# The Limits of Command and Control

David Young

Thesis submitted for the degree of Doctor of Philosophy

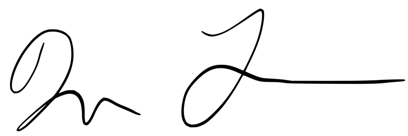
Department of Cultural, Media, and Visual Studies,

University of Nottingham

August 2020

*I, David Young, hereby declare that this thesis represents my own independent work, except where referenced to others. It was carried out in accordance with the regulations of the University of Nottingham.*

*I further declare that the work in this thesis has not been previously submitted for any other degree.*



# Abstract

This thesis examines the role of the human operator in command and control systems designed and developed for the US Air Force during the 1950s and 1960s. As understood within the discourse of defence research, command and control involved the efficient capture and management of information from the battlefield in the pursuit of a particular military strategy. The digital computer, although then still very much the highly protean object of military-industrial-university research networks, was repeatedly proposed as a crucial technology that would allow for greater and more accurate control of the battlefield.

I explore the discursive terrain occupied by the human operator through an analysis of two command and control systems, selected for their significance in employing digital computers to automate previously manual military practices. Firstly, I examine the operational principles established for Air Force crews in the SAGE system deployed in the late-1950s, tracing their elaboration within a series of psychological studies of stress led by psychologists at the RAND Corporation. In the absence of an actual Soviet invasion, SAGE crews fought simulated air wars while the effectiveness of their collective performance was systematically quantified. The second case study turns to the US Air Force's 'anti-infiltration' programme that targeted and bombed convoy routes used by the North Vietnamese Army to deliver supplies into South Vietnam. I focus on the role played by photo interpreters and systems analysts in the collection and verification of data used to confirm so-called

‘vehicular activity’ and ‘truck kills’.

In histories of Cold War technopolitics, both of these case studies have frequently been presented as exemplars of the application of a quantitative, computational rationality to the planning and conduct of military strategy. However, for all the extensive discussion in this literature about the central role of digital computers in automating parts of these systems, there still remained human operators who clearly played a significant, if seemingly recessive, role in their day-to-day functioning.

My discussion of these case studies is based on close textual analyses of ‘grey media’—the technical and administrative writing produced within bureaucratic institutions such as the US military and its defence research contractors. I foreground the effects grey media had on structuring and standardising specific operational practices, and consequently how it delimited the respective roles played by the human operator and the machine in the production of information about the battlefield.

Drawing on a Foucauldian understanding of power as it functions through institutional discourse, I argue that the human operator was instrumental in codifying and authenticating information generated by and for the computer. This varied from the regular re-structuring of data in machine-readable forms, to the longer-term tasks of quantifying the strategic effectiveness of the system. Far from simply making the processing of information more efficient, these computerised systems were enmeshed in a vast and contradictory ‘regime of practices’ in which manual work proliferated. I contend that in order to fully grasp how digital, networked technologies have reshaped the field of possibility in war, foregrounding the grey, recessive role played by the human operator is vital.

# Acknowledgements

My sincere gratitude to my supervisors Dr Andrew Goffey at the University of Nottingham and Prof Scott Lucas at the University of Birmingham. Your expertise, encouragement, and guidance over the past four years have been instrumental in helping me to focus and craft this thesis, and in a deeper sense, also to develop personally as a researcher and a writer.

My thanks also to the Midlands3Cities team for their assistance. The M3C/AHRC studentship provided me with the financial support that allowed me to dedicate my time to research, and furthermore, supported a lengthy archival visit to the US which was so vital to this project.

I wish to thank Dr Colin Wright, Dr Franziska Meyer, and the staff at the Centre for Critical Theory, whose pastoral support and friendly presence helped to engender an atmosphere of camaraderie and solidarity throughout my time at Nottingham that so enriched my PhD experience. My colleagues at the Digital Culture Research Network have also made a significant contribution to this experience, from the conferences to the research retreat, and the many stimulating discussions in between.

Indeed, I have made many friends during my time at Nottingham who have been continuous sources of inspiration and joy for me. My thanks to Dr Niki Cheong who, from his ambassadorial welcome on my first day in the office to his advice on the final draft of this thesis, has been—and no doubt will continue to be—a wonderful friend.

I am also immensely grateful to Dr Niall Docherty and Dr Ivan Markovic for the coffee chats during which I learned so much; to Dr Abi Rhodes, Robert Stenson, and Thirza Wakefield for being exceptional allies from the very early days; and to Emma Humphries, Sam Wilkinson, Betti Bodi, and Louis Cotgrove for making the office an entertaining place, rather than just a series of desks with slightly underpowered PCs. You have all been encouraging, creative, and generous friends: seeing all your faces in the unlikely location of Dún Laoghaire will forever be a standout memory for me.

To an older, dear friend: Dr Jeremiah Ambrose, thank you for the (lengthy) discussions about life, the PhD, and everything. The perspective you provided furnished me those vital twin senses of both the surreal and the down-to-earth. *You were here.*

The extent of my gratitude to my parents, Al and Mary, and my sisters, Nicola and Deborah, is immeasurable. They have been unwavering in their support and, despite me living overseas for almost exactly one decade to the day as I write this, always have me feeling close by. Thank you all for everything.

To Tigger (2007-2020): a great source of distraction with immaculate timing, always knowing when we both needed a walk in the park.

Finally, to Suzy: it is no exaggeration for me to write that this thesis would not have been possible without your endless warmth, understanding, love, and belief. I dedicate it to you, and I look forward to us jointly observing the concentric circles of Olinda as they grow in the coming years.

# Table of Contents

# List of Figures

# Glossary

| | |
|---|---|
| 7AF | 7th Air Force, based at Tan Son Nhut, Vietnam |
| AAA | Anti-Aircraft Artillery |
| ABCCC | Airborne Battlefield Command and Control Center |
| ADC | Air Defense Command |
| ADSEC | Air Defense Systems Engineering Committee |
| ADSID | Air Delivered Seismic Intrusion Detector |
| AN/FSQ-7 | Digital computer at the core of the SAGE system |
| ARPA | Advanced Research Projects Agency |
| BARREL ROLL | Operational codename for northern Laos |
| BDA | Bomb Damage Assessment |
| CIA | Central Intelligence Agency |
| COLOSSYS | Coordinated LORAN Sensor Strike System |
| COMMANDO HUNT | Interdiction campaigns run twice-yearly in Laos |
| CONFIRM | COiNcidence Filtering Intelligence Reporting Medium |
| DC | SAGE Direction Centre |
| DCPG | Defense Communications Planning Group |
| DMZ | Demilitarized Zone between North Vietnam and South Vietnam |
| DOD | Department of Defense |
| ECM | Electronic CounterMeasures |
| ECCM | Electronic Counter-CounterMeasures |
| FAC | Forward Air Controller |
| FCDA | Federal Civil Defense Administration |
| GOC | Ground Observer Corps |
| IDA | Institute for Defense Analyses |
| IGLOO WHITE | Codename for electronic barrier, 1968-1972 |
| INTERDICTION | Strategy to destroy NVA convoy traffic before they reach SVN |
| IPC | Information Processing Center |
| ISC | Infiltration Surveillance Center, Nakhon Phanom, Thailand |
| JASON DIVISION | Group of physicists who advised on defence problems |
| MACV | Military Assistance Command Vietnam |
| MUSCLE SHOALS | Codename for electronic barrier, early 1968 |
| NDRC | National Defense Research Committee |
| NORAD | North American Air Defense Command |
| NSC | National Security Council |

| | |
|---|---|
| NGAF | National Guard Air Force |
| NPIC | National Photographic Interpretation Centre |
| NVA | North Vietnamese Army |
| OR | Operations Research |
| OSA | Office for Systems Analysis |
| OSRD | Office of Scientific Research and Development |
| PID | Photographic Intelligence Division |
| PRACTICE NINE | Codename for electronic barrier, late 1967 |
| PROJECT CHARLES | Study group convened to examine problems of air defence |
| PROJECT CHECO | Contemporary Historical Evaluation of Combat Operations |
| RETAINS | REal-Time Air INterdiction System |
| ROADWATCH | Ground observers tasked with counting NVA truck traffic |
| ROLLING THUNDER | US Air Force bombing campaign in North Vietnam |
| SADEYE | Type of cluster bomb used to destroy trucks in IGLOO WHITE |
| SAG | Scientific Advisory Group |
| SAGE | Semi-Automatic Ground Environment |
| SDC | System Development Corporation |
| SDD | Systems Development Division |
| SEA | Southeast Asia |
| SRL | Systems Research Laboratory |
| SSTP | SAGE Systems Training Program |
| STEEL TIGER | Operational codename for the Laotian Panhandle |
| STP | Systems Training Program |
| SVN | South Vietnam |
| TACS | Tactical Air Control System |
| TAO | Target Assessment Officers |
| TFA | Task Force Alpha |
| TOR | Training Operations Report |
| U/I | ‘Unidentified’; term used in Photo Interpretation |
| USAF | United States Air Force |
| WHIRLWIND | Digital computer on which AN/FSQ-7 system in SAGE was based |

*But words are still the principal instruments of control. Suggestions are words. Persuasions are words. Orders are words. No control machine so far devised can operate without words, and any control machine which attempts to do so relying entirely on physical control of the mind will soon encounter the limits of control.*

William Burroughs, *The Limits of Control*.

# Chapter 1

# Introduction

## 1.1 The Operator

> Imagine trying, for example, to direct a battle with the aid of a computer on such a schedule as this. You formulate your problem today. Tomorrow you spend with a programmer. Next week the computer devotes 5 minutes to assembling your program and 47 seconds to calculating the answer to your problem. You get a sheet of paper 20 feet long, full of numbers that, instead of providing a final solution, only suggest a tactic that should be explored by simulation. Obviously, the battle would be over before the second step in its planning was begun. (Licklider 1960, 5)

Writing in an article titled ‘Man-Computer Symbiosis’ published in 1960, the computer scientist and psychologist J.C.R. Licklider reflected on a ‘fantastic change’ that had taken place in the recent design of ‘information and control systems’: the ‘mechanical extension of man’, in which machines were understood to have served as augmentations of the arm or the eye and controlled under direction of the human, had given way to a new class of system in which the human was there ‘more to help than be helped’ (1960, 4). For Licklider, this apparent shift in the operational role of the human—from the central position of control to a position of support and observation—was directly associated with significant developments in digital computing that had taken place over the previous decade. He had been in a privileged position to view this shift. In the years preceding this article, he had worked on the interface design for the US Air Force's Semi-Automatic Ground Environment (SAGE), an extraordinarily influential system which brought inventions and innovations in numerous areas now widely understood as foundational in digital computing (Edwards 1997; Redmond and Smith 2000). Despite its lengthy list of unprecedented technical accomplishments, the 'fantastic change' which SAGE represented was also described by Licklider as a partial failing on the part of its creators: it was a system 'that started out to be fully automatic but fell short of the goal' (1960, 4). Licklider anticipated that the next 'paradigm', succeeding the 'humanly-extended machine' represented by SAGE, would amount to a closer coupling of the human and machine, a 'symbiotic relationship' of mutual extension which could provide the capabilities to plan and make decisions at the requisite tempo (1960, 4).

'Man Computer Symbiosis' has been a prominent point of reference in the history of Cold War computing, notably due to the author's now-familiar vision of a future of human-computer interaction organised around a digital network comprised of 'thinking centres' (Abbate 1999; Turner 2008; Ceruzzi, Aspray, and Misa 2003; Campbell-Kelly et al. 2016; Waldrop 2018; Edwards 1997). However, what is most pertinent for this research project is the questions it raises about the role of the human operator in digital, networked command and control systems of the future. Licklider was by no means alone in speculating on this: similar discussions were prevalent in think tanks and amongst defence contractors throughout the 1950s and 1960s (notably those by Baran 1960; Dalkey 1962). His concern with the timelines of problem formulation, computer processing, and the unpredictable exigencies of battle—and whether it would be over before the strategist could begin to analyse 'the data'—is one that arises on numerous occasions in these discussions. Licklider's article serves as an exemplary record of these attempts to take stock of the shifts in the field of possibility thought to be opened up by digital human-machine systems, and at a time when the digital computer was very much in a schematic state. Licklider suggested that in the next developmental phase of such systems 'it seems likely that the contributions of human operators and equipment will blend together so completely in many operations that it will be difficult to separate them neatly in analysis' (1960, 6). Yet, as he pointed out elsewhere, this unsystematic development of systems was an issue of particular concern to him. New methods were urgently required to manage this problem, he argued, or else 'we shall bury ourselves in uncontrolled complexity' (1963, 641).

Focusing on the United States during the early decades of the Cold War, this research project examines the relations between human operators and machines through a study of two command and control systems developed for the US Air Force: firstly, a training programme designed by the RAND Corporation and eventually applied to the above-mentioned SAGE air defence system in the late 1950s; and secondly, the role of photo interpreters and systems analysts in the computerised 'electronic barrier' system (codenamed Operation IGLOO WHITE) designed to target and bomb North Vietnamese Army supply convoys supporting the insurgency in South Vietnam. In documents authored by the proponents of these programmes, the systems described in these case studies were presented as novel and complex configurations of the human and the machine that facilitated the more efficient collection, processing, and management of information (ADSEC 1950b; Chapman et al. 1952). However, these systems were not invented on a clean slate, but proceeded as efforts to automate and optimise manual procedures which had been previously diagnosed as inefficient or disorganised.

The inquiry presented in this thesis is based on archival documents, the vast majority of which consist of declassified internal reporting, technical manuals, memoranda, and studies. Following a period of initial archival research at the National Archives and Records Administration (NARA) and the Library of Congress (LoC), the immense quantities of paperwork produced by and about these systems further sharpened this inquiry to examine the recessive administrative and bureaucratic dimensions of these 'semi-automatic' systems. Additional archival research conducted remotely with the Virtual Vietnam Archive at Texas Tech University, the Charles Babbage Institute, and the Air Force Historical Research Agency further revealed the centrality of administrative documentation in the day-to-day operations of command and control systems.

It is the *semi-automatic* qualities of these systems that are primarily under scrutiny in this thesis: for all the extensive discussion about the increasingly central role of the computer and the network in these command and control systems, there still remained *operational personnel* who clearly played a critical role in their functionality. Rather than focusing narrowly on their technological elements, this research project instead opts to inquire into the various manual operational practices that remained in place in spite of—or even, because of—the development of human-machine systems. In carrying out this inquiry, I examine how they figured into the broader knowledge practices that shaped the design and elaboration of these systems.

The term 'defence research' is used throughout this thesis as an overarching descriptor for a heterogeneous array of scientific and engineering research primarily funded by the US Department of Defense and which played a significant role in the design and evaluation of command and control systems. The respective operational performances of the human and the machine were the subject of considerable scrutiny within this sphere of discourse. In analysing command and control as it was articulated by defence researchers, it becomes clear that the coherent functionality of these systems was by no means taken for granted: reading through the extensive quantities of manuals, studies, reports, and memoranda produced about them, administrators, scientists, and engineers alike were very much aware of the various ways in which the systems did not cohere as intended. These systems indeed represent technological elaborations in the field of possibility opened up by human-machine systems—elaborations whose individual qualities warrant critical attention. However, their operational coherency should not be overstated, nor should the continued role of the human be downplayed in accounts of their design and elaboration: to do so risks taking military and industrial claims about the 'accuracy' or 'efficiency' of advanced weapons systems for granted.

What we find in this discourse are the remnants of a significant effort on the part of mathematicians, engineers, psychologists, and economists to devise techniques that purported to measure the efficiency of command and control systems, diagnose systemic problems, and offer potential opportunities for optimisation. Working in organisations such as the RAND Corporation, the Scientific Advisory Group, and the Office for Systems Analysis, these defence researchers debated the applicability of fields such as information theory, systems analysis, and experimental psychology to the management of 'live' systems such as SAGE and the electronic barrier. A significant quantity of military resources—both in computer time and 'man hours'—was dedicated to supporting these continuous research programmes. This effort responded to a problem of oversight: neither Air Force command, the US government, nor the defence researchers themselves had a clear picture of whether their command and control systems were meeting their designated objectives. Consequently, the operational practices which animated these command and control systems were not only directed outward onto the battlefield. To a significant degree, they also gazed inward in an attempt to manage and optimise what I refer to as the system's *operational logic*—that is, the ways in which its discrete constituent tasks were, in the minds of the defence researchers, intended to be seamlessly distributed across humans and machines.

## 1.2 Grey Areas of Defence Research

Neither case study examined here is new to the literature on histories of Cold War strategy and technology. SAGE in particular has been the subject of extensive scholarship, with the scale of the project reflected in the wide range of disciplinary perspectives on the system's development. For instance, Redmond and Smith (2000) and Ulmann, Pappert, and Brunell (2014) offer technical histories of SAGE's central 'AN/FSQ-7' computer, focusing primarily on the development of its hardware and software through highly detailed discussion of the engineering problems involved. Other scholars have examined SAGE's emergence within the practices of post-war systems engineering (Hughes 2000), neoclassical economics (Mirowski 2002), software engineering (Ensmenger 2012; Slayton 2013). The electronic barrier, on the other hand, has received comparatively sparse examination, with most (typically brief) discussions of it referring back to accounts of the system first described in Dickson (1977) and Gibson (2000). Both of these accounts of the barrier accentuate its technological novelty, and rely on fragments of contemporaneous journalistic reporting, a congressional inquiry, and interviews.

Less common, however, are inquiries which foreground the discursive qualities of Cold War defence research as it pertained to these programmes, particularly as it circulated in the cross-institutional channels between civilian think tanks, the government, and the Air Force. Edwards' (1997) *Closed World* is one notable example of this. His account charts a history of defence computing in relation to what he calls 'cyborg discourse', from the start of the Cold War to the 'Star Wars' of the Reagan era. In constructing his account, however, there is less focus afforded to the ways in which this discourse encompassed the field of administrative media which proliferates in complex bureaucracies such as the US military.

It is this focal point on how these systems were imagined and inscribed in technical manuals, reports, memoranda, and working papers that distinguishes this research project from the existing literature on the politics of Cold War computing and its associated cultures of defence research in the United States. These documents do not just serve as historical sources here: the aesthetic and discursive qualities of the documents themselves are the subjects of critical inquiry. The decision to largely base the discussion on this type of material proceeds from the argument made by Fuller and Goffey (2012, 11–14) that such 'grey media', precisely because of their recessive and seemingly banal qualities, are worthy of scrutiny. As elements of an 'institutional' discourse, they authorise and standardise what Foucault calls 'regimes of practices' (2002a), imbuing them with a capacity to codify and prescribe understandings of relations between the operator and the battlefield—whether the battlefield was simulated in a monumental digital computer, or 'felt' as seismic tremors by distant fields of electronic sensors.

In the literature on Cold War computing, numerous descriptive terms have been used to refer to the collective array of knowledge practices which shaped the development of command and control systems. For instance, terms such as 'war sciences' (Galison 1994), 'cybersciences' (Keller 1995), and 'cyborg sciences' (Mirowski 2002) abound in the literature, emphasising an assumed shared interest in cybernetics on the part of scientists and engineers developing military computing systems in the 1950s and 1960s. Crowther-Heyck (2015) places the concept of 'system' at the centre of defence research, with its defining quality being the firmly-held belief that the entire world can be explicated and controlled in systematic terms. What is of central interest in this research project is how this sphere of discourse conceptualised and produced an understanding of the human operator as an actor within a 'system'. The eminence of cybernetics as a unifying descriptor for these practices in the literature is understandable given the frequency of discussion around information flows, control processes, and 'human-machine organisms' in the original technical discussions surrounding these projects. This is not to say that the activities that took place under these umbrella terms were homogeneous, however. This arena was distinctly interdisciplinary and diverse in scope, with projects often shaped by collaborations between defence researchers whose area of specialisation included experimental psychology, economics, electrical engineering, physics, military command, and mathematics.

One of the recurring themes in this thesis is the way in which these practices, to varying extents, acted in tension with 'established' disciplines in the domains of science and engineering, borrowing from them concepts, metaphors, and frameworks. This theme directly concerns the configurations of power and knowledge that coalesced in the post-Second World War cultures of defence research in the United States. This is especially explicit terms in the emergence of 'human factors engineering' and its central role in the design of computationally simulated nuclear wars in order to train air defence crews to use the SAGE system in the 1950s. A decade later, systems analysis became a 'style' of inquiry used to extrapolate broader statistical trends and strategies from data gathered from the electronic barrier's bands of sensors across the Laotian jungle. In using the broader term 'defence research' in this thesis, I do not take for granted the scientificity of this discourse. Their exponents repeatedly described what they practiced as a processual and iterative, and even speculative, mode of research that sits in tension with what RAND researcher Malcolm Hoag called ' "Science" with a capital "S" ' (1956, 18). These qualities arise repeatedly in the administrative reporting of defence research and development institutes, with the RAND Corporation being particularly influential in this regard. It was in RAND memoranda that both the concepts and applications of 'systems training' and 'systems analysis' were incubated and developed into formalised, if somewhat contentious, knowledge practices.

This project does not aim to determine whether these command and control systems could be judged as 'successful' in a strategic sense. A cursory search of the Defense Technical Information Centre's (DTIC) repository returns a lengthy list of theses and academic studies from military researchers at defence universities and research institutes which attempt to answer this very question. Written *within* and *for* the military as an institution, such studies are conducted in order to learn lessons about past failings and shortcomings and are often framed in order to contribute to the development of 'more efficient' or 'more accurate' weapons systems. This study adopts a much more circumspect attitude to the conditions of technological change and what counts as progress, and how they intersect with the imperatives shaping the development of command and control systems and the institutions charged with managing and administering them. In this respect, this project has numerous overlaps with the burgeoning interdisciplinary domain of 'critical military studies'. This field has been described by Basham, Belkin, and Gifkins (2015, 1) as an effort to approach 'military power as a question, rather than taking it for granted'. Its practitioners might therefore be interested in the ambiguous boundaries between the 'civilian' and the 'military', and the 'ways in which military apparatuses classify and bureaucratise bodies and minds shaped by combat' alongside the ways in which such classifications are defied and resisted (Basham, Belkin, and Gifkins 2015, 1). Indeed, in focusing on the figure of the human operator as constructed by the civil-military imbrications of defence research, these concerns are central to this project.

Despite the relatively recent institutionalisation of 'critical military studies' as a field of scholarship, there is a very lengthy list of publications stretching back many decades which could easily fit under this umbrella term. Much of this work aiming to grapple with the Cold War period does so by charting the legacies of strategic thinking with regard to the design and deployment of contemporary weapons systems. Works by MacKenzie (1990), Hables Gray (1997), Virilio (2009), and Halpern (2015) all address the question of military power from widely diverging perspectives. Such studies are valuable when it comes to rupturing the assumed 'disruptive' novelty of contemporary computer and network technologies—a point which recent scholarship on unmanned drones has done much to problematise (see for instance Gregory 2011; Chamayou 2015; Shaw 2016b; Parks and Kaplan 2017). In doing so, these studies make visible the multiplicity of interests and contingencies which have shaped military defence systems over longer timelines while describing the incompatibilities and mistranslations involved.

A number of texts which adopt other national and global perspectives have been important resources for this thesis, specifically for their approach to mapping the institutional imbrications of the civilian and the military in defence research. Work on the British context of defence research (notably Law 2002; Agar 2003; Thomas 2015), which detail how cross-institutional bureaucratic entanglements shape the development of large computing and weapons development projects, have provided helpful guides for drawing such considerations into the foreground. Jones-Imhotep (2017) offers an important account of the problem of systems maintenance in US military systems transferred to the Canadian arctic, demonstrating how systematic incoherencies arise in the process of translating technologies from one environmental context to another. Hecht's (2011) edited collection *Entangled Geographies* provides a global perspective, featuring accounts of large engineering projects including irrigation in Saudi Arabia and South Africa's nuclear programme. Other histories that have proved valuable for this research project have been those of Medina (2011) on the Chilean 'Cybersyn' project during the Allende government, and Peters (2016) on the (attempted) construction of the Soviet internet. Despite their subjects being rather different to those which I explore here, in these accounts the institutional and bureaucratic dimensions of command and control are very much front and centre, and conceptualised as key elements of the systems under scrutiny.

An early plan for this research project adopted a genealogical approach, aiming to describe a series of successive command and control systems, identifying and explicating the discontinuities along these lines of descent in order to diagnose provenances and irruptions in the field of possibility in warfare. This genealogy was intended to be organised around four case studies. In addition to SAGE and the electronic barrier discussed here, I had originally intended to examine the Joint Surveillance Target Attack Radar System (J-STARS) as it was deployed in the First Gulf War, and also the Ground Control System (GCS) which houses the pilots of unmanned aerial vehicles such as the MQ-1 Predator and MQ-9 Reaper drones. This changed amidst the process of gathering primary sources: upon visiting NARA and the LoC, what became of paramount interest for me was the vast abundance of administrative documents produced about and by command and control systems. To have carried out research across this lengthy time frame (from 1945 to the present), however, would have meant a loss of focus on this sphere of administrative discourse, and ultimately risk re-treading ground already explored in depth by historians of defence computing such as Hables Gray (1997) and Edwards (1997).

Rather than map out a genealogy, the focal point of my project ultimately came to rest on an analysis of the administrative and managerial dimensions of command and control. This marks a departure from the existing literature in a number of ways. Firstly, the question shifts onto the conditions in which the figure of the human operator (also commonly referred to as the 'human factor' or 'component' in the archival material discussed later) comes to exist in discourse; and secondly, how its function within the process of the design and development of a command and control system is elaborated through administrative media such as manuals, reports, and memoranda. This analysis is conducted by concentrating on a particular discursive space in each case study—on the task of systems training in the context of SAGE; and on the task of photo interpretation in the context of the electronic barrier. Both of these operational roles in the respective systems were the subject of extensive debate in working papers and studies over *what* could be automated, and how the role of the human might be increasingly optimised and managed was inscribed in manuals and other instructive documentation. On this point I agree with Agar (2003): in his study, bureaucratic discourse is vital to understanding the elaborations in computing and conceptualisations of the British civil service as a 'machine' in the mid-20th century. The material, aesthetic, and discursive qualities of computing technologies are conceptualised in this research project as mutually entangled and reinforcing.

Both the form and content of grey media are the subject of discussion in my case studies. In other words, it is not only what is said, but the various ways in which command and control is expressed—as a list of operational positions, a flowchart, a map, a diagram—that matters here. I contend that an analysis of this media domain shows that discussions of the human operator were considerably more nuanced than has typically been allowed in histories of Cold War computing. In paying attention to this inward institutional gaze and examining how the human operator was figured within it, this project addresses a gap in the existing literature: to the inquiries that examine the extension of the domain of the computer in the conduct of war, here I offer an analysis of the extraordinary degree of *manual* operational and administrative work carried out in support of these semi-automatic systems. In doing so, I complicate the supposedly 'real-time' and 'semi-automatic' qualities of these human-machine systems, and elucidate the immanent, parallel institutional conflicts between uncertainty and control, ad-hoc practice and systematic procedure, operation and optimisation. To 'operate' within the system was not just to sit at a computer terminal and observe a screen, but to be inscribed within the system as a 'component' carrying out some task in support of its functioning. The resultant understanding of command and control that is produced here then is one that additionally encompasses the extraordinary administrative and managerial effort involved in keeping the system *systematic* and the operators *operable*.

## 1.3 Structure of Case Studies

The year that Licklider's article was published serves as the midpoint of the approximately 25-year period which this research project spans. The historical scope of this inquiry is bookended by the massive mobilisation around the issue of air defence following the Soviet atomic test and the withdrawal of American troops from Vietnam in 1973. By the time Licklider's article was published, over 20 of SAGE's direction centres were operational and wired into the national perimeter of radar outposts, picket ships, and observational aircraft. Defence strategy had shifted considerably too: following the so-called 'shock of Sputnik', ballistic missiles and thermonuclear bombs represented the primary existential threat to the United States. With SAGE designed to monitor the airspace for enemy *planes* rather than *missiles*, the issue of its premature obsolescence circulated amongst Air Force command and the US government (Ulmann, Pappert, and Brunell 2014). Nevertheless, as the biggest single defence project of the decade, SAGE was a major boon to the weapons industry. Perhaps SAGE was one of the defence projects on Eisenhower's mind as ended his second presidential term with the famous 'military-industrial complex' speech. In the address, he stated that 'the solitary inventor, tinkering in his shop, has been overshadowed by task forces of scientists in laboratories and testing fields', and warned that the American people must 'guard against the acquisition of unwarranted influence' in the immensely profitable arms industry (Eisenhower 1961). Meanwhile, American involvement in Southeast Asia was escalating. With ex-Ford Motors executive Robert McNamara recruited for Secretary of Defense by President Kennedy, the developing situation in Vietnam was translated into quantifiable and *computable* flows of information, and conducted in a style that is described by some commentators as having much more to do with corporate management than the so-called 'art of war' (Dickson 1977; Gibson 2000). It is against this backdrop that the discussion of my case studies unfolds.

My study of the US continental air defence (Chapter 4) focuses on inquiring into its *semi*-automatic configuration by looking at the ways in which operators were trained to use the system. Part I examines how, during the late 1940s and early 1950s, defence researchers identified an array of national security concerns that redefined what constituted effective air defence. Prominent amongst these concerns were the emergence of the Soviet Union as an 'existential' threat in military and governmental discourse, the political developments and outbreak of war in East Asia, improvements in aircraft technology (flying range, speed, and altitude), and the Soviet Union's atomic test in August 1949. These concerns set the scene for a renewed effort to rapidly improve the existing air defence system—the so-called 'Manual System'. This effort centred on the burgeoning discipline of human factors engineering, and trialled through a series of experiments conducted at the Systems Research Laboratory (SRL). The field of human factors engineering emerged in response to problems of machine design a decade earlier amidst the war emergency, chiefly to correct rising operator errors in new classes of aircraft of unprecedented complexity. The SRL, however, represents a discursive elaboration of this field as it applied to air defence. In the SRL reports, the concept of the 'human operator' was predicated on a model which conceptualised the air defence system as an 'organism' which 'processed the commodity of information' (Chapman et al. 1952, 1959). This model became the basis for the formalisation of their experiments as a new theory and programme for 'optimising' communication practices in human-machine organisations—what they called 'systems training'.

Part II of the case study examines the process through which the air defence system was reimagined as being built around digital computers, and the implications this held for the operator. I analyse three documents (Air Defense Systems Engineering Committee 1950a, 1950b; Loomis 1951) which set out the key initial schematics for the SAGE system, contrasting their concept of the 'human element' with that of the SRL. The physicist George Valley argued for the necessary centrality of the digital computer in the system (1950b). To convey this argument, Valley also proffered reconceptualisations of the enemy, the battlefield, and the crews of the eventual SAGE system in terms of information flows which exceeded the managerial capabilities of human operators. What is particularly revealing is the way in which these two defence research programmes and their attendant conceptualisations of the operator's role converged: systems training was formalised just as SAGE's engineers realised that they didn't have any existing programme to teach Air Force personnel how to use the computers nor how to work as part of a collective crew. However, a number of reports dating from the late 1950s and early 1960s document how factors such as the institutional and bureaucratic structures of the Air Force (crew rotation, for instance), the psychological isolation engendered by the organisational design of the SAGE Direction Centre, the costs involved in continuously retraining crews in light of new technological developments, and the unfamiliar complexity of the visual interface, all undermined the effort to 'optimise' the operation of the SAGE system.

The second case study (Chapter 5) shifts to an examination of defence research as it pertained to the 'anti-infiltration programme' in Laos and South Vietnam, and its development into the electronic barrier system, codenamed Operation IGLOO WHITE. Part I of this case study examines the ways in which operators constructed 'evidence' of a 'successful strike' on a North Vietnamese truck along the complex of supply routes referred to as the 'Ho Chi Minh Trail'. This chapter primarily focuses on the years 1964-1966, the period before the sensor-barrier and the IGLOO WHITE programme had initiated, but when the core strategic problems of 'infiltration' were being formulated by the defence strategists. Photographic interpretation was instrumental in this measurement process—a practice which, for the specific kind of tacit knowledge and analysis it demanded, had to be performed by a human and remained a crucial dimension of the barrier programme even as other operations were successively automated. The effort to take and interpret these photographs, however, were delimited by a range of contingencies, including the weather, the emergent attacks on reconnaissance aircraft from NVA artillery, and the oft-remarked on 'impenetrability' of the jungle. The resultant uncertainties were, to the minds of the defence researchers at least, scaffolded with characteristic techniques of systems analyses and operations research. It is in these reports, whereby the authors struggled with an absence of quantitative, evidential data, that the concept of a sensor-barrier system was first proposed.

In the second part of this case study, I examine a set of documents which detail the first study, initial deployment, and the continuous elaboration of the IGLOO WHITE sensor-barrier between the years 1966-1973. In these documents, the 'interdiction effort' was conceptualised as a continuous negotiation of technological capabilities and countertactics—the pivotal observation instrument in charting the trends in this negotiation would be seismic and acoustic sensors. The 'operator' in IGLOO WHITE adopted an administrative role, manually interpreting data and collating it in order to rapidly dispatch aircraft to bomb zones of activity. To support the vast appetites of the OSA for data, the operator also was implicated in the construction of longer-term trends and patterns in truck detections. Whether or not IGLOO WHITE was militarily successful—and there is some evidence that suggests it wasn't (Dickson 1977; Gibson 2000; Edwards 1997)—it was productive of a way of quantitatively 'knowing' the battlefield that gained an authoritative quality amongst military planners and strategists: the 'evidence' of activity produced by the sensors and analysed by the operators informed and justified the coordinates of an intensive bombing campaign. What is important to recognise is that the range of contingencies and uncertainties immanent in IGLOO WHITE were not ignored. They were in fact the subject of extensive discussion, leading to the invention and employment of a range of operational techniques to scaffold the veracity of the kind of claims the system was capable of producing about the battlefield.

In the concluding section of this thesis, I will reprise the main themes that have arisen in the case study discussions, while situating them broadly within more recent developments in human-machine command and control systems in the United States Air Force. In doing so, I return to the question of what a study of these systems organised around analytic readings of the grey discourse of defence research can facilitate, and how it might address gaps in the literature on contemporary digital, networked warfare.

# Chapter 2

# Literature Review

## 2.1 Introduction

The history of Cold War technopolitics has been a lively domain of scholarship for a number of decades, one that remains today an area of productive analysis and elaboration. The reasons for this continued attention are various, and might be understood to be a consequence of: the broadening availability of newly declassified or catalogued archival material; theoretical shifts and expansions in scholarly approach, particularly those which adopt feminist and postcolonial perspectives; and renewed interests in finding prehistories for our present, ostensibly 'novel', technopolitical circumstances in the military-industrial-academic complex of the Cold War. The broadness of this domain means that there are a diverse range of disciplines with obvious interests in charting this history, from scholars of management theory to urban geography, and from economics to software studies. Although myriad histories of Cold War defence research have been effectively detailed at length already—and especially so for the US context—I argue that gaps in the literature remain which present further opportunities for analysis and insight. I suggest here that the discursive contexts of defence research in this era, and in particular the ways in which 'human operator' are constituted within the 'grey media' of research and development institutions, warrant further critical attention.

Below I set out to successively 'zoom in' to groups of literature which aim to map how relations between humans and machines are constituted within specific social and technical contexts. In the opening section, I turn to a field of scholarship which has been central to these discussions—that is, science and technology studies (STS). With its roots in sociology of science, STS as a discernible field crystallised in the 1980s. While this research project has not been conducted as a sociology of command and control systems, STS raises a set of relevant questions which significantly shaped how we think about writing histories of technology. As I will explain below, there are numerous schools of thought within STS, each of which tends to draw the distinctions between society and technology along slightly different lines, and with varying degrees of ambiguity. I thus begin with a survey of key frameworks which fall within the domain of STS, with particular reference to case studies examined by their authors from the approaches of 'social construction of technology' (SCOT), 'actor-network theory' (ANT), and 'historical sociology'.

Following this, I look more closely at the body of literature which aims to map the scope and implications of digital computing and networking in the United States in the aftermath of the Second World War. As I have suggested above, the scholarship on this topic is vast, and heterogeneous in its focal points. Therefore, I opt to concentrate on a set of themes which have been especially central in the shaping of this research project. Firstly, I look at histories which take the 'engineer' as a protagonist of 1950s and 1960s computing. Following this, I explore a series of influential texts which aim to historically situate and describe the concepts of 'information' and 'control' in terms of their centrality to Cold War strategic thinking. Building on from the above, I engage with a set of texts which inquire into the characteristics of 'Cold War rationality' in American science and engineering—or, as some scholars explore, the extent to which such a thing can be said to exist.

## 2.2 Mapping Human-Machine Relations

The explicit 'semi-automatic' configuration of SAGE foregrounds a key concern in this research project in that it emphasises a continued presence of the human in a highly complex, computational system. In other words, automatic processes are necessarily entangled with human actions and decision-making processes. In IGLOO WHITE, there was a similar effort to introduce computers with the understanding that they would make pre-existing manual practices more efficient. The analysis in my case studies thus inquires into how the figure of the human operator informs, and is informed by, a set of relations between formally codified operational practices, emergent contingencies, and the technoscientific discourses of defence research. In short, there is an interest in the entanglement of institutions, technologies, and individuals in the research and development of military systems.

Sergio Sismondo (2010, 11) explains that STS scholars work from an understanding that 'there is no privileged scientific method that can translate nature into knowledge, and no technological method that can translate knowledge into artefacts'. In addition, they aim to problematise objective, a-social understandings of scientific knowledge, and argue that 'claims, theories, facts, and objects may have very different meanings to different audiences' (Sismondo 2010, 11). In short, STS takes as its object of analysis scientific facts and technological artefacts, and aims to demonstrate the social contingencies which inform their construction. As such, this domain bears important significance for this research project, as it engages with a set of underlying but vital questions concerning the relationships between technological change, the extent to which we might consider technological artefacts to be ‘stable’, and the variety of social forces which delimit their operational design and use.

In their edited collection *Shaping Technology/Building Society* (1992), Wiebe Bijker and John Law contextualise a series of essays (Wiebe E Bijker 1992; Bowker 1992; Law and Callon 1992) as an inquiry into the question of whether ‘technologies have trajectories’? To examine this proposition through specific case studies involves the multiplicity of forces which shape technological change, with a particular emphasis on the various social contingencies that act upon technologies. Bijker and Law’s response pursues an analysis of what they call the ‘heterogeneous contingency’ of technological change (1992, 17). In other words, this means adopting an understanding of technology that is responsive to its developmental context, one that ‘twists and turns as social and technical circumstances change’ (Wiebe E. Bijker and Law 1992, 17). The analysis therefore has to consider the ‘network of relations’ between both human and non-human entities and the circumstances which variously delimit, modulate, and reify these relations (1992, 10). To question whether a given technology has a trajectory—meaning, an intrinsic, determinative pathway of development and mode of use in the world prescribed at the point of invention—is therefore to contest essentialist conceptualisations of technological development, and to reattach it with the range of pre-existing contingent forces which shape its elaboration. To refute essentialist narratives of progress is to counter the notion that any technology can be explicated through a set of unifying properties, but becomes a technology through its social imbrication. ‘Technology’, they write, ‘is born of the social, the economic, and the technical relations that are already in place’ (1992, 11).

Empirical case studies are central to STS scholarship, with ‘almost all insights in the field grow[ing] out of them’ (Sismondo 2010, viii). John Law (2008) contends that, for many STS practitioners, their scholarship tends to focus on the specific and eschew generalisation and refuse straightforward divisions between theory and data (2008, 629). The reason for this, he argues, 'is because in STS theory is not first created and then applied empirically. Theory and data are created together'. Case studies worthy of analysis need not be monumental or spectacular—in fact, mundane technologies whose form and mode of use we might take for granted are frequently the subject of extensive discussion. Through a systematic, empirically-grounded analysis of its social contexts, STS scholars aim to recover from those contexts the myriad contingencies which shaped its development. A bicycle (Pinch and Bijker 1984), a door-closer (Latour 1988), a fluorescent light (Wiebe E Bijker 1992), a refrigerator (Schwartz-Cowan 1999) are argued to be fundamentally socially contingent, shaped by an interplay of forces and interests and with no predestined trajectory. The feminist sociologist of technology Madeleine Akrich writes, 'even study of the technical content of devices does not produce a focused picture because there is always a hazy context or background with fuzzy boundaries' (Akrich 1992, 205). These 'fuzzy boundaries' complicate what counts as social or technical, and the factors which inform the 'stability' or 'coherency' of a technology. What is considered to constitute a factor, and the relations drawn between relevant factors, vary depending on the STS framework or methodology in question.

Writing from a Social Construction of Technology (SCOT) perspective, Bijker's essay 'The Social Construction of Fluorescent Lighting' offers some useful points of departure for querying the purported 'stability' of technical artefacts. Understood within the domain of SCOT, 'stability' pertains to the distinctive ontological fixity of a technology which persists while the technology in question is developed. Here, Bijker offers a counternarrative to linear, teleological visions of technological change: the fluorescent lamp 'was continuously reshaped and redesigned by the various social groups involved' (Wiebe E Bijker 1992, 75). Bijker examines the negotiations between the electrical utilities and the manufacturers on the subject of the higher efficiency of fluorescent lighting and the impact on profits for the utility companies as a consequence of the reduction energy consumption of American households. This is not just a case of a new technology coming into contact with the marketplace; rather, through the negotiation of utilities and manufacturers, the technology and the market was structured in a way that facilitated the technology's circulation. The technology up for discussion in Bijker's account is obviously examined within a rather different arena than the command and control systems I focus on in this thesis, but his account does serve to demonstrate how the interplay between various groups continue to define and shape a technological artefact following its inception. Technologies do not appear in the world fully-formed and functionally stable, he argues. Rather, they are necessarily 'invented' in relation to a social context, and further elaborated as a consequence of their 'interpretive flexibility' (see for instance Pinch and Bijker (1984)).

The limitations of SCOT, however, have been identified by other scholars who aim to account for the ways in which technologies both reify and are generative of power relations across society. Langdon Winner has criticised SCOT for its unidirectional perspective, which only accounts for the social contingencies involved in technological development. What is missing, he argues, is an explicit engagement with the way technology also shapes the social. He writes:

> What the introduction of new artefacts means for people's sense of self, for the texture of human communities, for qualities of everyday living, and for the broader distribution of power in society—these are not matters of explicit concern. (Winner 1993, 368)

Grint and Woolgar echo this point, arguing that SCOT 'underplays the importance of the ways in which even established technologies are interpreted and used in the aftermath of "interpretative closure"' (Grint 1997, 24). In Pinch and Bijker's SCOT methodology, the study of 'interest groups'—that is, individuals who 'share the same set of meanings, attached to a specific artefact' (Pinch and Bijker 1984, 30)—play a formative role. However, the processes through which such groups are constituted, or indeed constructed by the scholar, are largely occluded from the analysis. Winner (1993, 369) notes a set of associated problems concerning questions of 'power' which are largely missing from the methodology: Who determines the boundaries of an interest group? What groups of people are suppressed or excluded? While SCOT offers productive techniques of charting technological change, it requires additional theoretical support to engage with questions of power.

Bruno Latour's writing on the relations between science, technology, and society have been enormously influential, and indeed sometimes controversial, in this field of scholarship. In the early 1980s, Latour was a founder and proponent of actor-network theory (ANT), a branch within STS which seeks to describe socio-technical change in terms of relations (*networks*) between human and non-human elements (*actants*). In his foundational book *Laboratory Life* (1979) written with Steve Woolgar, Latour 'follows the actors' at the Salk Institute, observing the scientific processes practiced to investigate the social contingencies which shape the production and publication of 'facts'. While his own approach, in both methodology and thematic concerns, has changed considerably since his work in the 1970s, for Latour the social contingencies which inform the construction of facts and artefacts are central in his inquiries. In his essay 'Technology is Society Made Durable' (1991), Latour attempts to engage with questions of power as domination through the case study of the Kodak camera. Latour sets about doing this by mapping a network comprised of various actants. The notion of the actant is theoretically crucial in Latour's work: it imbues both humans and technical objects with the capability to act, and by extension, to shape society and technology.

In this regard, Latour affords agency to both human and technical actants. He provides the example of a museum curator who, seeking to describe the history of consumer photography, might opt to present a series of successive camera models in a vitrine. In doing so, the range of surrounding factors—for example the 'photographers, subjects, markets, and industries'—'get transformed into a context in which the technical object moved, grew, changed, or became more complex' (1991, 114). Latour makes use of what he calls 'association chains' to describe the shifts in technologies operate through a human-machine dichotomy, charting incremental developments in terms of whether a given transformation in the object involves the appending of a 'human-like' or 'non-human actor' (1991, 110).

However, analytic tools such as association chains become rather unwieldy when applied to the study of the large computing systems, whereby a multiplicity of parallel developments happen simultaneously and sometimes, as in the cases of SAGE and IGLOO WHITE, in mutual contradiction. Distilling such projects down to diagrammatic representations of technological change introduces a set of analytic and conceptual problems, risking imposing an impression of logical organisation onto their development that elides questions of socially-embedded structures, hierarchies, and politics. In this sense, Latour's writing on how actor-networks of humans and objects cohere tends to elide considerations of the role played by power in their formation.

John Law—generally regarded alongside Latour, Madeleine Akrich, Michel Callon as one of the founders and prominent practitioners of ANT—describes ANT as 'a disparate family of material-semiotic tools, sensibilities, and methods of analysis that treat everything in the social and natural worlds as a continuously generated effect of the webs of relations within which they are located' (2007, 141). An ANT scholar 'assumes that nothing has reality of form outside the enactment of those relations' (Law 2007, 141). In a foundational text in the domain of ANT, Michel Callon writes:

> technical objects must be seen as a result of the shaping of many associated and heterogeneous elements. They will be as durable as these associations, neither more nor less. Therefore, we cannot describe technical objects without describing the actor-worlds that shape them in all their diversity and scope. (Callon 1986, 23)

ANT has been an enormously influential—and indeed also a considerably controversial—framework for explicating science and technology as webs of relations between the human and the non-human. John Law (2007) suggests that describing it in the abstract is to somewhat misrepresent what ANT is actually about. For him, it becomes most productive when applied as a lens in the examination of a specific case study.

