console screen would command the computer to calculate the number of movers, their speed, and their direction' (Shields 1971, 24). The analyst could 'override the computer and adjust its assessment to agree with his own, insuring that the analytical judgement and background of the operator were always the final authority' (ibid., 25).

The decision to designate an area to be cluster bombed was the outcome of an instituted process of manual analysis, with a defined set relations between sensors, computers, and operators. This analysis was shaped by the personal development of an intuitive, tacit knowledge of the peculiarities and contingencies embedded in the whole assemblage of technologies which printed these numbers onto the CONFIRM sheets once every five minutes, or which rendered them electronically on-screen as a homogenous entity, a 'glowing white worm'. While this process was successively computerised over the course of the programme, this was not quite the 'automated battlefield' once lauded by General

Westmoreland. Analysts necessarily had to continue playing a vital role in interpreting the incoming data, translating it into evidence of enemy activity, and consequently legitimising and designating actionable zones for aerial assault.

A Memorandum on the Subject of Killing Trucks

In addition to the role played by TAOs detailed above, trained analysts were also crucial in documenting the supposed operational 'success' of the system. In the discourse of military strategists, this was typically measured in quantities of 'truck kills' relative to other known quantities, such as aircraft sorties or sensor activations. Confirmation of a 'truck kill' generally came from the interpretation of aerial photography by TFA analysts, and as such, were prone to the same sets of limiting conditions which limited surveillance efforts before the electronic barrier.

[[Figure 4]]

'As early in the morning as light and weather permitted', reconnaissance aircraft were dispatched to survey strike zones from the preceding night and take photographs for interpretation back at the ISC (HQ 7th Air Force 1970, 50). It was on the basis of these images that key estimated trends of the interdiction effort's destructive effects were constructed. Such trends, visualised as weekly and monthly time-series charts, were the subject of generous commentary in reporting on the COMMANDO HUNT series of operations which ran twice yearly beginning in 1969 until 1973 (Henry 1970; HQ 7th Air

Force 1970, 1971; Layton 1971). Although not the only intelligence source in the campaigns, the barrier was nevertheless an 'integral' element, contributing to the 'selection of interdiction points' and the 'calculation of the input and throughput of the enemy resupply system', among other things (HQ 7th Air Force 1970, 157). Calculating input and throughput data—the number of trucks detected entering and travelling through the trail—required significant manual analysis, and in particular, the destructive effects of air strikes (ibid., 237–239).

The capacity for a photo interpreter to examine the aftermath of a strike on a suspected convoy—a task referred to as Bomb Damage Assessment (BDA)—in order to accurately quantify truck kills was contingent on factors such as cloud cover, foliage, deliberate camouflaging activity, and delays in surveying the area contributed to widely recognised uncertainties in the resultant data. For instance, a COMMANDO HUNT III report noted that the quantity of trucks designated as damaged/destroyed following BDA was notably lower than the recorded number of airstrikes (ibid., 50). The gap between the two datasets was explained by propositions that the NVA had 'removed or camouflaged' trucks hit by bombs, thus obstructing the BDA analysts. The report also stated that 'results were hard to observe because of poor weather, dust, smoke, and foliage over the target', and that target areas were 'not observed for 35 per cent of the total sorties flown' (ibid., 68).

One year later, the conclusions that could be drawn from BDA were still limited. A report documenting the events of COMMANDO HUNT V noted that 'in many cases the strike crews were not sure of the exact location of their strikes', and concluded 'photographic confirmation did not provide a statistical base strong enough to draw any inferences about the total number of destroyed or damaged trucks' (HQ 7th Air Force 1971, 58, 191).