The potentialities of ANT have attracted lively debate and critique—particularly early applications in which the resultant networks are flat, disembodied, and implicitly viewed from 'nowhere'. David Bloor (1999) argues in the unequivocally titled article 'Anti-Latour' that Latour's work is founded on a set of problematic suppositions concerning fundamental concepts in the sociology of scientific knowledge. In her review of Latour's *Science in Action*, Olga Amsterdamska (1990) critiques his framing of the production of scientific knowledge as a kind of 'empire-building'. This 'imperialist' tone has been elaborated on as a point of criticism by Anderson (2009, 392), who contends that Latour reaffirmed simplistic notions of colonial power in key works such as *The Pasteurisation of France* and 'depopulating' the local in his account of an Amazonian laboratory in *Pandora's Hope*. Yet, Anderson (2009, 392) appears to overreach somewhat when he cites the geographer Steven Shapin's (1998) contention in an article titled 'Placing the View from Nowhere'. Anderson suggests that Shapin critiques Latour's use of 'imperialistic and militaristic language'. What Shapin actually argues here is that this terminology is a deliberate strategy on the part of Latour, a technique to 'draw attention to the ways in which patterns of military domination, colonialism and worldwide trade have established channels which integrate the world and which standardise its knowledge and its practices' (7).

Prevalent feminist critiques of ANT's conceptualisation of socio-technical assemblages question whether this framework sufficiently engages with questions of 'power' (Quinlan 2014, 1). In her book *Whose Science? Whose Knowledge?*, Sandra Harding argues that the works of ANT scholars are ‘flawed by their inability to provide a reasonable account of the social causes of their own production and the high value rightly accorded to so many of their insights’ (Harding 1991, 168). In response, Harding proposes the adoption of a ‘strong objectivity’, via what she calls ‘standpoint theory’. This theoretical position, which incorporates ‘causal analyses not just of the micro processes in the laboratory but also of the macro tendencies in the social order’ (Harding 1991, 149), bears resemblance to Donna Haraway’s (1988) concept of ‘situated knowledges’. Haraway here calls for us ‘to become answerable for what we learn how to see’ (1988, 583). Of particular importance for this research project is her invocation of ‘the science question in the military’. She writes: ‘Struggles over what will count as rational accounts of the world are struggles over how to see’ (1988, 587).

The question of where the ‘power’ is in the network matters a great deal when accounting for what elements and forces can be understood as ‘internal’ or ‘external’ to it. Isabelle Stengers defends Latour’s reticence to invoke power as a universalising explanation for how the ‘networks of alliances’ of practices, actions, and passions cohere. However, it is critical to account for how notions of ‘expertise’ are constructed and scaffolded in relation to specific practices and institutional spaces, and confer on individuals a capacity to speak authoritatively. For Stengers, ‘power is not beyond the network’, but

> it qualifies the network and sets limits to it, that is, points where the notion of interest changes meaning, where one ceases to address oneself to the protagonists one is trying to interest, and where strategies presupposing that an interest can ‘command itself’—or at least be treated as such—begin to appear, which opens the strategies to risks and perils. (Stengers 2000, 126)

Calls to consider the ‘situatedness’ of the scientist—and indeed being attuned to the particular vantage point of the scholar examining the construction of scientific or technical knowledge—pose considerable theoretical problems and contraditions, not least regarding the positionality of the scholar themselves. In her article 'Sex and Death in the Rational World of Defense Intellectuals', Carol Cohn (1987) conducts a participant-observer study of a think tank that retains a focus on questions of power and discourse, the social and the technical. Although Cohn doesn't situate her work in an STS context, this text is helpful in interrogating the relations between institutions, discourses, and practices. In addition, her focus on the authoritative function of this field of discourse in sanctioning particular conceptualisations of weapons technologies assists in foregrounding this problem of situatedness in the construction of military technologies. She inquires into how defence researchers devise a technostrategic lexicon to construct a rational account of nuclear strategy, and by extension, a way of seeing the world that erases the devastating violence of nuclear war:

> I found myself aghast, but morbidly fascinated—not by nuclear weaponry, or by images of nuclear destruction, but by the extraordinary abstraction and removal from what I knew as reality that characterised the professional discourse. (1987, 688)

The relations between humans and the unimaginably destructive force of nuclear weapons in Cohn's account are described through an analysis of technostrategic discourse which engenders a particular type of coherence between the social and the technical. Namely, a 'paradigm' that erases the body, replacing it with the 'referent' of the weapon (1987, 711). As Cohn points out, this discursive terrain has a totalising, almost seductive effect that captures the individual within it: 'You become subject to the tyranny of concepts. The language shapes your categories of thought' (1987, 714). She expands on this:

> Language that is abstract, sanitised, full of euphemisms; language that is sexy and fun to use; paradigms whose referent is weapons; imagery that domesticates and deflates the forces of mass destruction; imagery that reverses sentient and nonsentient matter, that conflates birth and death, destruction and creation—all of these are part of what makes it possible to be radically removed from the reality of what one is talking

> about and from the realities one is creating through the discourse. (1987, 715)

Cohn firmly places the way technical 'problems' are explicated and constructed within a particular discursive lexicon, and how this lexicon presupposes ways in which subsequent technical solutions can be constructed. Within the cultures of defence research in the United States during the Cold War, the knowledge practices of science and engineering were directly implicated not only in the 'solutions' to problems of military strategy and technology, but in the processes of modelling the world in a way that identified these problems in the first instance.

## 2.3 The Technopolitics of Technical Practices

The tensions between the social and the technical described above are particularly evident in histories of technology which foreground and politicise forms of technical knowledge and their associated practices. Such accounts necessarily delineate the extent to which engineers shape technological development, act in response to existing technological affordances and contingencies, or (typically) some combination of the two. Precisely where in the spectrum a given history is situated matters a great deal: on the one hand, we have eminent social constructivists such as Thomas Hughes who describe the engineer as a problem-solver, an individual capable of rationally organising a palette of resources in order to realise a predefined technical vision (1979). Alternatively, for Langdon Winner, questions concerning the technopolitics of engineering, and specifically the ways in which technologies are expressive of existing power relations in society and in turn shape social action and relations, are firmly situated in the foreground of his work.

In his book *Autonomous Technology*, Winner proposes that the tendency for much STS scholars to only map the 'web of relations' which define their case studies is unhelpful, for it doesn't sufficiently engage with the implications of these relations or the ways in which they are constituted in relations of power. Describing efforts to 'quantify' technological change as a 'triumph of instrumentation' rather than 'an earnest effort to advance our understanding' (1977, 7), Winner calls for consideration of their political contexts and implications. For him, part of the problem concerns language, and specifically, the amorphousness of the word 'technology'. Winner argues that 'the same technologies that have extended man's control over the world are themselves difficult to control' (1977, 28). He contends that, as technological systems have become more complex and greater in scale, there has been a corresponding effect of estrangement with implications for the agency of the human:

> Human beings still have a nominal presence in the network, but they have lost their roles as active, directive agents. They tend to obey uncritically the norms and requirements of the systems which they allegedly govern. (1977, 29)

Engineering is not simply about problem-solving, he argues: it also involves the identification of a circumstance as a problem, its articulation in particular discursive terms, and its materialisation in a technical artefact. In other words, to gain a sense of how engineering is political requires an engagement with the systems of knowledge which in part determine what exists as a 'problem' in need of an engineer, and the kinds of people who count as benefactors imagined in its 'solution'.

This perspective runs counter to a prevalent approach in functionalist histories of technology where the existence of a social need is presupposed. In his book *Rescuing Prometheus*, Thomas Hughes traces what he characterises as the emergence of a new type of management which shaped the engineering of large technical systems following the second world war. The 'heroic inventors and managers' of the 19th and early 20th century are replaced by tales of 'systems builders' such as

Jay Forrester and General Bernard Schriever in the design of SAGE and the Atlas missile programme (2000, 7). In contrast to their predecessors, Hughes proposes that systems builders work with the interconnections *between* components—both in a technical and organisational sense—in unprecedentedly vast and complex engineering projects, rather than the individual components as discrete objects in themselves. For Hughes, their skill was therefore in their ability to rationally manage the relations between dazzlingly large arrays of subprojects and their attendant teams of scientists and engineers. He writes that the systems builders 'energetically and effectively countered the bureaucratic tendencies common to large projects and organisations; they held at bay political forces that would subvert technical rationality' (2000, 10).

Systems building in Hughes' sense is a useful frame through which to examine and explicate complex engineering projects, particularly in that it emphasises the heterogeneity of technologies, instituted standards, and organisations which typically constitute them. When assessing complex command and control systems, for instance, this is a vital point. Yet, it also raises the problem of the myriad political relations which delimit and modulate the system in question. Hughes' account of SAGE in *Rescuing Prometheus*, for instance, implies that the sphere of defence research only responded to a pre-existing geopolitical need, rather than articulate and shape the terms of that need through a particular configuration of discourses. For Hughes, the relations of power which prescribe and frame 'problems' in a technical discourse, designate the individuals capable of 'solving' them, and mobilise the capital required in research and development, are largely absent from his account.

In addition, the figure of the 'entrepreneur' in Hughes' account is an indissoluble entity, a matter-of-fact actor central to the historical record. The predominant mobilising force behind the systems that he studies is the ingenuity of a limited cast of geniuses—figures such as Edison and von Neumann, for instance—and their ability to recruit other organisations and institutions to their cause. For John Law, taking the figure of the entrepreneur as a 'given' raises contradictions with the understanding of technologies as being comprised of social and technical networks of actors:

> Heroes are built out of heterogeneous networks. Nevertheless, when they (we) deconstruct agents into their components and their artifices, there is a kind of sampling problem. This is because we tend to choose to do it on heroes, big men, important organisations, or major projects. So why does this happen? And what are its consequences? (Law 2008, 12)

One consequence is to downplay the role of various forms of resistance which arise in the building of systems. In asserting that these systems builders 'single-mindedly and rationally dedicated the enormous funds at their disposal to providing national defence', Hughes neglects to engage with the role played by the systems builders in defining concepts such as rationality, threat, or defensive system. This perspective is particularly surprising given that one of the four case studies of his book is SAGE, a system that Paul N. Edwards shows was notoriously beleaguered with delays and overspends and ultimately was only of questionable strategic importance (1997, 110).

An attunement to the technopolitics of engineering raises the issue of how the 'need' for large engineering projects such as SAGE or indeed IGLOO WHITE were discursively constructed and legitimised by their proponents at the time. Furthermore, it also directs us to examine the implications of this discourse for the resultant technical conceptualisation and operational logic of the command and control systems themselves. For instance, Edwards' notes that it was not at all self-evident to military commanders that the computerisation of air defence made sense, on both strategic and institutional levels. In fact, Edwards argues that it ran contrary to established traditions of military command (1997, 96). Following on from Edwards' assertions in *Closed World*, Jon Agar states that

SAGE constitutes a qualitative shift in the organisational management of the US Air Force: it was 'not only computerised, but also, to an even greater extent than before, bureaucratised' (2003, 419).

The technical concept of SAGE—and indeed, IGLOO WHITE—first arose amongst civilian defence researchers, and as such, it represents a shift in the locus of strategic planning and defence policy from within the military itself to defence research institutes populated by cyberneticians, psychologists, and systems analysts such as those at RAND. Paying attention to the ways in which 'threat' and 'defence' were constructed as issues of information management within this discourse highlights a whole array of contingencies and relations which are omitted from systems building accounts of digital computing.

Despite his misgivings regarding Hughes' centring of the entrepreneur in histories of technological change, John Law nevertheless had seen some value in the notion of systems building in his earlier work. Law's interest in the heterogeneity of technical objects, and the range of forces which interact in the course of their development, is present in his widely-cited essay 'The Case of Portuguese Expansion'. The case studies examined in this thesis are of course very different from that which Hughes examines in the aforementioned texts, but Law's approach is instructive. He takes a more radical approach than Hughes in mapping the elements of these systems: environmental contingencies such as the wind and tide, techniques and technologies of navigation, approaches to boat building, and geopolitical relations all figure into his system. This theoretical approach, what he calls 'heterogeneous engineering', 'seeks to deal with the "social", the "economic", the "political", the "technical", the "natural", and the "scientific" in the same terms' (Law 1987, 249).

The computer, however, is not a singular technical object, and demarcating the bounds of its development is a considerable historiographic challenge. Where and how we identify the 'agents for change', as Campbell-Kelly et al. (2016) put it, and envision their relations to shifts in technical understandings and operational use of computers in specific contexts is thus crucial to engaging with their technopolitics. In their book *The Information Machine*, Campbell-Kelly et al. (2016) present the development of digital computing as a series of technical hurdles and engineering challenges overcome by a select cast of prominent mathematicians and engineers. The function of the book, as they describe it, is to inquire into how the computer transformed from a single-purpose, monumental calculator emerging within the domain of military defence—and chiefly applied to the prevailing problems such as nuclear weapons and ballistics—to a personal, general purpose device fit for activities ranging from word processing to business administration (2016, xi–xii).

A consideration of the role that digital computing played in legitimising ways of seeing the world as 'information' is, however, largely absent from this history: The machines and systems designed by Charles Babbage, John von Neumann, and Bill Gates are explicitly described as technically heterogeneous, but unified in their common function as 'information machines'. A technopolitical history of the computer should rather highlight discontinuities in what counted as 'information' over this timeline. To do so is to demonstrate the pivotal role played by technical discourses of science and engineering—filtered through the significant military imperatives of the Cold War—in shaping the design, development, and operation of computers.

James Cortada's histories of digital computing, recounted in *The Digital Flood* (2012) and the three-volume collection *The Digital Hand* (2008), offer accounts that foreground the figure of the engineer and the economic transformations induced by the new technology. In the former, central to his account is the process of diffusion—that is, how the technologies and practices of computing spread throughout American society, and its relationship with broader economic circumstances and policies. Cortada presents a clear picture of the communities of engineering as well as the diverse institutional demands on computer research—and indeed as he makes clear in *The Digital Hand*, it was the enormous institution of the US Department of Defense during the Second World War and beyond that was pivotal in funding the early practice and diffusion of digital computing. The kind of histories recounted in these texts help us to chart the series of technical increments involved in the engineering of digital computers (such as SAGE's central AN/FSQ-7 computer) and the technical challenges involved in developing their software. In maintaining this focal point, the details of how computer systems such as SAGE shaped their operational contexts—and in particular, what it meant to be an operator within a human-machine system—necessitates a deeper discussion of the role of the engineer and their 'situatedness', producing an account of them as agents beyond 'problem solvers'.

In the post-war cultures of American defence research, the proponents of numerous burgeoning practices positioned their specialisations within the broad rubric of 'engineering'. The tenets of human factors engineering, systems engineering, and software engineering—all of which had intimate links with the RAND Corporation—were all outlined and formalised in handbooks and memoranda in the early decades of the Cold War. Nathan Ensmenger's (2012) detailed account of computer programming, specifically as it emerged at RAND and the System Development Corporation (SDC) in the 1950s, does manage to critically probe the social and political implications of software engineering in particular. Ensmenger shows how, at least in part, the rebranding of computer programming as 'software engineering' in the 1960s was an effort to establish the work as an esteemed profession and imbue it with an explicit disciplinary rigour, from a 'black art' to a formalised 'science' (2012, 16). He shows how this negotiation was entangled with efforts to masculinise computer work, resituating the technical work of 'wiring up' and programming computers which was chiefly carried out by women under a new disciplinary title that excluded women. The gender politics of computing has been explored in greater detail by Chun (2004), Abbate (2012) in the US context, and, in the British context, Hicks (2018). The question of who counts as an expert, what counts as expert technical work, and the role established disciplinary titles play in this, is made abundantly clear in their work.

The historian of Cold War technoscience Rebecca Slayton (2013, 3) contends that 'computing draws attention to the messy, evolving relations between social organisation and technological development and use'. Indeed, for Ensmenger, the evolving relations between the social and the technical, between 'expertise' and the designated technical function of computers in particular institutional contexts, is an important dimension of his inquiry. For engineers to plan and design a 'computerised' office was not merely to impose a new technology onto pre-established relations, it was to reimagine the workplace on a more fundamental level:

> When a firm in the 1950s wanted to computerise its accounting operations, for example, the software that it had to develop included not only computer code but an analysis of existing operations, the reorganisation of procedures and personnel, the training of users, the construction of peripheral support tools and technologies, and the production of new manuals and other documents. (Ensmenger 2012, 6–7)

Ensmenger is thus attuned to the ways in which efforts to computerise are productive of much larger and more complicated effects than the direct substitution of human operators with machines in a particular technical process. The discursive effects are felt in the SDC's recharacterisation of itself as a 'software factory', a space of production where 'skilled personnel' were supposedly replaced with 'superior process' (2012, 61).

> The conflicting needs and agendas of users, manufacturers, managers, and programmes all became wrapped up in a highly public struggle for control over the occupational territory opened up by the technology of computing. (2012, 234)

Even a brief investigation of the relations between the sometimes contradictory interests of computing researchers, the computing industry, and military commanders complicates histories which privilege the narrative of the genius engineer. There is little doubt that the works of imperious figures such as John von Neumann, JCR Licklider, and Norbert Wiener were enormously consequential, yet defence computing projects were rife with the 'conflicting needs' enumerated by Ensmenger. In *Closed World*, Edwards describes the negotiation of these conflicts as 'mutual orientation' (1997, 81–83). This is the discursive process through which the goals of the various actors involved are brought into collective alignment. The concept of mutual orientation allows Edwards to link the concerns of researchers—notably, obtaining funding—with the broader institutional configurations which delimit and shape that research. The promise that the eventual SAGE system would allow for a hitherto unprecedented automation and centralisation of control, for instance, convinced funders to support the project and reconsider the management of aerial strategy. In turn, the application of the pre-existing Whirlwind computer to the problem of air defence also encouraged on the part of its proponents a reconceptualisation of the technical architecture of digital computers.

The SDC, a corporation intimately linked with prescribing the operational dimensions of the SAGE system, is exemplary of this. However, in Ensmenger's discussion, the politics of software engineering is implicitly inscribed, as opposed to being taken up as a subject of extensive analysis, in his account of the struggle for control as it proceeded within institutional spaces. In focusing on the tensions surrounding the definition and practice of software work, the impacts of such work for the operator in the resultant computer systems is beyond the scope of his account. David Noble's book *Forces of Production* (2011), the politics of automation on the factory floor function as his focal point. Noble examines the relations between technologies of automation and industrial labour via the struggles for control over the production process in machine shops in post-war America.

For example, the servomotor, developed at MIT in the early 1940s to precisely control the movement of anti-aircraft guns, found application in the 'Automatic Factory' following the war (Noble 2011, 47, pp. 67-69). He also makes important connections between numerical machine control and the Whirlwind—one of the first digital computer designs and later used in SAGE's command and control centres. The market, he claims, had written off numerical control as being uneconomic. It was rather largely the demands of 'defence readiness' and military command and control systems—namely SAGE—which had ultimately supported its realisation.

The implications of the hyphen in *human-machine systems* indicates both a mutual boundedness while suggesting a sense of two distinct, discrete realms of things and actions. The ways in which these realms are delimited, or even understood as distinct and separable, has been an extensive theme in STS scholarship. According to Grint (1997), however, we must resist positioning technologies as external to 'traditional sociological variables such as class, gender, organisation and power' if we are to understand their politics (1997, 7). Although they contend that approaches such as SCOT have been largely successful in reorienting such histories away from the base of technology as a primary determining factor, they argue that ultimately SCOT scholars end up 'reaccommodat[ing] it as one among several independent variables which determine action and behaviour' (Grint 1997, 7). In other words, the social and the technological, although entangled, are nevertheless still treated as if they are discrete and separable concepts. As such, technologies are implicitly conceptualised as being 'impervious to the interpretive activities of humans' with 'objective effects which can be measured and predicted and largely unaffected by the human actors involved' (Grint 1997, 7). This disposition, what Grint and Woolgar refer to as 'technicism', is not uncommon in histories of Cold War defence research—particularly in the technical histories of major engineering projects such as the Semi-Automatic Ground Environment.

To avoid reproducing the problem of technicism, Grint and Woolgar propose an understanding of machines as 'texts' that thus require interpretation. In doing so, they eschew essentialist conceptualisations of technology, instead emphasising the 'contingency of interpretation' in their modalities of use (1997, 93):

> This then sets the frame for an examination of the processes of construction (writing) and use (reading) of the machine; the relation between readers and writers is understood as mediated by the machine and by interpretations of what the machine is, what it is for and what it can do. (1997, 70)

There is a theoretical pitfall here, as Hutchby (2016, 450) notes, in eliding material and aesthetic dimensions of technologies, thus envisioning them as a blank surface onto which 'users' project their own readings without resistance. Hutchby proposes an analysis of technical affordances—that is, the structures of 'usership' designed into technologies which can be either implicit or explicit, although not necessarily prescriptive. A counter to this point can be found in Grint and Woolgar's own deployment of another textual metaphor in this study: that of the 'script', or the anticipated mode of operation inscribed in the design of the technology as envisaged. for instance, by its engineers.

Attending to this process of 'configuration'—of 'defining, enabling, and constraining' the user (Grint 1997, 74)—opens up the possibility of bringing the issue of power into the foreground while retaining ideas of process and negotiation. Furthermore, what is also key here are the ways in which this configuration fails to map onto the actual users tasked with running these machines. This has been productively extended along feminist lines of enquiry by STS scholar Madeleine Akrich. She writes: 'like a film script, technical objects define a framework of action together with the actors and the space in which they are supposed to act' (Akrich 1992, 208). For Akrich, the qualities of these roles and spaces of action are modulated by beliefs or assumptions held by the innovator about the anticipated end-user of the technical object. Scripts in this sense can therefore be understood as the effect of a configuration of power and knowledge, which in a given case might be modulated by an interplay of institutional, gendered, racial, class, and colonial relations. It is important to assert that a script need not entirely determine the use of a technical object, however. Scripts can also be resisted and reconfigured—or 'de-scripted' to use Akrich's term—as she demonstrates in her accounts of electrical infrastructures in the Ivory Coast and Burkina Faso.

With this concept of the 'script', we return to those predominant common concerns of STS scholars, even if they differ in where they place emphasis: drawing out the dual effects of contingency and trajectory in the development of technologies, and delineating the ways in which technology and society are co-produced. Suchman (2002, 92) similarly aims to problematise and 'replace the designer/user opposition' by drawing on feminist critiques of objectivity, with specific reference to Haraway's notion of situated knowledge. Haraway and Harding foreground the social relations and conditions which produce and institutionalise notions such as 'expertise'—more specifically, those who are its subjects, and those who can speak authoritatively. Lucy Suchman extends Haraway's focus on technoscience into the domain of interface and IT systems design, reminding us to ask the question 'who is doing what to whom here?'. Designers, she notes, don't 'design from nowhere' (2002, 95). Suchman's discussion in this article possesses a broad scope, but the brief reference to a prior study into her study of work and organisational hierarchies at a large law firm raises a pertinent theme for this thesis. While she reports that attorneys identified the work of litigation support as 'mindless, routine form of labour representing a prime target for automation', the inquiry contradicted this:

> These 'document analysts,' as the supervisor called them, were engaged in carefully examining and encoding the thousands of documents used to assemble each case with the goal, vigorously instilled by their supervisor, of creating a valid and usable database for the attorneys. (2002, 98)

The article extends some points first raised in her influential book *Plans and Situated Actions* (1987), in which she contested established cognitivist paradigms of human behaviour through examining the foundations for mutual intelligibility between humans and machines. She notes that the proliferation of computer-based technologies in society, each introducing new 'complexity and opacities' for their users, produces the 'paradoxical objective that increasingly complex technology should be usable with decreasing amounts of training' (1987, 18). This observation introduces a vital consideration in writing histories of human-computer systems: the question of how what Suchman calls 'mutual intelligibilities' are constructed across and within what are explicitly understood as systems comprised of individuals, practices, institutions, technologies. Systems building histories, or those which afford a privileged agential position to the esteemed figure of the engineer, frequently fail to identify and engage with these problems.

In the context of Cold War defence research, this question becomes particularly pertinent as they implicate particular rationalisations and anticipations of what Galison (1994) calls the 'enemy other' (discussed below) in the engineering of the system. Law and Callon (1992) engage with this matter through their case study of the Royal Air Force's ill-fated TSR2 jet aircraft. In their inquiry, they adopt an 'actor-network' approach to map out the interplay of forces and contingencies that contributed to the failure of this large-scale, complex, defence engineering project. Law later expanded this work, detailing the background and development of the TSR2 in greater detail, in his book *Aircraft Stories* (Law 2002). Whereas the essay co-authored with Michel Callon affords attention to the political background of a general election in the United Kingdom and the main political parties' own policies with regard to defence spending, the full-length book is much more concerned with heterogeneity. Law opens the book with an explanation of what he means by 'decentering the object':

> An aircraft, yes, is an object. But it also reveals multiplicity—for

> instance in wing shape, speed, military roles, and political attributes. I am saying, then, that an aircraft—an 'individual' and 'specific' aircraft—comes in different versions. It has no single centre. It is multiple. And yet these various versions also interfere with one another and shuffle themselves together to make a single aircraft. They make what I will call singularities, or singular objects out of their multiplicity. In short, they make objects that cohere. (2002, 2–3)

To demonstrate this, Law adopts the strategy of a 'naive reader' in order to analyse a text—sales brochure about the TSR2, produced by its manufacturer. In one sense, this strategy of discourse analysis can be seen to correspond with Foucault's focus on 'positivities' and 'functions' described in *Archaeology of Knowledge* (2002b): Law examines this document in terms of what is said and what is shown, taking the manual as a set of interrelated but distinct elements, including perspective drawings, tables, maps, flowcharts, and diagrams. These elements cohere, Law suggests, but they only do so precariously and with uncertainty (Law 2002, 33).

This focused examination of a perfunctory 'grey' text, paying close attention to how it attempts to describe a technical object or operational procedure, is an important theoretical and methodological reference point for this research project. Examinations of administrative documents—for instance, concerning patents in Geof Bowker's work (1992)—are not uncommon in studies of technoscience. As objects of analysis, they can offer rich insights into the role of contingency and the coproduction of system and operator. What is especially revealing about *Aircraft Stories*, however, is how it revises Law's earlier attempts, including the essay co-written with Callon above, to describe the TSR2 in an approach explicitly grounded in the discourse and framework of actor-network theory. Law draws on feminist technoscience, in particular Donna Haraway's 'Situated Knowledges' referenced previously. In doing so, he responds to what he saw and described in his accounts of the TSR2 written in the 1980s, specifically his concern that through the process of writing these stories about the aircraft, he felt he was being 'constituted as the person who would document this project definitively' by its erstwhile engineers and military proponents (2002, 54). To have done so, he explains, would have been to cooperate with a set of military interests—namely, to assess whether the project was worth cancelling, and 'what might be learned' for future military research and development programmes. Law's prior approaches to producing knowledge about the aircraft becomes a point of critique in the latter book, which in its structure deliberately foregrounds heterogeneity, ontological instabilities, and the standpoint of the author.

The pertinent tension in the works cited above can be summarised as disagreements over the extent to which engineers can be understood to invent not only material artefacts, but also to be implicated in the practical definition and reformulation of discursive concepts which privilege some problems and solutions over others. Donald MacKenzie's study of ballistic missile development in the United States during the Cold War, titled *Inventing Accuracy* and taking the form of what he calls a 'historical sociology', probes these tensions. For him, the study of missile design carried out in this way goes much further than a technical discussion of gyroscopes or the channels through which defence policy is negotiated. MacKenzie describes his approach as a 'technological "window" into crucial divides in nuclear thinking', a perspective which highlights disagreements between different schools of thought in the domain of nuclear strategy. Fundamental beliefs about military strategy after the bomb, for instance the question of whether a nuclear war could every truly be 'won', played out in the negotiation of the design of the most minute sensors (1990, 2). MacKenzie argues that what counted as 'accuracy' was conceptualised and negotiated by scientists, engineers, and strategists in response to a set of integrated factors ranging from military demands and budgets, scientific and engineering practices, estimations of enemy military force and strategy, and geopolitical circumstances. His key finding exemplifies this:

the destructive force of thermonuclear weapons meant that accuracy became less important. Technology and strategic-thinking were fused.

MacKenzie's account of missile guidance accepts as its starting point that what counts as accurate 'has been a shaping force [that] has itself been shaped' by technology (1990, 3). For MacKenzie, the story of the gyroscope is told through its transformation into a 'technology of power'. Precisely how power operates in MacKenzie's view is not thoroughly unpacked, however. MacKenzie's account describes how the gyroscope was an instrument that became increasingly important in ventures in war and navigation, its development responding to a complex set of relations with geopolitical interests ranging from Arctic exploration to the demands of warplane navigation, and later, its defensive counterpart: anti-aircraft weaponry.

The research discussed in the section above—in particular those of Noble (2011), Grint (1997), Suchman (1987). Law (2002), and MacKenzie (1990)—raises questions with regard to their respective case studies which also introduce productive lines of enquiry and conceptual tools for the study of command and control systems. Firstly, where should we situate the figure of the operator within the development of command and control systems? What processes of configuration are involved, and how might they be constructed in the technical and administrative media of defence research? Secondly, there is the issue of heterogeneity: that is, to examine these systems in terms of coherencies and incoherencies between myriad elements rather than totalising, orderly arrangements of humans and machines. Finally, there are the relations between the construction of scientific and engineering concepts and the technical design of the system. 'Accuracy', as MacKenzie shows us, did not have a singular meaning: rather, it was 'invented' in relation to geopolitical, technical, and strategic considerations and contingencies.

## 2.4 'Inventing' Information?

In histories of Cold War technopolitics, accounts of the knowledge practices which emerged out of the research institutes of the Second World War frequently focus on their shared preoccupations with concepts of 'system', 'information', and 'control'. In doing so, such studies often propose (whether implicitly or explicitly) a corresponding shared set of concerns, approaches, and imperatives—what some claim amount to a distinctive Cold War 'rationality'—across these practices. To provide just a few examples taken from prominent histories, 'cyborg sciences' (Mirowski 2002), 'cybersciences' (Keller 1995), and 'war sciences' (Galison 1994) have been proposed to respectively explain shifts in economic thought, biological theories of 'life', and conceptualisations of the enemy in war across the natural and human sciences in the 1950s. These descriptors frequently emphasise connections with cybernetics, digital computing, and the military patronage of research and development via a supposed common preoccupation with information and control. A key matter that arises here is the extent to which Wienerian cybernetics can be employed as a point of inception for the purported shifts in the discourses of science and engineering that followed the Second World War: did 'information' and 'feedback' mean the same to a physicist as a behavioural psychologist, for instance? As Dayé (2016) cogently argues, a more concentrated scrutiny of specific practices which are thought to comprise 'first order Cold War social science' reveals significant disparities in what types of problems can be subjected to 'scientific' scrutiny, and the frameworks through which this scrutiny manifests.

Nevertheless, the notion of a distinctive Cold War 'rationality' or 'discourse' in the think tanks of 1950s America is an enduring trope in scholarship on computing research during this era. Erickson et al. (2013) take operations research as a starting point to chart the ambiguous terrains of 'rationality' and 'reason' in the interdisciplinary research and development institutes of 1950s and 1960s America, tracing its development in nuclear strategy and behavioural psychology. Crowther-Heyck (2015, see also 2006, 2008, 2014) identifies what he calls the 'age of system', the exemplary exponent of which being the Nobel-prize winning economist and management theorist Herb Simon. For Crowther-Heyck, this 'age' is marked by a turn toward the study of things as 'information-processing' organisms (2015, 83), and the study of action that takes the *context* in which a 'decision' is made (as opposed to the *decision-maker*) as its object of analysis (2015, 128). For both Heyck and Erickson et. al., Simon's theory of bounded rationality, which shaped thought across the domains of military strategy, management science, and economics, is exemplary of this reformulation of what counted as 'rationality'.

The framing of these discursive unities holds important theoretical implications for writing histories of technology, because they shape how we think about 'information' and the ways in which these practices theorise the relations between the human and machine. This sphere of discourse is what Rohde (2013, 7) refers to as the 'grey area'—that is, 'the frontline in the intellectual and political battles over the militarisation of national security expertise'. Located at the intersections of the military, industry, and academic institution, this domain of discourse was instrumental in defining the problems and delimiting the field of possibility.

> Research in the grey area never conformed to the scientific ideal of pure, objective inquiry directed at the discovery of universal truths. The requirements of national security influenced the direction of study, challenging researchers to protect their intellectual autonomy from what many scholars considered to be the polluting effects of external influence. (Rohde 2013, 7)

The influence of defence research in constructing a perspective of global affairs is keenly examined by Farish (2010), who notes a quite literal shift in world view expressed through the polar maps of 1950s American war rooms. The seemingly ever-imminent potential for an over-the-top polar assault put the North Pole at the centre of the map, a vast open space that was then only just about traversable due to recent technological developments in aviation engineering.

Scholars of this era broadly agree that it is crucial to understand the foundational claims of cybernetics and information theory should one wish to address the shifts in the relations between scientific research institutions, military imperatives, the computer, and the geopolitical imperatives of the Cold War. In his widely cited article 'The Ontology of the Enemy' (1994), Peter Galison argues that wartime developments in the frameworks of game theory, operations research, and cybernetics informed techno-strategic reconceptualisations of enemy, machine, and by extension, war. For him, these frameworks—what he terms 'war sciences'—recast the battlefield as a 'mechanised' zone animated by stochastic processes, a calculative space where 'the identity of intention and self-correction was sustainable, reasonable, even "obvious" ' (1994, 263). The implications of such a view, he argues, was

> an image of human relations thoroughly grounded in the design and manufacture of wartime servomechanisms and extended, in the ultimate generalisation, to a universe of black-box monads. (1994, 265)

Galison's interest in 'Ontology of the Enemy', as he later explained, lay in 'how experiences of technologies could shape the notion of selfhood and then how a certain notion of selfhood could open up new kinds of technologies' (Packer 2016, 3167). The cybernetic image of the world as 'nothing more than the mutual internal relations of [...] incoming and outgoing messages' (Galison 1994, 255–56) is a response to wartime exigencies and a technical configuration—the relations between pilot and aircraft, gunner and gun—constituted in terms of control and communication.

Galison notes that the implications of this cybernetic view of the world was felt far beyond the particularities of Second World War fire control: its influence can be traced across social science and postmodernist discourse (1994, 256–57). Writing in her book *Beautiful Data* (2015), Orit Halpern offers a corrective to Galison's focus on cybernetics' ontological implications: cyberneticians, she argues, were not interested in essence, but in process. Command and control systems do not feature prominently in Halpern's history. However, she presents them as an example of this 'new imaginary' ushered in by cybernetic thought, in which 'response time was the critical feature driving the system, [producing] a new understanding of teleology that was not about progress, linearity, or conscious humanist effort, but rather a new mode of technical thought' (2015, 44).

Halpern's interpretation of cybernetics, in terms of its preoccupation with process, helps to reinforce the mutability of the relations between the transmitter and receiver of messages: through the modulation and control of feedback, these relations are continuously being remade. This seemingly open-ended mutability, however, doesn't quite capture the various forms of resistances which circumscribe the relations between transmitters and receivers in the discourses examined in the case studies here. With regard to command and control, relations are not only delineated through informational flows, but also institutional protocols and the diagrammatic, theoretical distribution of humans and machines across a system—what I refer to as the 'operational logic' of command and control. An attunement to the tensions between the theoretical open-endedness of cybernetics and its institutional applications are necessary when examining command and control: mutability and change can rather be described in terms of systemic incoherency and contingency.

Nevertheless, it is difficult to separate out characteristically 'cybernetic' terminologies and models from the broad arrangement of knowledge practices associated with the constellations of think tanks in 1950s America. Writing in *Machine Dreams* (2002), Philip Mirowski describes the characteristics of this rationality via a study of its impression on economics. Alongside cybernetics, operations research and game theory are prominent elements in a collection of practices that he terms 'cyborg science':

> Here and there, a cyborg intervention agglomerates a heterogeneous assemblage of humans and machines, the living and the dead, the active and the inert, meaning and symbol, intention and teleology, and before we know it, Nature has taken on board many of the attributes conventionally attributed to Society, just as Humanity has simultaneously been rendered more machinelike. (Mirowski 2002, 13)

Evelyn Fox Keller situates cybernetics within a larger grouping of what she sees as associated endeavours in post-war science and engineering. Referring to them collectively as 'cyberscience', she describes how 'information theory, cybernetics, systems analysis, operations research, and computer science'

> might be thought of as loosely linked endeavours sharing a common task (the analysis of complex systems), a conceptual vocabulary for dealing with that task (feedback and communication–circular causality), and a mode of representation (of complex systems as interacting networks or circuits). (1995, 84–85)

Given her definition of their shared 'conceptual vocabulary', the list of practices Keller describes could arguably be extended to take in the various burgeoning fields in the human sciences professedly offering new theories of 'mind', a subject which Cohen-Cole (2014) has examined more recently. But what is important in Keller's account is the processual control—the 'doing'—of such systems:

> For cyberscientists, Life (especially corporate life, electronic life, and military life—the modes of life from which these efforts emerged and on which they were focused) had become far too unwieldy to be managed by mere doing, by direct action, or even through the delegation of 'doing' to an army of underlings kept in step by executive order. (1995, 85–86)

Setting aside the 'corporate' and 'electronic', Keller's proposition that military life had, at least for this cabal of scientists, necessitated a new mode of technical management that exceeded the capability of 'mere doing' in its various forms is worth closer examination. The theme that the world had become unmanageably complex was a recurrent one in this sphere of discourse, and frequently used to justify highly experimental and costly research and development programmes in defence computing. However, the matter of what implications this push to systematise and computerise held for the ‘underlings kept in step by executive order’ is not examined in detail here. Indeed, in many accounts of Cold War technoscience which deploy cybernetics as a unifying descriptor often miss out on how this discourse was also explicitly engaged with the management of the more perfunctory, recessive, day-to-day administration of systems that, due to the particular type of tasks involved, *necessarily* had to be carried out by the human operator. This analysis is beyond the respective purviews of both Mirowski and Keller. However, a more rounded sense of the mutual shaping of cybernetics and management requires an inquiry into how this discourse shaped the grey dimensions of command and control systems, and in particular, the figure of the human operator.

Wiener and Bigelow’s experiments with their prototypical AA Predictor in the early 1940s is not the only possible point of inception for this purported ‘era’ of science and engineering. Others locate the kernel of Cold War rationality external to the realm of ‘cybernetics’. David Mindell (2002) shows how many of the core concepts associated with Wiener’s work in the 1940s had already been examined in this grey areas between commercial enterprises, research institutions, and academic centres before the war. Mindell describes how anti-aircraft guns, developed entirely separately but in parallel to Wiener’s experiments with Julian Bigelow, exemplify the central concepts of cybernetics before Wiener formally and publicly proclaimed it as a discipline in his defining 1948 book (2002, 232). Furthermore, the emergence of such technologies and indeed cybernetics itself should be understood not purely as a response to technical demands, but in relation to the organisational management of wartime defence research. Vannevar Bush’s restructuring of the National Defense Research Committee (NDRC) in the early

1940s, facilitating cross-disciplinary project-based work, is credited in part with facilitating invention and experimentation in the domain of control technologies.

Other scholars locate key elements of the discourse of Cold War defence research in a broader historical timeline. Both Johnston (1999) writing on 'machinic vision' and Bousquet (2018) on military perception, for instance, invoke Virilio's (2009) impressionistic history of modern technologies of war as being first and foremost occupied with the 'logistics of perception'. In adopting this analytic lens, Virilio produces an account of military technoscience that emphasises how 'the history of battle is the history of radically changing fields of perception' (2009, 10). Virilio's account, and by extension those of Johnston and Bousquet which heavily draw on it, raises the question of who—or indeed *what*—is doing the perceiving, and how this is encoded and standardised as operational practice.

However, although such inquiries draw on archival 'grey media' to varying extents, they don't conceptualise this domain of discourse as a significant element of the command and control system in itself. I propose that, should we wish to understand the ways in which relations between operators, machines, and the 'enemy other' are institutionally configured, we must look beyond the technical inscription of information flows to take into account the less spectacular but nevertheless significant practices of management in command and control systems. In such contexts, information management can be understood to encompass not just the real-time communications between the battlefield and the war room, but the myriad streams of internal documentation produced by and about these systems.

The administrative practices, systems, and technologies devised throughout the 19th and early 20th centuries to manage the proliferation of paperwork, and indeed those individuals who were the subjects of the paperwork, have been discussed in the work of JoAnn Yates (1990), Lisa Gitelman (2014), and Ben Kafka (2012). Yates' *Control Through Communication* is a particularly insightful resource that explains the ways in new communications technologies emerged in response to, and also proceeded to shape, management in American manufacturing and railroad firms at the turn of the 20th century. While she points out that some pivotal communications technologies were available long before their eventual application to corporate workplace management, other technologies such as carbon paper acted as 'facilitators, enablers, and encouragers of information flow' (1990, 22). As envisaged here in accounts such as Yates, information in relation to a socially constructed managerial problem—larger organisations, faster production rates and delivery speeds—to be solved by new practices and technologies.

The sphere of defence research as it pertained to command and control systems is quite obviously beyond the purview of these works. Nevertheless, in emphasising how forms of institutional discourse are bureaucratically structured to play into established managerial practices, these accounts pose questions that highlight the relations between industrial, academic, and military approaches to 'management' and 'control'. Seb Franklin (2015) locates what is often framed as a distinctly 'cybernetic' logic of control in much more diffuse practices, some exemplars of which can be found in the writings of industrial capitalists and bureaucrats in the late-19th century. Cybernetics is not seen as a clear moment of inception for a new 'cultural logic', but one element in a coalescence of practices, concepts, and imperatives with deeper roots in scientific management, census tabulation, Babbage's writing on the division of labour and industrial automation. The effect, Franklin proposes, is a 'cultural logic' of 'digitality': a set of processes which 'promise to make the world legible, recordable, and knowable via particular numeric and linguistic constructs' (2015, xix). These processes necessarily involve 'filtering'—the assignment of digital values to specific worldly phenomena and therefore making them 'computable', while excluding others. Control is both inscribed in technical artefacts as well as constructed through technical practices: what counts as 'information', and what can be structured as data, is key.

The core imperative of Franklin's study—charting the tensions between 'digital-symbolic representations of the social' and the 'continuous, rich and multiple experience of actual social existence'—helps to clarify the particular conceptualisations of the human subject which arise within this cultural logic of digitality. The capacity for institutions such as RAND to authenticate such conceptualisations, and in so doing, normalise the idea that 'information' is a worldly resource that can be readily extracted with sufficiently 'advanced' computer systems, is a key element in his account. Jon Agar's *The Government Machine*, which examines the introduction of computers to the British civil service, introduces the problem of writing histories of technology with regard to how we think of 'information'. Calling for the term 'information' to be treated 'sensitively', Agar (2003, 13) emphasises that it should not be separated from its 'techniques' and without regard for the institutions—he refers its regulatory and social functions—which delimit what counts as 'information'. In other words, in writing the history of the computer in relation to governmental bureaucracy, he aims 'not to reify and essentialise information' but frame it 'in context' (Agar 2003, 13).

The social construction of 'information', its disciplinary associations, and the extent to which the late-20th century can be described as the 'information age' has been widely discussed in histories of computing. Ronald Day (2014, 2) for instance argues that the notion of an 'information age' is a recurring 'futurological trope used for professional self-advancement', one that has risen to prominence in discourses of European documents management in the 1930s, post-war cybernetics in the United States, and more recently alongside the world wide web. What is especially useful in Day's account is the discussion of information in terms of its institutional functions and supports and the kinds of theorisations about the world which it affords (2014, 25–28). In short, it fundamentally concerns the control of a technical model of the world constituted as information. For Day, the implications of distinctly cybernetic concepts such as command and control are imbricated with grander humanistic concerns:

> 'Command and control' are socially prescriptive as well as scientifically descriptive terms in cybernetics, and the 'science' of cybernetics cannot be separated from the politics of 'man' in Western culture. (2014, 50)

Ronald Kline's *The Cybernetics Moment* (2015) asks similar questions of how 'information' came to serve as a defining concept in post-Second World War American culture. While utopian notions of an 'information age' and the revolutionary force of the computer abounded in the popular imaginary of the Cold War, diverse definitions of information also proliferated (2015, 112). Kline examines these shifting, emergent meanings within this purportedly distinct 'age' by constructing an 'intellectual and cultural history' of what he calls 'information discourses' (2015, 5). For him, enduring themes in these discourses include the analogies between computers and the human brain; the use of 'feedback' as an explicatory tool for complex worldly phenomena across the sciences; and the abundant academic and journalistic speculations on how the computer might transform work through automation. Kline is primarily interested in the 'public' emergence and effects of this discourse, and as such, he examines formally published material, including journalistic profiles and articles, academic journals, and published works by key 'cybernetic' thinkers. There is far less discussion afforded to the ways in which these discourses circulated internally within and between civilian and military institutions, however: the extent to which discursive formulations of humans as machines—and indeed, machines as humans—permeated in corporate, factory, and military contexts through instructional forms of media such as manuals, reports, and regulatory documents goes unexamined here.

Kline and Day's respective accounts of cybernetics and information complicate singular definitions of these terms, and reveal their historical military-industrial-academic contingencies and valencies. Cybernetic concepts, however, can also be used as historical lenses to survey longer histories of war and technology, as De-

Landa proposes. In his book *War in the Age of Intelligent Machines*, DeLanda's account is built on the curious rhetorical position of what he calls the 'robot historian', a perspective which foregrounds the role of 'thresholds in the development of technology' (1991, 7). He writes:

> While a human historian might try to understand the way people assembled clockworks, motors and other physical contraptions, a robot historian would likely place a stronger emphasis on the way these machines affected human evolution. (1991, 3)

The military is conceptualised by DeLanda as a 'higher-level machine', one 'that actually integrates men, tools and weapons as if they were no more than the machine's components' (1991, 4). For him, the imperatives of command and control have a longer history that stretches back long before the development of the digital computer or indeed Wienerian cybernetics. However, DeLanda also argues against the idea that the development of networked and computerised command and control systems have led to any substantive 'improvements' in the strategic management of war. While he offers a wide-ranging history that provides evidence of the relations between 18th century military thought on logistics and wargaming with the post-war emergence of command and control, he does so by appropriating many of the metaphors which defined post-war thought in game theory, cybernetics, and operations research. For instance, DeLanda describes arms races in terms of 'feedback loops' (1991, 63) command as the management of information (1991, 72), and tactical units 'as an information-processing machine' (1991, 59).