[[Figure 5]]

The figures reported by the Air Force were met with scepticism by some in government at the time: a 1971 Senate subcommittee report into the electronic barrier stated that 'truck kills claimed by the Air Force last year greatly exceeds the number of trucks believed by the Embassy to be in all of North Vietnam' (Edwards 1997, 4). Leonard Sullivan, a strategist and deputy director of 'Southeast Asia Matters' at the Office of Defense Research and Engineering during the Vietnam War, noted the dubious reputation of the statistics produced about the anti-infiltration programme:

> Scepticism over the accuracy of the Air Force's claimed truck 'kills' in Laos ranks second only to disbelief of the Army's 'body count' numbers as the longest standing argument over US effectiveness in SEA [Southeast Asia]. (1971)

For Sullivan, the numbers did not add up. 'We have no photographic evidence to support the vast wreckage that should have accumulated on the Laotian landscape', what he estimated would have been a rate of 'at least 10 carcasses per mile of road or trail in Laos' (ibid.).

The ways in which data generated by the barrier system could be employed analytically to construct a knowledge of the Ho Chi Minh Trail region was the subject of extensive discussion amongst defence researchers until IGLOO WHITE was wound down in 1973. The contradictions between data collected through the electronic measurement of vibrations in the ground and data via the manual interpretation of aerial photographs of bomb sites were widely acknowledged from the early days of IGLOO WHITE. After over four years of devastating nightly bombing sorties broadly targeting areas of *suspected* convoy movement, the electronic barrier still churned out contradictions between the electronically 'sensed' and the manually interpreted and analysed.

Conclusion

IGLOO WHITE has a place in genealogies of remote, computer-mediated warfare, but not because it represents an omniscient surveillance apparatus or the 'automation' of war. Rather, the operation serves as a reminder that, when examining systems which purport to computerise particular operational tasks in the present, we should look to the ways in which manual operational work might persist, or reappear at other points, in the system. Focusing on photographic interpretation here demonstrates how, in the move to systematically expand the scale and quicken the pace of interdiction, the need for this necessarily *manual* practice proliferated with the deployment of the electronic barrier. The later introduction of computers, which represented the movements of detected convoys as a 'glowing white worm' on a computer screen thousands of miles away at the ISC, did not simply replace the analytic gaze of the photo interpreter. Rather, it introduced new tacit practices into the system, where trained analysts had to learn to distinguish between the 'noisy' activations generated by the weather, ordnance, or electrical faults, and those triggered by the movement of truck convoys.

The proliferation of sensors corresponded to an immense increase in the amount of 'data' being produced, introducing further administrative problems pertaining to the management of this information and the coordination of resources to verify it. While some of those who reported and evaluated the barrier system struggled to make this data cohere with the aerial photography of the trail, what could be sensed and interpreted numerically became operationally 'real'. The resultant data was used by strategists as a basis to legitimise the allocation of further resources—in aircraft, bombs, interpreters, and analysts.

It is therefore important to assert that IGLOO WHITE *was* an extraordinarily violent and devastating operation. However, it was not so because the computerisation of 'killing trucks' worked as planned, but due to the willingness of US strategists and commanders to commit enormous quantities of military resources in an effort to overcome the considerable ambiguities embedded in the system. This prompted a series of apparent reconfigurations in the human-machine system, implicating the technical (such as employing drones as 'relays'), operational (using powerful explosives to make up for inaccuracies in locating enemy activity), and analytic (employing new techniques to more 'accurately' calculate the quantities of trucks destroyed by the system).

While the information generated by the barrier system was sometimes drawn into question, there was nevertheless a very real commitment to aggressively acting on the data. This is a pattern replicated more broadly across other operations in Vietnam: Belcher notes with regard to hamlet surveys that 'war managers and military commanders acted as if the HES accurately represented reality, and planned accordingly based on its statistical and cartographic outputs' (2019, 432). That Laos experienced one of the most devastating bombing campaigns of the Cold War at the hands of the US Air Force—yet was never formally at war with the United States—was made possible and exacerbated by the information pathologies that characterised IGLOO WHITE.