Adopting such terms as descriptors is a very deliberate rhetorical position, intended to redeploy 'cybernetic' terms as instruments of critique in order to map out the 'machinic' relations which he sees as being formative in modern militaries. To refer back to Haraway, to write history in this manner also reifies a militaristic way of 'seeing' and theorising the world, and risks reproducing the logic of this discourse rather than showing the rules of formation which underpin it.

These histories of information and cybernetics, whether as a very public postwar discourse or as longer standing features of military thought, probe the role played by greyer discursive forms in cultivating and scaffolding ‘logics’ of operational coherency, human-machine communication, and problems of military strategy. Further inquiry is required into how such resonances are recorded and explicated in the administrative documents which nevertheless proliferate in computational systems in spite of their intended automative capacities. The tensions between digital representations and lived experience at the core of Franklin’s text provide a template here for a set of tensions in the study of command and control systems: from their operational logic as rendered in information-flow diagrams to the types of contingencies and incompatibilities which tend to arise in institutional bureaucracies; and from the abstractions of the battlefield produced by command and control systems to the granular interpretive work that filters real-world events and actions to produce quantitative, computable data.

The design and management of Cold War command and control systems provides rich material for the development of case studies. Part of what is at stake in such enquiries is the problem of how power is codified in systems, not only in the relations imposed through their technical design, but in the discourses which surround their operational use. In this sense, both James William Gibson’s Technowar (2000) and Edwards’ *Closed World* mentioned above can be considered closest in theoretical scope and intent to my research project. Gibson writes:

> It is best, then, not to think of a political and economic power structures making decisions about Vietnam and intellectual knowledge about the war as two separate categories, but instead to approach the search for war in terms of how power and knowledge operate together at a deep structural level of logic. (2000, 11)

Gibson conducts his examination through by situating US strategy in Vietnam in relation to the logic of ‘technowar’—that is, the inextricability of military power from technocratic and scientific knowledge, and vice versa. This logic is surmised by Gibson as the effect of an understanding of war in which 'machine system meets machine system and the and the largest, fastest, most technologically advanced system will win. Any other outcome is unthinkable' (2000, 23).

One base on which we might develop a critique of the quantitative logic of technowar and the enclosures of 'cyborg discourse' is to focus on the various 'supports' which permit such machine systems to persist in one form or another. In doing so, a challenge to the ways in which the notion of a 'machine system' conjures images of autonomous and automatic decision-making systems run by supercomputers, eliding the often ambiguous but nevertheless vital roles played by humans, can be constructed. As Elish (2017, 1104) notes, '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'. In her account of IGLOO WHITE, the system is presented as emblematic of the rift between notions of an 'automated battlefield', and the covert proliferation of operational work carried out by humans in remote command and control rooms (2017, 1107). Elish's account of IGLOO WHITE places it within a series of developments of military technologies that dislocate the human operator from the physical terrain of the battlefield. In this sense, it fits into the prevalent strand of contemporary 'critical military studies' scholarship which seeks to find in the Cold War a set of provenances for contemporary 'drone' and 'networked' forms of warfare. While Bousquet (2008), Bishop (2015), and Shaw (2016a) identify IGLOO WHITE as a schematic form of the contemporary development of autonomous weapons systems, they are less attuned to the way operational contingencies and resistances complicate notions of 'automation' in human-machine systems.

In *Closed World* (1997)—a key reference point for this research project—Paul N. Edwards presents an account of the technopolitics of computing in the United States, focusing once again on the various think tanks, commercial computing companies, and academic institutions which shaped American society between 1945 to the 1990s. He deploys two analytics to do so: firstly, 'closed world discourse', which amounts to a 'language, world view, and set of practices' inflected by a fusion of the mathematical and the militaristic via the systematic modelling of the world (1997, 15); and secondly, 'cyborg discourse'—that is, the 'field of techniques, language, and practice in which minds are constructed as natural-technical objects [...] through the metaphor of computing' (1997, 21). As he explains in the introduction to the book, a Foucauldian understanding of discourse as materially contingent and power as 'relational' and 'productive' is central to his inquiry (1997, 40).

> Discourses 'create and structure experience', he writes, they should be understood as a collection of fragments grouped and interconnected around a 'support'. The support is the object at once studied and invented by the discourse that surrounds it. (1997, 38)

Edwards' concept of 'closed world discourse' aids his analysis of the totalising rationality of systems-thinking which fundamentally shaped defence research and development throughout the Cold War. The windowless architectures of the command and control rooms of both SAGE and IGLOO WHITE are exemplary of this: events of the external world were entirely mediated by information flows between remote electronic sensors and centralised computer systems. Consequently, the images of the battlefield produced in such environments were filtered through computational processes, privileging and reinforcing a quantitative worldview while eliding that which is not readily 'measurable' or deemed strategically irrelevant.

Matters of 'measurability' link these fields of literature—specifically, how rationalities, technical devices, and assemblages coalesce to delimit what should be measured and facilitate what is to be done with the resultant information. In the context of military command and control systems, such issues are drawn into sharp focus. Edwards' (1997) history of Cold War technopolitics is an exemplary text that highlights the relations between systems, enclosures, and knowledge in cyborg discourse. What is missing from Edwards' text, and this domain of literature more broadly, is an interrogation on the function of 'grey media' and the role it plays in shaping and describing the role of the 'operator' in such systems. Grey media, examined for its aesthetic and discursive qualities rather than drawn upon as primary records on which to develop a historical account of a system, provides a perspective on the development of command and control systems which foregrounds their deeply institutional, bureaucratic dimensions. The resultant vision of the system then is not limited to the configurations of humans and machines, but the broader arrays of administrative processes which shape their continued elaboration.

## 2.5 Conclusion

The problem of the production and management of information opens up a key line of enquiry that goes underexamined in this literature: the tensions between the diagrammatic functionality—that is, the 'operational logic'—of a human-machine system and range of administrative procedures such systems accrue to support this functionality. Rather than focus on the ways in which these systems might represent the successive 'automation' of war as in the literature discussed above, the central aim here is to look for the manual residues which persisted in spite of this effort to automate. With regard to SAGE, a substantial proportion of this concerned the preparation, management, and analysis of training simulations designed to prepare operators to act cohesively in an anticipated nuclear war scenario. In IGLOO WHITE, we encounter these residual manual practices in the techniques through which 'information' had to be interpreted, structured, and assessed in order to be made pliable to the demands of computation. A command and control system is an intensely institutionalised space, where relations between humans and machines are inscribed in myriad administrative documents such as regulations, manuals, and orders, and documented extensively in internal reports, memoranda, studies, and working papers: an attunement to the contradictions present across this field of documentation opens up a space to examine these ruptures between operational logics and administrative practices, instruments and individuals, contingencies and technical elaborations that comprise command and control systems.

Such tensions became imminent and palpable in the material weight of materials encountered in the archival research process. Through an engagement with various archives in the early research phase of this thesis, I was struck by the abundance of *paperwork* that these semi-automatic, digital systems generated. Images of cool, darkened rooms staffed by operators sat at banks of computer terminals that are continuously presented in accounts by Edwards, DeLanda, Virilio, and others seemed at odds with the unwieldy administrative procedures and inquiries inscribed in this bureaucratic material. If we are to understand a command and control system not just by the human-machine relations, but additionally take in the institutional dimensions of such information systems, we gain a much more complicated account of the role of the 'operator'. To 'operate' within a command and control system is not just to manipulate a computer terminal, but to carry out some role in the 'system' that makes its functioning possible—including filling out reports, interpreting a table of data, assigning to events and conditions a quantitative and computable value, transcribing spoken words, or correctly filing away a document. In order to fully grasp how digital, networked technologies have reshaped the field of possibility in war, foregrounding the grey, recessive role played by the human operator is crucial.

Of particular interest are the ways in which these institutional documents describe and theorise the discursive propensities of defence researchers, map and group their interdisciplinary practices, and explicate the relations between discourse, practice, and computer technologies. While much of the above literature share case studies (SAGE, in particular), protagonists (Wiener and John von Neumann, for instance), and theories (of reason and rationality), they vary in the extent to which they problematise prominent concepts such as 'information', or attend to the heterogeneity of 'cybernetics'. Furthermore, these texts tend to downplay, and occasionally outright ignore, the more prosaic dimensions of the operation and design of these systems. What has emerged as a principal interest in this research project then are the administrative materials which describe the intended operational practices of these systems, and more specifically, the ways in which the linkages between its human and machine elements are described and, to borrow from Grint (1997), 'configured'. Pushing the Foucauldian notion of discourse as a support further than Edwards does, I have opted to focus on the field of 'grey media' in order to map out how these practices are configured.

The accounts of the Semi-Automatic Ground Environment (SAGE) and IGLOO WHITE discussed here cannot but play into the broader issues and themes raised above, whether the scholar in question does so explicitly, or by taking their theoretical perspective or their data for granted. With this in mind, a critical part of what is at stake in writing the history of defence research projects is not just the (it must be said, nevertheless challenging and worthwhile) task of transcribing events or charting incremental technical developments which comprise large computing projects such as command and control systems., Rather, it can also critically reflect on and foreground the aesthetic and discursive qualities of the very materials—grey and recessive as they may be—which make much of this scholarship possible. A great deal of the literature in the domain of STS has successfully problematised the relations between the human and machine in the design of large computing projects, and help to explain how relations between instruments, individuals, and institutions congeal and cohere. What I propose here, however, is a need for an approach that foregrounds how 'knowledge' is constructed and authenticated through bureaucratic processes, and mapping the individuals and machines understood to be capable of producing it within a particular institutional context. Grey, administrative media provide a rich basis on which to construct this. Paying attention to such materials, in the manner I detail in the following chapter, offers a way of addressing this missing piece in the literature.

# Chapter 3

# Theoretical Framework

## 3.1 Introduction

Command and control systems are prolific generators of documents. They are the subject of almost endless paperwork during the process of their research, development, and deployment. In their live operation, they also generate extraordinary—and as I will argue, often unmanageable—quantities of documents about the battlefield. Conducting close readings of these documents, with a particular focus on 'grey' administrative documentation, allows for an analysis of the ways in which they indicate shifts in configurations of institutional power and knowledge, with implications for what it means to act as an 'operator' within complex, human-machine systems. Of course, documents take multiple forms, and as such, they play diverse roles within institutions. Mapping out the connections between these forms and the roles they play in the elaboration of the operational logic of a system is a central aim of this research project. In this chapter, I draw on Foucault's concept of the regime, a theoretical lens which he used in two notable interviews in the late 1970s, to provide me with a conceptual framework for the kinds of analysis the rest of the thesis engages in. I argue below that the document is not just the by-product of institutional bureaucracy: it is an element that plays an important part in the formation and support of a regime. It is a materialisation of discourse which has the capacity to codify and prescribe terms and practices, to reinforce existing norms and delineate new procedures, and to count as knowledge. This is not necessarily to say that the texts of these documents are representative of the actual day-to-day occurrences within a particular command and control system, or that they provide an unfiltered base on which to construct a history of my case studies. Rather, I argue that they express a set of institutional relations between power and knowledge which had radical implications for the management and planning of strategy and, more broadly, how warfare could be conceptualised in terms of information flows.

This chapter sets out the key analytic concepts which will constitute my theoretical framework. The use of these concepts informed not only how I explored the thematic of command and control systems across their technical and operational dimensions, but they also shaped decisions about the kinds of materials I prioritised in the analysis of my case studies. I have deliberately opted to focus on the discourse of 'grey media'—that is, the various kinds of technical and administrative documents which arise and proliferate in complex bureaucracies such as the US military. This research project is thus an inquiry into the institutional design and operations of command and control: the primary aim is not to provide a factual history that aims to correct understandings of my case studies which may have hitherto been ignored or misrepresented, nor is it to join the array internal military histories which attempt to determine whether these command and control systems can be considered strategically 'successful'. Indeed, as I discuss later, Foucault's approach to writing history runs counter to such imperatives. The focus of this research project is situated on the level of the fields of discourse through which command and control systems are shaped and elaborated. In order to do so, I engage with the specificity of what is said in the myriad administrative and technical documents produced during the planning and in the daily operation of command and control systems.

The discussion below is divided into four interrelated sections, each of which details a key theoretical concept and how it helps me to address the concerns of this research project. I begin with a discussion of the concept of the 'regime'. The concept of the regime—referred to as the 'regime of practices'—helps to bind two aspects of this research project: the ways in which discourses become institutionally codified, and the interrelations between power and knowledge. I then discuss how conceptualising power as relational, productive, and immanent to society has shaped the development of my inquiry. The third section provides an account of Foucault's 'archaeological' work, explaining how the functions and unities of discourse which he proposed in his book *The Archaeology of Knowledge* have shaped my analysis of the discourse of Cold War 'defence research'. In the final section, I explain the theoretical implications and imperatives of basing the analysis of my case studies on 'grey media' and an understanding of the document as an element within a regime.

## 3.2 Regimes and History

The question of how specific institutional practices arise at a given moment, what they arise in response to, and the subsequent elaborations which they undergo is central to Foucault's historical analyses. An insightful point of departure for developing an understanding of its function in his work is a roundtable discussion from 1978, published as 'Questions of Method'. In response to a comment made by his interviewers about his work, he offers a lengthy explanation that details how his analysis of institutions is organised around an effort to chart the relations between practices (encompassing the said and the unsaid), and power and knowledge. In a key passage, he remarks that guiding his analysis of institutions

> is a question of analysing a 'regime of practices'—practices being understood here as places where what is said and what is done, rules imposed and reasons given, the planned and the taken-for-granted meet and interconnect. To analyse 'regimes of practices' means to analyse programs of conduct that have both prescriptive effects regarding what is to be done (effects of 'jurisdiction') and codifying effects regarding what is to the known (effects of 'veridiction'). (Foucault 2002a, 225)

This short extract sketches out an array of themes and issues which feature centrally throughout Foucault's thought: the 'regimes' which delineate action, the notion of 'conduct', and the factors which shape fields of possibility and the 'taken-for-granted' in discourse all arise in various forms and implications in his archaeological work from the early 1960s to his genealogies of the late 1970s and early 1980s. Although forging a meticulous, systematic account of the interplay between these concepts as they are deployed in his lectures, interviews and books, is a rather complex and elusive endeavour and beyond the scope of this chapter, the concept of the regime helps me to apply a power/knowledge analytic to identify the emergence and regularities of institutional discourses. As a key aim of this project is to explicate the characteristics of and interrelations between the discourses of defence research, the imperatives of military strategy, and the operational practices of command and control, Foucault's concept of the regime acts as a useful rubric to examine how these links are inscribed in the grey, institutional documentation of these systems.

This concept of the regime also arises in a second interview from the late 1970s, which further clarifies what is at stake in this term for Foucault and how it has informed my theoretical framework. In this text, published under the title *Truth and Power*, Foucault discusses 'the regime of truth'. This evokes the 'regime of practices' in that it focuses on the interplay of institutional statuses, practices, conditions which make support the production and formulation of knowledge. He writes:

> Each society has its regime of truth, its 'general politics' of truth: that is, the types of discourse which it accepts and makes function as true; the mechanisms and instances which enable one to distinguish true and false statements, the means by which each is sanctioned; the techniques and procedures accorded value in the acquisition of truth; the status of those who are charged with saying what counts as true. (Foucault 1980, 131)

The distinctive theoretical standpoint here is that the analysis is focused on the level of the conditions of possibility for forms of knowledge. For Foucault, the effort then is to chart the constitution of specific discourses as knowledge through their enmeshment in a broader set of established elements, which to give a non-exhaustive list, might include practices, technical instruments, models, formal methodologies, spaces, and figures who have an institutional status. As he describes it above, these elements have the capacity to 'sanction' propositions, delimiting the extent to which they can be accepted, mobilised, and taken for granted as true within—and perhaps beyond—their associated institutional context.

Within the sphere of defence research, that which is taken for granted directly implicates the individuals which this discourse simultaneously targets and erases.

Foucault's relational analytic assists in identifying and isolating the constitutive elements in a discourse which authorise and normalise specific 'realities' and 'regimes'. In his work, Foucault tends to describe discourses in topological terms—for instance as 'grids', 'fields', and 'systems of dispersion'. By mapping out discourse in terms of its adjacencies, overlaps, resonances, and disparities with other contemporaneous instituted practices and environments, his inquiry involves the broader conditions and supports which contribute to a regime of truth emerging at a given moment, and which allow it to be taken for granted as reasonable, self-evident, and legitimate. Crucially, a discourse is not understood to exist in isolation, but in relation to a range of other elements which variously are in a process of instantiation, elaboration, or descent. To examine these conditions of possibility of a discourse, Foucault examines the tensions between rising, coexisting, and obsolescing regimes, their corresponding institutional environments, and the discontinuities that exist between them over time. An inquiry conducted on this basis is what Foucault calls 'effective history' (Foucault 1984).

A crucial quality of 'effective history' is that it problematises the position of the historian within their own domain of knowledge. Contemporary writing on the Cold War tends to reinforce groups of sciences in accordance with a purportedly 'common' rationality while underemphasising the heterogeneities of their moments of inception, imperatives of elaboration, and their constitutive technical practices. 'Effective history' acts as a position from which to interrogate these purported commonalities by identifying the disparities and overlaps between them, and the mechanisms which underpin and scaffold the kinds of knowledge they were seen to be capable of producing. To reframe this in the terms discussed earlier, it is what we might understand as the analysis of 'regimes'.

The outbreak of war in Korea, the event which for the Americans is known as the 'loss of China', and the end of the Truman Administration all feature as prominent 'events' in the history of 1950s air defence in the United States. In this case study however, I avoid focusing on the broader series of events which narrativise the burgeoning 'Cold War' between the two superpowers. In arguing that SAGE represented a technological and strategic moment of reconfiguration in the realm of air defence, I focus instead on the greyer technical and administrative field of discourses through which this reconfiguration was negotiated and materially advanced. In doing so, I seek to identify and analyse a regime of practices, a constellation of instituted frameworks and discourses which are productive of a 'general politics of truth'. The case study of continental air defence in the 1950s focuses on the emergence of 'human factors' research which aimed to quantify the operator as an element of complex human-machine systems. The 'electronic barrier' case study similarly does not include a timeline of the distinct moments which comprise typical narratives of American involvement in Vietnam. It begins instead by focusing on the practice of photographic interpretation and intelligence construction with respect to its formal, instituted discourse—the terms, the procedures, and the technical apparatuses involved. From this point, I explain how various components in this chain of intelligence construction were subsequently automated to address contingencies and uncertainties. The focal points for analysis then are these moments of reconfiguration—what Foucault commonly refers to as 'irruptions'—in order to examine the conditions that give rise to them. This theoretical perspective thus alters the level of analysis, shifting it away from the causal distribution of events over time and the various periodisations which are entrenched in the existing historical scholarship, and reorienting it around reconfigurations of power and knowledge in specific institutional discourses.

My inquiry is based on a conceptualisation of command and control system that is divorced from its purely instrumental, military definition. Command and control is not *just* an arrangement of individuals and machines occupied in the task of coordinating the allocation of military weapons and resources; it exists within a complex of discourses, knowledge practices, institutional sites, hierarchies—in short, it emerges out of and in response to existing regimes in the sciences and the military. Conducting historical research organised around the analysis of the rise and qualities of a distinctive 'regime', with its associated 'programs of conduct' and 'general politics of truth', thus draws into the foreground the question of how power functions in mutual support with knowledge. What Foucault calls 'veridiction' and 'jurisdiction', or respectively the effects which delimit what can be known and what is to be done, are both thoroughly interconnected with this question. This analytic thus also raises the problem of what regimes respond to, the heterogeneous factors which play into their elaboration, and the specific constitutive practices which, within the sphere of their 'general politics of truth', are understood to be capable of producing knowledge claims that can be taken for granted.

## 3.3 Power and Knowledge

Before discussing Foucault's concept of power/knowledge and how it functions as an analytic in this research project, it is useful to clarify his distinctive theory of 'power' as it is deployed throughout his work and incorporated into my theoretical framework. Firstly, power is not an external 'supplementary structure' that is imposed from 'over and above' society (Foucault 2002a, 323). Instead, it is immanent to and co-extensive with society: 'It seems to me that power *is* "always already there", that one is never "outside" it, that there are no "margins" for those who break with the system to gambol in' (Foucault 1980, 141). Secondly, power is not simply repressive and prohibitive; it is also productive: 'power would be a fragile thing if its only function were to repress, if it worked only through the mode of censorship, exclusion, blockage and repression' (1980, 59). Finally, power is not something that is possessed and wielded over others; rather, it exists through relations. In a succinct summary of Foucault's unique theory of power, Dreyfus and Rabinow (2016, 117) write:

> Foucault shows us a radically new interpretation of both power and knowledge: one that does not see power as a possession that one group holds and another lacks; one that does not see knowledge as objective or subjective, but as a central component in the historical transformation of various regimes of power and truth.

Foucault describes this understanding of power in the important essay 'Subject and Power' in multiple phrases which emphasise its relational qualities. He describes power as 'action on others' actions' (Foucault 2002a, 340); he states to express power as a form of governmentality is to structure the field of possibility (2002a, 341); he refers to it as 'the conduct of conducts' and the 'management of possibilities' (Foucault 2002a, 341).

The word ‘conduct’ is of special significance in Foucault’s thought. As with ‘regime’, it is a word that recurrently arises across his lectures, books, and interviews. The connotations of this word are unpacked in his 1978-79 lecture series *Security, Territory, Population*:

> Conduct is the activity of conducting (*conduire*), of conduction (*la conduction*) if you like, but it is equally the way in which one conducts oneself (*se conduit*), lets oneself be conducted (*se laisse conduire*), is conducted (*est conduit*), and finally, in which one behaves (*se comptorter*) as an effect of a form of conduct (*une conduite*) as the action of conducting or conduction (*conduction*). (Foucault 2007, 193)

This understanding of conduct opens up an analysis of the scope of managerial activities which encompass command and control. These systems have ‘programs of conduct’ in their design: they anticipate particular modes of use, they presuppose a specific characterisation of war and strategy, and they are predicated on a model of interaction between the human operator and the computer. Power then is not held by the Commander and imposed unidirectionally on subordinates, nor is it possessed by the defence researchers without resistance to those operators who act as ‘elements’ in these command and control systems. It is expressed through the formal institutional relations between individuals, in the technical protocols between subsystems and between instruments and their operators, and the standardised technical discourses that prescribe and designate system functions.

Understanding power as relational and thoroughly imbricated with the conditions through which knowledge is produced and valorised in a given institutional context directs my analysis towards the study of documents as discursive conduits which express, articulate, and prescribe practices of command and control. The intention is to interrogate how these instituted operational practices, and the design of the systems themselves, are set out in the various forms of ‘grey media’ which describe their planning and functioning. Of course, this is not to suggest that the documents offer a clear picture that represents the day-to-day operations of command and control as they really were. It opens a possibility to envision them as elements of a regime of practices, and more specifically, to examine how they express the modalities that sanction statements and delineate the techniques and procedures that define the operational limits of command and control—that is, the boundaries which circumscribe what can be sensed, processed, and targeted by the system.

It is the qualities of and relations between these practices that are central to my analysis of the forms of knowledge which made command and control systems not only possible, but also appear to be strategically and politically indispensable. Part of the analysis centres on the terms in which this purported 'need' to systematise operations was explained by the proponents of these enormous, experimental, and rather risky research programmes.

Foucault clearly states in a number of key texts that the production of knowledge and the circulation of power are mutually enmeshed: 'There can be no exercise of power without a certain economy of discourses of truth which operates through and on the basis of this association' (Foucault 1980, 93); 'It is not possible for power to be exercised without knowledge, it is impossible for knowledge not to engender power' (1980, 52). Adopting this analytic approach in this research project marks a distinction from the prevailing approaches in scholarship on the history of Cold War technoscience: the focal point is the way in which the tensions between 'information' generated and processed by systems and the forms of expert 'knowledge' that direct and evaluate their functioning are resolved through the codification of discursive practices. In each case study, human factors engineering and systems analysis respectively both contributed to this epistemic scaffolding, whereby a strategic knowledge of the battlefield arose through the elaboration of quantitative lenses and thresholds for what counted as 'true'. The training and evaluation of US air defence in the 1950s involved a set of instituted techniques thought capable of measuring the organisational coherence of a human-machine system in part through an analysis of the frequency and 'types' of speech uttered by the crew members. In the case of the anti-infiltration programme in Vietnam, the thresholds of 'evidence' for convoy traffic were largely predicated on relations between the manual analysis and interpretation of individual aerial photographs and sensor data, and in broader aggregation, the intuitive style and quantitative techniques of systems analysis.

Foucault's preoccupation with power puts the political constitution of these systems firmly in the foreground: it identifies the various technical and procedural supports which legitimise and sanction propositions. This attunement to how a procedure, incorporating actions of both humans and machines, can be institutionally understood as capable of being productive of 'knowledge' is at the foreground of my account of the Systems Research Laboratory (SRL) and also the functioning of the 'electronic barrier'. Part of the discussion in my case studies thus concerns how defence researchers frequently drew on more established, institutionalised knowledge practices in order to assert, describe, and justify their propositions, even while acknowledging that their data was partial, speculative, or predicated on subjects that happened to be readily-available and amenable to quantification. The examination of human-machine organisations as 'organisms' at the SRL, for instance, exemplifies this. When it comes to the analysis of a key proposition in the elaboration of a command and control system, such an approach facilitates an alertness to how elements of scientific discourse function in combination with more speculative modes of inquiry to validate and authenticate certain knowledge practices, and to produce their corresponding cohorts of experts.

The adoption of a power/knowledge analytic grounded in the specificity of discourse, focusing on precisely *how* command and control systems are described and documented, has fundamentally informed the structure of discussion in my case studies. Each section is anchored in the examination of a particular 'grey' document and its constitutive array of statements, which are then situated in a wider formation present in other documents thematically, technically, or organisationally associated with them. In contrast to Edwards (1997) and Gibson (2000), the analysis carried out in the case study chapters here is much more tightly structured around an examination of specific documents produced in the planning or daily operation of the systems. The decision to primarily focus on these instances of 'grey media' drawn from the archives allows for this granular examination of these 'acts of formulation', or in other words, precisely *how* things were said. What becomes important then, for instance, are the choice of metaphors used by scientists to explain the strategic problem pertinent to the system, the diagrams which visually prescribe the operational logic of a system, the data structure codified in a table intended to convey 'progress' in a campaign, or the protocols which the human operators of a command and control system were instructed to act in accordance with.

## 3.4 Statements and Discursive Formations

The core imperative of Foucault's works of the 1960s is the charting of 'systems of knowledge' in the human sciences and their process of codification in institutional discourse. In *The Order of Things* (2001b) for instance, Foucault rejects the typical periodisations and structures established in histories of reason in the human sciences, instead proposing a radical alternative to mapping out their organisation based around the 'functions' and 'unities' of scientific discourse. On numerous occasions, Foucault asserts that this is not an effort in retrieving some latent, hitherto unseen rationality that explains this organisation in its entirety, but of probing the conditions which made them possible and the precise terms in which they are expressed, and identifying the ways specific knowledge practices within this domain exist in support and conflict with one another at defined historical moments. As he writes in the preface, he is interested in inquiring into the ‘modalities of order’ which permit the creation of a ‘positive basis of knowledge’ across the human sciences, and to ‘rediscover on what basis knowledge and theory became possible’ (2001b, xxiii). Foucault’s elements of discourse cannot be neatly superimposed onto grammatical, authorial, or disciplinary groupings of knowledge. These elements—the statement, the discursive formation, and the episteme—serve as the central operators within this topological survey of discourse, whereby what is said is situated along and within ‘distributions’, ‘systems of dispersion’, ‘fields’, ‘surfaces’, ‘grids’, ‘planes’, ‘spaces’, and ‘proximities and distances’. As with power/knowledge, this approach to discourse analysis focuses on its relational functioning within historical junctures and institutionally delimited spaces.

In *The Archaeology of Knowledge*, a schematic definition of exactly what constitutes a statement is only constructed after an extended, exploratory discussion. ‘One should not be surprised’, Foucault writes, ‘if one has failed to find structural criteria of unity for the statement: this is because it is not in itself a unit, but a function that cuts across a domain of structures and possible unities’ (2002b, 97–98). Foucault firstly outlines his understanding of what constitutes a ‘statement’ in terms of what it is not: we learn that it is not simply a proposition, nor is it a sentence, nor an ‘act of formulation’. He provides the example of the letters on his typewriter: while he says that the typewriter’s keyboard is not a statement in itself, the sequence of letters ‘A,Z,E,R,T’, when listed in the typewriter’s manual, constitute ‘the statement of the alphabetical order adopted by French typewriters’ (2002b, 96). The latter example is positioned within an established, instituted order embedded in the history of the operation of the typewriter; that it arises in a manual is also pertinent, as the manual is a didactic genre of document, produced to prescribe and codify. In this sense, it is exemplary of ‘grey media’. The question of power here, although not explicit in *The Archaeology of Knowledge*, is thus central to the function of a statement. Gilles Deleuze, writing on Foucault’s proposed units and unities of discourse, retrieves the immanent power relations and immanent order in the rules which govern the appearance of statements with regard to the example of the typewriter:

> […] AZERT, on the keyboard, represents the focal point of power or of power-relations between the letters of the French alphabet, depending on which one crops up, and the typist's fingers, depending on which one is used. (Deleuze 2006, 12)

In the interview 'Truth and Power' referenced earlier, Foucault retrospectively framed the mode of historical analysis which defined his archaeological work throughout the 1960s as an effort to describe the regimes of truth which circulated in the human sciences in the 18th and 19th centuries. The pivotal works in this era of Foucault's thought are *Madness and Civilisation* (2001a), *Birth of the Clinic* (2003), and *The Order of Things* (2001b), with the form of discourse analysis deployed in them becoming the subject of elaboration and critique in *The Archaeology of Knowledge* (2002b). When his interviewers suggest that the 'question of power' and its discursive function were novel characteristics of Foucault's method in these works, Foucault responds by emphasising his surprise at its absence from the texts: 'I'm struck by the difficulty I had in formulating it', he states, 'what else could I have been talking about […] but power?' (1980, 115). As his subsequent books, lecture courses, and interviews make abundantly clear, for Foucault the examination of configurations of power involves the interrogation of its techniques, functions, relays, and supports—or as he succinctly describes it in *Discipline and Punish*, its 'microphysics' within specific institutional contexts (1991, 26).

I will return to the connections between different types of documents and the statements they contain in a later section in this chapter; for now, though, what is important is that the statement holds a status within a broader 'system' or 'order' of discourse. Foucault states: 'we must not seek in the statement a unit that is either long or short, strongly and weakly structured, but one that is caught up, like the others, in a logical, grammatical, locutory nexus' (2002b, 97). In this sense, the constitution of a statement is not a question of 'what', but of 'when'; it is by encountering it as an element in a broader configuration—within a 'general politics of truth'—that it functions as a statement. The statement can be identified, either by 'intuition or analysis', by focusing on its 'enunciative function', or in other words, the way in which it is expressed as authoritative in a particular discursive context. In short, it is inextricably contingent on its relations with the systems of knowledge to which it refers.

The organising imperative of his archaeological work of the 1960s concerns the 'systems of dispersion', or the 'rules' which describe the function of these statements. These systems are 'discursive formations' (2002b, 41). He seeks to analyse them in terms of how it might be possible to discern 'an order in their successive appearance, correlations in their simultaneity, assignable positions in a common space, a reciprocal functioning, linked and hierarchised transformations' (Foucault 2002b, 41). He writes:

> To undertake a history of the sciences at this level is not to describe discursive formations without regard to epistemological structures; it is to show how the establishment of a science, and perhaps its transition to formalisation, have come about in a discursive formation, and in modifications to its positivity. (2002b, 210)

Discursive formations thus cut across established orders predicated on common object, thematic, style, and logic; they are not confined within the disciplinary bounds of discrete knowledge practices. In this way, they help to identify the configurations of power and knowledge within this discursive space. The function of statements, their rules of formation, and their collective systems of dispersion can be mapped out in terms of the various supporting elements within a regime, as discussed earlier.

The implication for this research project is that the ways in which the myriad 'sciences' of the Cold War are periodised, delimited, categorised, and seen as mutually integrated can be drawn into question. We can instead examine them in terms of thresholds and relations, by examining discourse in what Deleuze calls a 'transversal or mobile diagonal line' that cuts through the historically-formalised groupings of phenomena and statements (2006, 20). Their distribution transgresses 'disciplinary' silos, a common 'alphabet of notions' or thematic permanencies (Foucault 2002b, 41). The coexistence of discourses at a given moment cannot explain the basis of a discursive formation on its own: 'An "age" does not pre-exist the statements which express it, nor the visibilities which fill it' (Deleuze 2006, 42). In many classic histories of Cold War-era American science and engineering, the considerable heterogeneity of scientific and engineering practices is effaced through their unification on the basis of some purportedly shared overarching rationality. From an archaeological standpoint, we might begin to interrogate the 'rules of formation' of statements in Cold War science, or perhaps go further, and probe the terms on which it is usually thought possible to write of Cold War science as a coherent discursive formation or episteme given its multifariousness.

In their book *How Reason Almost Lost Its Mind*, Erickson et al. (2013) discuss the extent to which a unitary 'Cold War reason' can be said to exist, what its characteristics might be, and its connections with the prevailing contemporaneous political and strategic problems. Given that the period we know as the Cold War comprises myriad phases and events—as I have explained above, 'reversals' and 'reconfigurations' of power and knowledge—the contrasts between the knowledge practices that converged in the effort to construct immense, unprecedented command and control systems are just as important as their regularities. Rather than reduce these practices to a single, explicatory rationality or reason, I opt instead to examine them in terms of their general politics of truth and the practices which sanction and validate statements. The statement and the discursive formation provide me with a theoretical framework for mapping out the terrain of this general politics of truth and the plays of power within it: the former places our attention on examining scientific discourse in terms of how it functions within a constellation of technical instruments, established texts and procedures, and institutions; the discursive formation is characterised by the disposition of this constellation and the distribution of its constituent statements. A discursive formation can thus be understood as a common set of techniques of recording, formulating, and sanctioning that exists across a field of statements.

Hayden White writes:

> for Foucault, the formalised consciousness of an age does not change in response to 'events' occurring in its neighbourhood or in the domains staked out by its various human sciences. On the contrary, events gain the status of 'facts' by virtue of their susceptibility to inclusion within the set of lexical lists and analysis by the syntactical strategies sanctioned by the modes of representation prevailing at a given time and place. (1973, 30)

In the cases of US continental air defence and the 'electronic barrier' respectively, there was a concerted effort on the part of the proponents of 'human factors research' and 'systems analysis' to enframe their practices within the domains and engineering and science. This played out through the schematisation and formalisation of methodologies, the invocation of models and metaphors drawn from other established sciences, and by designing empirical, quantitative experiments based around novel 'scientific' technical devices. The concept of the discursive formation aids in ascertaining the rules, formulations, and practices through which these command and control systems were framed by their proponents as indispensable, and their operational logics presented as strategically legitimate. For example, that the SRL was described by its inaugurators as a 'specialised computer' and their model 'an information processing centre' is important: it resonated with an emerging pattern evident across the programme in which air defence was explicated in terms of a problem of information management. For the defence researchers involved, the logical solution to the problem was a more efficient information-processing system.

The problems with Foucault's archaeological approach have been the subject of critique, including by Foucault himself in the closing chapter of *Archaeology of Knowledge*. This effort to provide a framework while simultaneously negating the possibility of any systematic laws or formal archaeological methodology confines its use as an analytic technique to a limited and perhaps contradictory mode of historical inquiry. In their critique of archaeology, Dreyfus and Rabinow (2016, 83) write:

> Since such a study is situated outside of the serious meaning and truth claims of the sciences studied, it should not claim serious meaning and explanatory power for itself. Rather, to be consistent, it would have to be what Foucault is fond of reminding us it is, nothing more than 'a pure description of the facts of discourse'

As Dreyfus and Rabinow state here, Foucault's archaeological work offers far more than a pure description of the facts of discourse. But this contradiction does not negate its theoretical utility, if deployed with some modification. In the context of this research project, the specific logics—or *counterlogics*—of Foucault's archaeological framework are less important than what the framework allows in the analysis of defence research as a discourse. Read in relation to the concept of the regime in 'Truth and Power' and 'Questions of Method' described earlier, it becomes clearer that the logical, grammatical, and locutory nexus of the statement is thoroughly enmeshed in the interplay of power and knowledge. In this research project, this analysis is conducted on the level of grey media—that is, the forms of literature particular to and structured by the administrative procedures of an institution, such as memoranda, reports, studies, manuals, and briefings. To do so, however, also requires a consideration of how these 'genres' of grey media exist as elements within a configuration of power/knowledge, and how the statement can be adapted as a base for constructing an analysis of this configuration.

## 3.5 Documents and Greyness

In her book *Paper Knowledge* (2014), Lisa Gitelman offers a 'media history of documents' that highlights the role shifting knowledge practices, technologies, and institutional forms play in the production of knowledge and the materiality of documents. Gitelman opens her inquiry with a consideration of the document as constituting a 'genre' of 'epistemic objects' (2014, 1). For her, in the document 'knowing' and 'showing' are mutually entangled: the document is simultaneously a record and a demonstration that something is known (2014, 1–2). Gitelman's 'document' resonates with the Foucauldian notion of the 'regime' discussed earlier. The 'know' and 'show' functions of the document interrelate with the practices which prescribe what is to be done and codify what is to be known. Examined as an element within a regime of practices, the document is a material support of discourse with a distinct politics of its own: it both shapes, and is shaped by, relations between power and knowledge. Grey media is therefore envisaged in this thesis not just as the unimportant by-products of bureaucratic institutions such as the US Air Force and its associated think tanks and research organisations. Rather, grey media have effects that codify and prescribe forms of knowledge and relations of power.

While Gitelman focuses on the politics of paper documentation in her book, she adopts a conceptualisation of the document as a genre that exceeds a precondition of printed matter. Referring to the French librarian and historian Suzanne Briet, Gitelman notes a 'thing' can be a 'document':

> [...] Briet proposed in 1951 that an antelope running wild would not be a document, but an antelope taken into a zoo would be one, presumably because it would then be framed—or reframed—as an example, specimen, or instance. [...] Any object can be a thing, but once it is

> framed as or entered into evidence—once it is mobilised—it becomes a document, an instance proper to that genre (Gitelman 2014, 2–3).

In this thesis, the status of 'document' is understood with regard to its relationship with an instituted regime of practices and its capacity to function as an example, a specimen, an instance, or something which can be mobilised as an evidential support. The antelope in the zoo, as in Briet's example, functions as a subject within the discourse of zoology and a specimen—an exemplary instance of the wild antelope—presented as public spectacle; the group of people trying to plan a birthday party in Robert Freed Bales' laboratory discussed in Chapter 4 become an abstracted instance, a model of a general collective organisation of people trying to complete a shared task. Bales' laboratory was not just a clinical site of examination. Analysing it in terms of the regimes discussed earlier, we can understand it as a configuration of instruments, statuses, and practices of observation which made the complex and emergent behaviour of individuals *knowable* in standardised, quantifiable terms. These 'human interaction systems' (Bales 1950) were structured and made *computable*.

In *The Birth of the Clinic* (Foucault 2003), this capacity for configurations of power/knowledge to confer this status of 'document' onto individuals—what Foucault refers to as a 'case'—is an especially strong theme. Taking the 19th century clinic as his case study, Foucault examines the emergence of what he argues is a new form of institutional discourse organised around examining, treating, and speaking about individuals who suffer with certain diseases. When examined by the 'clinical gaze', the individual was not regarded as a 'patient', as they might be in the hospital for instance. This individual was selected by virtue of the 'instructive quality' of their particular case, their capacity to serve as an exemplar for a particular disease or set of conditions, rather than their need for medical treatment (2003, 70). For Foucault, they were treated as an object on which the 'text' of their disease was inscribed as a set of coded symptoms: they are not 'examined' but ‘deciphered’ (2003, 71–72). In terms which Foucault used in his later work, we can conceptualise this as the individual, through the process of decipherment, becoming the target of a configuration of power and knowledge: the authority of its doctors, within the institutional space of the clinic, to produce an intelligibility, which in turn has the effect of reinforcing the accepted force of this authority and the individual as an object constituted by their ‘case’.

Foucault (1980, 51) asserts: ‘We should not be content to say that power has a need for such-and-such a discovery, such-and-such a form of knowledge, but we should add that the exercise of power itself creates and causes to emerge new bodies of information’. The publication of the *Human Factors Engineering Handbook* detailed meticulously the variety of instruments employed by military psychologists to measure and produce averages of the physical and cognitive characteristics of soldiers—anything from the average length of reach of a cadet (Kennedy 1949, II–I–I–2) or the optimum ambient light conditions to heighten visual performance of personnel operating radar scopes (1949, III–II–II–6). This handbook was an effort at setting standards and norms, not only to purportedly ‘optimise’ the body of the soldier for increasingly complex machines of war and vice versa, but also to establish and authenticate Human Factors Engineering as a field of scientific knowledge. This effort to set out the discursive domain of human engineering, including its norms and averages, its terms and models, produces what Foucault would describe as an effect of crossing a ‘threshold of scientificity’ (Foucault 2002b, 206). This effort to establish its legitimacy through formalising a ‘general politics of truth’ for charting the relations between human and machines, is hardly concealed in the foreword for the *Handbook*. Rear Admiral Luis deFlorez writes: ‘it will serve as the first step in forming a nucleus for an essential branch of our sciences—Human Engineering’ (Kennedy 1949).

Regimes are intensely generative of documents: in Bales’ laboratory, specially trained secretaries used ‘interaction recorders’ to categorise all ‘acts’ of speech in accordance with a pre-determined, finite array of possibilities: ‘shows solidarity’, ‘asks for opinion’, ‘shows antagonism’ (1950, 258). Theories about group organisation were then extrapolated from empirical observations of activity and the recorded interactions. The group themselves, in the ostensibly pure neutrality of the special room, thus function as an instance of social organisation from which a broader, generalised knowledge—what Bales refers to as ‘empirical norms’ (1950, 261)—could be developed. The apparent success of the practices which Bales’ established caused it to be employed as central techniques of examination in the SRL, whereby norms regarding human-machine organisation were produced, elaborated, and recorded in an extensive corpus of memoranda and reports. In IGLOO WHITE, analysis reports were churned out across varying temporalities, by the minute, hour, day, week, month, season, and year. Within this mass of documentation, the North Vietnamese troops were recharacterised as information flows of detected vehicular activity and supply tonnes—streams of numbers that serve as the basis for spatial and temporal maps that aimed to describe and document norms and patterns of behaviour.

In charting the relations between power and knowledge, the myriad documentary forms which institutions produce in their everyday operation are an important topic of my analysis because they serve as the grounds for work that is undertaken in those institutions. As Ian Hacking (1979, 42) writes, for Foucault systems of knowledge:

> are not to be studied by reading the final reports of the heroes of science, but rather by surveying a vast terrain of discourse that includes tentative starts, wordy prolegomena, brief flysheets, and occasional journalism. We should think about institutional ordnances and the plans of zoological gardens, astrolabes, or penitentiaries; we must read referees’ reports and examine the botanical display cases of the dilettanti. Many of these examples of things to read and examine are quite literally anonymous.

The records examined in my case studies come under various other titles, such as memoranda, reports, manuals, orders, studies, handbooks, operating instructions, working papers, and briefings. In different institutions, these genres were often associated with quite specific administrative procedures and held various epistemic purposes, from speculative schematics to empirical ostensibly 'objective' histories of past programmes. The Institute for Defense Analyses (IDA), a think tank that carried out influential work for the US Air Force during the 1960s, produced three kinds of publications: the *report* was the 'result of a major research project' and was 'intended to be an authoritative contribution on its subject'; the *study* was a 'less formal document and less comprehensive in scope'; the *research paper* was subject to peer-review and could be authored by multiple people (see front-matter of Deitchman et al. 1966).

The 'report' as understood today is a relatively recent document genre. Auger (1998) links its status as a major form of technical writing to the Office for Scientific Research and Development (OSRD). Under the stewardship of Vannevar Bush the OSRD radically reinvented the organisational structures of defence research during the Second World War, supporting pioneering work on radar, anti-aircraft predictors, and human factors engineering. After 1945, there remained the problem of organising the wealth of reports produced during the war, in addition to the masses of technical writing which continued to proliferate even after the OSRD was dissolved. Given the sensitivity of the information contained in these reports, the systematic coordination of this knowledge was especially vital. Various different organisations were established over the following decades to manage access and storage of these documents on behalf of the Navy and Air Force, with one of the more prominent of these repositories now known as the Defense Technical Information Centre (DTIC). Alongside RAND's vast repository of memoranda, the DTIC's collection of reports was an especially rich source of material for my case studies.

The memorandum became the *de facto* method of publishing research internally at the RAND Corporation, with hundreds of such documents on a broad range subjects produced during the 1950s and 1960s. Writing on the role of the memo in the organisational practices of modern bureaucracies, John Guillory (2004, 111) highlights how epistemic functions played out across arbitrary distinctions in genres of writing in modernity. He explicates this in terms of an 'epistemic axis', on which 'literary/journalistic' writing was positioned at one pole and 'scholarly/scientific' at its opposite. The writing of reports and memoranda occupied the middle-ground of 'informational writing'. What is important here is to think of this axis as a gradient rather than a striated set of categories: 'informational writing' is an intermediary grey area, an ambiguous space where qualities of the report and the reportage might still commingle and overlap. Guillory (2004, 112) suggests:

> all of the writing we consider to be the most intrinsically interesting—literary or journalistic, scholarly or scientific—amounts to only a small percentage of the writing of modernity, crowded to the poles of the epistemic axis. In our epoch, large numbers of people write, are even compelled to write, but they do not for the most part write poems or scientific papers; they fill out forms, compose memos or reports, send interoffice emails. This writing is informational, and it has the same generic specificity as any other kind of writing.

Following Fuller and Goffey (2012), I refer to these documents produced by 'informational' writing as 'grey media'. The starting point is to not take these kinds of documents simply as the banal, inconsequential products of sprawling institutional bureaucracy, but as expressions and conduits which shape—and are shaped by—institutional power and knowledge practices. Fuller and Goffey (2012, 11) write: 'greyness is a quality that is easily overlooked, and that is what gives it its great attraction, an unremarkableness that can be of inestimable value in background operations'. Investigating how grey media both document *and* shape the design, operation, and material qualities of computerised command and control systems is thus a central line of inquiry in my research project. As such, the epistemic functions and qualities of different genres of informational writing, and the ways in which they prescribe relations between humans and digital computers with regard to automation, become an important consideration.

The concept of 'greyness' in archival studies is not new. For the archivist, 'grey literature' represents a category of printed material that is 'half-published', residing uneasily somewhere between the public and the private (Auger 1998, 2). What counts as grey literature is indeed a fairly grey area, determined to a large degree by the writing practices and technologies of a given institutional context or era. The questions which grey literature presents within the disciplinary field of archival studies have significant implications for the framework I have adopted in this research project, and of course, in archival research practices more generally. How to decide what material should be stored, according to what principles, and the basis on which it should be catalogued, all co-determine the extent that these are accessible, and how this access is mediated by the affordances of the information taxonomies of the archive.

Auger notes that questions around grey literature—or what was originally referred to as 'reports literature' (1998, 4)—date back to the early twentieth century, and 'coincides almost exactly with the development of the aeronautics and the aircraft industry' (1998, 12). This obvious military connection runs throughout the history of grey literature, and specifically concerned the need to manage the half-published status of classified documents (1998, 1). Alongside the OSRD mentioned above, grey literature is also closely associated with the Atomic Energy Commission and the development of nuclear weapons (1998, 14). The custodians of technical and scientific knowledge which has been classified as 'national secrets' had to be capable of facilitating its distribution to meet the demands of related knowledge work ongoing in defence research, while also prohibiting access to spies. Remnants of this 'greyness' are still evident, even when they have been divorced from their sites of inception and re-catalogued in the archive: declassification stamps, exclusive distribution lists, and leading pages describing their movement from the closed domain of defence research to the public repository are frequent characteristics of the grey media that form the base of my case studies.

One collection that is exemplary of this is the appropriately verbosely-titled 'Secret Classified Registered Documents Relating to Friendly and Enemy Orders of Battle in Southeast Asia', held at NARA. The boxes within an extensive set of 'Logistics Flow' reports (7th Air Force 1972) that recorded weekly truck traffic statistics across specified zones in Laos and South Vietnam. Over the course of their lifetimes, many of these Pattern Analyses have accumulated an array of administrative markings as they were produced, circulated, received, classified, and transferred to the archive for eventual storage. In this document, these inscriptions are particularly obvious, to the extent that they distract from the original text of the document. The red patterned border, a stark warning sign, emphasises its 'Secret' classification, and a red 'NOFORN' stamp indicates that the document is to be seen by American personnel only. Other stamps imprint its date of production, various serial numbers, and a table that lists what is probably the document's internal distribution list. The double-bureaucracy of the military and archive are flattened into a single document in this image: by order of the archive, it was photographed on a page with a declassification number, a stipulation of the archive to demonstrate that due procedure has been followed in providing the researcher with access to the document. The request is logged and traceable, inscribed in a meta-archive that logs the history of interactions between individuals and the repository.

Even after they have been afforded this public status, they remain immersed in the complicated politics of access which mediate interactions at sites such as NARA. Given such officious procedures, these documents function in contrast from those that are made public through more ostensibly transgressive actions, such as the 'leak'. Fuller and Goffey (2012, 103) write that 'the leak can be understood as

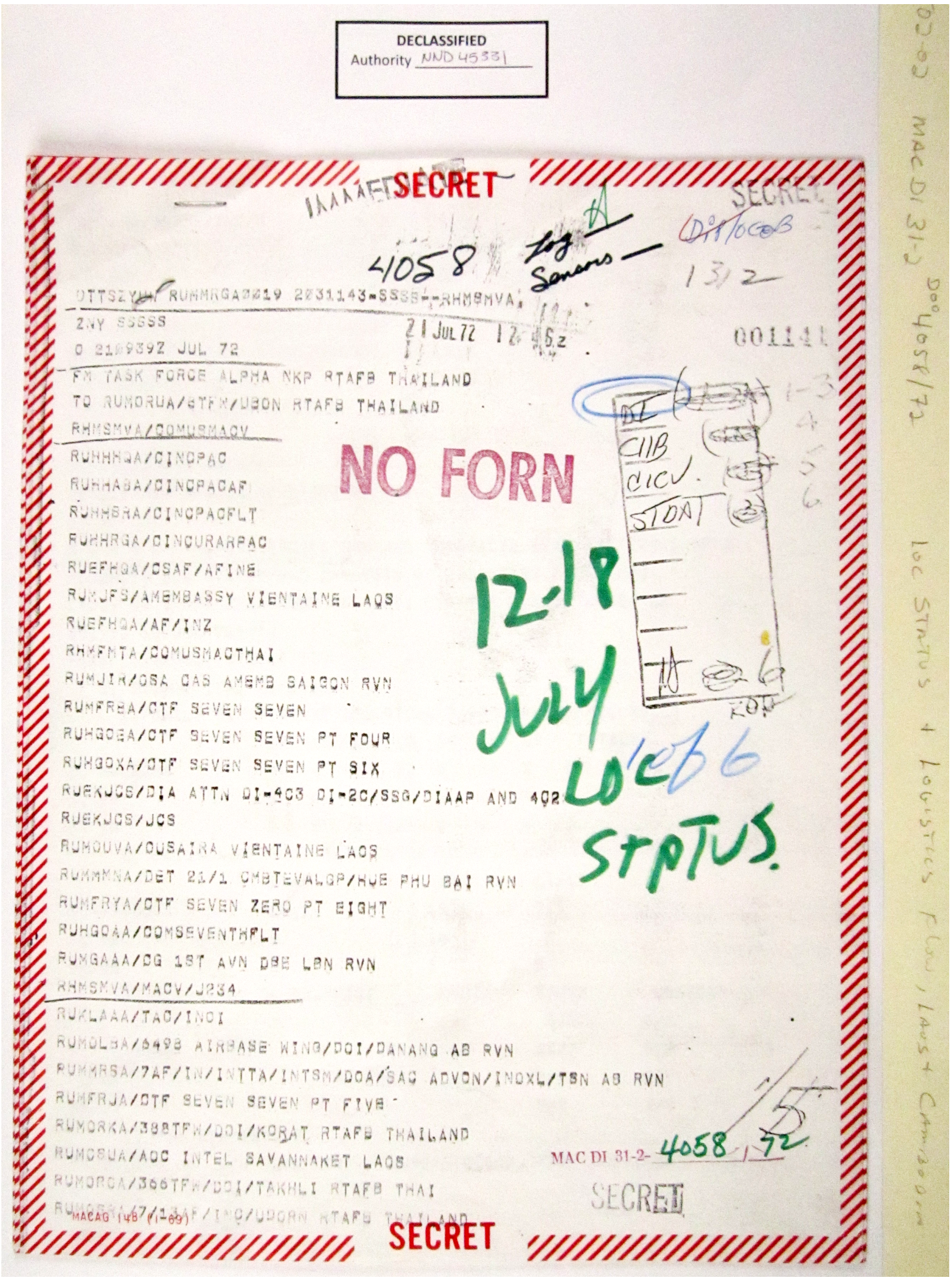


Figure 3.1: Digital photograph by the author of a Line of Communication Status and Logistics Flow report generated at Task Force Alpha (1972), with Declassification Sheet and code number visible.

a speech act with an unwilling speaker, but it can also remain simply as a grey anticipation, a document waiting nowhere for the eyes of no one, held in abeyance by a forensic disinterest' (Fuller and Goffey 2012, 103). The kind of documents I refer to throughout my case studies have been produced and made public—this is 'public' in a formal sense, not necessarily in terms of their practical accessibility—through a diverse range of procedures.

It is this sense of 'grey anticipation' that resonates with the innumerable documents in that 'half-published state' examined throughout this thesis (Auger 1998). In an article simply titled 'The Archive', Bowker (2010, 212) emphasises a crucial distinction that concerns 'the ability to recall (can be recalled) and the actual act of recalling. Between the two yawns the chasm of what actually is remembered: most of any archive consists of *potential memory*'. This distinction arises in myriad forms across archival studies, notably in Steedman's assertion that in the archive we 'only find the middle of things', 'discontinuities', 'stories caught halfway through' (2001, 45). Navigating such documentary multiplicities evokes Foucault's opening sentence in *Nietzsche, Genealogy, History*:

> Genealogy is grey, meticulous, and patiently documentary. It operates on a field of entangled and confused parchments, on documents that have been scratched over and recopied many times. (Foucault 1984, 76)

Through their process of production and circulation within the highly secretive and controlled spaces of the US military, its attendant institutions of defence research, and their subsequent storage within archival structures, the documents examined in the following chapters have accrued marks and scratches. The information held within has in some instances been bleached and faded, in others the detail of an image completely lost through the bitonal digitisation process where the interstitial shades of grey have quite literally been elided. However, their institutional 'greyness', mediated both by the institutional points of inception and subsequently through their cataloguing and storage within a strict archival system, remains palpable in their content and their aesthetic forms.

## 3.6 Conclusion: Regimes and Archives

This point returns us to the opening discussion about the analysis of regimes and how this informs historical enquiry. Jeremy Packer (2010, 91) proposes that to engage with the archive is to be immersed in a set of problems which themselves are the subject of critique in Foucault's archaeological and genealogical frameworks. Packer writes:

> One could look at how the notion of the archive is invoked as a mechanism for providing proof, for legitimating arguments, for verifying the thoroughness of an investigation, in short, to credentialise, authorise, legitimise, and stylise the veracity and authenticity of a historical investigation. In some ways, such an ideal of the archive is rooted in a search for origins, of which Foucault is so critical.

The materials held at NARA and the DTIC put the researcher very much in the middle of an entanglement of grey, bureaucratic media which continuously pose the question of information management, both via their aesthetic forms, their content, and the cataloguing systems. Understood in this way, the archive itself is constitutive of a regime of truth, and functions as an instrument in what Foucault describes as the 'historian's history' in 'Nietzsche, Genealogy, History' (1984, 87). The intention here is to explain the relations of power and knowledge which shaped the discourse of command and control, from its schematic, theoretical design set out in 'studies' and 'working papers', through to the formalisation and analysis of its operational practices in 'manuals' and 'reports'. I argue that taking the document as a ground for a critique of institutional discourse permits us to examine how grey media are both descriptive, and indeed prescriptive, of shifts in configurations of institutional power and knowledge.

Grey media has a 'recessive power', but the quality of this power and its relationship with broader structures of knowledge is multifarious and shifting. Fuller and Goffey (2012, 12) suggest that the analysis of grey media 'calls for a kind of suspicious attentiveness, the cultivation of a sensibility able to detect minor shifts of nuance, hints of a contrast where flatness would otherwise be the rule'. One location where we begin to find these contrasts are in the so-called information-flow diagrams which aim to graphically visualise the way command and control systems are intended to function—an implicit acknowledgement that the textual explanations which accompany them in these documents are perhaps not getting the message across. The shifts of nuance and contrast arise in the various ways in which the operational logics of these systems are explicated: information flowcharts proliferate across various scales which don't map on to one another; to accurately represent the system in its totality would result in a diagram so complicated as to lose its explicatory function.

This example of the operational flowcharts which are the subject of extended discussion in my case studies are especially instructive of how grey media, the concept of regime and the interplays between power and knowledge intersect. They are graphical statements which are expressive of a way of conceptualising the solutions to strategic problems; by making some elements visible while ignoring others, they present their own rules of formation; on an operational level, they prescribe what is to be known and codify what is to be done. Examining such instances of grey media as a statement, in terms of its function within a broader discursive formation, allows for an analysis that charts the interrelations between the discourses of defence research and the schematic, operational logic of command and control systems.

# Chapter 4

# The Air Defence System

## 4.1 Introduction

The question of which operational tasks to designate to the human and which to the machine was at the forefront of American defence research in the 1950s, and nowhere more so than in the subset of problems specific to continental air defence. This chapter examines how responses to this question, informed by psychologists at the RAND Corporation and engineers on the Scientific Advisory Group, coalesced in the technical design, administration, and operation of the SAGE system deployed across the United States in the late 1950s and early 1960s.

This was an extraordinarily bureaucratic system, and as such, recounting the development throughout this decade makes for a rather unwieldy task. The story of air defence in 1950s America is replete with codenames and acronyms, false starts and obscure experiments, monumental systems and far-flung installations, and a lengthy list of defence researchers with distinct disciplinary interests. Indeed, the sprawling, confusing, and seemingly incoherent qualities of air defence are in an important sense the point of discussion here. Any account must necessarily be selective, and as such, this case study navigates this circuitous terrain by maintaining a focus on the function of the ‘human operator’ of the system, tracing its elaboration in the ‘Manual System’ of the late 1940s through to the ‘semi-automatic’ configuration active throughout the 1960s. This period saw immense elaboration and expansion in the discourses and practices of defence research, particularly with regard to computing hardware and software, but also in the discourse of management and human factors research as it pertained to military contexts of command and control. An account of the operator told with respect to these developments, and explicated through the grey media of defence research and institutional documentation, highlights the myriad ways in which the air defence system acted in contradiction to its imagined operational logic.

Part I of this case study sets out the ways in which the prevailing fascination around ‘digital computing’ and ‘information theory’ amongst defence researchers at RAND contributed to the elaboration of a discursive regime that refigured operators as ‘factors’ and ‘components’ of systems that could be observed and quantified. As I outline below, this refiguration cannot be entirely explained solely by looking at the military context of air defence: this regime can also be understood as a significant elaboration of management theories developed by Frederick Winslow Taylor and Frank and Lillian Gilbreth earlier in the twentieth century. Rather than intending to explicitly set out a series of actions and thus control the individual worker at the atomic level of specific manual actions, the SRL’s approach sought to observe and cultivate improvements in performance across the organisation *as a whole*. The techniques of simulating invasion scenarios developed at the SRL had significant implications for training the human operators in air defence, having the effect of reconceptualising air defence in terms of problems of information management. Operators and machines alike were said to be part of an ‘information-processing centre’, a ‘computer’ that could be optimised to process the events of the ever-imminent invasion (Chapman et al. 1952).

Part II shifts to a defence research programme which proceeded in parallel to the

SRL experiments. The Air Defense Systems Engineering Committee (ADSEC), spearheaded by the physicist George Valley, authored two important reports in 1950 that inquired into the state of the Manual System. The reports concluded that only a considerably more automated system, with a digital computer at its centre, could produce anything approaching effective air defence. The schematic system described in the ADSEC reports were the basis for the design elaborated in subsequent studies, eventually becoming the Semi-Automatic Ground Environment (SAGE)—the nation's first command and control system organised around a network of AN/FSQ-7 digital computers. It is the '*semi*-automatic' quality of the system that is of utmost interest here, however. I examine how the superimposition of the SRL's training practices onto the technical design of the SAGE system in the latter half of the 1950s highlighted resistances in the operational logic prescribed by both programmes. Contrary to the rational system of information management envisaged by its proponents, by the mid-1960s, SAGE became a point of reference in internal histories and inquiries. In these documents, it was presented as an exemplar for software and hardware sprawl, emblematic of the hostile contradictions between military bureaucracy and the efficient management of human-machine command and control systems.

## 4.2 Part I: The Manual System

### 4.2.1 Air Defence as National Duty

That the Air Force should take command over national air defence was not a foregone conclusion. In an institutional history on the evolution of command and control authored by defence researchers at the Institute for Defense Analyses (IDA) in 1975, the authors noted the Air Force's predisposition toward investing in 'offensive' strategies. Air *defence*, on the other hand, 'was regarded within the Air Force as necessary in theory but not in terms of resource allocation' (1975, 89). For such a young service, only founded as a separate branch of the Armed Services following the National Security Act 1947, the prevailing conception of air defence was bound up with formative institutional politics, the spectacular mythologies of the Army Air Force, and the commanders vying to shape its strategic identity.

The primary issue though was not whether some sort of defence was required, but oriented around the question of the terms and conditions of what an *effective* defensive strategy might be. For the leaders of the Strategic Air Command—the Air Force's elite bomber wing—a fleet of advanced nuclear-equipped bomber jets served as a sufficient defensive deterrent. An alternative high-profile programme, proposed in 1948, was the Radar Fence Plan (codenamed Project Supremacy). In another internal history of air defence in the early Cold War, Kenneth Schaffel wrote that during an air emergency in 1948 where anxieties of a Soviet invasion ran particularly high, wargames and exercises harshly exposed the limitations of the existing air defence system. He recorded that 'countless difficulties of varying complexity arose in all the emergency defence areas' and that 'air defence forces were generally disorganised and inadequately manned, trained, and equipped' (Schaffel 1991, 80). According to Schaffel, the emergency had been called to secure a reported $600 million worth of funding support for Project Supremacy, but this request ultimately floundered in Congress.

These evident inadequacies and the lack of urgency around rectifying them can partially be explained by what a War Department article dating from 1947 termed 'the cushion of time'—an effect of the favourable circumstances of geography and the technical state-of-the-art ("War Department Thinking on the Atomic Bomb" 1947, 6). In the immediate aftermath of the Second World War, the technical constraints of bomber plane fuel efficiencies and aircraft engines had put the United States practically out of reach for its most dangerous opponent. Consequently, a Soviet first-strike surprise attack would have been effectively impossible to initiate without a staged build-up nearer the American homeland—a strategy that would have acted as a fairly loud early warning alarm for the Pentagon. In either case, the US military would be afforded with time to prepare and conduct a counterattack. Nevertheless, the War Department article also warned against complacency, and claimed that this 'cushion' had effectively already been lost by the time of its drafting. With the anticipated advancements in Soviet nuclear weapons, the jet engine, and a new more robust generation of bomber planes, the US was becoming a viable target from the air. Geographic, political, and technical relations between the superpowers conflated to define what counted towards security, consequently inducing new imminent defensive necessities while casting older strategies out into obsolescence.

Crucially, any viable air defence system could not only act as a barrier that prevented hostile aircraft from entering US airspace; it also had to permit the large (and quickly increasing) quantities of inbound civilian commercial and freighter aircraft travelling to major airports across the country (Van Vleck 2013). Before the Soviet atomic test, there was no consensus around what kind of system could fulfil both tasks while satisfying the offensive predilections of the Air Force, attaining political backing across government, *and* do so on a budget that still facilitated its expedient deployment.

The actual air defence system active during this period of debate was an unevenly distributed array of radar stations positioned along the coastlines of the US. Incoming radar data was coordinated in regional Direction Centers housed in Quonset huts—lightweight prefabricated buildings that could hardly be described as secure. In its technical form and operational practices, it was a thoroughly heterogeneous assortment of control stations, radar outposts, patrolling picket ships and airborne command centres, antiaircraft guns and even a substantial force of volunteer civilian plane spotters. The July-August 1949 issue of *The Antiaircraft Journal*, a publication whose readership included numerous branches of the Armed Forces tasked with air defence, provided a diagram that communicates the organisational complexity of the system (see Figure 4.1). This diagram does not depict the system in its entirety: rather it illustrates the various appendages linked to a *single* Air Defense Control Centre, of which there were multiple positioned across the country. Although the diagram communicates a startlingly complex system, from this level of abstraction their constituent operational practices and the population of personnel who animated them are invisible.

In an issue of the *Antiaircraft Journal* published just one week after Truman's announcement of the Soviet atomic test, a feature on the air defence system celebrated the role of the National Guard Air Force (NGAF). The article stated that sixty per cent of the radar operating squadrons were made up of NGAF volunteers, with the remaining radar stations comprised of full-time Air Force crews located around 'foremost target areas' (1949, 11). NGAF personnel, as imagined by the article's author, were motivated by the promise of vibrant and lifelong camaraderie as well as participating in the honourable, patriotic duty of national defence. He wrote: 'Fortunately, it is also a kind of duty that has a special appeal to qualified citizens. In many cases the air defence duty is directly related to their profession or hobbies as well as is the protection of their own homes' (1949, 10). This duty involved not only operating the various radar and coordination posts, but also

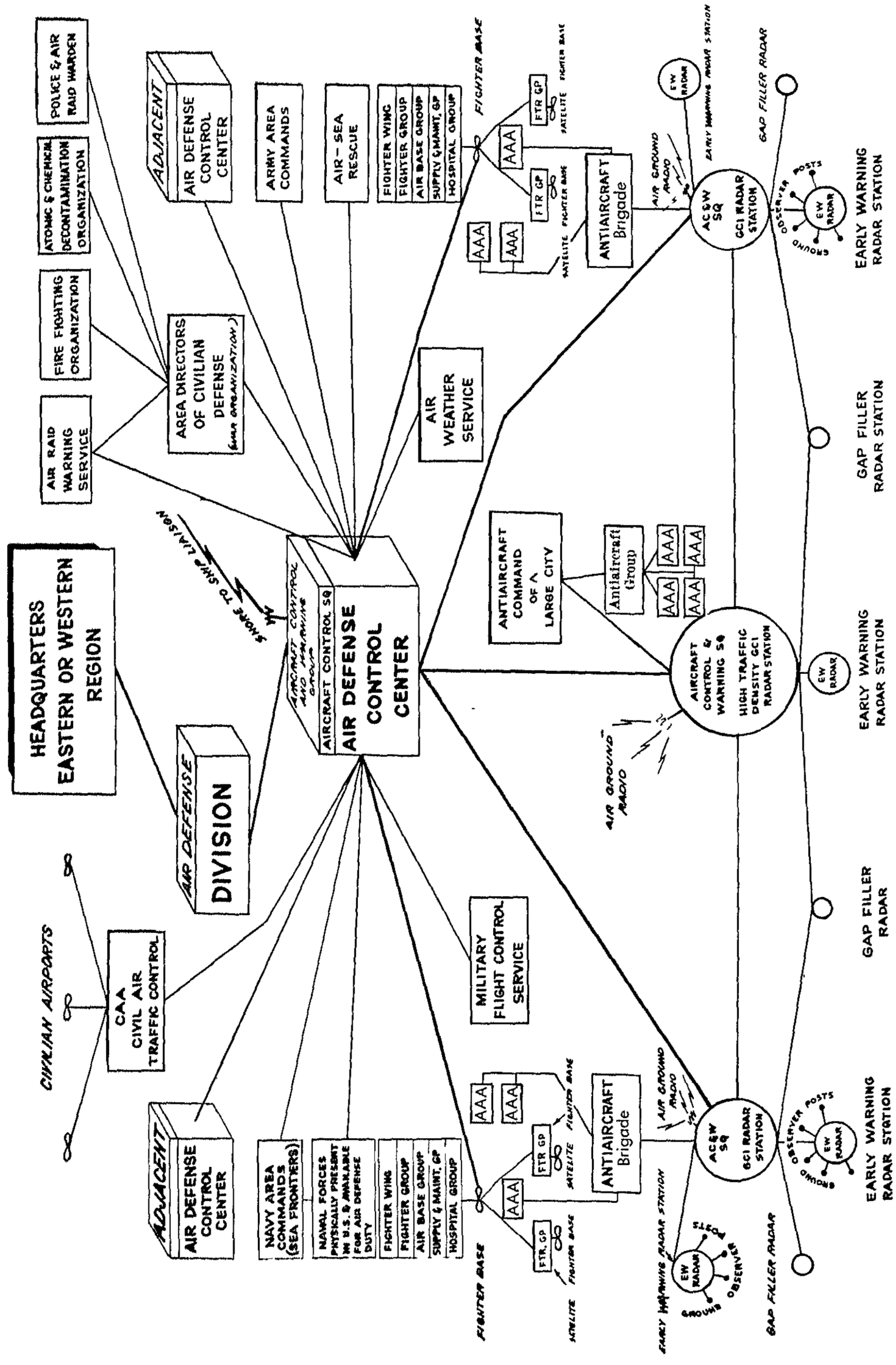



Figure 4.1: Diagram of the ‘Air Defence System’ in July-August 1949 issue of *Antiaircraft Journal*.

required Guardsmen to undertake a modest schedule of training drills. Volunteers participated in a two-hour drill once a week, at least 48 times a year, although this was frequently exceeded during bigger wargames and regional exercises.

These northern expanses offered neither spatial nor temporal security: according to a report authored by the Air Defense Systems Engineering Committee (ADSEC) in 1950, this terrain was soon expected to be traversable by Soviet jets, and due to the curvature of the Earth, it frustrated the line-of-sight functionality of radar and thus compromised the value of early warning systems. It was widely expected that attacking aircraft would fly in low beneath the horizon, virtually undetectable to radar installations until they had almost reached their targets (ADSEC 1950a, 1950b). Any system tasked with providing early warning thus had to grapple with operating across three dimensions, rising off the flat surface of the map to account for the curvature of the earth and the problems of verticality posed by high-altitude, long-range jet aircraft. Where Air Force radar coverage literally fell short in this way, members of the Ground Observer Corps (GOC) surveyed the skies from their designated watch posts.

Dating from the Second World War, the GOC was a distributed force of civilian volunteer all over the country, recruited to watch the skies from the doorsteps of their own homes. As a guide issued to Ground Observers in 1951 put it, they stood as a ‘bulwark of freedom’ in the face of rather grim circumstances:

> For the first time in our history, a potential enemy has the power to make sudden, devastating attacks on any part of our country. The broad seas which have protected us up to now have been cancelled out by fast, long-range planes; and the huge forces formerly required for significant damage have been made unnecessary by the atomic bomb. A single plane carrying an atomic bomb can now wipe out an entire city. It is a dangerous situation. (Department of the Air Force 1951, 1)

The guide also described the whole process that would initiate upon a Ground

Observer reporting a sighting. This process was the Manual System at its most manual: the protocol set out that observers would compare sighted aircraft with the aircraft profiles in their *Ground Observers Guide*, and phone in information to their associated Filter Centre. The Filter Centre was jointly operated by civilians and Air Force personnel, and tasked with the management of information coming in from Observer Posts. Here, different sightings from multiple observation posts were compared and aircraft tracks physically mapped out on a large table in order to build up a picture of the airspace. In the event that a suspicious track was identified, the aircraft location and its estimated targets were then relayed by one of the staff to Ground Controlled Intercept (GCI) radar, which would direct scrambled jets to an interception point.

While the claims the guide made regarding the systematic organisation of the GOC and the Manual System as a whole are contradicted in inquiries carried out by other defence researchers (ADSEC 1950a, 1950b), the GOC served an important purpose. Historians of US civil defence following the Second World War emphasise the psychological impact and disciplinary purpose of organisations such as the GOC (see Clymer 2013; Farish 2016; Grossman 2001; McEnaney 2000). The Federal Civil Defense Administration (FCDA), established in 1950 to 'provide a plan of civil defence for the protection of life and property in the United States from attack' (81st Congress 1951, s. 2), further bolstered efforts to foster grassroots initiatives in national security facing, among other threats, a Soviet assault from the air. FCDA strategists, as McEnaney remarks, 'openly admitted their mission to market civil defence as a mental state—a psychological orientation toward military readiness' (2000, 34). This intention was not disguised, but expressed explicitly in air defence journals such as the GOC's official magazine *Aircraft Flash* and the above-mentioned *Antiaircraft Journal* that were distributed to members of various organisations involved in the air defence of the United States. Quoting from a 1953 issue of *Aircraft Flash*, Farish expresses the grandiose political weight attached to the practice of observing: ‘as a ground observer, you were defending not only a physical space but also a “moral and ideological entity” ’ (Farish 2016, 644). In the sense of the various voluntary and reserve organisations contributing to air defence, the ‘manual’ quality of the system was precisely the point: those involved performed were recruited to perform a national duty with the effect of reinforcing the role of the population as vigilant patriots.

Following the news of the Soviet atomic bomb test, the National Security Council (NSC) was convened by Truman to inquire into the near-future of US military strategy and the defensive disposition of the nation. The resultant NSC-68 report, titled *United States Objectives and Programs for National Security*, provides a snapshot of what were seen by the Council at the time as primary mechanisms of US power and security: those of political instruments such as containment, alliances, and the purported stability of liberal democracy (National Security Council 1950, 22); the growing economy which facilitated ‘rising standards of living’ and the funding of military research and development (1950, 25); and finally, the ‘greatest military *potential* of any single nation in the world’ (1950, 31, emphasis mine). This ‘potential’—imagined through a conflation of economic, demographic, technological, and political factors—had to be quickly realised in order to ‘[gain] the initiative in the “cold” war’ (1950, 33). Amongst their myriad recommendations to bolster national security, the NSC expressed the necessity of ‘greatly increased air warning systems, air defences, vigorous development and implementation of a civilian defence programme which has been thoroughly integrated with the military defence systems’ (1950, 37).

When it came to the military dimension of the air defence system, its fairly lacklustre effectiveness was the subject of extensive discussion amongst defence researchers in the early 1950s. As the demands of British air defence had years before, this imperative in turn led to the formation of strategic advisory panels, scientific investigations, and research programmes at centres such as MIT and

Stanford, promising new advancements in computing technologies. There was, however, another burgeoning area of research that also developed into a highly influential dimension of the Manual System: that is, 'human factors engineering'. Rather than focus primarily on how new technologies might ameliorate the system, researchers in this domain focused primarily on the physical and psychological capabilities of the operator.

### 4.2.2 The 'Human Factor'

At the annual Current Trends in Psychology conference in 1952, the human factors engineer John L. Kennedy presented a paper prefaced with the following questions:

> How can we deal with the complexity of real human affairs? What methods, preferably scientific and objective, can be utilised or developed for predicting the behaviour of complex, interacting systems? (Kennedy 1952, 1–2)

Kennedy relayed that he had recently strayed from his typical disciplinary terrain of behavioural psychology, and through collaboration with a range of specialists active in areas including mathematics, philosophy, physics, engineering, and social science, he found that these questions were a common concern. Indeed, should we seek a set of imperatives that would discursively link many of the central preoccupations of defence research during the 1950s, the above questions would serve as an apt template. A new 'field'—one which Kennedy had a significant hand in founding—attempted to approach these problems not by focusing on the invention of new machines, but by focusing on the human operator. Variously referred to as 'human engineering', 'design engineering', and 'human factors engineering', this area gained a new currency following the Second World War as the systems in which humans played a part became increasingly complicated to operate.

Part of the problem of dealing with the 'complexity of real human affairs', for human factors engineers, required extensive testing of the psychological and physiological limits of the operator, circumscribing them in quantifiable, systematic detail. To invoke Haraway's critique of science and engineering here, we should understand the ways in which such human limits were measured and demarcated as an effect of the 'situatedness' of the scientists and engineers within their disciplinary contexts. Given the prevailing imperatives of the war emergency and the funding sources of the late-1940s, this situatedness was framed to a substantial degree within a militarised way of seeing the world [-haraway_situated_1988, p. 587]. The set of methodologies devised and modified for use within this new field were heavily imbricated with the discursive tendencies of post-war defence research, whereby ideas of 'information' and 'systems' featured prominently in the construction of a specialised knowledge about the management of war—from the macro level of strategy to the micro level of the individual operator.

Paul M. Fitts, one of the pioneers of ergonomics and human engineering following the Second World War, wrote in a 1947 article that 'up to the present time psychological data and research techniques have played an insignificant role in the field of equipment design' (1947, 93). While some studies had been carried out in Britain and the US during the latter years of the war, aiming to quantify among other things the effects of the arrangement of cockpit instrument panels and the design of control knobs and gauges on pilot effectiveness, such research was not generally considered a priority by military leadership. For Fitts, the importance of this work particularly in the design of aircraft was without question: 'There probably is no other engineering field in which the penalties for failure suit the equipment to human requirements are so great' (Fitts 1947, 93). The importance of this research had gained some institutional acknowledgement with the founding of the Psychology Branch of the Army Air Force's Aero Medical Laboratory, just before the Air Force became an autonomous service. In his role at the Psychology Branch, Fitts aimed to extend this research into problems pertaining to displays, systems engineering, control, and the study of the perceptual and physical limitations of the human operator. The Psychology Branch oversaw projects under the following mission statement:

> Psychological research to determine the capacities of individuals to operate new types of equipment as an aid in the designing of such equipment to the end that the final project will be best adapted to the man who must use it. (1947, 94)

John L. Kennedy was also active in arguing for the importance of human factors engineering at the time. In 1949, following three years of research and collation under Kennedy's stewardship and with an editorial team that included Fitts, the Institute for Applied Experimental Psychology at Tufts College published the *Handbook of Human Engineering Data for Design Engineers.* Echoing the guiding rationale of the Psychology Branch, the lesson of the Second World War as stated by Kennedy in the *Handbook* was that 'a machine must not only perform well, but its instruments and controls must be made clear and easy enough for an average man to handle quickly and accurately' (Kennedy 1949, III:1). With support from the Office of Naval Research (ONR), the publication was afforded some formal legitimacy. In the *Handbook's* foreword, Rear Admiral Luis deFlorez wrote:

> Up to the present, we have been able to keep up with technological progress by education and training. But we have now reached the point where the machine has dwarfed the man, for the characteristics of the individual—the human machine—have not changed in the memory of man and will not change for countless generations to come, while the man-made engine is capable of ever increasing power, scope, and speed of operation. We must, therefore, consider man's capabilities as a constant in contrast to the unending progression of the machine. (1949, i)

For deFlorez, as these systems became increasingly complex to the degree that advanced machines were ostensibly operating beyond the limits of human capabilities, misuse became more probable. These modern machines—equally capable

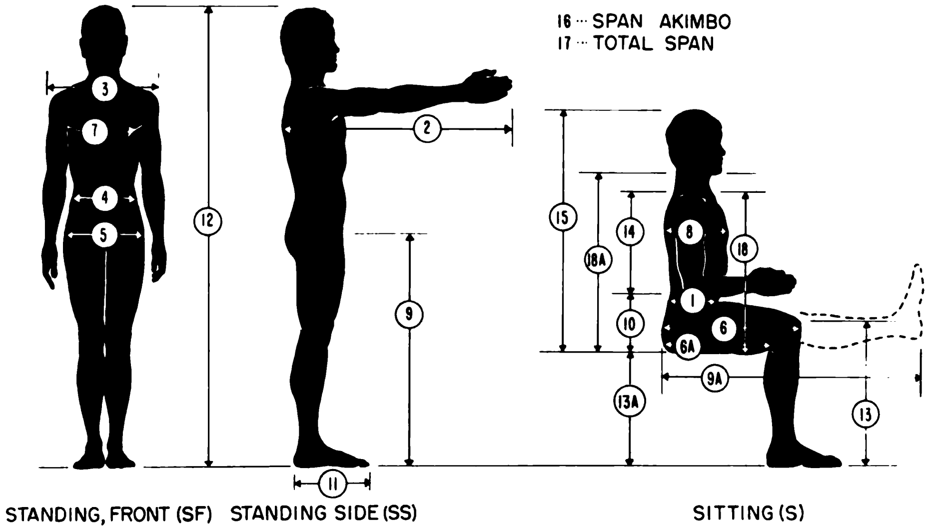



Figure 4.2: Body Measurements for the Adult Male in Kennedy's *Handbook* (II:I:I:2). 'The measures selected are all such as might conceivably be of value in planning apparatus and machinery in which the anatomical measurements of a human operator would be a significant variable'.

of 'performing miracles' as 'producing catastrophes', as he put it—thus had particularly drastic repercussions if misused, especially in the military context. The imperatives of human engineering were twofold: firstly, for 'man'—and indeed they almost invariably presupposed *male* operators and in a more general sense than just the *soldier*—not to lose control of his machines; and secondly, to facilitate an optimal engineering of the machine in order to make maximum use of the intellectual and physical faculties of the operator. On both counts, human factors engineers thought it necessary for those who designed new machines to anticipate and facilitate the characteristics and the inherent limitations of the bodies and minds which would eventually operate them, across a range of environmental and situational contexts (Kennedy 1949, i).

The *Handbook* was an attempt to produce an abstraction of the operator in the form of a quantified portrait of an 'average human being' whose limits were measured across a range of physiological and mental categories. This abstraction would then function as the standard template against which all military machines would be designed in future, and to theoretically 'eliminate the danger of making an operator the bottleneck in this man-machine system' (1949, I:I:I:1). This project to constitute the body as an atomised, quantifiable assortment of capacities evokes the 'microphysics of power' set out by Foucault in *Discipline and Punish* (1991). Foucault's account of disciplinary mechanisms that targeted the body of the solder is specific to the militaries of the 18th and 19th century, for instance in relation to their manipulation of the rifle during drills. There are major qualitative differences here between the particular types of bodies and objects that Foucault discusses and those which occupied the minds of human factors engineers. Understood as regimes, however, the underlying 'programme of conduct' is rather similar in both instances: to measure, standardise, and ultimately command the optimum meshing of the machine and its operator.

For Kennedy, the objective was ambitious. If human factors engineering could be institutionally interlinked within the new post-war culture of military research and development in the United States, the effect would be that every dimension of each machine—every cockpit, computer console, gun, and instrument panel—would anticipate the body and mind of this average operator. Of course, a central marker of the 'situatedness' of any statistical project is that a claim to represent an average is hedged by the pool of subjects from which it is calculated. To be more accurate then, accounting for the *Handbook's* pool of subjects drawn from the at-hand supply of local college students—i.e. exclusively males at an age that made them available for military service. As such, we might say that the portrait of the operator was only the 'average' male student of Tufts College. Writing a couple of years later about the motivations behind the project in the *Annals of the New York Academy of Sciences*, Kennedy admitted this methodological limitation:

> Many human functions reported in the handbooks will be based upon

> samples taken from college sophomores, and, when we get a population of over 100 cases, we are reasonably happy. [...] In order to determine the limits of human performance with precision, it will be necessary, in the future, to sample the behaviour of large and unselected groups of individuals. (Kennedy 1951, 1136)

In serving as a purely functional reference manual to guide engineers, the production of the *Handbook* was an effort to legitimise the field by codifying a set of techniques capable of producing and validating knowledge about the operators of systems. Prior to the *Handbook*, much of this research proceeded in parallel but without methodological coherency, scattered across various other disciplinary specialisations, institutions, and sites of analysis. Kennedy recounted that it was fairly typical for two studies to employ rather different measurement devices and methods and record their findings according to units. 'One way to bring order into the chaos of slightly different experimental procedures', he wrote, 'is to do as the physical sciences have done, namely, establish operationally defined standards for units, variables, subjects, and procedures' (1951, 1138). Kennedy cites the historian of psychology Edwin Boring:

> If the facts of any subject cannot be subsumed under a few big theories, at least they can be brought together, systematised, related, and made accessible. Handbooks do just that and they are necessary tools of science. (1951, 1136)

In this effort to legitimise its status, we can in retrospect see the *Handbook* within a broader regime of practices firmly grounded in positivist forms of enquiry. Complex behavioural conditions (such as stress) or actions (such as decision-making) could be explained through the rigorous measurement and analysis of data collected through experiments. This regime also incorporated the discursive terrain of information- and systems-oriented ontologies then prevalent in defence research: humans and machines were seen as factors, components, or elements, of bigger circuits of information flows. In this sense, the production of the *Handbook* was an attempt to consolidate and standardise a disciplinary discourse and set of shared paradigms, 'codify' terms and models, and 'prescribe' techniques understood to be capable of producing 'truths' about human-machine systems.

We are reminded throughout the introduction and opening section of the *Handbook* itself that much work remained to be done, and caveats were issued in acknowledgement of its experimental nature. The awareness of the schematic quality of human factors research was even reflected in the very layout and publication format of the book: rather than arranged as a linear sequence of pages, it was 'prepared in loose-leaf format so that additional material may be added and so that confusing or useless information may be deleted' (Kennedy 1949, iii). The model of the 'average', albeit compromised, human being which the *Handbook* aimed to produce could thus be corrected and refocused, and some attributes discarded if deemed unimportant while others could be added and further developed, their measurements rendered with more refined detail. In his foreword, DeFlorez wrote that the book itself 'serves as a challenge to those who want to know more and strive for greater accuracy' (1949, i).

In a number of respects, however, the kind of enquiry described in the foreword and introductory section of the book was not altogether new to theories of managing systems of humans and machines. The imperatives outlined by Kennedy resonates with some aspects of the theorisation of industrial management as a kind of 'Science' half a century earlier. In particular, there are clear commonalities between Kennedy's project and the work of the industrialist and founder of scientific management, Frederick Winslow Taylor. Taylor's own statement in the introduction of his book *The Principles of Scientific Management* echoes the *Handbook's* imperative to study 'unified systems' rather than individual components: 'In the past the man has been first; in the future the system must be first' (Taylor 2003, ii). By explicitly positioning his approach as 'Scientific', Taylor was making a claim about its methodological formality and rigour, and propounding that the knowledge it could produce about the management and capabilities of labourers could be taken seriously.

The primary imperative of Scientific Management—to maximise prosperity for the employer and, at least as Taylor (rather dubiously) claimed, also the worker—required tackling a whole range of inefficiencies which for him were well-entrenched in virtually all forms of manual labour at the turn of the century. Taylor was frustrated by the lack of a specific programme that joined up and standardised factory work. His efforts were particularly focused on the eradication of the 'rule-of-thumb' traditions of tradecraft which resulted in widely varying approaches to the same task from one person to the next, and the apparently endemic problem of 'soldiering'—that is, the various tactics labourers employ in order to avoid doing 'a full day's work' (2003, 4). Despite Taylor's claim for an equal concern for the worker, Scientific Management was quite evidently primarily invested in the prosperity of the employer: Scientific Management was first and foremost a system of control of which the workers were the subjects, a body of evidence that determined purportedly inarguable standards for what counted as 'productivity'. In other words, it was a regime of standardised observations, measurements, and remunerations that produced a disciplinary power which set limits and thresholds for the labourer. The purported scientificity of Scientific Management was a core element of this power, reframing its techniques as disinterested quantifications of productivity as opposed to the variable, subjective whims of the shop manager.

The ostensibly 'Scientific' techniques to eradicate these inefficiencies involved the study of physiological capabilities of individuals with respect to a given task. As Taylor documents, this included amongst other things the determination of the minimum amount of rest required for the worker (2003, 39–40), as well as the best means of training workers and standardising the most efficient use of the relevant equipment and materials. In a study that anticipated the techniques of post-war human engineering, albeit for the simple shovel, Taylor provided the example of a time study which aimed to precisely define the optimum load at which a 'first class shoveler' could do 'his biggest day's work' (2003, 46). The imperative of this study was not just to train the labourers, but to engineer a set of new standardised shovels in order that it would naturally accommodate the optimal average loadweight for a variety of materials (2003, 47). This standardised instrument also facilitated for Taylor an ostensibly objective benchmark for the amount of manual labour achievable in a day by the worker. The effect, he wrote, would be that the matter of 'what constitutes a fair day's work will be a question for scientific investigation, instead of a subject to be bargained and haggled over' (2003, 106). Professedly 'reasonable' limits and expectations of worker productivity would thus be quantified and prescribed according to 'objective' methodologies, with the consequence that deviation from these expected norms could be sharply distinguished. Even the most perfunctory of implements—such as Taylor's shovel—thus became an institutionally validated and normalised tool. Consequently, it was thoroughly integrated within the power relation between the Scientific Manager and the worker by defining the acceptable conduct of 'a day's work'.

The section of the *Handbook* on 'motion economy' also has a clear precedent in the Gilbreths' own techniques of Scientific Management. As Frank and Lilian Gilbreth understood it, their work was about devising techniques that would allow for the 'elimination of waste'. In a 1915 article, they wrote that 'its primary aim is conservation and savings, making an adequate use of every ounce of energy of any type that is expended' (Gilbreth and Gilbreth 1915, 208). One of the key elements of this was the prescription of a variety of standards whose basis lie in scientific observation and measurement (1915, 212). The Gilbreth's technique of 'motion studies', in which they filmed factory workers with a film camera in order to record and chart bodily movements, aimed to extract as much productive labour out of the worker as possible. 'Through motion study and fatigue study', they wrote, 'we have come to know the capabilities of the worker, the demands of the work, the fatigue that the worker acquires at the work, and the amount and nature of the rest required to overcome the fatigue' (1915, 213).

For the Gilbreths, the controlled space of the laboratory was a key site to observe worker behaviour and invent new mechanisms and procedures that would enable the worker to produce 'more output for less effort' (1915, 215).

> Here the worker to be studied, with the necessary apparatus for doing the work and measuring the motions, and the observer, investigate the operation under typical laboratory conditions. The product of this is data that are more nearly accurate than could be secured with the distractions and many variables of shop conditions. (1915, 214)

In the sanitised space of the Gilbreths' laboratory, extraneous noise and distraction were mitigated, certain variables fixed as constants while others were scrutinised, tracked and measured in order to discern the optimal parameters for maximising productivity. Following this process of examination and data analysis, the optimal variables describing the conditions of the laboratory, the worker, and the instruments required to accomplish the work in question were fixed, and served as a 'practical working model of what the shop conditions must be' (Gilbreth and Gilbreth 1915, 214). The perfected conditions of the laboratory would be subsequently reconstituted in the live workplace:

> When the best method of doing the work with the existing apparatus has been determined in the laboratory, the working conditions, as well as the motions which make this result possible, are standardised, and the working conditions in the shop are changed, until they resemble the working conditions in the laboratory. (1915, 214)

According to Taylor and the Gilbreths, the management of workers required an array of measurement devices, procedures for keeping records, controlled spaces for observing and experimenting, as well as its own carefully determined techniques of human-machine organisation. 'The development of a science', wrote Taylor, 'involves the establishment of many rules, laws, and formulae which replace the judgement of the individual workman and which can be effectively used only after having been systematically recorded, indexed etc.' (2003, 24). The laboratory for the Gilbreths, or the field study for Taylor, both acted as possible sites where certain facets of labouring could be fixed in place while others were analysed, quantified, and mediated, and always measured by some criterion of efficiency.