Foregrounding embodiment and tacit knowledge allows us to examine these processes of mutual configuration between humans and machines, and trace out their effects on the operationalisation of violence. Crucially, it also allows us to do so while problematising the spectacular claims of defence researchers and military commanders who celebrate the surgical precision, machinic autonomy, and advanced sensory capabilities of the technologies involved. Indeed, as Wilcox (2017) and Suchman (2020) make clear, the interpretation of imagery persists today as a tacit, manual practice in contemporary drone warfare, even as analysts train novel regimes of machine vision with the intent of 'automating' it in the future. Suchman calls for a critical examination of the labour that goes into training image classifiers thought to be capable of computationally distinguishing civilian from enemy combatant. Of course, this distinction is one which the US military as an institution has itself been notoriously incapable of, and indeed tactically reluctant to, make with any specificity (TBIJ 2020).

In case studies such as IGLOO WHITE, internal documentation can be unexpectedly candid in documenting the recessive persistence of interpretive work, and how it is mutually configured by institutional procedures, sensory affordances, and computerised systems. Inquiries that proceed from this vantage point allow for a critique of the persistent human-machine entanglements in computational, remote warfare—one that highlights the embodied practices that cannot be readily remodelled or captured by the discrete, structured logics of technical devices and information flow diagrams.

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Figures

Figure 1: 'Side view of an CH-3E helicopter dropping an ADSID (Air-Delivered Seismic Detection Sensor) sensor over Laos' (Gaston, 1968).