While the work of Taylor and the Gilbreths might represent a prototypical kind of human factors research, the approach of Kennedy and his colleagues represented an important elaboration in this line of management theory—one that would be enormously influential in continental air defence throughout the 1950s and 1960s. Rather than the mechanistic movements of the manual labourer or the machine worker, the focal point became the 'decision' and the ways in which it reverberated across a system comprised of humans and machines. In a sense, this represents a retuning of the focal points of managerial theory in America, encompassing not just the factory but the new environment and types of work that was characteristic of 'organisations' such as the corporation. Alongside this shift in environmental context, came a corresponding shift in inquiry: the effort was no longer on how to adapt the human to the machine through increasingly granular disciplinary mechanisms such as production targets and observation, but on engineering new systems moulded to facilitate the optimal decision-making capabilities of its human 'components'. Unlike in the factory, efficiency could not be quantified or stimulated in the established terms of rates or piece-work: information-processing became the new modality for charting organisational unity and effectiveness.

The kind of human factors research that Kennedy pursued in the late-1940s dealt with the physiological and cognitive limits of the human factor, drawing on a range of military problems and contexts as he questioned what would most effectively facilitate the training of operators in techniques to increase the efficiency of their communications given these limitations. In the preface of the publication, Kennedy wrote:

> It is too often assumed that men can learn to do anything. The data of this book really supply information on the practical limits of human performance and sensitivity, beyond which the man, as a control device for machines, begins to break down. The machines of the future must be designed with these human limitations explicitly considered. (Kennedy 1949, iii)

It's worth dwelling briefly on the phrasing here that positions 'man' as a 'control device for machines': characterising the operator here as a 'device' extends the metaphors of unified systems of humans and machines that propagated amongst defence researchers at institutes such as the National Defence Research Committee (NDRC) during the Second World War. While the operator of an anti-aircraft gun would have their aim corrected by the machine, in Kennedy's formulation it was the human operator who was correcting the machine.

As Mindell (2002) contends in his history of control engineering before and during the Second World War, we should not look only to cybernetics to explain the prominence of such metaphors in the discourse of defence research. The cross-disciplinary NDRC constituted the formative professional years for a new generation of scientists and engineers. The RadLab, based at MIT and charged with the development of radar and fire control systems of unprecedented technical complexity, was particularly influential in this regard. The pertinent conceptual shift was, as Mindell puts it, 'transforming the Radiation Lab from a radar group to a system integrator and transforming the human operator into a dynamic component' (2002, 270). As he notes elsewhere, the NDRC's 'Applied Psychology Panel', of which Kennedy was a member, also pursued this conceptual shift. A prominent theme of this discourse is the description of the human operator as analogous to a control device whose behaviour can be explained, quantified, and predicted through the logic of feedback and circulation of information. It was not only the behaviour and attributes of the enemy being distilled into time series datasets and explicated through feedback loops: the mind and body of the human operator and the complex human-machine organisations they acted within were also subject of such inquiries.

The RAND Corporation, where Kennedy worked in the early 1950s, was a prominent exponent and elaborator of this variety of systems-thinking. In 1951, Kennedy set up a small experimental programme at RAND titled the Systems Research Laboratory, with the intention of exploring psychological theories of stress and group organisation amongst air defence crews in the Manual System. Contrary to the propositions of other defence researchers to *automate* as much of the air defence system as possible using digital computers (as we will see in Part II of this case study), the SRL developed into an experimental training programme designed to explore the possibilities of improving the efficiency of the Manual System's 'human factor'—that is, the dozen or so operators who staffed each of the many Direction Centers set up across the country. As Kennedy found out over the course of the SRL experiments, the issue of how to circumscribe the limits of the system was crucial to the management of the 'human factor'.

### 4.2.3 A New Laboratory

In his address at the *Current Trends in Psychology* conference referenced earlier, Kennedy offered an admission of a failing in the *Handbook* which, for him, was exemplary of a pattern across various fields of science engaged with the analysis and management of human-machine systems. As he expressed it, it was a problem of 'component thinking', whereby the constituent elements are carefully analysed, at the expense of a thorough investigation and consideration of the manner in which they interact. He stated:

> [The scientist] studies the components intensively and, many times, is piously content to leave the problem of interaction of components to some future time or to solution by wisdom. I am particularly sensitive

> to this criticism in relation to the field of human engineering, where, it seems to me, component thinking has dominated the efforts to establish it as a substantial scientific contribution to the real world of human affairs. […] The *Handbook* answers many component questions having to do with the parts of the human and his environment, but it is woefully weak in answering systems questions. (Kennedy 1952, 3)

Kennedy pointed out that this was partially an issue of scale: a given element may itself constitute a subsystem, and as such it may make sense to narrow the scope of analysis. However, there remained the problem of designing complex systems whose parts are guaranteed to function and interact in a reliable, predictable, and efficient manner. The key question for Kennedy was 'what do we have to do to the parts in order for the whole system to perform the overall task we wish it to perform at some level of predictability?' (1952, 5–6). The situated worldview embedded in this quest to make systems predictable has distinctive military inflections: to command and to know that the command will duly be carried out.

Two weeks before delivering this paper, Kennedy had embarked on a research project at the RAND Corporation that purported to go some way to answering this question. This programme would have a major influence on the 'human factors' issues of the SAGE air defence system as it was deployed in the late-1950s. The project was carried out under the title of the Systems Research Laboratory (SRL), with the initial aim being the examination of problems of group organisation, and how teams learn to manage high-stress working environments. The project's initial links with air defence crews were somewhat arbitrary: it was only following a discussion with RAND engineer M. O. Kappler, who was familiar with the operational problems of the Manual System, that an air defence Direction Center was proposed as a viable site of analysis (Baum 1981, 15). The SRL's team was complete when Kennedy was joined by the psychologists Robert Chapman and William Biel, and the mathematician Allen Newell—the latter being a prominent figure and collaborator of Herb Simon in early formative artificial intelligence research. Operating out of an unlikely location at the back of a billiard hall in Santa Monica, California, the SRL team conducted simulations of World War III in a carefully constructed replica of a Manual System Direction Center, replete with banks of radar scopes, weapons directors, and a situation board.

When the SRL was established, RAND was a newly formed autonomous organisation, only spun off from the Air Force in 1948. For a few years prior to this it had existed as an internal partnership between the Douglas Aircraft Company and the Air Force, so there was a close, if brief, history of collaboration between RAND's staff and problems of aerial strategy. RAND's original mission, as Claude Baum states in his history of the corporation, was to 'study the problems of intercontinental warfare and to recommend cost-effective programs to the Air Force to attain greatest security for the United States' (Baum 1981, 15). It is also the exemplary Cold War 'defence research' institution. RAND was a fairly diverse interdisciplinary space employing representatives from across the human and natural sciences, albeit those who mostly held shared interests in the modelling techniques of operations research, game theory, information theory, and cybernetics—in other words, had a firm interest in quantification. In its standard publication format, the RAND memorandum, it prolifically published a diverse array of theories that proffered to systematically approach defence problems in areas as varied as Air Force supply chains (Renshaw and Heuston 1957), the deployment of troops in counterinsurgency operations in South-East Asia (Weiner 1959), and the likely effects of thermonuclear war on the American economy (Kahn 1960). In addition, there was the enormous contribution made by the SRL in the areas of organisational management and the method of 'systems training', and its instrumental role in the establishment of the field of software engineering (as noted by Ensmenger 2012). Numerous histories of Cold War technopolitics have noted that, across these varied applications, considerations of modelling 'situations', optimisation, and examinations of the rationality of decision-making were frequently central (Edwards 1997; Mirowski 2002; Light 2003; Abello 2008; Erickson et al. 2013; Bessner 2015; Halpern 2015; Crowther-Heyck 2015; Weinberger 2017).

In a paper dating from 1955, John L. Kennedy and Robert Chapman captured one of the prevailing concerns of the SRL project, and an issue more broadly associated with defence research at RAND in the 1950s. The paper proposed the existence of a 'technological society' characterised by an unprecedented reliance on large human-machine systems of unprecedented complexity. They argued that these systems were expanding to a scale 'beyond comprehension' for their operators (Kennedy and Chapman 1955, 1). They wrote:

> As the systems have grown in size and complexity, the tasks of the men who run them have too. Bigger and more complicated machines won't necessarily give us better results. It's necessary to understand the behaviour of the men who operate these systems, and since systems are run by teams and not by individuals, understanding the critical human elements of these systems means going beyond individual psychology into the terra incognita of organisational behaviour. (1955, 1–2)

This was a shift away from the observation of individual performances and the meticulous prescription of actions—both of which lay at the core of Taylorist notions of Scientific Management as it was applied in practice. In this way, the SRL reports represent a break with industrial managerial theory and 1940s human factors engineering. The constitution of the 'system' as a whole was prioritised as the object of analysis, explicated through a theory of organisational psychology inflected with the terms, models, and metaphors of cybernetics and information theory that were shaping the interdisciplinary discourses of defence research. An effect of this discursive shift was that the rationalisation of operational practices was no longer just the domain of the manager: the operators themselves were recruited into the effort to dynamically *self-optimise* and *manage* themselves as integrated elements of the system. Every action had repercussions for other parts of the system, and thus the process of making the system more efficient was reframed as an effort of iteratively tuning the relations between each ‘element’ and measuring the level of organisation of the system. Feedback, information, and control were pivotal concepts in this style of management. Kennedy and Chapman’s remarks quoted above, however, raise the question of precisely *how* human behaviour was understood to figure into complex human-machine systems in the context of their experiments, and the ways in which it could be ‘objectively’ measured.

Their answer to this question was explicitly framed as a speculative process. The SRL was a research programme without any initial hypothesis but largely organised around the development of an open framework (Chapman et al. 1959, 263). What they were doing was *not* traditional laboratory science, they explained, even though they heavily drew on established concepts, models, and methods (Chapman et al. 1952, 1959; Kennedy and Chapman 1955; Chapman 1956; R. L. Chapman and Weiner 1957). To examine the behaviour of and relations between humans and machines in a Direction Center, they claimed that they had to devise a radically new approach to studying group organisation.

Introducing the research programme in a 1952 RAND memorandum, Chapman stated that ‘experimental techniques will need to be stretched beyond their present development and a class of models will have to be chosen which the stretched techniques may possibly encompass’ (Chapman et al. 1952, 2). A later paper delivered to the Air Force’s National Research Council symposium likened their laboratory to a ‘wind tunnel’ that would ‘expose the weak points in the design of the prototype [Direction Center]’ (Kennedy and Chapman 1955, 6). Elsewhere, they described the experiments as a ‘search for a framework for comprehending organisational behaviour’ (Chapman et al. 1959, 252), and ‘an ambitious investigation at the frontier of knowledge where the terrain is not well mapped and the research tools are being developed as needed’ (1959, 250). Despite these speculative, experimen-

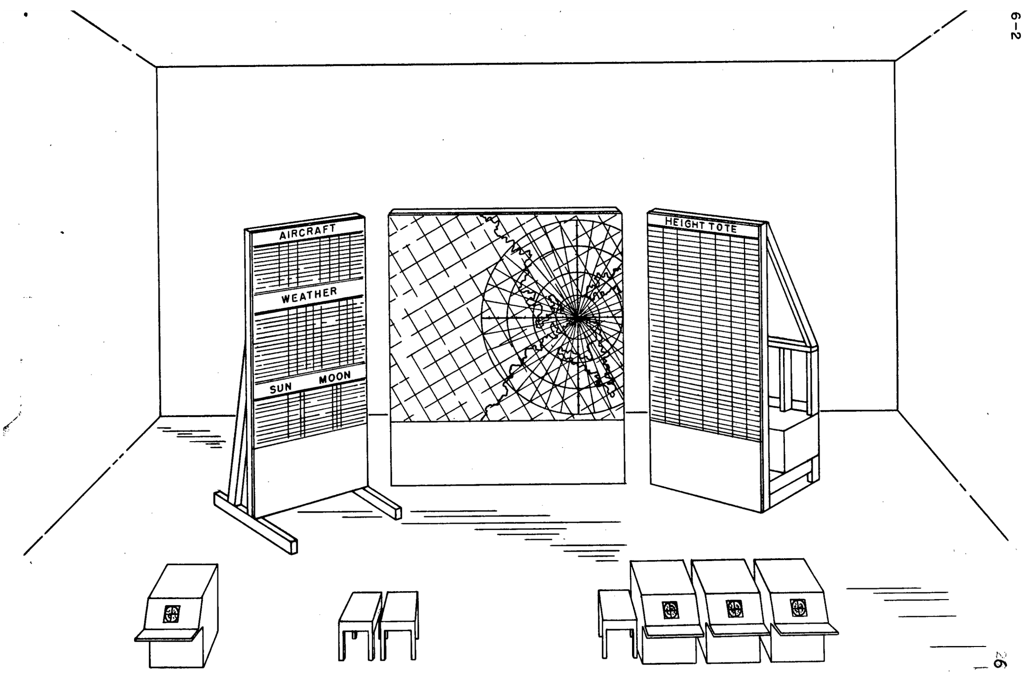



Figure 4.3: Illustration labelled 'View of experimental room B from observers deck', from the 1952 SRL memo.

tal qualities, the SRL held firm beliefs that they could produce a knowledge of group organisation which could be mobilised to manage the human factor in air defence systems of unprecedented complexity. In that the experiment series aimed to produce a knowledge of group behaviour, and developed into a programme to prescribe operational procedures, the SRL functioned as a controlled site for the development of a regime of practices.

Over the years 1952-1954, the SRL facilitated four studies codenamed Casey, Cowboy, Cobra, and Cogwheel. Each study dealt with a set group of about forty subjects in a series of experiments that spanned six weeks, amounting to about 200 hours of laboratory time (Kennedy and Chapman 1955, 3). The basic format of the studies was well-defined from the outset: the group of subjects underwent a series of missions in a model air defence Direction Center, each mission simulating a carefully designed and controlled invasion scenario. During the simulations, their collective performance was measured across a series of parameters while the workload—i.e. the number of aircraft in the virtual airspace—was increased and the organisation became more 'stressed'. Following each experiment, the team would be brought into a meeting room for a debriefing session, and provided with quantitative feedback of their collective performance. They were presented with a set of statistics regarding their successes and failures at identifying friendly and hostile aircraft, the psychologists' and subjects' observations would be shared and discussed, problems identified, and opportunities for further efficiency would be sought out for the subsequent experiment.

Casey, the first study, acted as a prototype, and involved a group of college students. The following three worked with Air Force personnel with experience of working in Direction Centers, and with the culmination of the fourth study, it was clear that the project had expanded beyond its initial speculative purview. The SRL's preoccupation had shifted from the analysis of group interaction to defining a set of methods that could, according to the project leads, act as a general training programme for the efficient performance of human-machine organisations. At least as they reported themselves, the results were positive from the outset:

> In the process we found that this system would perform better than had previously been thought possible—the crew learned. As a result, a number of psychologists are now busy putting this training technique to work in improving the performance of a system important to our national security. (Chapman 1956, 1)

For the SRL's team of scientists, it was crucial for the laboratory to reflect as closely as possible the features and atmosphere of the actual Direction Centers of the Manual System. In a retrospective article published in the journal *Management Science* in 1959, Chapman succinctly stated their approach: 'to get behaviour worth studying, we tried to make the simulated environment genuine enough for the crew to respond to them as if they were real' (Chapman et al. 1959, 251). When it came to the fidelity of the simulation, however, it is important to identify what mattered to the psychologists. Indeed, reports on the SRL experiments document significant efforts to not only simulate the technical apparatuses of the Direction Centre, but also something much greyer and more ephemeral: the *emulation* of the institutional discourse of the Air Force became an important fixture in this regime.

The historian and erstwhile RAND employee Claude Baum opens his history of the corporation with an evocative passage that emphasises the fidelity of the SRL's simulated 'Direction Center' to the live air defence posts of the Manual System. He writes:

> As the newcomers' eyes adapted to the dim light, they saw a team of men in intense concentration: some seated at consoles watching small blips move across backlit picture scopes, others swiftly plotting tracks on transparent display boards, still others receiving and relaying messages over headphones and intercoms, while the voices of aircraft pilots crackled over loudspeakers. These 'boys in the back room' appeared to be directing an air battle raging over the United States and Canada. (1981, 11)

Everything described above was, of course, carefully simulated or manufactured in order to reproduce a notional reality of the Direction Center. In the early studies, the picture scopes were not the typical radar scopes, but bespoke machines constructed for the laboratory displaying rolls of paper printed with mock-up flight trajectories generated by a computer; the 'aircraft pilots' were the SRL's team reading off scripts; and the voices phoning in from the notional adjacent radar installations were taken up by more crew members. Less apparent were the observational facilities: discreetly-placed microphones recorded all discussion in the laboratory space; telephones were bugged which enabled any conversation to be 'tapped at will' (R. L. Chapman 1957, 7); and an observation room where the scientists and their assistants could view and annotate experiments from behind a two-way mirror.

Although the design of the interior was carefully considered, this simulated environment went beyond producing an architectural facsimile of the Direction Center. What is particularly interesting about the SRL's experiments was the attention to recreating the institutional atmosphere and discourse of the Air Force in the laboratory. The matter of how to engender an 'operational atmosphere' imbued with these formal discourses, practices, hierarchies was the subject of extended consideration and trialling, particularly during the Casey study (Chapman et al. 1959, 258). Chapman wrote that a 'more realistic military culture' was engendered in subsequent studies through an approach to managing the experiments in a way that replicated the bureaucracy of the Air Defense Command in the laboratory. The SRL staff communicated with the crew 'solely in the name, form and style of the Air Force' (Chapman et al. 1959, 258). As if to prove that grey media serve a critical institutional function, the SRL staff produced a raft of documents that amounted to an administrative library—'a laboratory series of division regulations, memoranda, and special orders' which set out standard practices, protocols, and the institutional organisation of the crew (Chapman et al. 1959, 258).

Furthermore, the grave implications of the simulated invasions was also performed as 'real' in briefings. In a script for an internal film documenting the Cogwheel experiment in 1954, Chapman delivered a speech that drew on the fraught disposition of national security and the ever-imminent threat of nuclear attack:

> But have you been brought here to defend against the air situations that you know so well? No, you have not. You know the world situation is tense. Tomorrow it could be hostiles that you're tracking. And a plane that gets through could mean an A-bomb over one of your cities. The strike will come. But when? Where? And, how many? [...] And the question that remains to be answered is—can you stop them? (R. L. Chapman and Weiner 1957, 17)

Having gone to such lengths to simulate both the bureaucratic organisation of the Direction Center and grander political narratives of security and threat, it

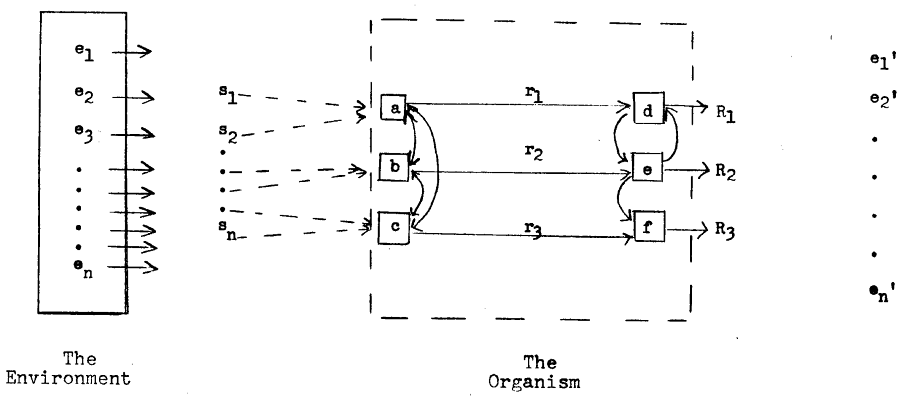



Figure 4.4: Illustration labelled 'Schematic Diagram of the Environment, the Stimulus, the Organism and Its Reponse', from 1952 SRL memo (p. 14).

was crucial for the SRL staff to maintain these atmospheric and motivational effects during the actual experiments. The contrivances of the laboratory and the scripted nature of the scenarios presented in the experiments had to fade into the background, leaving a set of emergent tasks and decisions for the air defence crews to manage and adapt to as if the invasion was 'real'.

### 4.2.4 Information Processing

Across the lengthy list of memoranda, papers, and occasional journal articles published by SRL staff, we recurrently encounter a set of metaphors and models used to explicate the organisational relations between humans and machines. Attention to the discursive positioning of these experiments—the specific terms and analogies employed—are key here as they indicate how the SRL team envisaged their work within the broader discourse of defence research, and post-war psychology more broadly. As such, they served both an explicatory and legitimating function: these metaphors described a set of theories of human-machine organisations as types of systems and human perception as a form of information-processing.

They did so while explicitly employing terms and concepts from other more institutionally established specialisations within post-war defence research.

Firstly, the model which they employed to theorise these relations was that of the 'organism'—what they defined as a 'complex system with parts so integrated that their relation to one another is governed by their relation to the whole' (Chapman et al. 1952, 10). In a 1952 memo introducing the programme, Chapman explained the theoretical implications for this choice of term. Firstly, the organism emphasised a holistic system-wide analysis. In other words, it was a study of the relations *between* what were understood as 'elements' or 'parts', rather than the parts themselves. Secondly, they used the organism to frame their experiments within a behaviourist understanding of learning, whereby learning is examined through the control of environmental stimuli (the appearance of a new aircraft on a radar scope, for instance) and the resultant observation of response (the crew's decision whether to prioritise tracking it). Finally, they believed that the organism was thus in a constant state of adaptation, and that this adaptation could be managed through the careful modulation of stimuli. Learning could be engendered by managing the quantity of 'information' flowing through the organism. This concept of the organism and its theoretical implications were later described as 'key notion for explaining the behaviour of the four crews studied' (Chapman et al. 1959, 250).

The second set of metaphors used in describing the model employed in their experiments possessed distinctly computational qualities, producing an operational logic of human-machine relations explained entirely through information flows. Chapman described their laboratory as a 'specialised computer which grinds out the consequences of humans interacting with hardware and each other' (Chapman et al. 1952, 1). Their laboratory was recast as a particular type of organism which they called the 'Information Processing Center', a zone of control and observation where humans and machines alike were conceptualised as receptors, processors, and broadcasters of information, and with decision-making itself becoming an act of 'information processing' (1952, 3). Chapman stated that 'the number of ways its internal and external behaviour can be measured and these hard numbers sorted, analysed and related is limited only by the talent and stamina of the researchers involved' (1952, 2).

This operational logic of information processing not only shaped the theoretical arrangement of humans and machines in the simulated Direction Center, but also informed the ways in which the SRL sought to open up the actions of the crew members to a system of measurement. The model of the IPC posed a set of problems around precisely *what* counted as information, how it should be measured, and the kind of techniques that could be employed to open it up to analytic scrutiny. The SRL required some variable that could be compared over a series of experiments to demonstrate whether or not the crews had collectively 'learned' to become more efficient. As such, the problem was what criterion might serve as evidence of a more optimal organisational constitution. One type of 'information' that they were particularly interested in was verbal: 'The IPC processes only one commodity, information; a good deal of it will flow in verbal form' (1952, 22). The evidence of 'learning' was the spoken words of the human operators—not *exactly* what was said, but the *quantity* and *type* of things that were said, and to *whom*. 'In the Direction Center', they later wrote, 'changes in the use of information are exposed in what crew members say to each other' (Chapman et al. 1959, 251).

The SRL staff devised a schema to categorise different types of phrases uttered by operators. The SRL team aimed to graph the number and 'type' of phrases against the rate of information introduced into the system—this being the number of aircraft appearing on the radar scopes at any one moment. However, precisely how to count and schematise what a team of 40 or so operators said during a single session was a significant task that introduced its own information-processing problems. Consequently, a parallel system of observation, with its own training requirements, standardised set of technical instruments, and their attendant operators was required. While the design of the laboratory readily facilitated eavesdropping into conversations between operators, the team opted to employ an experimental technique for the standardised coding of speech drawn from the work of Robert Freed Bales. A prominent social psychologist who worked at RAND in the early 1950s, Bales' work often dealt with issues around group organisation and the social factors in decision-making—albeit often in rather more perfunctory task environments than an air defence Direction Center. Devising techniques to systematically convert conversational speech into a quantitative 'code' was of central interest in his work: 'Talk is an elusive object of study', Bales wrote in a RAND memo, 'in spite of the fact that a good deal of it exists' (1954, 1). As he detailed in a 1954 article for *American Sociological Review*, with an adequately designed group interaction laboratory and adequately trained 'technical observers', however, all of this 'talk' could be opened up to quantitative analysis (Bales and Flanders 1954).

Bales' toolkit of procedures and technical devices, and in particular his invention 'the interaction recorder', were designed to quantify qualitative 'information'—that being the fluidity of group conversation and the myriad gestural cues which comes with it (1954, 774). In other words, it allowed for the imposition of a systematic grid onto what might otherwise be understood as unstructured data. By coding speech according to a formal methodology, Bales believed he had opened it up to a distinctive type of quantitative analysis that sought out patterns in types of communication 'acts', and as a result, could map the social relations between individuals in a group. The interaction recorder, a consistently unspooling roll of paper on which notations were printed, functioned as a control interface for a trained observer to timestamp and code acts between individual subjects according to a set of twelve standardised categories, including 'shows solidarity', 'gives opinion', and 'shows antagonism' (Bales 1954, 5a).

An analysis of the function and associated procedures which these standards made possible provides an insight into the 'general politics of truth' of this regime. Bales thought of his twelve categories of communication acts as exhaustive. By his measure, it could provide a 'unique and appropriate classification for every act that might be observed in communication between persons in any sort of situation' while also being uncomplicated enough so that it could be recorded in real-time (1954, 6).

> Member 1: 'I wonder if we have the same facts about the problem? (Asks for opinion) Perhaps we should take some time in the beginning to find out. (Gives suggestion)'. Member 2: 'Yes. (Agrees) We may be able to fill in some gaps in our information. (Gives opinion) Let's go around the table and each tell what it said in his case. (Gives suggestion)'. (1954, 8–9)

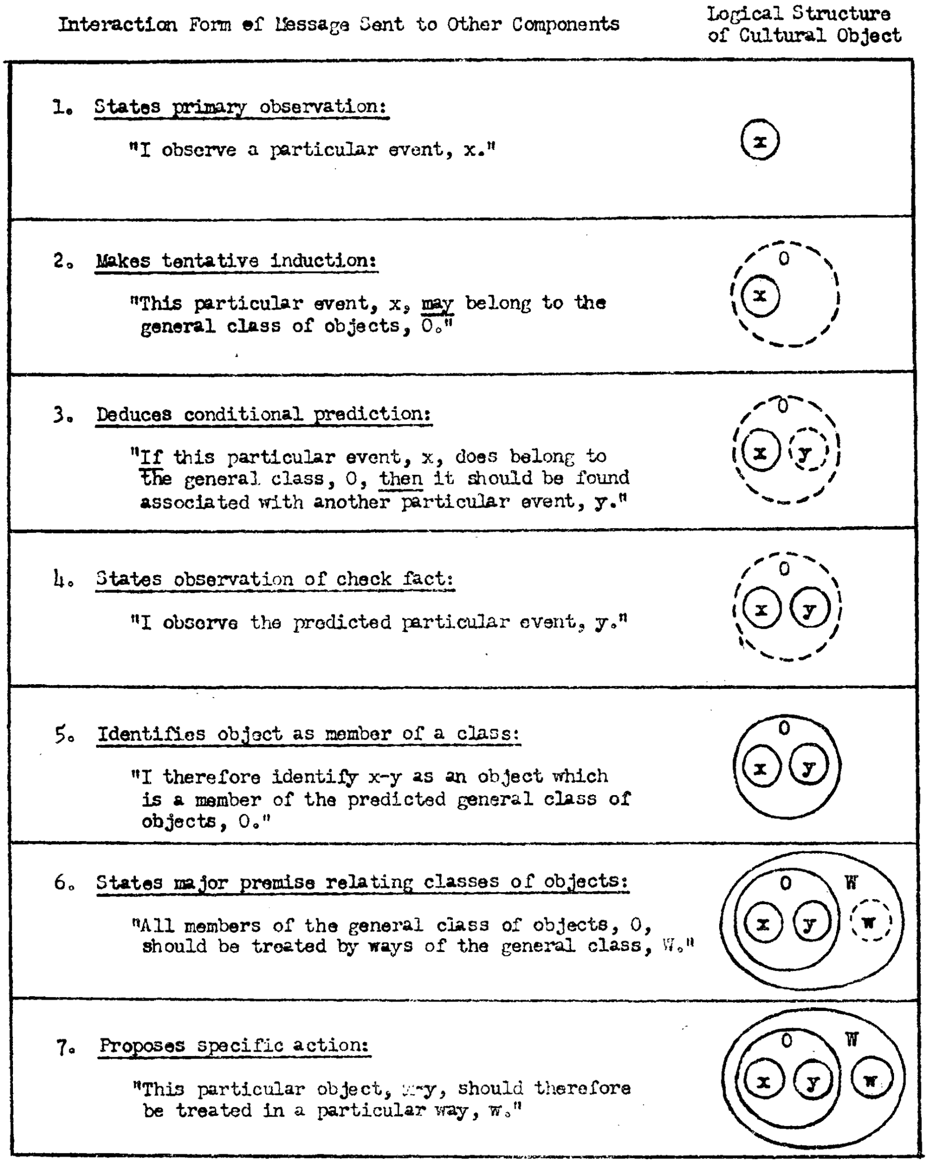
The scientificity of this methodology was further embellished by Bales through the recording process. In a given experiment, as many as five observers trained in using the interaction recorder would quickly write down the identification number of the person speaking and to whom along with the category number, with events recorded typically 'at a rate of 15 to 20 per minute' (1954, 5). As Erickson et al. (2013, 121) note, this rate of work was presumably very demanding on the observers, and even more so given that Bales' method also attempted to account for the subjective disparities in codings between those recording the conversations. Observers in turn had to be observed and controlled in order to bolster the method's claim to scientific objectivity: lights on the interaction recorder would illuminate to signal any deviations between their respective codings and act as something like a calibration mechanism, merging their analyses toward each other. Any deviations between the observers' datasets would later be averaged out, producing a quantitative record of a group interaction experiment from the notional 'average' observer. In functioning as methodological implements to convert a rich discursive environment into a stream of numbers, such information could be rendered as a set of descriptive tables and graphs, and subjected to further analysis, comparison. Importantly, constructing such information as a series of numbers in accordance with a particular data structure rendered it intelligible to the computer, opening it up to processing on a scale otherwise burdensome for human calculation.

Alongside this computational possibility, the universalising aspirations of Bales' methodology are quite clear in his 1954 RAND memo:

> 'The study of social interaction on the face-to-face level assumes a broad significance when one recognises that what goes on in a small decision-making group is a microscopic prototype of the processes and problems that characterise a wide variety of communication and control networks, both human and electronic'. (Bales 1954, 2–3)

The discursive framing of his theory of group organisation echoes that of the SRL. For Bales, any social group—whether a chess team deciding on a chess problem or an air defence crew fighting off a simulated invasion—was a communication network whose definition was shaped variously by the 'functions' of its 'human components'; their respective processes of making decisions, cooperating and producing information; the social relations between them; and the negotiation of a 'common culture' of shared 'norms' (1954, 6–7). In a summary statement which evokes the logic of stochastic processes in wartime fire control, Bales wrote: 'It appears that social interaction, in common with a large class of control mechanisms, depends upon error and correction of error as a means of guidance in approaching the goal' (1954, 9). Bales concluded that social interaction amounted to a teleological process comprised of a finite set of possible relations and 'events' which would ultimately culminate in a *decision*.

When Bales' work brought him to RAND in the early 1950s, he collaborated with the SRL, exploring how the social organisation scenarios he had been working on previously might provide insights into the management of the Direction Center.



| Interaction Form of Message Sent to Other Components | Logical Structure of Cultural Object |
|---|---|
| 1. States primary observation: "I observe a particular event, x." | |
| 2. Makes tentative induction: "This particular event, x, may belong to the general class of objects, O." | |
| 3. Deduces conditional prediction: "If this particular event, x, does belong to the general class, O, then it should be found associated with another particular event, y." | |
| 4. States observation of check fact: "I observe the predicted particular event, y." | |
| 5. Identifies object as member of a class: "I therefore identify x-y as an object which is a member of the predicted general class of objects, O." | |
| 6. States major premise relating classes of objects: "All members of the general class of objects, O, should be treated by ways of the general class, W." | |
| 7. Proposes specific action: "This particular object, x-y, should therefore be treated in a particular way, w." | |

Figure 4.5: 'Seven types of component acts in building a group decision', from Bales' 1954 RAND memo (p. 10a).

Bales saw a direct correlation between air defence and his universal model of group organisation. The process of air defence—the continuous analysis of radar scopes, tracking aircraft, comparing flight plans, calling for interceptions—can be reduced into a 'symbol-aggregating-and-transforming-process', or to put it more simply, a chain of 'decisions' (Bales 1954, 11). Yet for Bales, the social context was pivotal in the way individual decisions interlinked with one another:

> The job of any such decision-making organisation is essentially to build and maintain through means of communication and evaluation a sufficiently complex and commonly accepted symbolic structure to guide or control further stages of behaviour and other operating units. Effective decision-making is basically a continuous process of building and maintaining a structure of cultural objects which in their totality constitute the common culture of the organisation affected. (1954, 11)

Within the environment of the Direction Center, the 'structure of cultural objects' as used here implied the rules that might include agreed terminologies, hierarchical relations, division of tasks, and the common imperative which the group as a whole ideally worked towards. For air defence crews, part of the structure of cultural objects then were notions of duty, command, assignment, instituted operational practices, and so on. In other words, it can be understood as an accepted set of norms which govern the actions—spoken or unspoken—of the operators.

Extrapolating any 'scientific' theories of group organisation from their experiments required the SRL team to engage with the problem of objectively structuring these flows of information in such a way that would open them up to scientific analysis. The issue, in Chapman's (1952, 22) words, was humans' 'addiction' to 'the use of a set of symbols, language, which is very hard to code'. Yet, it was this discursive dimension of human-machine organisations which was crucial for the SRL to analyse if they were to understand how they prioritise, adapt, and learn. Drawing on and incorporating Bales schemas to code language, the SRL produced a framework which could assign any speech act a standardised, computable, quantitative notation. They (1952, 23) described a prototypical classificatory system based around what they state are the two categories of information *necessary* in an organism: 'that which has to do with establishing a routine for problem solution, and that which carries out the operation once the routine is determined'. These two types of information were respectively labelled 'set' and 'performance'. A third type, termed 'therapeutic', effectively amounted to any speech act that didn't easily fit within the former two categories but which served 'to promote the processing of performance information' (1952, 24). The categorisations outlined here only provide a snapshot of the SRL's method in the very early stages of their programme—the precise terms, categorisations, and granularity of these discursive schemas very likely changed over the course of the four studies. The crudeness of these three categories of speech, even if they were but a mere sketch of what would later become a more developed schema, highlights the tensions between purportedly 'objective' and 'scientific' methodologies and what Kennedy (1952, 1–2) described as the 'complexity of real human affairs'.

Despite the explicitly speculative nature of their research programme, the SRL reached a rather firm conclusion quite quickly: they believed that they had successfully devised a model which permitted the quantitative assessment of group organisation and the function of 'stress' in organisational learning.

> Just what does an air-defence crew do to maintain effective performance in dealing with a task that keeps getting harder and harder? A rather obvious answer is that it spends its efforts more efficiently. With each increase in the number of tracks the crew had to deal with saturation seemed imminent because the crew found it more and more difficult to continue handling each track with its current procedures. But each time that saturation seemed imminent, some way of simplifying the job was found. (Kennedy and Chapman 1955, 8).

'Perhaps the most important result of these experiments', Kennedy and Chapman wrote, 'is that such concepts as stress, rate of learning, and so on can be described quantitatively' (1955, 9–10).

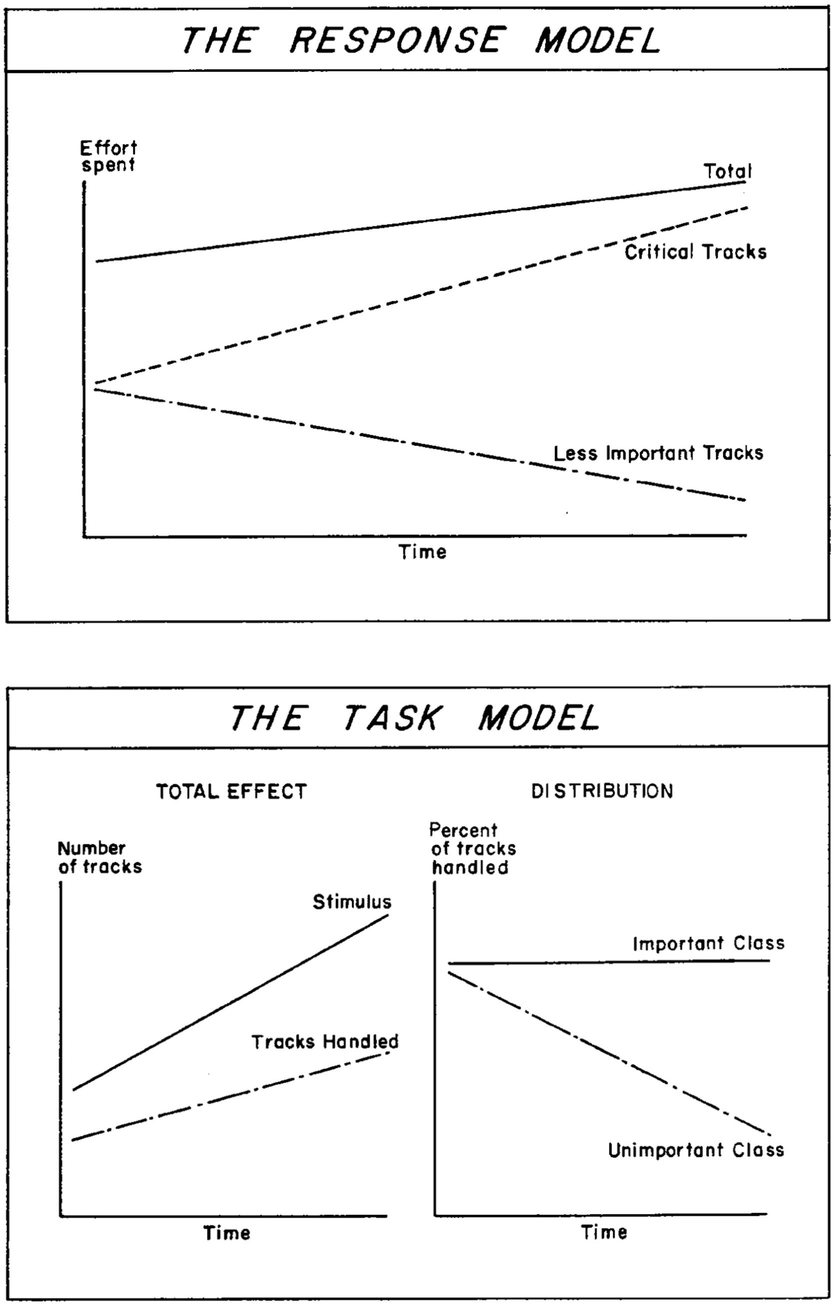



Figure 4.6: Two graphs depicting the 'Response Model' and 'Task Model' of the experiments from Kennedy and Chapman (1955). Tracks refers to the number of inbound aircraft vectors displayed on the radar scopes, and was used as a criterion in calculating the 'information processing' and 'learning' rates of the crew.

However, to quantify required the team to devise a model of learning which, as has been detailed above, was at its core mediated within the discourse and imperatives of post-war defence research: devising techniques which permitted the most efficient and predictable melding of bodies and machines. Their model was located at the points of convergence between experimental psychology and the then-influential discursive formation of the information sciences: humans and machine elements alike were understood purely as recipients, processors, and emitters of information. For the SRL psychologists, measuring the rate at which information circulated across the 'organism' represented an objective account of learning. Stress, in this model, was likewise understood in terms of the rate of 'information load' in the organism. Its affective dimensions were only important in so far as they could be used as catalysts to stimulate behavioural improvisations amongst the crew that increased the efficiency of information processing.

Efficiency, measured primarily in terms of the speech patterns between operators against the rate of information introduced into the system (1955, 9a), occluded an enormous swathe of contingent factors that inevitably shape human-machine organisations, and not least those institutional context as notoriously bureaucratic, hierarchical, and expansive as the United States military. The simulated Direction Center was quite clearly only intended to examine a particular operational facet of the workings of the air defence system—the crew of a Direction Center. However, with the creation of such experimental models, the potential dissonances between the model and the environment in which it can be thought to be adequately applied have to be dealt with. The limits of the 'organism' model, when removed from the controlled site of the laboratory, were less clearly rendered. The system of relations extended beyond the crew to the broader configuration of protocols, interests, and regulations of the institution itself.

The retrospective account of the programme in *Management Science* was comparatively more candid in detailing the considerable difficulties and technical challenges they experienced as a laboratory. The information-processing problems experienced by the laboratory itself were, they admitted, quite significant:

> For observers to penetrate, with the naked eye, the devious machinations of a growing organisation, to translate behaviour into meaningful codes, and to maintain a standard set over the entire experiment is a data collection problem that can only be described as horrid. (Chapman et al. 1959, 262)

The irony of a research project designed to explore the collective management of 'information' itself coming under substantial strains in its own information management has been noted by Ghamari-Tabrizi (2012): 'The SRL scientists were not as nimble as their subjects. The task load was too difficult: they could not distinguish between what was important and what was not' (2012, 286–87). Despite the purported omniscience of the laboratory, a quality attested to by the lengthy discussion of its observation facilities in the many memoranda describing the project, Chapman et al. (1959, 263) themselves admitted that 'only part of the data has been successfully coded or explored at any length'. Buried in this abundant data, they mused that 'literally hundreds of pretty hypotheses have been lost in it' (Chapman et al. 1959, 263).

This issue, whereby command and control systems designed to make the management and processing of information 'more efficient' themselves succumb to the problem of information overload and paralysis, will be a recurrent theme in the second part of this case study, and in the study of IGLOO WHITE in chapter 5. Examining the elaboration of such defence research programmes as the formation of a regime of practices imbricated in broader yet specific discursive rules helps to identify the ways in which systems accrue systems: the solution to the first-order problem of the less-than-optimal performance of a Direction Center crew was opened up through an operational logic in which all action was a form of information processing. This itself produced a second-order problem of how to schematise, record, and process the information thought to have been produced by the crew. For them, the types and rhythms of 'acts' of speech could be used as a measure for the level of organisation in a system: an organised system was one that could 'discriminate' between 'important' and 'unimportant' information and identify sequential patterns, limiting its own communication practices in response (1959, 266).

### 4.2.5 Systems Training

In the late 1940s, the United States' air defence system was a highly manual and heterogeneous arrangement of active and reserve military and voluntary civilian forces. In the early 1950s, however, an effort to create a standardised approach to 'systematically' train air defence crews developed out of an experimental programme at the RAND Corporation. As described above, this programme explicitly described the events of some hypothetical Soviet invasion as a problem of information management. One possible framework to deal with this, they proposed, was to *simulate* possible invasion strategies, and chart the collective performance of an air defence crew in terms of their capacity to manage information.

Despite the admitted technical issues involved in the processing of this information, and the extent to which hypotheses *could* be drawn from it, the SRL was a deeply productive endeavour: it led to the generalisation of a set of principles, instruments, and a discourse that significantly shaped what it meant to be an 'operator' in the air defence system in subsequent decades. These principles were not explicit instructions for the operator on *precisely what to do* as with Scientific Management, but rather were intended to facilitate a context in which the operators as an organisation could *learn.* Notwithstanding the admitted issues pertaining to data collection and processing, the result was an understanding of organisational 'stress' and 'learning' wholly organised around the ostensibly scientific measurement of particular flows of information. Within this operational logic, the human operator became something like a *relay* in an information processing system, and thus to operate efficiently was to modulate and filter the flow of information with respect to the rest of the crew. In doing so, it further embellished and normalised the notion of computational metaphors in the analysis and management of groups of people in 'high-stress' scenarios.

The prescriptive effect was a disciplinary and technical regime for training individuals that left the laboratory and entered the very real Direction Centers of the Manual System dotted along the national perimeter. By the time the final Cogwheel study had completed in 1954, the SRL was already in discussion to institute their experiments as a training programme on behalf of Air Defense Command. This new programme worked on the basis of four key principles extracted from their experience with the crews in the laboratory: treat the organisation as a *whole system*; simulate the operational realities of war as much as possible; provide 'knowledge of results'; and reinforce a collective 'system goal' (Air Defense Command 1955). This was called the 'Systems Training Program' (STP), and by the late-1950s, it became the basis for training a new class of operators—not of a 'manual' system, but of new digital, networked, and computerised SAGE system. In this system, notions of 'information processing' were technically encoded in the design of human-machine protocols, practices, and interfaces.

## 4.3 Part II: The Semi-Automatic System

### 4.3.1 Diagrams of Control

In an extensive reflection on his central role in the SAGE project written in 1985, the physicist George Valley wrote that he was 'emotionally primed to respond' to the news of the Soviet atomic bomb test, 'the more so perhaps because I realised that my almost-completed new house was vulnerable to the blast wave of the first bomb to hit Boston' (1985, 198). At the time, Valley sat on the Electronics Panel for the Scientific Advisory Group (SAG), an organisation formed after the Second World War to advise the Air Force on its research and development programmes. It was largely comprised of scientists and engineers based at universities across the United States, albeit with Valley's academic home of MIT making up a significant contingent of the board. With its roots firmly in the military-industrial-academic relations established during the Second World War, its meetings developed into what one Air Force historian described as 'major forums of exchange' (Sturm 1967, viii) that shaped the research trajectories and priorities of the service.

The SAG counted a host of defence research luminaries as its members: the esteemed aerodynamicist Theodor von Karman served as Director, with engineers and scientists possessing experience in areas ranging from radar to nuclear weapons such as Ivan Getting, Vladimir Zworykin, and Enrico Fermi also on the board. Many of the SAG members spent formative years working at the NDRC during the Second World War, working on problems of fire control and ballistics, where techniques of automating hitherto manual calculations were key in the development of new defence technologies. Slayton (2013, 21) explains that wartime research on radar, fire control, and computing served as 'a training ground for the post-war scientific elite', cultivating a vast body of knowledge and technical proficiencies amongst a new generation of American scientists and engineers. A number of these figures of the ‘elite’ proceeded to apply their wartime expertise to the new field of problems in the domain of air defence strategy.

Shortly following the news of the Soviet test, Valley visited a Manual System radar station to get a sense of the capabilities of the air defence system. Later recalling this visit, he wrote:

> I didn’t see much, because there wasn’t much to see: mostly equipment brought back from the theatres of war, not well suited to the current need, and operated by crews that obviously lacked a suitable doctrine for the accomplishment of the air-defence mission. (1985, 198)

The limitations of the Manual System had already been evident for a number of years, and as such, Valley’s reported dismay might not have come as a major surprise to many Air Force personnel working in the domain of air defence. Nevertheless, Valley was afforded some institutional support from the SAG to put together a team to carry out a fuller analysis and make recommendations. A few weeks after Valley’s initial inspection, he established the Air Defense Systems Engineering Committee (ADSEC) to conduct this larger inquiry. ADSEC was a cross-disciplinary team of aerodynamicists, physicists, and engineers, a number of whom having spent their formative years at the National Defense Research Council working on problems pertaining to radar and anti-aircraft artillery during the Second World War. As we shall see below, the committee’s central proposition was to focus on how to manage air defence during a Soviet offensive, while setting aside longer-term strategies around decentralising key industrial and political centres for other groups to determine (see Galison (2001) for more on this). ADSEC would instead concentrate their efforts on developing an ambitious plan which would, in their own words, ‘prevent the effective detonation of enemy bombs by destroying or deflecting all of the enemy bombing aircraft’ (1950b, 1). The following mission statement acted as an organising imperative that shaped the ADSEC’s proposed schematic of a new air defence system based around a digital computer:

‘to produce maximum effective air defence for minimum dollar investment’ (1950a, 1).

ADSEC published two classified documents in 1950: an interim *Progress Report* in May 1950, followed by a *Final Report* five months later. Both reports set out the possibilities for dealing with a long list of technical issues endemic to communications links, the shortcomings of radar, and the capabilities of the operator. What we find in these documents are a set of metaphors and diagrams which employ much the same terms as those used by the SRL staff in their various memoranda published from 1952. Writing in the final report, ADSEC offered an uncompromising diagnosis of the air defence system:

> In analogy with man, ADSEC considers the contemporary Air Defence System to be lame, purblind, and idiot-like. Of these comparatives, idiotic is the strongest. It makes little sense for us to strengthen the muscles if there is no brain; and given a brain, it needs good eyesight. (1950b, 9–10)

The resonances of ADSEC’s metaphors with those of the SRL are even more explicit elsewhere in their reports. The committee’s final report opens with a brief albeit telling exposition around the definition of system and the proposition of the ‘organism’ as an analytic device for mapping and explicating the capabilities and demands of air defence. The Manual System, in their reports, was explicated as an ‘assemblage’ of ‘animate’ and ‘inanimate’ components working in unison to ‘achieve some defined purpose’ (1950b, 3). This statement is expressive of an operational logic of human-machine organisations closely interlinked with extant ideas and terminologies drawn from wartime control engineering, behavioural psychology, and 19th century biology, a discursive configuration identified by Karl Deutsch in his article ‘Mechanism, Organism, Society’ (1951). For ADSEC, the system was explicated as an ‘organism’ constituted by discrete instrumentally-defined elements, linked together by a chain of communication channels across which signals could flow from one point to another. These elements might be ‘sensory components, communication facilities, data analysing devices, centres of judgement, directors of action, and effectors’ (1950b, 3).

Given many of the committee had formative professional experiences working on automating fire control during the war, it is perhaps unsurprising that this technical knowledge carried through in the metaphors deployed to describe human-machine systems. Like the SRL’s psychologists, both humans and machines were presented as functionally-equivalent elements of the organism, their capacities to act understood in terms of the sensing, processing, and emission of information. Their particular disciplinary standpoints, mediated by the discursive formation of the information sciences, privileged a conceptualisation of organisations as information circuits—whether the organisation in question was an army or a simple mail-order business.

Aside from the difficulties with radar detection of low-flying aircraft, the most difficult issues for ADSEC can be distilled into two interlinked problems which they understood as being introduced by the operator: unstructured communications and slow operational speeds. The framing of these issues throughout both reports was consistently done through comparison with the ostensibly ‘rational’ predictability, fidelity, and high operating speeds afforded by the electronic machines. The report provides the example of the use of a Plan-Position Indicator (PPI) tube, a monitor which translates incoming electrical signals from a radar and displays it to a screen so that the information could be interpreted by its human operator. ADSEC wrote:

> The radar searches space methodically, and once the return signal is detected, the information is available. Furthermore, the information is in an orderly arrangement—namely the order in which the targets were first illuminated. All this advantage of speed and orderliness is lost by the use of the PPI tube. For a man scans the tube in his usual non-orderly fashion and so misses some of the data; the rest he succeeds in transmitting in some random order at a low speed to the remainder of the organism. (1950b, 6)

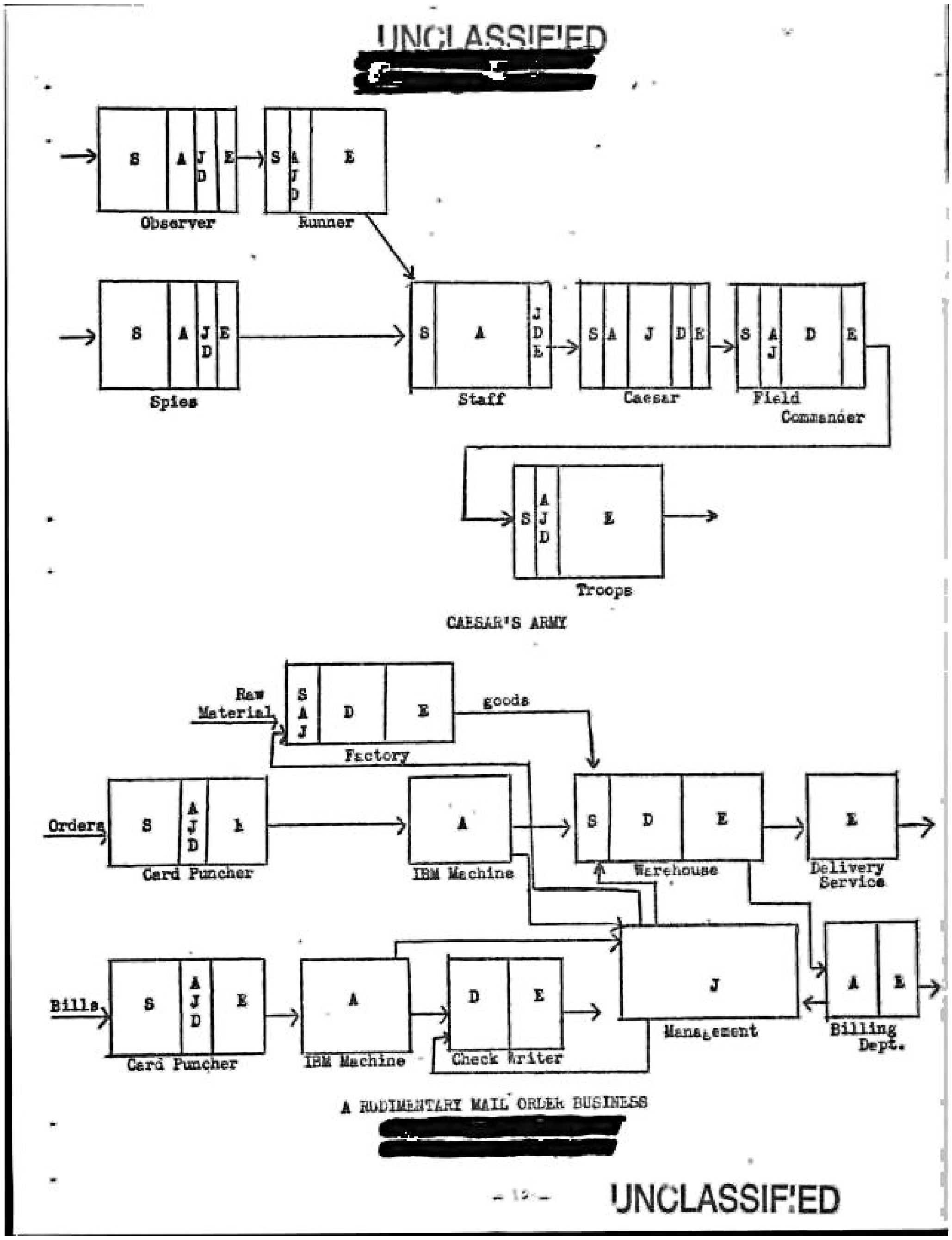



Figure 4.7: The *operational logics* of two organisms ('Caesar's Army' and 'A Rudimentary Mail Order Business') as presented by ADSEC in their *Final Report* (1950b).

The possibility of instituting some alternative arrangement of personnel to combat this is heavily downplayed: ‘it is scarcely conceivable that any amount of training, or the use of any number of men will ever succeed in getting the data onto the lines in as accurate a form as it originally was in the radar receiver’ (1950b, 7). Despite the common discursive qualities, this marks a clear disparity between the respective approaches of the SRL and ADSEC. For the latter, these points of translation from the domain of machine-readable electrical pulses to human-readable signs and symbols, from the inanimate to the animate, were envisaged as a source of operational friction to be minimised, if not occluded from the ‘organism’ entirely. In the Manual System, these points of translation existed across virtually every element, from its ‘sensors’ through to its ‘effectors’. The SRL on the other hand attempted to construct a space that employed psychological stress as a technique to force operators to devise new communication practices and optimise their organisational relations. In this sense, both approaches were keenly alert to the lines *between* the boxes on their information flow diagrams: their respective answers to the problem of how to manage the communication protocols which these lines represented, however, were rather different.

The influence of Claude Shannon is evident in ADSEC’s vision of the air defence system: information circulated across a system of conduits and components, the specificity of its meaning secondary to its expedient transmission and the minimisation of interference or ‘noise’. Understood according to Claude Shannon’s general communication system described in his landmark paper ‘A Mathematical Theory of Communication’, noise is external interference in a communication channel which modulates the quantity of information in a transmitted message. Thus, in a noisy channel, the ‘received signal is not necessarily the same as that sent by the transmitter’ (Shannon 2001, 20). The design and management of communication channels thus involves the minimisation of difference with respect to the bandwidth of the channels in question. In ADSEC’s account of the Manual

System, the human operator was thought to be far less effective in retaining the order of a message than a machine. For the radar and radio operator, the eye and the ear 'may add various false or non-pertinent modifications', they warned, 'they can only with difficulty be made to search in a methodical and exhaustive manner' (1950b, 5). ADSEC believed that information would inevitably be missed or modulated by the operator: whether misinterpreted, miscommunicated, misheard, or misdirected. The issue was that, as a system became increasingly complex and incorporated greater operator positions and machinic processes, opportunities for these errors of translation between humans and machines proliferated. With their idiosyncratic flair for characterising the human in peculiar terms, ADSEC wrote that the operator introduced 'unnecessary and unwanted brains into the organism' (1950a, 5). The solution was clear to ADSEC: relegate as much information handling as possible to the realm of 'electrical pulses' (1950b, 7).

To illustrate their argument for the central importance of the digital computer in their proposed air defence system, ADSEC presented a set of diagrams of 'organisms' that reconceptualised familiar types of organisations as information flow systems (see Figure 4.7). The relations of diverse 'organisms', including those of a 'Boss and Secretary', a 'coin-operated vending machine', a 'Rudimentary Mail-Order Business', and across the various branches of 'Caesar's Army', are all rendered as a schematic akin to an electrical block-circuit diagram (1950b, 11–12). In these diagrams we find visual examples of what I have referred to as the *operational logic* of a particular system, whereby the definitions of a system 'component' and the complex set of relations thought to exist between them is fundamentally shaped by the idea that everything can be explicated in terms of flows of information. For example, ADSEC's diagram described how 'the animal' is constituted by a distributed array of isolated sensors (eyes, ears, smell and so on) which are linked with a central component of analysis, judgement, and direction (the brain) which is linked to an array of length $n$ effectors (muscles) (1950b, 10). The diagram representing the ‘present air defence system’ emphasised the linear and ‘uneconomical’ division of tasks across its constituent sensors (radar and Ground Observers), data analysing devices (filter rooms), centres of judgement (control centres), directors (forward air controllers coordinating interceptions) and effectors (interceptor pilots and their aircraft) (1950b, 13). In following this operational logic, ‘organisms’ apparently as different as an animal and the continental air defence centre of the United States could be compared in equivalent terms.

The ‘organism’ was not just a heuristic device for understanding and quantifying the capabilities and behaviours of existing organisational systems. While it is certainly used in these terms to establish the limits of the Manual System as shown above, its primary purpose was to serve as a guiding framework for designing and legitimising new complex systems and mapping out the optimal distribution of humans and machines across its notional circuitry. For ADSEC, there was a lesson to be learned here that would be carried forward into the design of the new system: ‘One thing obvious is that the best organisations have only one centre of judgement; perhaps this is something to be copied’ (1950b, 14). They added:

> These diagrams are useful to give us confidence. If a two-bit mail order house organisation looks so complicated and works, and if the Air Defense System is simple and doesn’t work, then the obvious assumption is that the Air Defense system must be very complicated indeed in order to work; but then see what a simple diagram can be drawn for the animal. Consequently we need not expect to have to make an organisation of great complexity. (1950b, 14)

The tension between use of the organism as a metaphorical abstraction and in the formulation of an idealised operational logic—from a descriptive technique to a prescriptive statement—comes to the fore in the above rather weak equivocation. In addition, the quote ironically foreshadows the sprawling, bureaucratic, and extraordinarily expensive project that SAGE ultimately became.

These diagrams were explicitly used as the justification for a set of novel air defence system designs. The recommendations enumerated in the report range from those that could be acted upon immediately, and those that might be possible in the longer-term. The former were mostly fixated on improving managerial inefficiencies, hiring more human operators to assist with the administration of the overwhelming tasks of analysis and direction, arranging training scenarios, and making use of more advanced equipment already in use elsewhere in the armed services (1950b, 18–20). Although increased personnel might aid in the tasks of managing and coordinating the enormous quantities of information an invasion would precipitate, such an arrangement would be logically untenable in the long term according to ADSEC's diagnosis. They cautioned that even with these immediate recommendations in place, that 'close control with this system would hardly be practicable against more than 10 bombers per radar' and that it 'will not counter a blitz raid; it may be suitable for a war of attrition' (1950b, 20).

For Valley and his colleagues, the problem was fundamentally an insurmountable one of human limitations starkly revealed in the light of the new technological possibilities, destructive capacities, and operational speeds of warfare. According to the *Progress Report*, message rate of voice communication between human operators was 'about 100 times too low' to optimally and accurately relay information (1950a, 14); work at filter centres was both too slow and inaccurate (1950a, 15); and that there were 'far too few ground controllers in the system to handle its expected traffic by about 100 times' (1950a, 16).

For ADSEC, the answer to this conundrum of information overload was to deploy a digital computer to manage Direction Center tasks such as target tracking, provide a real-time situation-board depicting aircraft positions and their status, and direct interceptor aircraft to the enemy. The human elements of the system would instead handle decisions regarding whether to launch an interception. This was the so-called 'centre of judgement' in their proposed air defence organism. It would thus function as an advanced command and control system capable of rationally, predictably, and speedily managing the vast quantities of tactical information inherent in observing and managing the airspace, and making most efficient use of interceptor aircraft in the case of an attack (1950b, 28–30). ADSEC went further, however: they posited that the idealised air defence system is one whose sole centre of judgement is a machine, with no human operators at all. Such a system might at least be *theoretically* possible, they proposed, if based on the chess-playing algorithms published by Claude Shannon. They wrote:

> One could then have the results of manoeuvres tabulated as alternative strategic programs for a universal digital computer which would essentially play out the game according to the best move possible based both on the immediate tactical situation and on what has been learned in manoeuvres. (1950b, 30)

Once again, a speculative abstraction—a game of chess as a representation of the conduct of military strategy—becomes the basis for a real configuration of elements and the prescription of an operational logic of air defence. With this approach, a central computer would take over the management of the entire mesh of components and the networks it circulates across, and the air defence situation itself would become a 'game' autonomously played out over a real-time sequence of 'moves'. Furthermore, ADSEC suggested that such a system 'insures that the experience gained from painstaking studies of manoeuvres will actually be applied to war' (ADSEC 1950b, 30). In other words, and contrary to the propositions of the SRL, ADSEC suggest here that one cannot rely on the human operator to *learn* from the disciplinary procedures of formal training. The very speculative claim in ADSEC's *Final Report* was that the *machine* could function as the adaptive force in the system, an element capable of devising new techniques from past experience and sustaining the immense information load of an invasion of a fleet of Soviet nuclear bombers. What makes this speculative is that the digital computer was a protean machine whose technical possibilities and field of application was only being sketched out—there was no precedent for such a system.

Given the confident affirmations around the potential of the digital computer and the diagrams of control that legitimised its necessity throughout the preceding pages, it is interesting that ADSEC end on a considerably more pessimistic and guarded note. They concluded their *Final Report* with the following paragraph:

> ADSEC does not know if such a system can be made. It will not attempt on the basis of any paper studies to estimate its effectiveness even if it can be made. The reasons stated in this paper indicate the direction to go to make an optimum system. Whether it can be made and what it will do can only be answered by experiment and ADSEC encourage all who propose to carry out pertinent experiments. These ideas were not dreamed up over night, nor without consultation with many other interested groups; they are not regarded as fixed for all time; they will be altered in the light of continuing experiment. (1950b, 34–35)

Despite this acknowledgement of the speculative problems, and even the technological *possibility*, of their proposed system, the notion that the anticipated aerial invasion could in principal be understood and managed entirely through the pulses of electrical circuitry—as *information*—is never assessed. Even though these reports can be understood to exemplify similar 'rules of formation' as the statements around human-machine organisations in the Systems Research Laboratory's memoranda examined in Part I of this case study, the conclusions drawn were very different. For ADSEC, the conduct of war was the management of information, and the extent to which the human operator could be removed from their idealised air defence system was only delimited by the quickly expanding boundaries of technological possibility: although their proposed schematic was still heavily based on the Manual System in some respects, its operational logic transformed the role of the operator from a data analyst distributed across virtually every point of the system to a decision-maker whose presence was limited to the centre of judgement.

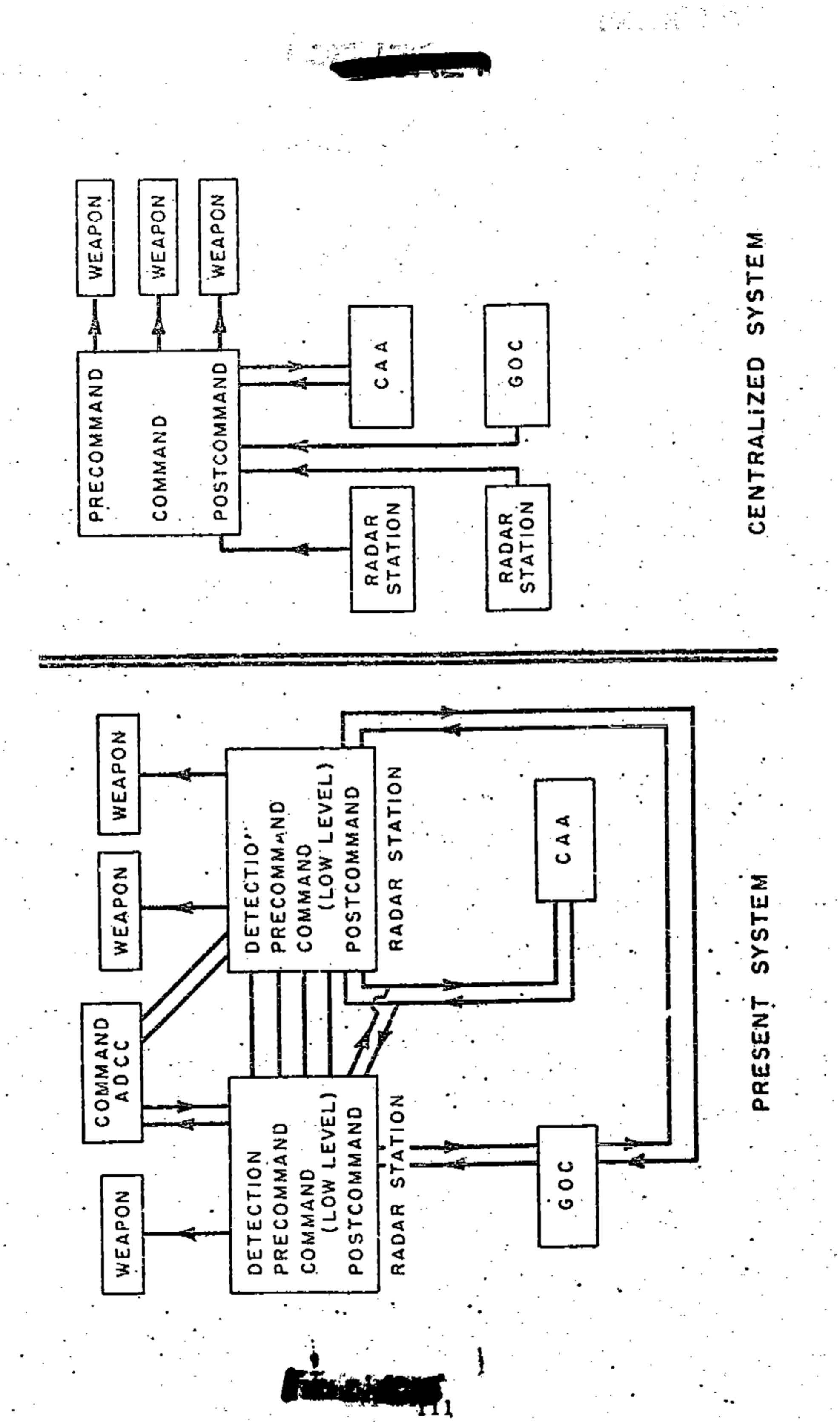



Figure 4.8: Comparison between decentralised (manual) and centralised (semi-automatic) configurations, Project Charles Report (1951, 111).

### 4.3.2 Jobs Unlimited in the 'Age of Automation'

Over the three years subsequent to its publication, the ADSEC report was followed by a number of experiments and studies continued to further alter and shape the ideas proffered by its authors, with further committees reassessing their practicalities and elaborating their technical development. One of the most important milestones in the early development of this new air defence system was Project Charles, a cross-disciplinary committee of scientists and engineers, again involving ADSEC's George Valley. The resultant three-volume Project Charles report, titled *Problems of Air Defense* and completed in August 1951, reiterated ADSEC's findings: the fundamental technical problems of radar, aircraft identification and tracking, as well as the human factors challenges of slow and 'noisy' communication between stations, all had ambitious yet workable solutions that centred on the digital computer. The controversial Whirlwind project, a prototypical digital computer originally designed to be an aircraft simulator, had already been under development at MIT for five arduous years under Navy sponsorship. However, it was recurrently beset with considerable delays and overspends, as Redmond and Smith (2000) have noted in their highly detailed technical history of the computer. With critical technical challenges still to be overcome, it was at risk of having its funding cut by its increasingly impatient patron. The members of the Project Charles committee were nevertheless optimistic about what further developments in digital computing research would facilitate:

> Our restrained views regarding any spectacular solution to air defence are counterbalanced by considerable optimism about the contributions to air defence that will be made by new basic technology. We think the electronic high-speed digital computer will have an important place in air defence, and the revolution that the transistor will bring about in electronics will open up quite new possibilities in aircraft and weapons control. (Project Charles 1951, vi)

As with the ADSEC reports, the Project Charles report was considerably more interested in the technical engineering of the project than the human factors issues of the system. Interestingly, the report acknowledged that the addition of the digital computer would not simply automate human operators out of the system: it would instead 'increase performance and traffic capacity': 'It is to be expected that a fully automatic system will require approximately the same number of men as now employed, but will do a more complete job' (1951, 112).

The contributors to the report sought the centralisation of operational functions into specific, discrete boxes in the system (See Figure 4.8). The lines between the boxes expressed channels through which 'data' or 'command' could flow (1951, 109). The digital computer would collect, process, and calculate positions and trajectories of aircraft, displaying real-time maps on various screen displays, and decisions pertaining to the management of the air space would be made within the regional command and control room rather than distributed semi-independent defence stations. Importantly, the report stated that a new type of operator would be required: 'A new system carrying on automatically many of the data processing functions will use men so differently from the way they are used in the present-day air defence system that present experience and prejudices are unlikely to be of great value' (1951, 115–16).

For the Project Charles study group, the function of the human operator in the system is imbued with a puzzling ethical dimension that delimited the extent to which they were involved with the system. We encounter a recommendation familiar from the ADSEC report: that the operator could be removed entirely, allowing a fully-automatic, autonomous system analysing and using data to make decisions. They suggest that, if such a system was technically possible, the degree of involvement of the human operator might change depending on the 'technical and political situation' at a given moment:

> While slow aircraft speeds and a state of relative world peacefulness exist, a large degree of human monitoring, evaluation and control may

> be desirable in the interests of safety. On the other hand, during a military attack, especially with high-speed weapons, the only choice may become fully automatic data analysis and utilisation. (1951, 110)

The human operator was thought to provide a greater level of scrutiny to the processes of the system in its semi-automatic state, acting as a line of oversight that could, for instance, intervene should the system mistakenly designate a civilian aircraft as enemy during the relatively pedestrian temporalities of peacetime. The human operators would, in this case, presumably be liable in the event of a catastrophic error. Yet, such cautionary measures would be immediately suspended in an invasion scenario, where the machine would take command unhindered by the lagging deliberations of the human 'elements' of the system. War now proceeded at a speed beyond the limits of human decision-making, they thought; only a computer could handle the speed of the new class of weapons that might be deployed, and as such, the ethical implications of a machine in autonomous control of weapons systems in the middle of a nuclear war could thus be brushed aside.

This proposition of a dual system whose degree of automation could switch on the basis of the political circumstances represents a rare slippage into the realm of speculation in what is otherwise a rather technical and systematic analysis of the mid- and long-term configuration of air defence. As with ADSEC, the technical realisation of fully autonomous system was recognised as a considerable challenge, and perhaps an impossibility. Nevertheless, the report recommended the continued development and repurposing of the Whirlwind computer for the air defence system, and the construction and testing of a prototypical system at Cape Cod, Massachusetts. As a programmable general purpose digital computer, the Whirlwind was thought to represent the most viable design for their proposed semi-automatic system, one that could be reprogrammed to take into account the shifting limits and strategies of the enemy 'by the insertion of a new set of orders on a paper tape' (Project Charles 1951, 111–12).

During this time, RAND was undergoing a corporate identity crisis not unrelated to the quickly expanding demands of air defence and digital computing. While RAND's founding corporate strategy was to work on a broad range of Air Force projects simultaneously, issues of air defence were beginning to take up an increasingly large quantity of its organisational resources. As Ensmenger (2012) details in his history of software engineering, RAND became *the* centre of programming in the United States as it took on the contract for programming the new air defence system. However, it is this issue of 'training' the human operator that is of prime interest in this case study, and RAND's portfolio was indeed considerably occupied with devising a programme to support crews of the Manual System's Direction Centers. Over a few short years, the SRL's experimental programme had evolved from a fairly obscure study of human organisation in high-stress situations, to a fully-fledged training programme designed to offer near-term operational fixes and facilitate a more rigorous communication practices in the Manual System. By the culmination of the fourth study, the SRL had been approached by the Air Force's Air Defense Command (ADC) who oversaw the existing radar stations and Direction Centers. They were asked to install their techniques across 152 sites across the country.

The consequence for RAND was a discernible shift in the corporate culture, with substantial internal restructuring. Should we seek some indication of the struggle RAND underwent to maintain organisational control over its sprawling portfolio, we can look to the proliferation of acronyms in their reports in the mid-1950s. In 1955, the SRL became the System Training Project, which was renamed three months later to the System Training and Programming Division. This then became the System Development Division (SDD), and their experimental techniques became largely institutionalised, codified in myriad manuals and memoranda under the banner of the Systems Training Program (STP). But two years later, the SDD was spun off into another organisation called the System Development Corporation (SDC), which specialise in the design, management, and analysis of 'systems training' in the SAGE System Training Program (SSTP), and additionally took over the task of developing the site-specific software for SAGE's Direction Centers.

For the engineers working on the SAGE project as well as the commanders in Air Defense Command, the need to indoctrinate the eventual crews of the SAGE Direction Centers was becoming increasingly important, particularly as they began to test the capabilities of the radar-computer interface with live intercepts. One of the SRL's founders, William Biel, was appointed as Vice President of the SDC. M. O. Kappler, the RAND engineer who originally encouraged John L. Kennedy to embed the SRL in an air defence Direction Center back in 1950, was designated President. In a press release announcing the incorporation, Kappler stated:

> At present, the energies and talents of the System Development Corporation are devoted exclusively to the problem of Air Defence. However, there is every reason to believe that these same specialised skills—in training and in computer programming—will find equal applicability in other military as well as non-military problems associated with the 'Age of Automation'. (System Development Corporation 1957, 4)

I dwell on this fairly dry expositional discussion about RAND's corporate identity and the bureaucratic process which led to the formation of the SDC to emphasise how problems pertaining to the human factor of the new air defence system precipitated a major structural change in the institutional cultures of defence research in 1950s America. At the time, RAND was one of the most influential defence research institutions in the country, and sectoring off a prominent division to form a separate corporate entity was by no means an inconsequential decision. Yet, the so-called 'age of automation' in fact produced a need for a host of new types of technical work, and at a quantity that overwhelmed the RAND corporation. The need for a range of new technical practices to deal with the highly specific and novel demands of digital computing is unsurprising, but this continuous readjustment of the organisation of RAND is another effect of how the complexity of managing the training and programming of large, complex software systems were underestimated by those charged with designed and managing them. As Redmond and Smith (2000), Ensmenger (2012), Slayton (2013) and others have shown, there was an urgent requirement to rapidly increase the national stock of programmers to facilitate the development of the semi-automatic system recommended by Project Charles—a problem which itself was particularly difficult to resolve expediently given the technical novelty of the system. At the time, individuals proficient in programming were rare, and even more so when the particular design and demands of SAGE were considered. Edwards (1997, 103) notes that the small team of 25 programmers initially dedicated to the project of developing software for the prototypical SAGE system 'represented about one eighth of all programmers anywhere in the world then capable of doing such work'.

A second reason for RAND's corporate schism was the immense computing and administrative challenge of training Manual System air defence crews. During the early SRL experiments, the tasks of preparing simulations, analysing group behaviour and preparing the 'knowledge of results' for Direction Center crews undergoing training imposed heavy demands on RAND's computing department. Recounting this period, Chapman et al. (1959, 262) wrote that 'a typical period of 100 minutes required about 10,000 cards and took 25 machine hours to process'. To describe this process as simply automatic is to elide a great deal of administrative work involved in the preparation and coding of systems training sessions. As the STP was rolled out across other multiple Manual System sites 'in the field', this multiplied the required technical resources as well as the number of scientific and administrative personnel charged with overseeing the actual training. Baum (1981, 26) writes that by 1956 the number of people working in the System Development Division responsible for computer programming and system training had grown to a thousand—'more than the rest of RAND put together'.

In 1954, the SAGE project had progressed to the phase of live system testing with the central computer—the AN/FSQ-7. At this stage of the project, SAGE's engineers were obliged to earnestly engage with the 'human factors' considerations of the SAGE system on a deeper level. To George Valley, this meant to engage with Air Force Commanders' less interesting and more prosaic questions regarding the command and control centre—to define precisely 'where the general was going to sit' and 'how many operator positions' the system would require (Valley 1985, 221–22). According to Marzocco (1956, 6) in his internal history of the STP, 'recognition of the critical training problem in SAGE' had led to discussions between RAND and SAGE teams in 1954. RAND's internal monthly newsletter, titled *The RANDom News*, gives a sense of the scale of change in the corporation's culture and organisational management precipitated by air defence.

One article, headlined 'Jobs Unlimited', advertised 'varied and interesting positions', including '35 or more psychologists' and 70 programmers (RAND 1956, 6) to meet the demands of training air defence operators and writing the software for SAGE. An article from another edition of the newsletter aimed to introduce RAND workers to the new prevalent class of 'Training Specialists' who 'in one way or another devote their energies to the conduct and continued development of the ADC System Training Program for the manual and SAGE systems' (RAND 1956, 6). This fairly sudden institutional change prompted some RAND scientists to explore the possibilities of utilising systems training to efficiently indoctrinate new staff to the practices and principles of the Systems Training Program itself (1956, 7). Among the available courses, employees could sign up to 'STP Problem Design' to 'clarify the relationship between the design of STP Problems, field training, and field feedback', or to 'STP Operations–Basic Programming' should they have wanted to understand the 'formulation of programs, logic of the computer, and how these activities might contribute to the STP' (RAND 1956, 7).

The SAGE System Training Program (SSTP) was proposed in 1955, and alongside its workforce of programmers, it proceeded to be one of the SDC's defining military contracts as it was eventually rolled out towards the end of the decade. Nevertheless, the SAGE Direction Center was, by virtually every measure, substantially different from the equivalent site in the Manual System. Over the following two years, the regime of 'systems training' further elaborated the operational practices, discursive formations, and organisational models developed during the SRL's initial four experiments. There were two central tensions in this process: firstly, there was the issue of how the SSTP had to deviate from its Manual System origins to accommodate the digital computer and the configuration of the SAGE system; and secondly, how the shift from the laboratory to the 'live' institutional site of the Direction Center impacted their experimental theories of human-machine organisation in command and control systems. The increased scale of the system generated additional tensions between its operational logic, and the various unanticipated (or at least underestimated) manual practices required to keep the system functional. Despite the purported 'age of automation' that the SDC was preparing to enter, the demand for highly trained human operators was growing beyond capacity.

### 4.3.3 Information and 'Indigestion'

> What do these strange flashing symbols signify to inexperienced operators? Those tiny specks moving from the right-hand corner to the centre of the SID [Situation Information Display]—do they signify uncorrelated radar trails? Can the data be correlated with an existing track? What buttons are to be used? What will happen in the Identification room if tracks are not updated? In case of error, how can the mistake be localised? Who errs—man or machine? (Rome 1961, 33)

In distinct contrast to the Manual System's Quonset Huts, SAGE's Direction Centers were monumental windowless concrete blockhouses. The buildings were divided vertically in accordance with particular technical functions. The first

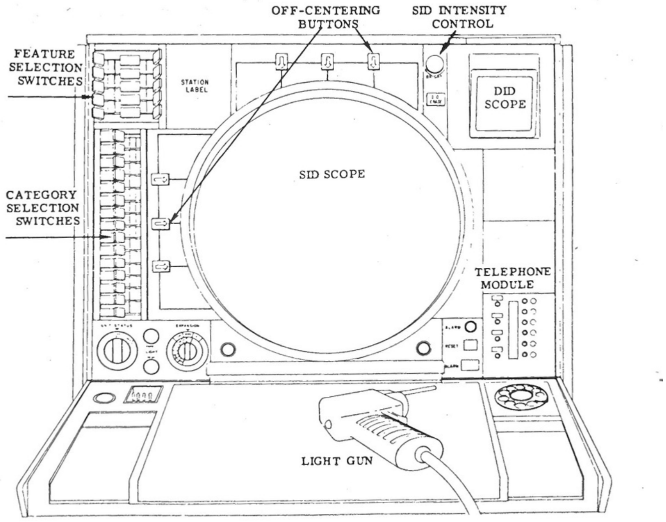



Figure 4.9: Situation Information Display (SID) Scope illustration from an operators manual for SAGE Displays dating from 1976 (Aerospace Defense Command 1976, 1:5).

floor was assigned for maintenance, cooling, and power generation. The second housed the duplex AN/FSQ-7 computers, a twin-setup so that if one machine went down or was required for training purposes, the other could immediately take over. Commanders could observe proceedings in the subsector from a command post on the third floor. The fourth was the operations level, with dedicated zones for weapons direction, radar mapping, air surveillance, and maintenance. Operators sat at individual SID scopes, using a lightgun and panels of switches to retrieve, modify, and input data. For the SDC team installed to oversee systems training, the fourth floor also contained their new laboratory, albeit one where institutional codes and regulations did not have to be simulated; they were already firmly in place.

A staff study carried out by RAND's System Development Division into the proposed SSTP began with the following two 'assumptions':

> Personnel being assigned to SAGE Direction Centers will have had only individual operator training and extremely limited contact with the AN/FSQ-7 computer system. Such personnel cannot operate effectively as an operations crew without intensive systems training.

> The capability of the SAGE System for the detection of unknown aircraft and for the close control of weapons requires that operations personnel be given comprehensive crew training under high load conditions. (SDD 1957, 1)

The SSTP was a direct translation of the principles developed during the initial laboratory experiments by Kennedy, Chapman, Biel, and Newell, and which were used to train Manual System Direction Center crews in the mid-1950s: a 'common goal' was established; the attack scenarios—called SAGE System Training Missions (SSTMs)—involved the simulation of invasions; the whole crew would be trained as a unit, rather than focusing on individual operators; and finally, crews would be provided with 'knowledge of results' in debriefing sessions, which would then be used as a basis for collective development in subsequent training missions. However, the staff study also stated that the technical and architectural design of the SAGE Direction Center were unfit for the purpose of training crews: equipment design, building layout, and personnel assignments had to be modified to adequately manage the training programme.

Charting the elaboration of the human factor from the Manual to SAGE systems, a technical memorandum authored by an experienced STP technician provides an internal perspective on the conduct of the programme. Written by a computer programmer (and as it happens, a scholar of Thomas Hobbes) named Beatrice Rome, the memo details the distinctive technical, architectural, and administrative differences between the Manual System and SAGE, and how these factors precipitated modulations in the principles and application of systems training. What becomes clear in Rome's account is the disparity between the operational logics of the theoretical 'training' programme conducted in a controlled site of the laboratory where variables could be temporarily fixed, and in the changeable site of the field where contingencies abounded. The regimes of the laboratory and the live direction centre existed in mutual tension, generating institutional, technical, and psychological frictions.

Rome noted that in the Manual System, the crews being training were ‘small face-to-face groups, each housed within a single room’ (Rome 1961, 25). In the Direction Centers, a core team of approximately 15 people performed all the main operational functions of surveillance, identification, and interception. This contrasted with the considerably more complex and bureaucratic SAGE system, which involved a crew of over 100 operators when fully manned, working at ‘considerable physical distance’ from each other. Operators were divided into subunits dedicated to ‘major defence functions’, with each function located in a separate function-specific area in the Direction Center building (1961, 35).

An additional difference between the two systems was that, in a SAGE Direction Center, crew members would almost exclusively communicate via the telephone or the computer, rather than face-to-face. Alexander et al. (1959, 2–3) described this ‘psychological isolation of the operators’ as one of the ‘main characteristics of the SAGE system’, with measurable impacts on the motivation and morale of the Direction Center crews. By the reports of SDC personnel such as Rome and Alexander, the systems training principle of the ‘organism’—whereby the collective are trained and reinforced together, in the process developing a common, shared culture and organisational morale—was substantially undermined by the technical segmentation of crews. The staff of the Direction Center were assigned to individual, operationally isolated units whose intercommunications were intended to be entirely mediated by electronic technologies, despite being sat beside one another.

To borrow a key term from Robert Freed Bales introduced in Part I of this case study, the ‘common culture’ of a SAGE air defence crew was undermined by its institutional and technical organisation. This was in fact abundantly clear to SDC personnel at the time. The human factors researcher Barry Jensen remarked that ‘certain aspects of the military culture are antagonistic to the training program’ (Alexander et al. 1959, 15). ‘In some radar crews’, he wrote, ‘50 per cent of the members will have been replaced within a year’ (Alexander et al. 1959, 15). This precise issue was one of the key points of inquiry in the US Comptroller General’s review of organisational inefficiencies in the SAGE project itself. At a time when SAGE’s overall personnel requirements were growing, the report states that about half a million dollars was spent putting novice console operators through extensive training procedures who were ‘already scheduled for early release from the service’, or who were subsequently ‘assigned to non-SAGE activities such as truck-driving and clerical work’ (Comptroller General of the United States 1962, 48). Following their own investigation, the Air Force surmised that 12.5 per cent of SAGE training centre graduates ‘were lost to the SAGE system’ before completing their required tour of duty at SAGE sites (1962, 51).

In her memo, Rome also commented on staffing issues at SAGE sites, explaining how turnover as a broader issue in the Air Force had consequences on efforts to train crews as cohesive units. With crew members joining and departing Direction Centers, maintaining some parity between their capabilities and levels of experience while planning appropriate training scenarios proved to an awkward endeavour: ‘Truthfully, because of heavy crew turnover and wide variation in experience from one crew to another, even in the manual training program “difficulty” was not a precise variable’ (Rome 1961, 36). It was not only the institutional bureaucracy of the US Air Defense Command that introduced resistances and ruptures that complicated the operational logic of the system and the training programme. The digital computer, although taking over the intensive labour of manual plotting and interceptor aircraft direction, had facilitated an immense scaling up of operations that produced corresponding issues of information management for both the operational staff and those overseeing the SDC's training programme. Crucially, information processing was not simply accelerated: the quantity of information collected and produced by the system had increased exponentially, producing a range of second-order administrative problems for operational personnel.

In some respects, the technical configuration of the SAGE system permitted the design of training simulations that could accurately recreate the operational experience of an invasion: for a given mission, the input received by SAGE's central computer could be switched over from the live radar stream to a magnetic tape playing pre-generated flight patterns. There was no qualitative alteration in the representation of data on the operators' screens. This point has been highlighted in a widely-cited story of an air defence crew at a NORAD base who, in 1979, apparently mistook a taped training simulation of an invasion scenario for an *actual* invasion, almost launching a counterattack on the Soviet Union (Schlosser 2013). These tapes, which Rome referred to as 'an arsenal or library of training situations', could be subsequently stored and used to re-trial certain missions and train new crews (1961, 37). Yet, with a more complicated organism, comprised of a wider range of technical devices and a greater human factor, simulation remained a rather complicated affair. Facilitating an SSTM required greater preparation and administrative resources to prepare scenarios, examine performance, and provide knowledge of results. In contrast to the Manual System, the number of support personnel required to support simulation increased significantly. A 1957 staff study carried out to prepare for the initiation of the SSTP recommended the use of over 30 personnel to 'simulate' adjacent air defence posts and units, such as interceptor pilots and local airbases (SDD 1957, Tab C, table 3).

Given that SAGE Direction Centers had larger crews, more operator positions, and banks of complicated computing equipment, the quantity of information produced during a system training session presented its own administrative problems for

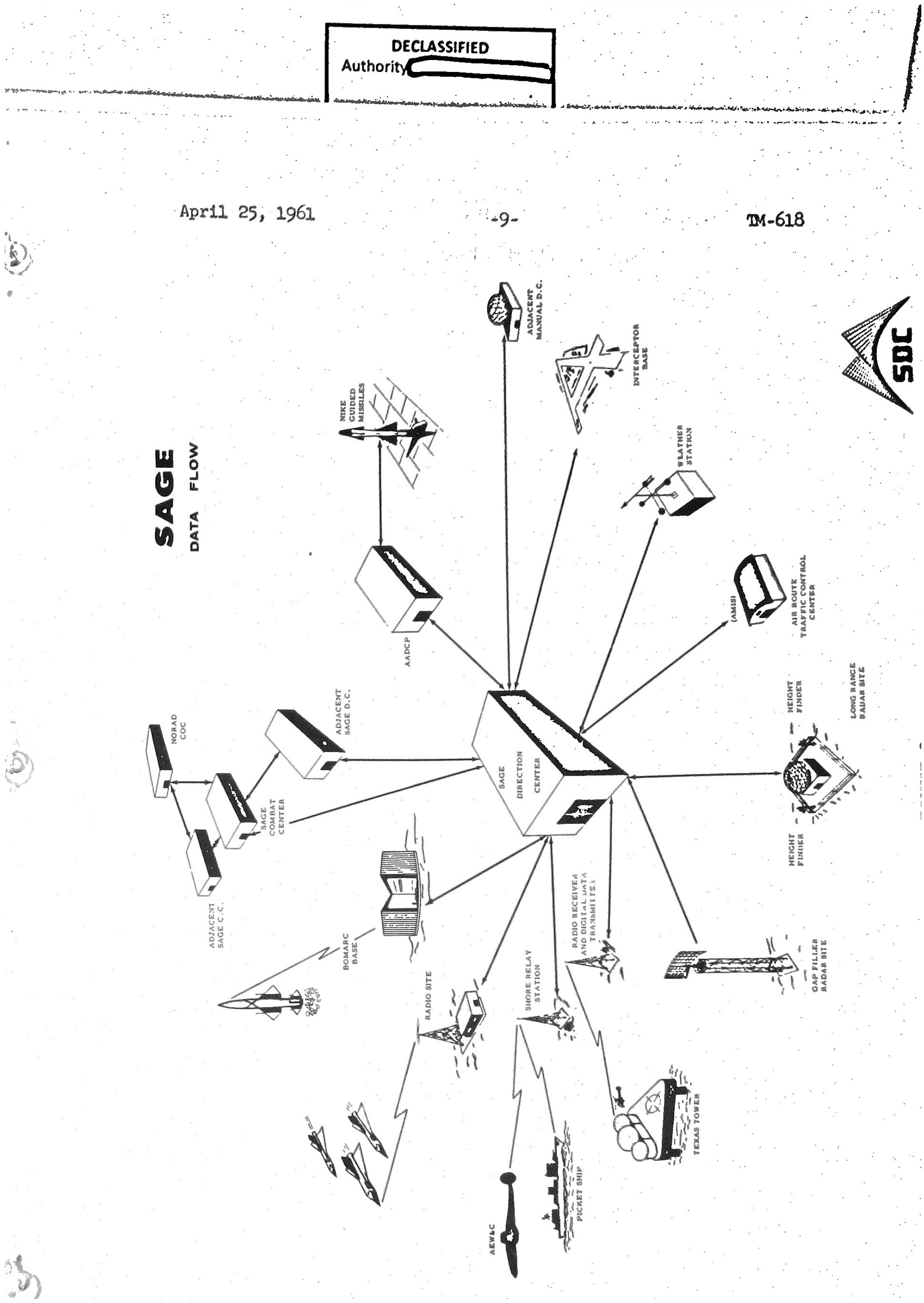



Figure 4.10: A diagram from Rome (1961) of the various infrastructural, sensory, and organisational appendages linked to a single SAGE Direction Center.