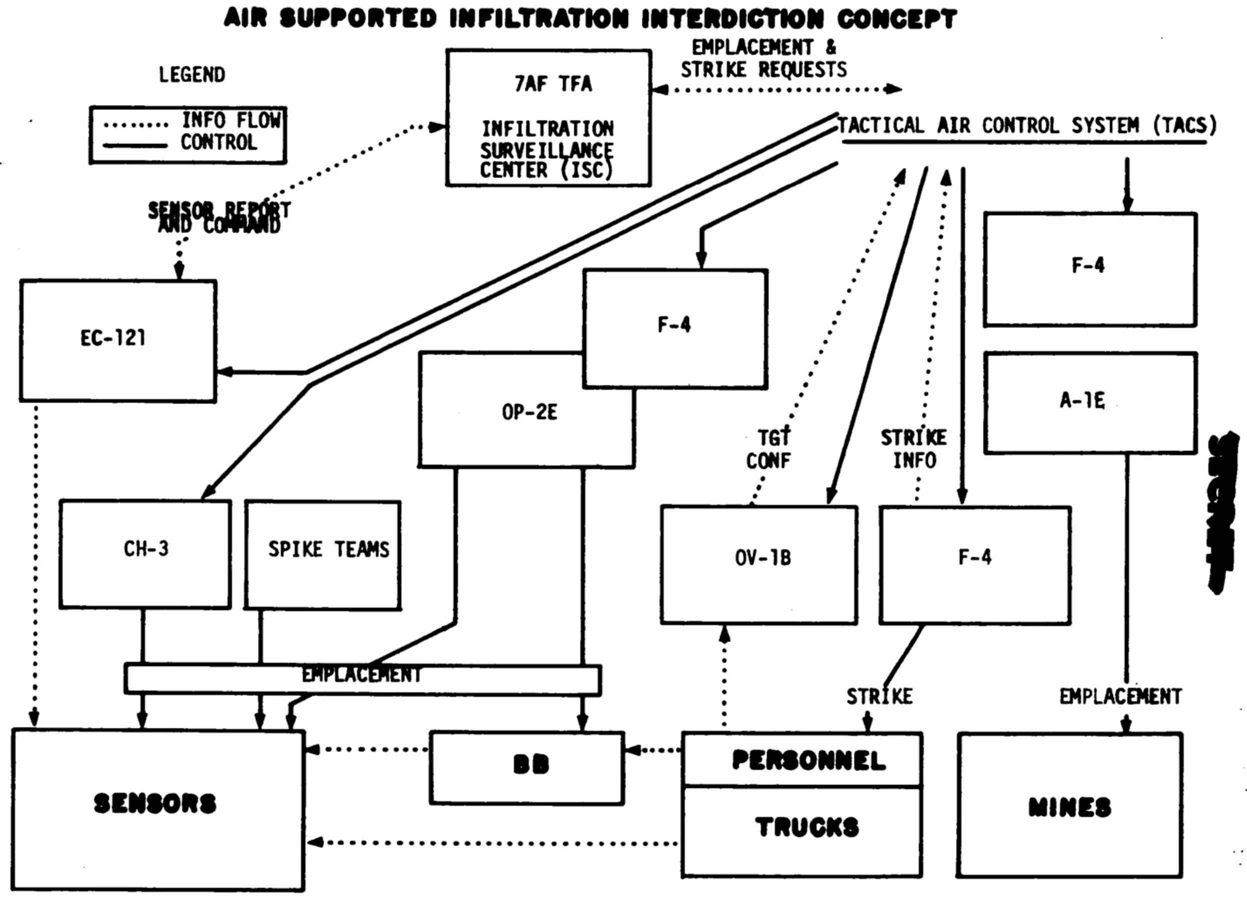

Figure 2: IGLOO WHITE, information flow diagram in CHECO Report (Gatlin 1968).

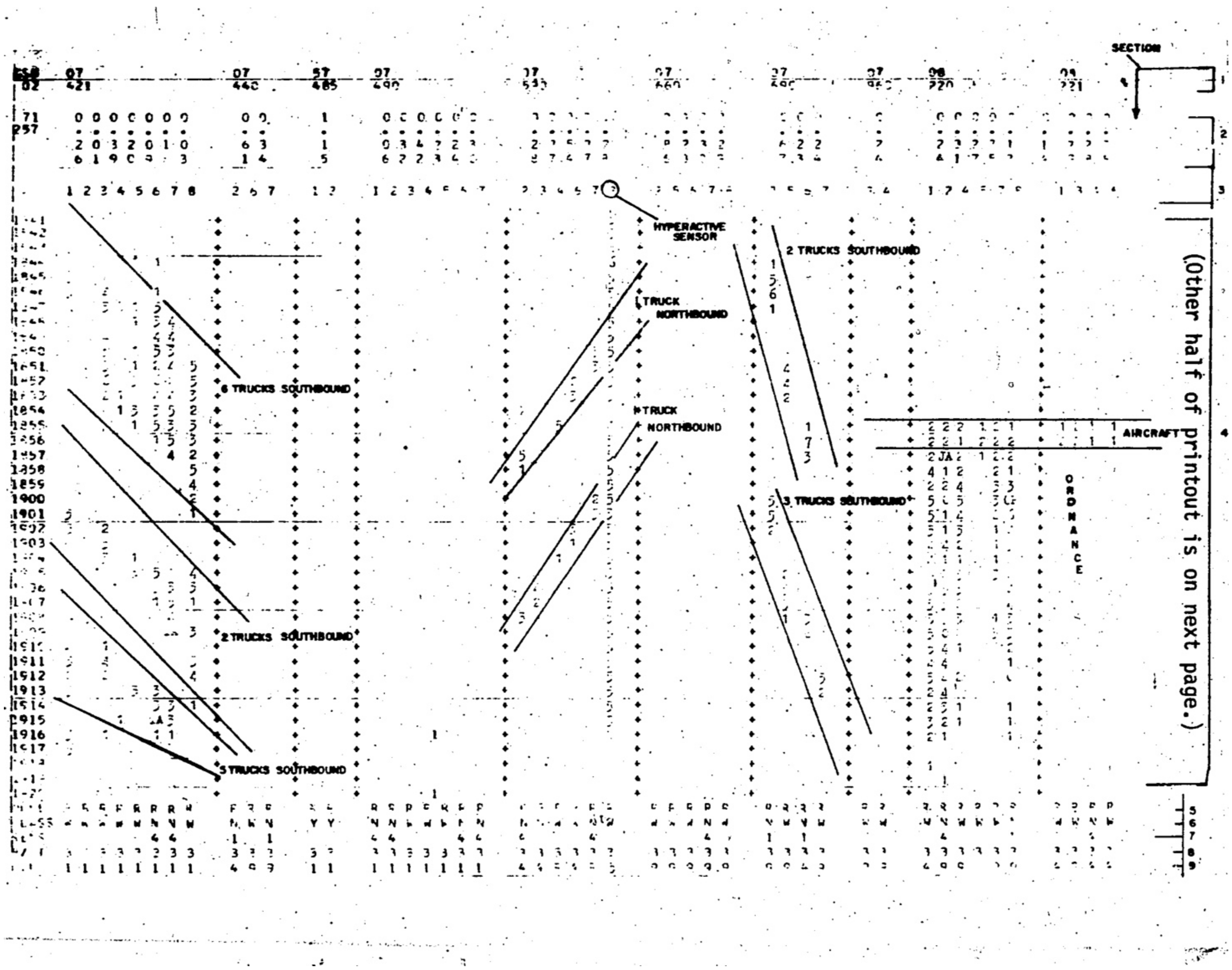

Figure 3: CONFIRM sheet sample from 1971 CHECO Report on IGLOO WHITE.