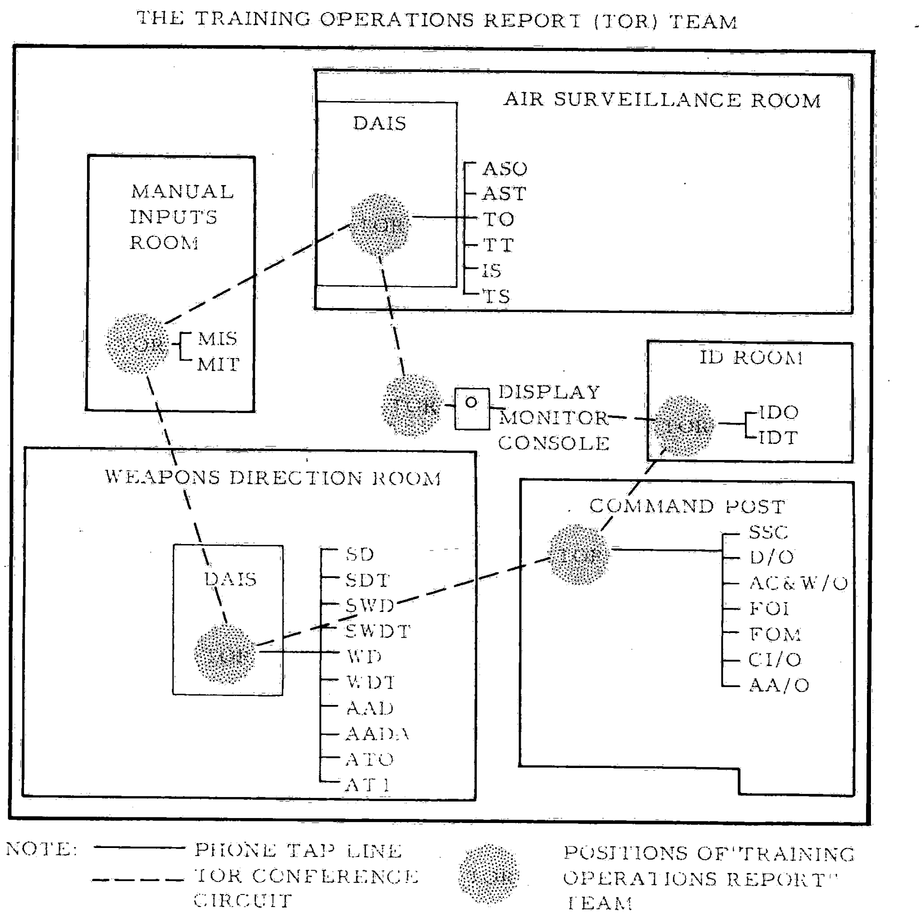



Figure 4.11: Diagram showing the positions of the Training Operations Report Team across the various system functions, from a 1957 SDD Staff Study, Tab B.

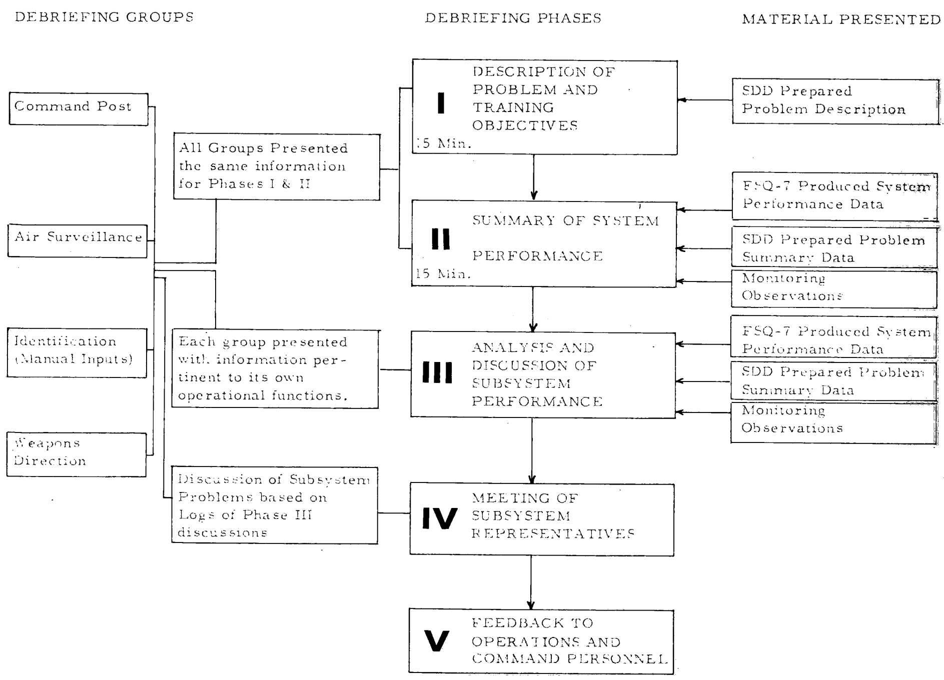



Figure 4.12: Charting depicting the structure of a systems training debriefing session, from a 1957 SDD Staff Study, Tab B.

training staff. SAGE's central computer automatically stored a highly detailed log of events, writing aircraft tracks, operator interactions, and other metadata to tape so that, if required, moments of the mission could be played back in debriefings. A team of six observers—double what was required in the Manual System—were stationed at strategic points in various rooms of the Direction Center, noting any 'decisions and actions not recorded by the computer' (Air Defense Command 1957, Tab. B, p. 2). All of this material had to be quickly but carefully aggregated and synthesised in order to provide the crews with feedback while carefully considering the psychology of criticism. Nehemiah Jordan, an SDC employee working on the SSTP, offered the following warning to the attendees of the 1959 Annual Meeting of the Human Factors Society: 'Too much information feedback gives indigestion' (Alexander et al. 1959, 10). As remarked on in the SRL studies, communicating only accurate and 'objective' information was paramount to a successful debriefing: criticism not rooted in 'facts' would likely lead to 'defensive behaviour which hinders the individuals concerned from facing reality' (1959, 10–11).

If the computer's ability to write performance data to tape might have helped with producing more ostensibly 'objective' records of missions, providing feedback was awkward in other ways. Jordan reported that debriefings were compromised by an apparent lack of prior consideration for the importance of training facilitation during the technical and architectural designs of the SAGE system and the Direction Center:

> […] the large size of the SAGE crew; the lack of adequate debriefing space; the complexity of SAGE performance which makes it difficult to give knowledge of results that is relevant to all crew members; and a marked decrease in the interdependence of the crew members because of the computer's mediation of much of their interaction (1959, 11).

Aside from the upscaling of the number of 'components' in the organism, there was the not insignificant matter of teaching operators how to use their machines. The methodology that defined the SRL studies and its training programme, favouring a relational systems-level analysis of the 'organism' over the purportedly prevalent examples of 'component thinking' in other human factors research, had to adjust to engage with SAGE's rather more complex configurations of machinic components (Kennedy 1952). While in the laboratory, their training model had largely worked with a fairly constant array of equipment and machinery. What complicated matters in the SAGE system was that, especially during the 1960s, the system was progressively interlinked with additional infrastructural components such as anti-aircraft missile batteries and other radar arrays.

The simulation was also sporadically updated with arrays of new features. 'Randomised kill probabilities' introduced uncertainty into the interception of simulated invading aircraft, and required additional tasks assigned to a 'kill monitor' who manually determined 'kill' and 'no kill' statuses by consulting a card on which random numbers were printed (HQ 25th NORAD Region 1962). SDC programmers later added 'Automatic umpiring' to the 'simulation program', which handed over the task of calculating 'kills' to the computer (Stromquist and Robertson 1962). The tumultuous 'feedback' between software simulation and strategy perhaps played out most clearly between the internal development of new computer programs to account for anticipated enemy techniques to evade radar detection. 'Electronic countermeasures' (ECM)—not to mention 'electronic counter-countermeasures' (ECCM)—simulations were also updated and appended to SAGE's software throughout the 1960s (Washington Air Defense Sector 1962). An SDC briefing (n.d., 275–81) on ECM capabilities introduced in 1968 set out new operational positions for crew members during SSTMs, enabling them to control simulated enemy aircraft and deploy digital 'chaff' and other forms of radar 'noise' that would interfere with the defence crew's ability to read the SID scope.

Attempts to make these corrections to better simulate the reality of an invasion served to further complicate and expand the need for training the human factor.

According to Rome, such updates altered the organisational cohesion of the crew: ‘Whenever a computer program is modified, the previous man-machine balance has been affected, thus creating a training lacuna’ (Rome 1961, 41). Systems Training was continuously engaged in a process of elaboration tied to the institutional protocols, regulations, and orders of the Air Force, the technical demands of military strategy, and the commercial interests of the SDC and the myriad other contractors that supports the SAGE system. Rome wrote: ‘System training could neither be indifferent to nor neglect subsystem and component skills. As a result, without sacrificing its traditional emphasis on system awareness and system skills, the system training program has nevertheless become more flexible and expansive’ (1961, 39). It’s clear from reading SSTP reports and memoranda that these components at least initially tended to baffle their operators. Rome argued that the substantial issues with training new operators were to be expected given that the SAGE hardware ‘had been designed with insufficient concern for the humans who were to interact with it’ (1961, 35). She wrote:

> The development of a training program for a weapons or command and control system is usually and unfortunately undertaken, if at all, only after the system is designed, perhaps even after it is installed and operating. The burden of adaptation is thus placed entirely on the human operator (1961, 47).

The temporalities of the SRL’s initial studies, while undoubtedly intensive, were very short-lived in comparison with the perpetual tasks of SAGE operations and training. Cogwheel, the final and longest SRL study, ran for six weeks. As such, in the controlled site of the laboratory, the variabilities intrinsic to the institutional structures and procedures of the ADC were artificially fixed as constants for the duration of the studies. Once the same operational logic was translated into the field, however, the perceived organisational limits of the organism sat in tension with the notoriously bureaucratic attributes of the US Air Force and the expanding field of possibility in technology and strategy. The assertion of the Project

Charles committee that ‘a fully automatic system will require approximately the same number of men as now employed, but will do a more complete job’ was inaccurate. Rather, there was a proliferation of additional operational positions across the whole administrative and organisational dimensions of systems training: individuals capable of designing, observing, recording, and analysing training sessions to support a continual ‘preparedness’ for an invasion thought by some defence researchers and military commanders to be forever imminent.

### 4.3.4 Forecasts

Throughout the 1960s, a number of reports critical of the ‘automatic’ designs of existing command and control projects were published with a view to learning lessons for the next generation of human-machine systems (United States Air Force 1964; Israel 1965; McMullen 1965; Parsons and Perry 1965). As one of the Air Force’s biggest research projects of the 1950s, SAGE could not have been far from the minds of the authors of these documents. One of these reports, titled *Project Forecast*, sought to establish research priorities for future defence systems. The ‘Data Processing and Display Report’, published as part of the project in January 1964, argued for the importance of ‘ “user”-oriented systems’ (1964, iii). The report described past systems as ‘expensive disappointments’, and concluded that, in order to avoid repeating such costly mistakes, the figure of the operator had to feature into the planning and engineering stages of the system (United States Air Force 1964, I, 3). The authors suggest that this should become more feasible as expertise and cost-effectiveness of such areas improved:

> The development of such a system does not represent so much a major extension of present techniques as it does a reorientation in our conceptions of computer systems. It is intimately tied up with technological advances that will make computers more easily accessible and more economic, permitting us to consider efficient support of the user, rather than efficient use of presently expensive logical machinery (1964, I, 3–4).

Contrary to the claims of human factors engineers, the proposition here was that it would be technological advances that would usher in the possibility of 'user-oriented systems'. Amongst the contributors to this particular volume of the *Project Forecast* report was the scientist J.C.R. Licklider. Having worked on SAGE's display consoles, he was particularly well-placed to offer diagnoses and recommendations into the matter of the report's subject of data processing and displays. Indeed, some of the conclusions reached in the report echo the central argument of his influential article published four years earlier on the design of networked, digital, real-time computing systems. In this text, Licklider had already set out what he believed would be the critical configuration of future human-machine systems by drawing on a biological metaphor of symbiotic organisms. He wrote:

> In some instances, particularly in large computer-centred information and control systems, the human operators are responsible mainly for functions that it proved infeasible to automate. Such systems [...] are not symbiotic systems. They are semi-automatic systems, systems which started out to be fully automated but fell short of the goal. (1960, 4)

Licklider identified the problem of the *interface* between the human operator and the machine, noting that existing computers were not effectively deployed to enhance 'scientific or technical enterprise'. He justified this proposition by referencing a time and motion study he had conducted, the subject of which was also himself. Notwithstanding the sampling problems, what he found was that his time was 'devoted mainly to activities that were essentially clerical or mechanical' (1960, 6). For him, the interrupted, stop-start rhythms of computer work in 1960 meant that a dialogical, symbiotic relationship was impossible. What was missing in the 'man-computer' relation concerned what we might understand as the human-machine 'interface', although Licklider himself did not use this term. 'The department of data processing that seems least advanced,' he wrote, were ‘displays and controls’ (1960, 9).

While SAGE represented relatively broad strides in this department, the issue of the ‘interface’ persisted in mid-1960s retrospective evaluations of prior command and control systems. An SDC study dating from 1965 noted the considerable involvement of human operators in SAGE despite early propositions of full-automation (Parsons and Perry 1965, 43). In this study, however, it was primarily the interface between different systems, rather than the human-machine interfaces that abound internally, that was of prime interest. For instance, this might concern the way in which information is translated between a ‘sensory’ system to an ‘analysis’ system—which in a military sense might mean across two different operational units, or perhaps even branches of the Armed Forces, and thus require some cross-institutional standards in discourse and practice. However, one of the issues which they noted was that the definition of a system was frequently determined by the limits of the particular institutional authority in question in cases where a more macroscopic model would be more representative. They called for the ‘interfaces’ *between* institutions and organisations to be considered in the design of large human-machine systems:

> Interfaces are like the weather. Everyone talks about them (and writes reports which are disregarded, because no man’s land belongs to no man), but no one does anything about them, or not enough. (1965, 93)

The domains of institutional authority, they argued, thus tended to arbitrarily bound the scope of the system, defining what is ‘outside’ or non-existent. The effects of this can also be seen in the technical development of SAGE, where bureaucratic tensions concerning oversight, expertise, and authority posed considerable complications for the integration of its various subsystems (Jacobs 1983, 327). Indeed, the tensions noted by Rome (1961) and Alexander et al. (1959) with regard to systems training are exemplary of how institutionally-delimited

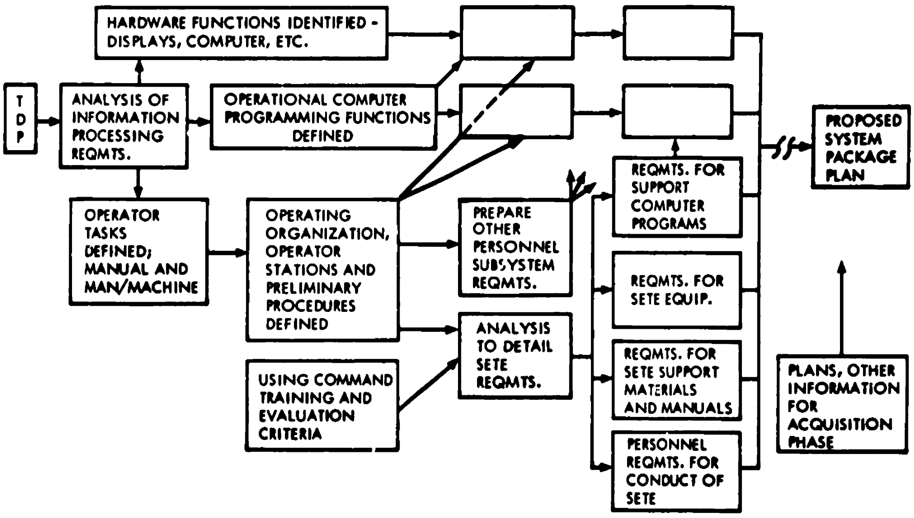



Figure 4.13: Flowchart depicting role of 'system exercising for training and evaluation' in the 'Project Definition phase' of system design (Biel 1967, 283).

programmes presented contradictions during the 'integration' phase.

The recurring recommendation of these reports can be summarised as a call to embed management and training rationales into the developmental phase of these systems, and to further institute them as a critical dimension of the elaboration of an operational logic. Israel's study of data-processing systems proposed that their automated portions should be considered as 'an iceberg, and a significant initial effort should be directed towards understanding and describing what is under the surface' (1965, 14). This move would be to counteract the 'strong and dangerous tendency for an engineer to design a system for himself to operate, and generally to operate for only short periods of time and at high, or at least interesting, load levels' (1965, 8). This tension between the 'engineering' and 'human factors' approaches, which were institutionally and functionally separate for much of the development of the SAGE air defence system, continued to be a contentious point of debate in the planning of new command and control systems. As I described previously, such tensions arise as a consequence of what we might understand as the superimposition of two different regimes: one theoretical devised in the laboratory; another in a context with myriad variables, always varying. Despite this, some faith in the SAGE project remained. Training and software development continued, and SAGE became something of a case study for those ruminating on how best to develop the next generation of complex command and control systems.

William Biel, a founder of the SRL in 1952 and the SDC's first vice-director, contributed to a volume on the role of psychology in national defence in the mid-1960s explicating the 'system life cycle phases' of Air Force projects (Biel 1967). The operator, he suggested, must be involved in the system design from the beginning (see Figure 4.13). Numerous SDC reports, studies, and technical memoranda from this period aimed to further legitimise key 'systems training' principles both as they applied to the operators of military command and control systems and other institutional contexts. For instance, Cooperband, Alexander, and Schmitz (1963) reported on the application of systems training to civilian air traffic control. Of course, it made corporate sense for the SDC to further legitimise the scientific validity and applicability of one of their most lucrative services. A 1966 memo, scoping the military and civilian market for the integration of SDC services, noted that 'although the systems training activities have been pursued with diligence and success, their extension into areas other than air defence has not been promising' (Carter 1966, 3).

Defence researchers at the SDC continued to be advocates of the organism concept in the 1960s, and using it to argue for the deeper involvement of human factors researchers and psychologists in the planning of command and control systems. Newlands and Grace (1963, 3) sought to legitimise the particular approach to human factors psychology developed at the SRL by explicating it in cybernetic terms, and finding common ground with the control engineers who designed human-machine systems. 'We see similarities', they wrote,

> between the approaches of the engineer, the cybernetician, and the psychologist. Inputs, information sources, and antecedent conditions look amazingly similar. All have a temporal, causal relationship to 'black boxes', communication channels, or intervening variables.

Porter (1967), a psychologist and SDC director of human factors research, made similar analogies in his contribution to a volume that aimed to detail the continued utility of psychological principles in national defence. The familiar model of the organism is once again called upon to describe the parallels between the functional elements of a command and control system and the exemplary cybernetic device, the thermostat. To do so, he argued, was to produce a 'map' that could help the 'system designer' identify the interactions between the parts.

These discursive propensities to 'cyberneticise' organisational psychology, and to explain it in terms that drew on Shannon's related understanding of information, were always present in even early SRL reports as we have seen. Newlands and Grace's proposition here though is emblematic of what Bowker (1993, 115–16) argues were the 'universalising' tendencies of cybernetics as a discourse, whereby concepts of negative feedback, control mechanisms, and systems science served as an explicatory 'alphabet and grammar' for diverse behaviours in the animal and machine. Bowker, drawing on the sociologist of science Susan Leigh Star, suggests that this functions as a kind of 'legitimacy exchange', a rhetorical support to bolster a statement that in turn reaffirms the discursive universality of cybernetics. We can conceptualise these continuous efforts to rethink the organisational design of command and control systems as a managerial discourse scaffolded by terms and models drawn from institutionalised knowledge practices—notably, ideas of control, information, and feedback drawn from the then-prominent field of communications engineering. In this discourse, the relations between humans and machines were theorised as information flows and their collective organisation defined instrumentally in accordance with operational functions. Despite the common rhetorical rubric employed by engineers and psychologists—and the insistence on the part of the latter that their practice was a type of ‘engineering’ too—it is quite clear that there remained tensions in precisely what lessons could be learned from the shift from the Manual System to the Semi-Automatic Ground Environment. The prevailing question in a number of these mid-1960s reports were strikingly similar to those of 1950: whether the development of new computer technologies could address the organisational problems that arise in the operation of complex human-machine systems.

## 4.4 Conclusion: Decisions

There is little disagreement amongst those who have chronicled the development of the SAGE system that it represents a technological break in the domain of defence research. For Edwards (1997, 99–106), SAGE is an 'archetypal' system 'responsible for a vast array of major technical advances'; Ensmenger (2012, 60) describes how the urgency of the SAGE system unleashed immense streams of funding with enormous consequences for the burgeoning discipline of software development; Packer (2013) and Ghamari-Tabrizi (2012) argue that it demanded novel types of 'cognitive' work on the part of its operators; and numerous articles in the *Annals of the History of Computing* have been dedicated to extolling the many accomplishments of SAGE's engineers, including a 1983 special issue (Astrahan and Jacobs 1983; Everett, Zraket, and Benington 1983; Jacobs 1983; Tropp 1983; Valley 1985).

The ways in which a distinct and contradictory notion of the human operator was cultivated throughout the development and deployment of SAGE is frequently downplayed, if not omitted entirely, from historical accounts. SAGE did indeed automate certain practices which in the Manual System were carried out by the human, notably the interpretation and display of radar data that so bothered ADSEC in their reports. However, SAGE also produced an array of additional practices requiring human involvement, not least in the immense and integral task of training the crews to actually use the system.

The disciplinary perspectives which informed the distribution of human and machine elements across the system converged on the same concept of the information-processing organism. For the SRL and ADSEC, however, the adaptive capacities of the organism were accounted for in distinct ways. In the case of the former, the adaptability of an organisation was permitted by the learning capabilities of its human constituents, thus privileging the role of the psychologist in the management and prescription of operational practices. For the latter, it was facilitated through the mutability of software made possible by the unprecedented AN/FSQ-7 digital computer, placing the software engineer as central in the system. That their perspectives differed on this point is unsurprising. But what is important here are the ways such differences informed a range of manual operational practices which acted as supports to the institutional and technical configuration of the system.

The model of the 'organism' invoked by ADSEC's engineers and the SRL's psychologists to explain the air defence system encapsulates the central problem that endured in the move from the manual system of 1950 to SAGE deployed at the end of the decade. Equipped with this model—what the SRL defined as a 'complex system with parts so integrated that their relation to one another is governed by their relation to the whole' (Chapman et al. 1959, 10)—both ADSEC and the SRL conceptualised air defence in terms of the management of information flows across humans and machines. The task of evaluating the efficacy of the organism thus became a process of capturing these information flows: designing invasion scenarios with rising 'information loads' to provoke 'stress', and coding the speech of the crews as discrete, measurable 'acts' as they endeavoured to fend off this simulated nuclear war. This made possible the construction and legitimisation of a knowledge of the human factor in which decision-making was reconceptualised as information processing, and training as an iterative process of balancing information loads. In this sense, ADSEC's wish to convert the human operator from a 'data analyst' to a 'decision maker' was something of a misnomer: data analysis and decision making became synonymous in an operational logic where everything could be understood as information.

However, although understood to be holistic, the 'organism' was not a totalising model of the system. Block-diagrams of information flow are explicit abstractions, and as such, they necessarily *omit* in order to be useful. The enduring problem thus arises in questions such as what functioned as a component, how the bounds of a component were drawn, and what the lines *between* blocks represented. With the beginnings of the SAGE Systems Training Program, it became clear that these diagrams imposed an overly-coherent and limited sense of what 'parts' constituted the 'whole' of the organism, and the manner in which they were mutually integrated. This problem is particularly evident in the move from the site of the laboratory to the Direction Center. In this transition, previously controlled aspects of the experiment such as duration of a 'shift', the configuration of the technical system, and the scale and constituents of the crew, were beholden to the established practices and bureaucratic organisation of the Air Force. Information proliferated, and it no longer had to be just carefully and efficiently managed by SAGE's air defence crews—it also had to be managed *institutionally* in order to stave off debilitating bouts of 'indigestion'.

This examination of the SAGE system attuned to the problems of contingency and expert knowledge highlights a discernible pattern that continues to be evident in purportedly 'disruptive' command and control technologies since the end of the Cold War. Firstly, military commanders and defence researchers promise greater degrees of 'informational awareness' managed efficiently, more autonomously, and with greater clarity by digital computers and networks, ostensibly leading to more 'surgical' modalities of killing. Secondly, the emergence of myriad contingencies which become abundantly evident once the technology is applied to the battlefield. These contingencies ultimately mean that the technology in question offers considerably less control and clarity than initially supposed, and with a great deal more lethality to civilians than initially assumed by its proponents. This then cultivates a strategic imperative to invest in and develop new, ostensibly more accurate technologies which can provide even greater informational awareness.

The voracious appetite for more information, and corresponding information processing systems of greater power, is evident in the shifts in nomenclature since SAGE: Command and control is no longer enough; according to contemporary

US military doctrine, Command, Control, Communication, Computers, and Intelligence must all be marshalled in a synergistic configuration that facilitates informational omniscience without incurring organisational overload and collapse.

# Chapter 5

# The 'Electronic Barrier'

## 5.1 Introduction

10th June 1968: Staff Sergeant Alton G. Gaston photographed the crew of a CH-3E helicopter dropping an object from the aircraft's hold; the object, a stark silhouette against the sky, has the appearance of an explosive projectile. The caption that goes along with Gaston's photograph informs us that this object is an ADSID—that is, an 'Air Delivered Seismic Intrusion Detector' (Gatlin 1968, 9). ADSIDs were a type of sensor widely used by the American forces across Southeast Asia to detect vibrations in the ground that might signal the movement of truck traffic. Most notably, they became a key component in the anti-infiltration programme active over the expansive Laotian regions of the Ho Chi Minh Trail. Following an ARPA-sponsored study carried out by a group of physicists in the late summer of 1966, electronic sensors such as ADSIDs were proposed as an instrument to facilitate the distributed observation of activity, extending the capacity for the Americans to surveil the 'impenetrable' and vast landscape of the trail region (Deitchman et al. 1966, 17). Linked into a command and control system with elements distributed across Thailand and South Vietnam, the whole operation

Figure 5.1: Photograph caption: 'Side view of an CH-3E helicopter dropping an ADSID (Air Delivered Seismic Detection Sensor) sensor over Laos' (Gaston 1968).

was envisaged to support and coordinate the rapid bombing of traffic along the 'infiltration system' (Deitchman 2008, 1).

By the mid-1960s. the logistical infrastructure used and maintained by the communist North Vietnamese Army (NVA) to support the insurgency in South Vietnam had become a significant point of concern amongst defence researchers at think tanks such as RAND and the IDA. This infrastructure, widely referred to by the US military as the Ho Chi Minh Trail after the communist leader of North Vietnam, was also used to shuttle supplies during the French re-occupation following the Second World War. To describe it as a trail, however, is to give a somewhat misleading sense of its scale and structure: it was often described as a carefully managed 'complex' or 'network' comprised of dirt paths, all-weather roadways, camouflaged supply depots, and dedicated teams of maintenance engineers (Deitchman et al. 1966; Schweitzer 1966; HQ 7th Air Force 1971). The infrastructure originated in North Vietnam, with tributaries woven into key staging locations in South Vietnam via the dense jungles and steep valleys of Laos and Cambodia. By December 1967, only fifteen months after the ARPA study's publication, ADSIDs and ACOUBUOYs (acoustic sensors) were being 'seeded' from the air in their hundreds along the meanderings of the busiest convoy routes (Gatlin 1968, 22). Upon 'activating' in response to the rumbling of a passing truck convoy, the sensor would automatically transmit its unique identifying signal to a relay aircraft orbiting overhead, which would proceed to forward on the signal to a remote command and control site known as the Infiltration Surveillance Centre (ISC) (1968, 8). The crew at the ISC could then 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, and finally call in a plane to intensely bomb the area in question (1968, 8).

This programme—comprised of an array of electronic technologies, relay aircraft, command stations, and bomber planes spatially distributed across sites in the Re-public of Vietnam, Laos, Cambodia, and Thailand—was referred to by a range of titles, the most enduring of which was *Operation IGLOO WHITE*. The organisational complexity of IGLOO WHITE is clear even from the cursory description of its procedural operation provided above. Any such account of this assemblage can only be considered a snapshot however: as I will emphasise throughout the second part of this chapter, the technical, operational, and administrative dimensions of the programme continuously shifted in response to the exigencies of the war and the range of uncertainties embedded in the anti-infiltration effort. Throughout the lifetime of the programme, new components were frequently appended to provide additional capabilities and automate previously manual routines, while the locus of command and control moved between a number of different remote sites located across Southeast Asia. IGLOO WHITE was commonly explained as a 'system' composed of 'subsystems' (see for instance Deitchman et al. 1966, 27; Gatlin 1968, 3; Caine 1970, 1; Shields 1971, 1), implying a structural and formal coherence that defined the operational interactions between its constituent parts. However, contemporaneous internal reports on the programme suggests that it performed in decidedly *unsystematic* ways in practice, thoroughly mired in ambiguity and uncertainty.

Before discussing the types of operational practices which emerged within the electronic barrier system, I provide an account of the interpretive and analytic processes through which quantitative data about truck traffic along the trails was produced in the early and mid-1960s. During this period, there was no computerised command and control 'system' in place: the surveillance of the region was carried out manually and, as noted by those who documented the processes involved, in a somewhat disorganised manner. One of the key practices involved in this process was 'photo interpretation', carried out by highly specialised human operators trained to assess aerial photography, translating the rich ambiguities of an image into a structured sequence of quantitative datapoints. I then 'zoom out' to the macroscopic perspective of the defence researchers who constructed patterns in trends in weekly and monthly truck traffic data. Systems analysis, as a 'style' of planning employed by the DOD in designing and evaluating military strategy in Vietnam, was of broader influence in the domain of defence research on the anti-infiltration programme: as an element in the regime of practices which comprised the programme, it was employed to draw general conclusions about the constitution and rhythms of the Ho Chi Minh Trail region from aggregated photographic interpretations.

## 5.2 Part I: Interpretation and Analysis

### 5.2.1 Photographic Interpretation

The United States was not at war with Laos, yet one of the biggest aerial surveillance and bombing campaigns of the Vietnam War took place over a vast territory in the east of the country. The target of this effort was the Ho Chi Minh Trail. The existence of the trail was known to US intelligence analysts long before President Lyndon Johnson initiated the ground war in 1965. During the successful communist uprising against the French over a decade beforehand, some trails had been used by Ho Chi Minh's army to stage key supplies and move personnel. Military Assistance Command Vietnam (MACV), the United States' primary in-country joint-service command established in 1962, had an active interest in the trail. Its staff had been attempting to systematically monitor truck and personnel traffic, albeit with limited success. Between 1964 and 1966, there was an intensification of analysis: a succession of separate reports authored by defence researchers and intelligence analysts at various US agencies and think tanks offered what they saw as evidence that the Ho Chi Minh Trail was undergoing a renewed phase of industrious expansion and maintenance. Many of these reports argued that the upsurge in investment on the part of the NVA—in economic, materiel, and personnel terms—signalled that the trail 'network' was of growing importance for the communist forces (see for instance CIA 1964b, 1965; Deitchman et al. 1966; Sturdevant 1964; Zasloff 1964).

Underpinning the extensive commentary on the Ho Chi Minh Trail was a resource-intensive intelligence collection and analysis programme conducted at defence research institutes across the United States. Surveys carried out by the Central Intelligence Agency (CIA), Institute for Defense Analyses (IDA), the RAND Corporation, the Scientific Advisory Group (SAG), and MACV referred to a multiplicity of progress metrics and data collection programmes concerned with the trail. This effort was what the US Army, Air Force, Navy and supporting agencies commonly referred to as the 'interdiction programme' and the 'anti-infiltration programme'. As was typical of other US military operations during the Vietnam War, it was difficult for defence researchers to ascertain the degree to which their plans actually fulfilled their stated objectives. The conditions of the roads, the types of truck commonly seen on them, the environmental and topological features of the region, and the patterns of convoy movements became the subjects of analysis for surveillance teams on the ground and in the air.

Virtually all of this effort had to be carried out manually, and often at considerable risk when piloted aerial surveillance missions were involved. The collection and analysis effort was driven by the hope of gleaning some insight into the trail 'system', identifying some facet of its configuration that might be exploited as a means to efficiently interrupt the free-flowing delivery of critical supplies into Vietcong-controlled hamlets in South Vietnam. At least prior to the construction of the so-called electronic barrier, the various techniques referred to in the production of these documents were used by defence researchers to get a sense, however limited or contingent, of the effects of the anti-infiltration effort and how the trail was being used by NVA troops. Indeed, it was widely admitted in the reports that the intelligence drawn upon to make claims about the trail region were shaped by a range of uncertainties beyond the control of the analysts.

Given this acknowledgement, there remains the question of how the authors of these reports framed the validity of their conclusions and legitimised their recommendations. What was the 'politics of truth' in this regime of practices—on what basis were claims authorised and mobilised as part of the anti-infiltration programme? The point of origin for many of the statements made about the Ho Chi Minh Trail were 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. This regime firstly 'othered' the jungle environment, casting it as an unwilling and evasive subject of aerial surveillance and control. In emphasising its otherness, defence researchers could then argue for the need for extraordinary measures and greater resources to codify a militarised knowledge of its topological features, weather patterns, and supply routes. This regime endeavoured to make the landscape legible in a way that fit within the quantitative logic that characterised American strategic thinking. For the Americans, the persistent otherness of the region legitimised the obsessive elaboration of more efficient, penetrative, and devastating apparatuses of surveillance and attack. The expert interpretation of photographs provided the base evidence that informed this elaboration.

Set up a few years earlier in the final months of Eisenhower's presidency, the National Photographic Interpretation Centre (NPIC) was still a relatively young intelligence unit. It had already played a pivotal role in one of the Cold War's most dramatic moments, the Cuban Missile Crisis. In 1962, its photo analysts were tasked with assessing a sequence of images taken by a U-2 spy plane which appeared to depict Soviet nuclear missile silos in Cuba. To whatever extent it was judged to be a failure or success of the US intelligence services (Wohlstetter 1965; Zegart 2012), this crisis was a defining moment in the early years of both the U-2 aircraft and the NPIC.

While aerial reconnaissance was not a new technique of the Cold War, the formation of a new dedicated photographic interpretation centre in the early 1960s reflected the increasingly anxious demands in the US Department of Defense (DOD) for photographic evidence of communist presence and operations across the globe. The situation in Southeast Asia was exemplary of this. Given the diffuse and emergent dynamics of the insurgency on the ground in South Vietnam, aerial perspectives were widely seen by the US military as critical in the effort to map out Vietcong presence and the support infrastructure which sustained it. The NPIC was a prolific producer of intelligence for US strategists wishing to identify new targets for devastating aerial assaults of cluster bombs and napalm, and also to assess damage after bombing missions. The development of a criterion, the designation of a particular zone as a 'target', and the subsequent analysis detailing whether the mission could be considered 'successful' played out through a heterogeneous and prolific corpus of documents, each often containing multiple charts such as the one displayed in Figure 5.2. The issue—one that was apparently abundantly apparent to numerous commanders in Vietnam—was that the intelligence they were based on was also often flawed and not nearly as certain as the succinct, specific assertions contained within suggest.

Figure 5.2 shows a single page of a chart purportedly describing 'vehicular activity' along three roads—routes 8, 9, and 12—in the Ho Chi Minh Trail region (CIA 1964a). The chart, classified 'Top Secret', was enclosed with a memo addressed to an unknown recipient on the 2nd April 1964 and originated at the desk of the Chief of the CIA's Photographic Intelligence Division (PID) at the NPIC. It is just one of many reports which professed to describe the quantities, trends, and infrastructures of North Vietnamese infiltration. Today, these documents often make for recalcitrant objects of analysis themselves: digital scans are occasionally glitched and distorted; some documents have faded causing loss of text following their conversion to monochromatic images; the optical character recognition produces something more akin to experimental typographic poetry rather than affording the reader the luxury of searching for keywords in the text. Furthermore, a notoriously bewildering classification policy denies any straightforward possibility to re-situate any single report within the bureaucratic network of documents from which it emerged, and to which it refers.

This document is comparatively clear except for the imposing black bars, characteristic of the CIA's redaction process. Given such obfuscations, on first glance, perhaps not very much at all can be gleaned about the process of constructing

TOP SECRET [illegible]

TCS No. 1667/64-KH
IB No. 173/64

25X1D

VEHICULAR ACTIVITY ON ROUTES 8, 9, AND 12 AS SHOWN ON [redacted]

| ROUTE & MISSION | LOCATION BY COORDINATES | NUMBER OF VEHICLES | TYPE OF TRUCK | DIRECTION | REMARKS |
|---|---|---|---|---|---|
| Route 8 [redacted] 25X1D | 18 26N<br>105 18E | 1 | ½ ton & Trailer | East | Only North Vietnam Coverage |
| Route 8 [redacted] 25X1D | Not Covered | | | | |
| Route 8 [redacted] | 17 24N<br>104 50E | 1 | U/I | East | 2 nm East of Thakhek (50% of Road Covered) |
| 25X1D | 17 23N<br>104 48E | 1 | U/I | N.A. | By oblique photography - dense jungle growth in many areas |
| Route 8 [redacted] 25X1D | Obliquity and cloud cover preclude analysis. | | | | |
| Route 9 [redacted] | 16 40N<br>104 51E | 1 | 3/4 ton | West | 10 nm NE of Changwat Savannakhet |
| 25X1D | 16 40N<br>104 56E | 1 | U/I | West | |
| | 16 41N<br>104 58E | 24<br>2<br>7<br>1 | 3/4 ton<br>3/4 ton<br>2½ ton<br>2½ ton | West<br>East<br>West<br>East | Seno Junction |
| | 16 41N<br>105 04E | 1 | 2½ ton | East | |
| | 16 40N<br>105 06E | 1 | 2½ ton | West | |
| | 16 41N<br>105 07E | 2 | 2½ ton | East | |
| | 16 42N<br>106 13E | 1 | 2½ ton | East | |
| Route 9 [redacted] | 16 37N<br>104 50E | 1 | 2½ ton | West | |
| 25X1D | 16 40N<br>105 58E | 1 | 2½ ton | East | 2 nm W of Seno Junction |
| | 16 40N<br>104 59E | 2<br>10 | 2½ ton<br>U/I | N.A.<br>N.A. | |
| | 16 40N<br>105 06E | 1 | 2½ ton | East | |
| | 16 41N<br>105 27E | 2 | 2½ ton | East | |
| | 16 42N<br>106 13E | 1 | 2½ ton | East | |

TOP SECRET [illegible]

Figure 5.2: Vehicular activity on Routes 8, 9, and 12 as shown on (REDACTED), from CIA (1964a, 2).

this chart. Although the document was approved for public release in August 2000, the mission names referring to 'passes' or 'sorties', most likely sometime in early 1964, remain redacted. The document code printed in its top-right hand corner—'1667/64-KH'—provides a faint suggestion that this may have been based on high-altitude satellite imagery. 'KH' was often used as a code for the KEY-HOLE satellite photography systems used throughout the 1960s by the CIA as part of the CORONA programme. Whichever way the images referred to here were taken, given the NPIC's involvement and the descriptors in the 'remarks' column, it is clear that the chart was the product of an analysis of a set of aerial photographs. The leading memo enclosed with the document states that the chart was compiled 'in response to the requirement requesting the determination of the amount and capacity of vehicular traffic on the major roads leading to South Vietnam' (1964a, 1).

I focus on this chart not to make the argument that it was a pivotal reference in the genesis of the whole electronic barrier programme. Rather, I wish to discuss it precisely because of its banal anonymity, so as to open up a discussion of the kind of uncertainties which contoured the factual limitations of wartime intelligence reporting in Vietnam. Charts, graphs, maps, and extensive commentaries were prolifically produced and scrutinised by defence researchers between 1964-1966, and analysed to provide insights into the way the trail was used and to prescribe possible strategies to establish control over the region. In addition, the chart represents a set of core problems involved in the process of producing a strategic knowledge of the Ho Chi Minh Trail region—problems which remained throughout the lifetime of the electronic barrier programme following its deployment in late 1966 (see Deitchman et al. 1966).

The practice of photo interpretation was one of a number of such activities that could neither be automated nor substantially optimised through the use of the digital computer. Indeed, the expansion of the data collection process in fact caused a corresponding increase in the demand for photo interpretation. As such, it served as the basis for the regime of practices that produced and verified the intelligence of the so-called 'interdiction effort', delimiting its geographies and quantifying 'progress' in reams of statistical data subsequently quoted by Defense Secretaries from the mid-1960s through to the early-1970s.

The credibility of a chart partially depends on the explicit specificity of its organisational schema. This chart is divided into a series of columns headed 'route and mission,' 'location by coordinates,' 'number of vehicles,' 'type of truck,' and 'direction'. A final column provides space for miscellaneous supporting or contextualising remarks regarding the data. Each row refers to a specific truck observation, organised into groups based on the route number and sortie. The information on the basis of which this chart was drawn up is absent, however: the chart itself has replaced the original images, distilling the features deemed pertinent for the purposes of 'interdiction' into a discrete interpretive schema. For the intelligence analyst wishing to put the data represented in this chart to use, a careful understanding of the photo interpretation process is either tacitly understood or an unnecessary distraction from the data itself. Factors such as the institutional status of the photo analyst, the depth of their experience, the kinds of training they have undergone, whether any other analysts might have examined an image to corroborate a difficult call, and their level of confidence in their interpretation, are not at all clear from this chart when read in isolation.

The language and techniques of photographic interpretation were standardised in an official NPIC glossary dating from 1966. In this document, there was a formalised protocol to be followed by NPIC analysts for assessing the 'interpretability' of an image (NPIC 1966, 20). The protocol stated that an assessment should take into account 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. An analyst could then assign a particular photograph a level of interpretability that is either ‘G’ (good), ‘F’ (fair), or ‘P’ (poor) (NPIC 1966, 20). In this chart, however, the aesthetic and technical qualities of the photograph were only afforded minimal remarks. The reader instead encounters a record of ‘vehicular activity’, a document which professes to merely report on a set of what might initially appear to be uncontroversial observations: the number of trucks at a particular location, their direction of travel, and the type of vehicle. The reader of this chart might thus take the veracity of such discrete unitary statements for granted: the orderly structure of the chart itself imbues much of its content with a forceful directness that suggests that its constituent data are clear, undisputed, unambiguous—a matrix of observations emerging out of a particular instituted ‘expert’ practice of photo interpretation and therefore understood to be ‘true’.

Writing in a 1965 RAND memo on the Cuban Missile Crisis and Pearl Harbor, Roberta Wohlstetter theorised the production of intelligence in a framework that borrowed key terminology and concepts from information theory. In her terms, ‘a sign, a clue, or a piece of evidence’ constituted a ‘signal’, and determining the point of ‘convergence’ of multiple signals allowed for the ‘crystalisation of a hypothesis’ about the target under scrutiny (1965, 12–13). Signals existed within a field of background noise—what she defined as ‘the background of irrelevant or inconsistent signals, signs pointing in the wrong direction, that tend to always obscure the signs pointing in the right way’ (1965, 2). Noise could be produced from heterogeneous sources, Wohlstetter noted. The deliberate action of the enemy, emergent uncertainties, operational problems and the ‘limiting conditions’ referred to above could all distract from and obfuscate the ‘true signals’ (1965, v). Forming verifiable and credible intelligence, or in Wohlstetter’s terms separating the ‘true signals’ from the ‘noise’, was a lengthy, complicated process almost inevitably beset by delays. She wrote:

> This time difference is one of the perpetually agonising aspects of in-

> telligence interpretation. Collection, checking of sources, and interpreting all take time. There is always delay between the intelligence source and the evaluation centre, and between the centre and the final report to the decision-maker. Even then, the decision-maker may merely request more information before taking action. (1965, 13–14)

Robert McNamara's advisors in the DOD tended to bolster the strength of their claims by drawing attention to the purported 'scientificity' and 'objectivity' of their methods. Wohlstetter similarly explicitly drew on metaphors and terms from established specialisations within defence research. However, she was more forthcoming in highlighting the role of speculation and guesswork in the everyday construction of intelligence. Throughout her RAND memo, she used terms such as 'estimate', 'inference', 'assumption', 'interpretation', and 'hypothesis' to describe an intelligence agent's relationship with their target of analysis (1965, 36–37). The resultant claims made about this target—whether it was determining the presence of a missile silo in Cuba or convoy traffic in the Laotian jungle—existed in relation to deliberate attempts to evade and misdirect this analysis, as well as a host of other emergent 'noisy' contingencies. Wohlstetter explained this in relation to the task of photographic interpretation:

> The complex inferences involved in the act of interpreting photographs are made possible only by a large body of assumptions of varying degrees of uncertainty, ranging from principles of optics and Euclidean geometry through technological, economic and political judgements. (1965, 37)

She added that 'an observation or its report does not seize us then and force any specific interpretation' (1965, 38). Referring to Pierre Duhem's critique of empiricism in physics, she suggested that an observation in the first instance implicitly depends on 'comprehensive theories about the measuring instruments' amongst many other things. Intelligence on the Ho Chi Minh Trail gathered from aerial photography relied on a faith in a chain of instruments and actions of varying degrees of complexity all working together, including but not limited


Figure 5.3: An NPIC Photo Analysis Laboratory depicting 'Low Altitude' and 'High Altitude' interpretation desks, from CIA (1962).

to: the camera and its internal embedded devices; the aircraft and the ability of the pilot to adequately manoeuvre amidst anti-aircraft artillery barrages; the pilot successfully triggering the camera shutter at the correct moment; the film development process; and finally, the trained analyst using the various lenses and other devices to aid the interpretation of the photographs (see Figure 5.3). The construction of a piece of 'intelligence' then relied both on standardised technical instruments and instituted forms of expertise with which 'valid' judgements and interpretations could be made.