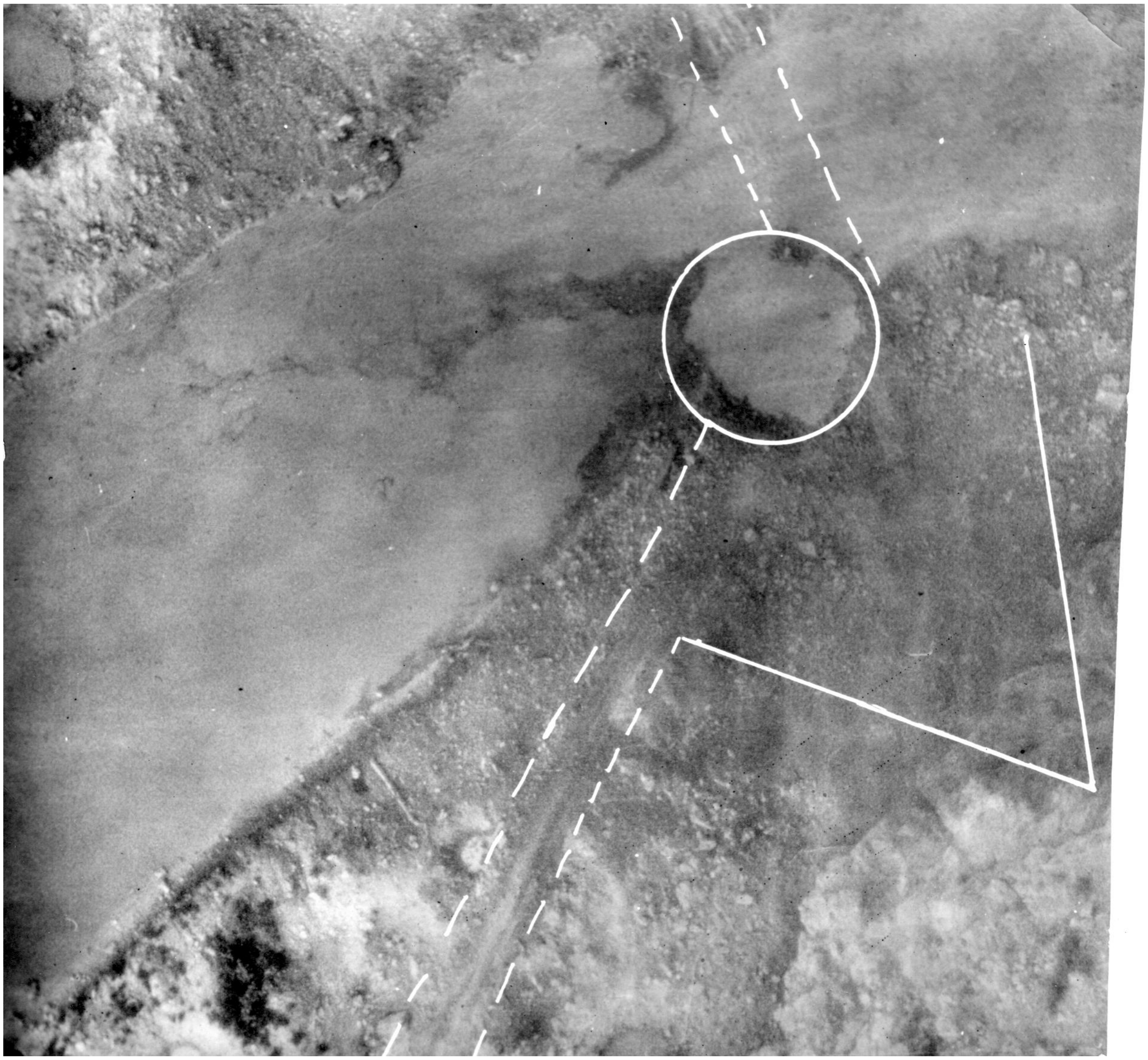

Figure 4: An aerial photograph annotated by TFA, demarcating crater, destroyed bridge, and roadway.

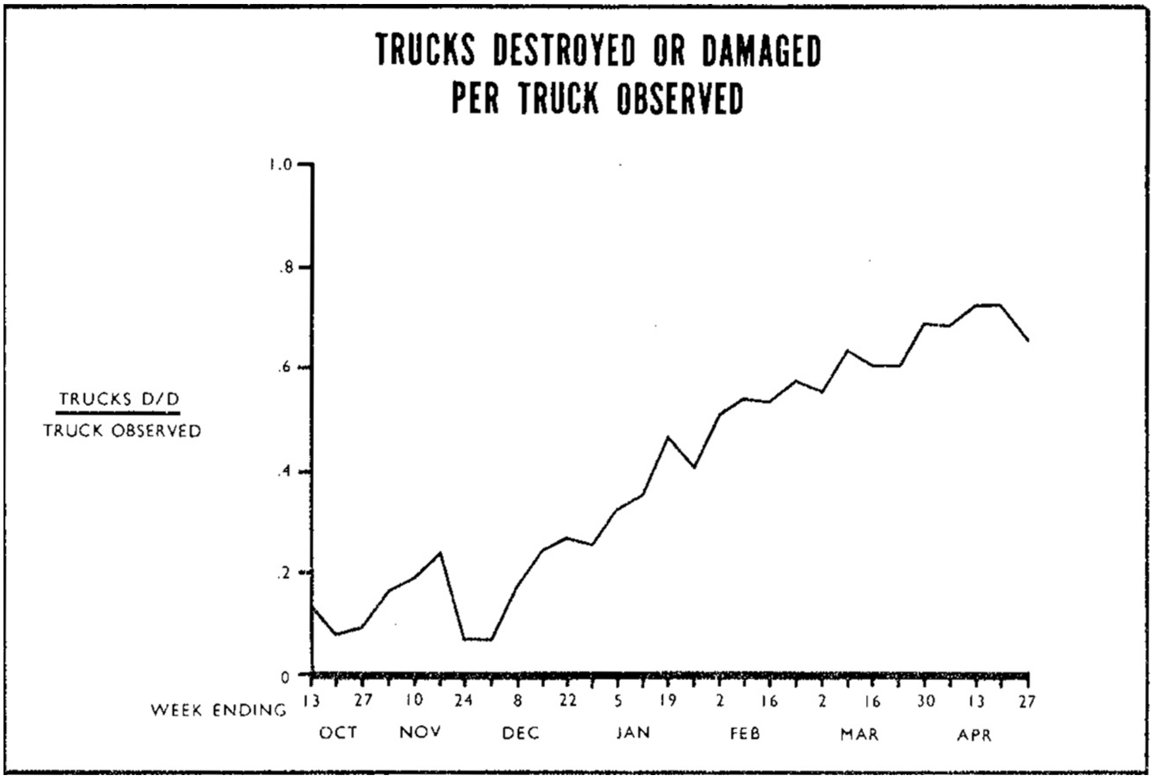

Figure 5: Trucks Destroyed or Damaged per Truck Observed, (HQ 7th Air Force 1971, 53)