Written only a few years after the Cuban Missile Crisis, Wohlstetter's memo contradicted the common assertion proffered by her contemporaries that the incident ultimately represented a veritable success for the United States. The political scientist Amy Zegart, revisiting Wohlstetter's memo in a 2012 article, suggests that for those actors aiming to retroactively evaluate and construct histories of intelligence production leading up to such crises, be it in an internal CIA inquiry or congressional investigation, Wohlstetter's approach produced its own 'analytic pathologies' (2012, 30). The conclusions of such assessments of crises tend to repeat one another, she argues: 'too few signals, too much noise, too many erroneous assumptions or inferences' (Zegart 2012, 30).

What is typically missed in such endeavours are 'the crucial role of organisations' and the structural, institutional and operational factors that shape the construction of intelligence claims. Beyond the technical instruments which permit a discursive object to be translated into another form—for instance, from a set of photographs to a matrix of observations in textual form—there is a regime of practices constituted by operational protocols and priorities, a standardised lexicon, distributed tasks and skillsets, and individuals embedded in formalised command hierarchies. It is the specificity of this regime that imbues the myriad grey media which emerge from it with an authoritative power, to sanction these media as 'documents' which can be taken seriously in spite of the uncertainties involved in the process of their production. These photographs were inspected by a 'gaze that mythically inscribes all the marked bodies, that makes the unmarked category claim the power to see and not be seen, to represent while escaping representation' (Haraway 1988, 189).

Afforded this analytic approach, we will more closely examine three rows (*Rows 6*, *4*, and *5* successively) of data in the chart.

| | | | | | |
|---|---|---|---|---|---|
| Route 9<br>[REDACTED] | 16 40N<br>104 51E | 1 | 3/4 ton | West | 10 nm NE of Changwat<br>Savannakhet |

*[Row 6]* reports on a set of observations along Route 9. Unburdened from any temporal or processual qualifications, there is nothing in this particular row that

would lead the reader to believe that it is considered to be anything but a set of incontestable observations with no hint or reference as to their process of construction. This is of course not to say that the statement that the truck was travelling west, for instance, was an unequivocal call: perhaps the photo analyst wrote this down after lengthy examination, as a matter of opinion rather than certainty that arose out of converging different clues in the image, or indeed, perhaps this was unambiguously and immediately clear. In *[Row 4]*, an uncertainty is introduced:

| | | | | | |
|---|---|---|---|---|---|
| Route 8 [REDACTED] | 17 23N 104 48E | 1 | U/I | N.A. | By oblique photography - dense jungle growth in many areas |

The row only answers some of the questions asked of it by the chart's structure. The truck type is labelled 'U/I'—shorthand for unidentified (NPIC 1966, 38). For the direction of travel, the analyst responded as one is taught to do when a form asks for information unknown: 'N.A.', *not available*. The row is negatively modalised by the statement in the remark column, which refers the reader of the chart back to the process of photo interpretation. 'Obliquity' is a noted problem in photo analysis, and is defined in the NPIC glossary as 'that condition in which the optical axis of the camera is titled appreciably from the vertical, often limiting detailed analysis' (1966, 9). Perpendicular perspectives where the line of sight from the camera lens intersects with the ground at a right angle were considered the ideal. The second remark alludes to the common problem posed by the environmental characteristics of the region. The jungle was often characterised by Air Force and CIA strategists in militaristic terms, citing it as a factor that limited the efficacy of both live aerial reconnaissance and post-sortie photographic analysis of the Ho Chi Minh Trail region (Deitchman et al. 1966, 18).

Data from *[Row 5]*, again pertaining to Route 8, is entirely missing from the chart. Instead, the row refers us to the conditions which entirely prohibited fruitful examination of the imagery:

| | |
|---|---|
| Route 8 [REDACTED] | Obliquity and cloud cover preclude analysis. |

In addition to the limiting factors of obliquity and natural camouflage which limited analysis in *[Row 4]*, this row introduces a third contingency: the weather.

In the leading memo with which the chart was enclosed, its author noted that 'detailed analysis was impossible, in many instances, because of obliquity, dense vegetation, and lack of photo coverage' (CIA 1964a, 1). A separate CIA memorandum, reporting on KEYHOLE passes during a truce in 1968, noted the problem of cloud cover as it pertained to satellite, drone, and manned reconnaissance missions. High-altitude satellite photography of Hanoi, for example, was only possible for an average of three days a month for most of the year, and low altitude photography very rarely being possible more than 15 days per month (COMIREX 1968).

Drawing these methodological uncertainties into the foreground, we can think of this matrix of observations as the outcome of a prior array of interpretations of a set of photographic documents carried out by a trained photo analyst. These exceptions reintroduce the history of the chart as a process of constructing its attendant claims through the interpretation of photographs, providing some sliver of an insight into the basis for this enigmatic set of discursive operations that filled out the chart's rows and columns. Juxtaposed with this memo, the utility of the chart, if not its credibility, as a document describing 'amount and capacity of vehicular traffic on the major roads leading to South Vietnam' is at least partially drawn into question (1964a, 1). Despite the acknowledged uncertainties encountered in the process of its construction, charts such as this were regularly produced to document and quantify observations from aerial photographs. It contributed to the formulation of a knowledge about the trail region which purported to accurately document movement along its routes, even contributing to the formulation of new interdiction policies and missions and the designation of particular zones for devastating barrages of aerial bombing.

### 5.2.2 Degrees of Uncertainty

Despite what Wohlstetter described as the 'degrees of uncertainty' necessarily involved in the practice of photo interpretation, it featured as a central element in the regime of practices that guided and delimited the anti-infiltration strategy. The strategic importance of the aerial perspective recharacterised the jungle in terms of its vertical illegibility, an 'othered' zone entirely described in terms of how its environmental features either permitted or denied surveillance. As with the chart discussed previously, the limitations of the pilot's-eye-view were frequently emphasised in many other intelligence documents on the trail region. The sheer expansiveness of the region, alongside the dense natural vegetation and seasonal monsoons, meant that the kind of 'limiting conditions' referred to in the chart's remarks column were rather common qualifiers in reporting on the anti-infiltration programme. For about five or 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 from an intelligence collection perspective (Schweitzer 1966, 6–7). Satellite imagery, although 'safer' to collect, was far more likely to be useless due to the probability of high altitude cloud cover, as the aforementioned CIA memo indicated (COMIREX 1968). 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.

In addition to these environmental factors discussed above, conditions for 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. In addition, the NVA reportedly 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 sortie rate increased in the mid-1960s, NVA truck activity was shifted mostly to after nightfall. Truck drivers allegedly turned off headlights or pulled into well-camouflaged parking spots when they detected a US aircraft approaching.

As a consequence of all these circumstantial and deliberate efforts to thwart observation, charts, graphs, and other data 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). Nevertheless, the policy of USAF armed reconnaissance sorties and photographic surveillance continued. The questionable quality of the intelligence generated through aerial photography was rather presented as justification for the expansion of new reconnaissance operations in Laos, and the need for more resources to overcome NVA countermeasures and the environmental factors hindering surveillance. The 'defoliation' programmes that were active in Vietnam were extended to the Laotian jungle (Roper and Chow 1966, 6; Deitchman et al. 1966, 21). In less euphemistic language, defoliation referred to the process of spraying hundreds of thousands of gallons of herbicidal chemicals (such as agents 'orange', 'blue', and 'white') from USAF aircraft, with the aim being to poison vegetation and make it more susceptible to burning. 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, rich jungle to a barren, blackened landscape—one more amenable to the US military's demands for expansive, omniscient view from the air (Collins 1967, 22–23).

There was a second surveillance programme which generated a substantial quantity of data about trail traffic. Known as the 'Roadwatch Programme', it was comprised of teams of civilian observers stationed on the ground in various key hamlets in the trail region (Rathjens et al. 1966; Schweitzer 1966). The so-called 'Roadwatchers' kept a tally of passing traffic, and reported back to US intelligence with data pertaining to the number of trucks and pedestrian porters, their estimated cargo in tons, and noted any other relevant habits or tactics displayed by the trail's many labourers. Although capable of providing more granular data and in a considerably subtler way than the aerial reconnaissance programme, it also had its own set of verification problems. The Roadwatchers' efforts to quantify the cargo loads were complicated by the trucks' canvas-covered trailers (Rathjens et al. 1966, 7). Instead, a flat estimate of 3 tonnes per truck was used, although a report suggested that this was somewhat arbitrary, noting that there was a 'significant amount' of 'uncertainty' in this figure (1966, 8). Furthermore, due to the decentralised organisation of the Roadwatch programme, the same convoy could be accidentally double-counted by two different observer teams along separate sections of trail. A SAG working paper evaluating the armed reconnaissance programme points out that information coming from Roadwatch was undermined by the fact that 'the observation effort is variable': 'observation points change frequently', they noted, alongside the 'probability that there is a duplication in reporting' as observers at different points might count the same convoy (Roper and Linsenmayer 1966, 1).

The purpose of these data collection efforts was not just to ascertain vehicular traffic as a set of atomised incidents, as was depicted in each row in the chart discussed previously. The true strategic value of the data for defence researchers and military planners was to use it to assemble averages and determine trends that could be used to optimise the allocation of aircraft and bombs to the interdiction process, or propose entirely new strategic possibilities for interdicting convoys. Making this statistical leap from the particular to the general, from a set of intermittent factual observations located at specific times and places to a greater pattern of activity, proved to be impossible to achieve without entering into a realm of substantial speculation. One study into intelligence reporting on truck traffic provides a sense of the problems involved:

> A typical truck count on route 911 over successive nights might be 110, 40, 0, 70, 30, 0, 0… with large convoys interspersed with very low levels of activity. It is difficult to do statistical analyses on data of this type to see what effect reporting gaps might have; the confidence interval will be very large. In addition, road coverage is not consistently for 24 hours. Finally, the data may be conservatively biased due to enemy road sweeps before heavy convoy movement. (Rathjens et al. 1966, 5)

In the above paragraph, the authors of the study pinpointed a problem that was not particular to just this highly manual effort to quantify traffic. It would also recur throughout the progressively technologised and automated iterations of the interdiction programme from the mid-1960s and in the electronic barrier programme until it was dismantled in the early 1970s. There was no control dataset that could be used to establish the approximate accuracy of Roadwatch and aerial reconnaissance data, nor was there any discernible statistically linear pattern in the movements of convoys. Virtually every facet of measurement was contingent on a chain of other factors: a leap in traffic during a given week could be explained by dry cloudless weather, by two or more Roadwatch teams mistakenly counting the same convoy, by aircraft being in the right place at the right time to spot traffic along a clear unobstructed section of path, or by a genuine uptick in traffic flow in comparison with previous weeks. As the paragraph quoted above makes clear, there was no discernible pattern in the recorded data, nor was there a suitably

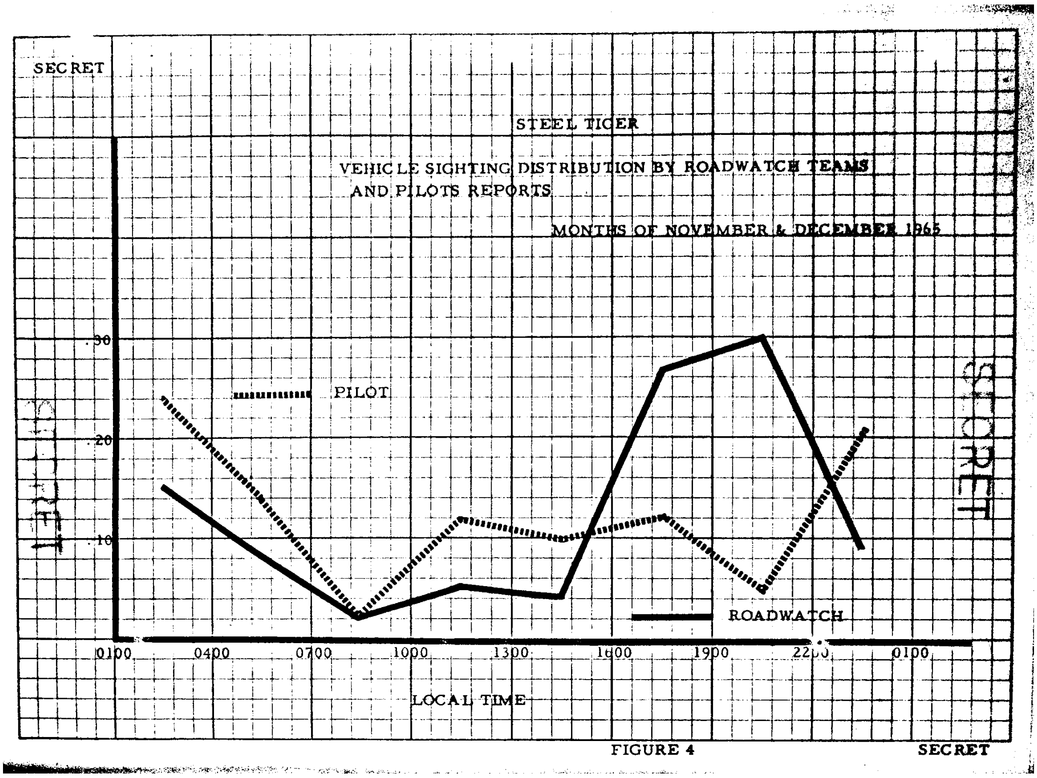



Figure 5.4: Vehicle Sighting Distribution by Roadwatch teams and Pilots Reports, from Roper and Linsenmayer (1966).

systematic data collection method which could serve as the basis for the creation of a sound statistical model. Nevertheless, even while acknowledgements of the endemic problems of uncertainty and contingency were acknowledged by their authors in the forewords and introductions, the plotting of data in graphs, charts, and maps proliferated, illustrating the claims and propositions of the authors of SAG papers, IDA reports, and RAND memoranda.

The graph depicted in Figure 5.4, included in Roper and Linsenmayer's working paper referenced above, professed to chart the correlations in truck traffic sighting times reported by armed reconnaissance aircraft (dotted line) and Roadwatch teams (solid line). The *y-axis* is the number of trucks observed, and the *x-axis* is the time of day. The graph was based on data collected during November and December 1965 in the STEEL TIGER area, a region that encompassed southern Laos up to the north-west of the demilitarized zone (DMZ). Roper and Linsenmayer noted that there was a significant disparity between reported truck sightings by Roadwatchers and pilots during the hours of 1900-2200 (1966, 2). Although they acknowledged elsewhere in the document that the Roadwatch data was unreliable, and that the NVA's reported use of truck-mounted radar could provide sufficient early-warning to 'considerably reduce armed reconnaissance effectiveness' (1966, 3), they reinforced the pattern in the graph through reference to another dataset. The authors suggested that, because the quantity of armed reconnaissance sorties was approximately level over the course of the 24-hour period, the fall-off in aerial sightings could not be explained by a corresponding reduction in sorties. The implication then was that there must have been an actual increase in traffic but that reconnaissance aircraft were not detecting them. Despite the array of uncertainties which the authors acknowledged had drawn the veracity of this data into question, the noted disparity between the graphed sortie rate and traffic observation nevertheless became the basis for what was framed as a possible shift in strategy: Roper and Linsenmayer proposed to 'improve the traffic interdiction programme' by dedicating resources to support more sorties during the evening hours (Roper and Linsenmayer 1966, 3).

Even when the seemingly inevitable uncertainties and contradictions inherent in the data collection process were understood by the teams of analysts producing these various reports, the idea persisted that the right metrics could cut through the uncertainties in the dataset, producing actionable and reliable intelligence about infiltration 'to achieve the maximum total results within the current operating constraints and conditions' (1966a, 3). Roper and Linsenmayer's 1966 report is exemplary of this, in which the question of how to improve the effectiveness of the interdiction programme played out over a range of metrics: 'number of trucks destroyed' per month; 'trucks destroyed or damaged per armed recce sortie'; '% of STEEL TIGER sighted trucks destroyed or damaged'; and many others made fleeting appearances in other documents ostensibly reporting the programme's progress. This proliferation of metrics in reports authored by defence researchers such as Roper was ultimately driven by the imperative to identify patterns in the data which might allow for further optimisation of the target identification and attack process.

The insights into traffic patterns contained in these reports were carefully constructed through a process of aggregating, filtering, intuiting, calculating, and converging different streams of data. This highly variable process of compositing datasets, coupled with a subject of analysis which held no discernible linear pattern, led to conclusions drawn from these data aggregations sometimes contradicted one another from one data period to the next. Two further SAG working papers released in early 1966 reached two different conclusions about the optimal sortie policy. One from March stated:

> For all programs in Laos, the 'point of diminishing returns' appears to have passed. That is to say, the rate at which these programs are producing militarily significant results is increasing at a lesser speed than the sortie effort. (Roper 1966a, 3)

A subsequent document published in April revised this:

> Results (for period December–March 1966) in terms of high quality targets such as vehicles and secondary explosions have increased at an even greater rate than sorties, indicated no 'point of diminishing returns' has yet been reached in sortie application. (Thompson 1966, 1)

If tracking the performance of the interdiction programme across a whole range of metrics allowed defence researchers to draw some broader, if dubious and often contradictory, conclusions about traffic along the Ho Chi Minh Trail, analysts also remained mostly confounded in their attempts to compose accounts that made more specific 'facts' cohere. RAND consultant and political scientist Joseph Zasloff articulated this explicitly in a memorandum dating from 1964. In the document, titled *The Role of North Vietnam in the Southern Insurgency*, Zasloff prefaced his findings with a couple of pages worth of commentary that emphasised the inherent ambiguities in his 'factual data'. He wrote:

> No single document, or set of documents, fully reveals the role of North Vietnam in the insurgency. The available factual data, many and diverse though they are, tend to be fragmentary; some must remain unconfirmed, their credibility notwithstanding. (Zasloff 1964, iii)

The resulting report, as he put it, was necessarily a '*composite picture* based on several kinds of evidence of varying precision and generality' (1964, iii–iv, emphasis mine). Zasloff's metaphor of a 'composite picture' here is a pertinent descriptor that highlights the broader epistemological problems of defence research as it pertained to strategy in Vietnam. As Zasloff admitted then, a knowledge of the Ho Chi Minh Trail region could only be partial and speculative, and as such necessarily had to be manufactured out of a range of interpretive and analytic processes.

As Biggs (2018) proposes in his book *Footprints of War*, a 'militarised landscape' pertains not only the physical space of the battlefield, but also incorporates the discourses and techniques of knowing and representing such spaces. The interpretation of aerial photography of the trail region, which by definition was a manual practice, relied on the capacity for trained operators to look for traces of activity which satisfied an institutional expectation for what counted as evidence—that is, the 'politics of truth' within this regime of practices. Between the clouds and canopy, the management of grey areas was pivotal in this process: the landscape was refigured as a zone that demanded a particular interpretive mode of looking before it could be susceptible to computational analysis.

Evidently, there were tensions between what could be speculated on, taken for granted, and proposed as strategy. However, for all the acknowledged uncertainties in the data collection and analysis processes, the kinds of documents discussed above still held an epistemic credibility of sorts. It was through the instituted methods of interpreting photographs, in combination with the analytic commentaries of the resultant aggregated statistics in the SAG reports, that a knowledge of the trail could be constructed. These diverse interpretive and analytic processes can be understood as elements within a regime of practices that not only codified a knowledge of the trail region in a standardised, quantitative form, but also prescribed and legitimised possible elaborations in the anti-infiltration strategy.

While the task of photo interpretation exemplifies the kind of ambiguities and conditions that affected the construction of this knowledge on the day-to-day reporting on the trail region, an examination of systems analysis reveals the ways in which 'uncertainty' was managed through instituted forms of expertise and quantification. The type of data-driven speculation at the heart of systems analysis can thus be understood as expressive of a broader politics of truth that scaffolded US decision-making in Vietnam. Its establishment as an 'Office' in McNamara's DOD formally sanctioned its centrality as a knowledge practice, legitimising an 'intuitive' but quantitative style of strategic-planning while further shifting the locus of decision-making from the military to the sphere of civilian defence research (Twomey 1999; Dayé 2016). As applied to the problem of 'interdiction', this style shaped how strategy could be quantified and assessed, contributing to the formulation of new, ostensibly more 'efficient' or 'optimal', operational programmes to bomb truck traffic along the trail.

### 5.2.3 Expertise

In 1966, scientists from the Institute for Defense Analyses (IDA) published a study describing the various methodologies used by the US DOD's myriad agencies and services to produce intelligence on the Ho Chi Minh Trail. The intention, as the study's introduction relayed, was to

> examine the methodology and learn how estimates are made, to note where differing estimates exist and why, to obtain a feeling for the range of uncertainties involved in the estimates, and how gaps may be filled in the future. (Rathjens et al. 1966, 1)

During the mid-1960s, the IDA produced copious documents for military commanders on Vietnam, and not least on the topic of interdiction. This particular study however, in focusing on the *process* and its organisational dependencies, provides an important insight into the way some kinds of 'intelligence' was understood, constructed, and mobilised amidst the exigencies of the Vietnam War. The author of the study examined a series of core metrics used by intelligence analysts to track the NVA's use of the trail infrastructure over time, including the two metrics which the chart discussed earlier aimed to describe, referred to here as 'estimated trucking into Laos from NVN [North Vietnam]' and 'estimated road capacity of the Ho Chi Minh Trail' (Rathjens et al. 1966, 1). The examination of each metric was split into a section which explicated the data within the context of the war, and a second section titled 'methodologies and uncertainties' which offered a critique of the data's production, outlining the factors which delimited its veracity. The operative word in the report is 'estimated'. The data discussed within, whether collected by aerial reconnaissance or Roadwatch teams, was always qualified with a degree of uncertainty.

US intelligence attempts to quantify the logistical capacity of a particular road, for instance, relied on a process that atomised that road into an array of interacting quantifiable characteristics. The authors of the IDA study noted that 'road width, shoulder width, surface type (unimproved or improved earth), gradient and curvature, […] road condition (poor, fair good), and sub-surface condition (wet, moist, dry)' were all taken into account (1966, 10). Based on the notional average of three tonnes of cargo per truck mentioned earlier, along with time for 'adequate road maintenance', the authors explain that analysts could then input the relevant values into the formula and compute the capacity of the road. They warned, however, that the 'methodology only yields *planning factors*, useful for rough calculation and for comparison of alternate routes, but whose absolute values may be inaccurate due to variations in local conditions, driver discipline, and so forth' (1966, 13, emphasis original).

Rathjens' approach incorporated central characteristics of the framework of systems analysis widely used elsewhere in US strategic planning and assessment of existing operations in Vietnam. During the 1950s, systems analysis effectively became the house style of strategic planning at RAND, and in the following decade, held significant influence over military planning in Vietnam: it informed the ROLLING THUNDER bombing campaign of North Vietnam, the notorious 'body count' policy, and was drawn upon by defence researchers in their frequent assessments of the efficacy of the anti-infiltration programme in Laos (see for instance Schwartz 1968; Henry 1970; Thayer 1975b). As a framework used in the construction of a knowledge of the Ho Chi Minh Trail region, however, it was widely explained by its proponents as sitting in tension with institutionalised quantitative scientific practices.

The heterogeneous practices which comprise systems analysis have a longer history. Its origins as a disciplinary framework lie in 'operations research' (OR) as practiced by military personnel, engineers, and scientists working on problems concerning the development of radar in Britain during the early stages of the Second World War (Thomas 2015, 34). During the war, OR was further elaborated and applied to problems ranging from determining targets in strategic bombing campaigns to optimising tactics in aerial combat (2015, 37–38). Throughout the 1940s, both during and after the war, OR was closely involved with the field of logistics management. As Erickson et al. (2013, 53) emphasise, central to the US application of OR after the war in major operations such as the Berlin Airlift, was the imperative to 'optimise': the aim was to find the most efficient way to allocate and conduct resources to achieve an overarching strategic aim—in this particular instance, the aerial delivery of supplies into a besieged West Berlin. As a discursive practice, systems analysis inherited OR's primary interest in determining the efficient balance of 'costs' in strategic planning.

Throughout the 1950s and early 1960s, systems analysis underwent what Thomas (2015, 269) describes as a period of 'methodological critique' which played out across a series of memoranda authored by RAND economists. Central to their debate was the extent to which systems analysis could be understood as either an 'art' or a 'science', and the implications of these categorisations on the validity and credibility of conclusions reached by its practitioners (Hoag 1956, 18). For its proponents, systems analysis was considered to be artful in that it relied on the intuition of the expert to translate real-world phenomena and relations into mathematical cost-benefit models. Yet what was frequently emphasised was that, despite this purported artfulness, this analytic approach was heavily based on formalised, ostensibly 'scientific' procedures. Their explanations of how systems analysis could be legitimately drawn upon to inform the planning of military strategy despite its intuitive and speculative qualities helps to identify what we might understand as its 'politics of truth'—in other words, the qualities that meant that it could be taken seriously when making decisions.

In a paper titled *An Appreciation of Systems Analysis*, the prominent RAND economist Charles Hitch wrote:

> Operations analysis and systems analysis are attempts to apply scientific method to important problems of military decision, even though the problems are not particularly appropriate for scientific method and would never be selected for the application of scientific method by a truly 'academic' researcher. (1955, 2)

A year later, Malcolm Hoag echoed Hitch's sentiments in another RAND memo:

> It is very clear that Systems Analysis as currently practiced, and probably as practiced in the future, is much more an art than a science.

> To be sure the analyst ought to employ whatever scientific tools are appropriate at particular places in the analysis, but his operations as a whole are not characteristic of 'Science' with a capital 'S'. (1956, 18)

According to Hitch and Hoag, systems analysis might incorporate, or perhaps emulate, particular techniques of measurement and calculation drawn from other instituted 'Scientific' disciplines. However, the particular ways in which these techniques were applied or combined relied on the intuitive and tacit knowledge of the analyst themselves. This is not to suggest a return to the so-called 'art of war' that had defined US military strategic thought before the proliferation of civilian defence research institutes in the 1940s and 1950s. As Edwards (1997, 120–21) explains, systems analysis focused on the relations between policy, technology, and strategy: 'models of rational action displaced Clauswitzian struggle'. It was commonly applied to problems of strategy where empirical data were fragmentary or even entirely absent: it was thus understood to hold a diagnostic and prognostic utility for defence researchers in the definition and evaluation of technological and strategic planning.

For the RAND researcher Olaf Helmer, this emphasis on the role of the systems analyst in defining the criterion and scope of a particular technostrategic problem required some further scaffolding if it was to function as a legitimate approach. Central to this was the figure of the 'expert'. He later argued that systems analysis could only be used objectively by 'replacing the surreptitious use of expertise by the explicit and systematic application of it' (1963, 3). For him, the figure of the expert—invariably male in these memoranda—was characterised in technical terms: he was a 'measuring instrument' who held a quantifiable 'degree of reliability' established through experience and past successes in making predictions (1963, 3–4). The nomination of experts had to also be carried out objectively:

> an effort has to be made to develop specific techniques for identifying expert performance and for processing data in the form of expert pro-

> nouncements into predictions of the greatest possible reliability (1963, 3).

What was additionally necessary, Helmer suggested, was having a dataset that would account for the patterns of bias evident in the past judgements of a particular expert, so that this bias could be filtered out of the propositions which a given systems analysis or OR study produced (1963, 4). The authoritative force of a statement could be further scaffolded through a quantitative modulation based on the past biases and errors displayed by a particular 'expert'. Precisely how one might design a model to adeptly detect, quantify, and filter bias without introducing its own bias in the process is not explained in this paper, however.

Hoag also noted how systems analysis might be 'abused'. Technical terminology and the aesthetic qualities of a chart—what we might understand as discursive supports which lend credibility to a proposition—can have an obscuring effect, he suggests:

> Many systems analyses share an impressive facade. The technical discussion is long and complicated, the charts elegant, the mathematical appendices formidable, and there is great display of jargon and virtuosity. Such a facade can reveal very good analyses or it can conceal very bad ones. (1956, 21)

Similar to Helmer, Hoag's solution to uncovering poor practice presents a problem of circularity. 'After all, "the solution to bad analysis is good analysis." How else do you know it is bad?'. Indeed, as applied to the question to the designation of target priorities in an immense bombing campaign, we might also ask how one might know if their analysis is 'good'.

In their memo *Military Planning in an Uncertain World*, RAND strategists Herman Kahn and Irwin Mann were somewhat derisive about what they saw as the 'fashionable' uptake of systems analysis. By contributing memoranda including *Techniques of Systems Analysis* and *Ten Common Pitfalls* to the RAND catalogue, both strategists sought to encourage a more rigorous application of systems analysis by elucidating core elements of it as a practice. For Kahn, the cost-benefit (or cost-effectiveness) curve was a core technique for strategic decision-making, and 'typical of the end product of most systems analyses': these curves 'tell you, *given certain assumptions*, how to spend your money and the kind of performance you can expect if you spend it that way' (1956, 35, emphasis original). To convert a line of qualitative reasoning pertaining to, for example, an air defence policy or a strategic bombing campaign into a numerical format—to change 'intuitive judgement' into a 'considered opinion'—'is as much of an intellectual invention as the steam engine or the telegraph is a technical invention' (1956, 36). What was implied here is that, despite any 'reasonable individual' being capable of following and intuiting the logic underpinning the kind of defence strategy they discuss in the memo, the intellectual authority of the expert coupled with the systematic, technological modality through which they reach their conclusion imbued their speculation with an additional validity. Implicit in the idea of a 'reasonable individual' is the specific standpoint of expertise and those whose intuitions can be taken seriously.

Invoking a notional conversation between a General and an Operations Analyst to explain the differences between 'intuitive judgements', 'considered opinion', and 'technical or scientific "fact" ', Kahn and Mann emphasise the importance of an analyst balancing intuitive ideas with quantitative evidence that 'indicate[s] reasonably explicitly the uncertainties' involved. 'Indulging *too often* in recommendations based only on some intuitive ideas', they cautioned, increases the likelihood that the analyst will 'become embroiled in day-to-day policy fights' (1956, 9). On the other hand, over-indulgence in abstraction on the part of the systems analyst at the expense of that which is 'mathematically untidy' might present another kind of problem. This was what they called 'modelism', or the pitfall of 'being more interested in the model than in the real world' (Kahn and Mann 1957, 1).

In delineating these military-civilian and intuition-expertise configurations, Kahn and Mann's document also foreshadows a significant shift in institutional expectations within the DOD in the 1960s concerning how strategic planning should be conducted and legitimised, and indeed, the various pitfalls it could be susceptible to.

Hitch's 1960 paper *Uncertainties in Operations Research* demonstrates the ambitions of practitioners of OR and systems analysis and their role in the formulation of military strategy and decision-making. He called for a shift in thinking amongst military planners:

> A shift from searching for the best way to choose between two contingently unsatisfactory answers *to searching for a better answer.* From a search for a better decision rule to a search for a better system. From sophistication in *judgement* to ingenuity in *design.* (1960, 5)

In 1961, the search for 'better systems' was formally instituted in the Department of Defense with the establishing of the Office for Systems Analysis (OSA). Charles Hitch was appointed Assistant Secretary of Defense, overseeing the OSA's research as the conflict in Southeast Asia escalated.

By the mid-1960s, defence researchers at the OSA were producing influential reports and studies of the situation in Vietnam at a prolific rate, ranging on topics from the Vietcong insurgency to the air war and bombing campaigns in the north (see Thayer 1975a, 1975b). Gibson (2000, 156–57) suggests that systems analysis, as practiced at the OSA and applied to the war in Vietnam, is emblematic of 'technowar'—the rationality of industrial accountancy employed in the planning of military strategy. Gibson's description captures some of the features of systems analysis as a discourse, but it is important to note that this was an effort to *impose* cost-benefit decision-making within a context that continuously confounded quantification yet equally continuously demanded decisions. Systems analysis as practiced at the OSA and RAND with regard to military strategy in Vietnam can rather be more aptly characterised by how it drew on terms of numerical precision from other disciplinary frameworks to scaffold what were rather speculative propositions based on, at best, often very partial data. That the debate over whether systems analysis constituted an 'art' or 'science' then may appear to be a curious distinction to draw when, across defence research more broadly, the proponents of diverse novel sub-specialisations vied to demonstrate the 'Scientific' credentials of their chosen practices. However, by privileging 'intuition', the legitimacy of systems analysis as a style of inquiry was thus contingent on vague but powerful notions of technical 'expertise', and by extension, institutional authority.

The question of how to optimally 'interdict' cross-border traffic along the Ho Chi Minh Trail, conceptualised as a problem of 'design' with obvious 'cost-benefit' considerations, was explored through numerous studies conducted at institutional centres such as RAND, the OSA, the SAG, and the IDA that quite clearly implemented aspects of this style of technical writing. The effect was that these 'problems of military decision' became a lively (and lucrative) arena for speculation amongst civilian experts at these think tanks, rather than commanders in the Armed Forces (see Twomey 1999, 236–37). In other words, those capable of making credible speculations were white, male, Americans accustomed to a specific, disciplinary culture of technical knowledge production cultivated at these institutions. Furthermore, such speculations were devised at considerable geographic remove from the battlefield—for instance, from the comfort of a wargame simulation room in Santa Monica, California (Weiner 1959).

A RAND memo from 1964, published in partnership with the Zasloff document referenced above, brought some key signature techniques of systems analysis to bear on the question of the NVA convoy routes. The memo documented in-country research carried out by C. V. Sturdevant sponsored by the high secretive and influential think tank the Advanced Research Projects Agency (ARPA). Speculating on the potential efficacy of two border-control systems, Sturdevant was clear about

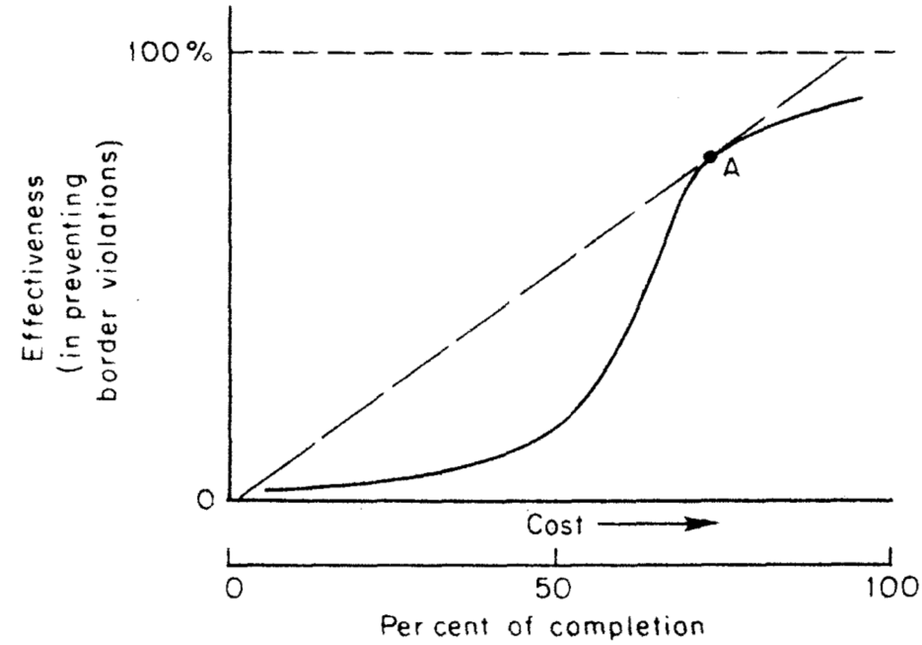



Figure 5.5: Graph of 'Cost-Effectiveness Analysis of "Barrier" method' in Sturdevant's 1964 RAND memo.

the challenges involved in attempting to exert control over the region. He wrote: 'Conventional means for effectively "sealing" its entire border to Viet Cong infiltration cannot be implemented by South Vietnam within the next few years, even with substantial outside help, for lack of manpower and other resources' (1964, v). He likened any attempt to control the breadth of the border to a trade-off inherent to the economics of industrial processing:

> The purer the degree of refinement of the chemical, the greater the cost; the more accurate or versatile the machine, the greater its cost. Beyond some point of very high performance, the costs tend to increase at a much higher (disproportionate) rate. (1964, 14)

The (somewhat vaguely rendered) cost-effectiveness curve shown in Figure 5.5 relied on speculations drawn from cross-border traffic data which Sturdevant himself regarded elsewhere in the document with a degree of scepticism. 'At present', he wrote, 'there is virtually no visual confirmation of, much less control over, the border traffic' (1964, 3). Furthermore, confirmation of intelligence about crossings suffered from that perennial problem of delay that Wohlstetter discussed. Citing a 1962 MACV document, Sturdevant stated that 'experience shows that confirmatory evidence relating to infiltration usually reaches [...] MACV some five to six months after infiltration has occurred' (Sturdevant 1964, 3).

Sturdevant evaluated both of his schematic anti-interdiction systems—termed 'barrier' and 'sieve' respectively—on the basis of 'effectiveness attained for unit of cost', with 'cost' encompassing not just fiscal considerations but also those of men and machines (1964, 14). The barrier concept involved the construction of a 'seal' that would trace the entire 900 miles of the South Vietnam land border, a physical and visual monument of power and control built with 'fences, walls, mines, moats' and requiring the use of Agent Orange and Napalm to destroy the jungle on either side of the border, creating open free-fire zones—anything that moved would be promptly fired upon without hesitation (1964, 15). The barrier, by his estimates, would be prohibitively costly due to the demand on personnel to police the barrier. Sturdevant's second proposal, the 'sieve concept', took the form of a line of disconnected patrolling stations. Although less costly by Sturdevant's metrics in terms of dollar-expense and manpower, it was also estimated by him to be a 'less effective' alternative to the barrier. Sturdevant ultimately concluded that neither the barrier nor sieve concept could deliver sufficient effectiveness to justify their prohibitive costs.

Sturdevant's proposals were confined to the realm of speculation, and neither were further pursued militarily in the form he had imagined. However, the concept of a barrier resurfaced at the SAG in a short working paper published in January 1966. The authors John Roper and Alfred Chow, who had been analysing the reported monthly truck sightings in 1965, advocated a new role for the human operator in the hope of overcoming the considerable limitations and shortcomings of aerial photography and Roadwatch observers. They suggested that ‘in view of the requirement for real-time reporting of location of enemy vehicular traffic, simple electro-mechanical devices may substitute for human reporters/controllers’ (Roper and Chow 1966, 2). Seismic sensors placed on bridges, for instance, could be used to detect truck traffic and transmit areas of activity to Forward-Air Controllers (FACs) for subsequent investigation. This could largely be accomplished with ‘off-the-shelf’ components: Roper and Chow noted the use of vibration-activated cameras were used during the Second World War to photograph trains. The experiment should be deployed ‘as soon as possible’, they recommended, in accordance with the dictum of ‘simplicity now, followed by more sophistication at a later time’ (1966, 3). Their working paper was quite schematic in its proposals, but Roper did proceed to investigate the capabilities of existing seismic sensors in a document published a few months later. This new system, titled RETAINS (Real-Time Air Interdiction System), employed devices comprised of a ‘geophone’ (seismic sensor), a ‘control unit’ to generate the tone for that particular device, and a ‘transmitter’ to broadcast the tone. Following field tests, Roper concluded that the sensors could indeed function as suitable replacements for the human reporters and controllers (Roper 1966b, 5).

That year, ARPA sponsored a new IDA study into a barrier programme for the South Vietnamese border. The study was carried out by the top secret ‘JASON Division’, a group of prominent physicists that included Murray Gell-Mann, winner of the Nobel Prize in 1969. In the preface to their report, they stated that their ‘ideas are not unrelated to proposals that have been made previously, but they are perhaps explored in more depth [...] and operations on larger scale [...] are envisaged’ (Deitchman et al. 1966, ii). Although prolific, reporting on the trail during this time remained very speculative, uncertain, and often contradictory. Deitchman and his colleagues necessarily required a certain amount of intuitive reasoning to judge, amidst the entanglement of contradictions, which reports could be ignored, which were outliers, and which had to be taken seriously. Drawing on the expertise of geologists, intelligence analysts, military commanders, diplomats, and a body of documents including aerial photography and road watch reports, the JASONs attempted to forge some 'consensus' out of the mass of contradictions about the trail. Summarising this challenge, they wrote:

> Trucks do/do not drive with the lights on; Troops do/do not ride on trucks through Laos; trail surfaces are/are not clear earth; infiltrating troops do/do not have a very hard time, with regard to health etc; supply depots along trails are/are not well stocked with food; way stations and overnight bivouacs are/are not easily moved and constantly shifting; sea infiltration does/does not exist; military supplies (not food) do/do not come through Cambodia; troops, presumably wounded, do/do not dead-head North in trucks. Each of these contradictory statements may be true for different parts of the system, or for a given part at different times. Because of this confusion, the outline of the infiltration system given below represents a sort of consensus, and is evidently subject to considerable uncertainty that will have to be resolved. (1966, 14–15)

The task of forging a certain narrative about traffic on the trail, as they admitted themselves, remained without resolution. Nevertheless, the JASONs proceeded to propose a new programme: an 'air-supported anti-infiltration barrier'. Unlike Sturdevant's proposal, this programme would not require manned patrolling stations, lookout towers, or other infrastructural support on the ground. After all, as the JASON's noted, the United States and South Vietnam were not formally at war in Laos, and as such, 'everything we do must satisfy the principle of deniability' (1966, 25). For the JASONs, the solution lay in remote, distributed technologies: sensors and radio-transmitters that could detect convoy movement, signal an armed reconnaissance aircraft circling nearby, and direct it in real-time to the relevant area. However, these devices were intended to *augment* rather than entirely *replace* the existing Roadwatch and aerial reconnaissance reports.

Rather than simply alleviate the burden of human reports and controllers, the JASONs expected that demand for such manual work would still remain high

(1966, 6). Within a little over twelve months, the first batch of sensors, mines, and cluster bombs were dropped over the Ho Chi Minh Trail by the USAF as part of a new 'real time' anti-infiltration programme. In reference to the crucial Route 9 highway used by the NVA in Laos, the operation was codenamed PRACTICE NINE. The system had the effect of producing a sudden and immense expansion of data about the Ho Chi Minh Trail, which itself required a corresponding increase in manual analytic work. The matter of whether a given sensor activation constituted verifiable 'evidence' of the presence of a truck was often highly ambiguous: and as such, the deliberative, tacit, interpretive work of the human operator as an analyst of numerical data and aerial photography remained central.

### 5.2.4 The Particular and the General

The scientists, intelligence analysts, and economists who authored these memos and studies intended to provide an account of traffic on the trail, while acknowledging that the data which shaped their conclusions and recommendations were uncertain, ambiguous, and undermined by a range of methodological limitations. By unpacking the chart in the opening paragraphs and considering how it is the result of an interpretive practice which necessarily relied on human judgement, it is possible to foreground the ways in which these uncertainties emerge out of the interplay between a chain of individuals, machines, and environmental conditions (CIA 1964b): a pilot had to fly in a specific manner conducive to photographic interpretation; sorties on cloudless days were thought to be usually more productive of data; the photo analyst had to use a set of formalised and tacit techniques in their interpretation of images, determining truck types and directions of travel and distributing them in accordance with a schema. The spaces in this matrix where the analyst was unwilling or unable to specify a concrete statement provide a glimpse into the points in this chain where certainty could be eroded, or entirely break down. In the process, the landscape of the Ho Chi Minh Trail region was refigured in accordance with the practices of aerial photography, its features spoken of in terms of the opportunities and resistances they posed to US strategic planning.

Similarly, systems analysts struggled with this move from specific empirical observations to the construction of grander models that could produce bigger claims and computationally extrapolate probabilities and patterns. As the systems analysts argued, their findings could be taken seriously precisely because they relied on their expert application of scientific techniques, even if the field of problems to which they were commonly applied was unsuitable for scientific analysis (1955, 2). For them, such techniques could imbue their array of techniques of speculation with an additional validity: systems analysis, and the analysts themselves, constituted a technical facility that could be drawn upon in the planning and evaluation of military strategy (Helmer-Hirschberg 1963, 3). They affirmed that, for all its purported 'artfulness', the kind of knowledge they produced could be taken seriously enough to serve as the basis for significant decisions in military planning and governmental policy (Hitch 1960, 5).

Such manoeuvres to expand the epistemic scope of strategic planning to include intuition, however, was not quite an effort to introduce new subjectivities into military planning on Vietnam. The kind of embodied, tacit knowledge held by experts was also bound with white, male, American subjectivity—one that tended to be dislocated not only from the jungles of Laos, but from the entire region of Southeast Asia. Distinctive characteristics of the 'style' of systems analysis became increasingly important in the elaboration of the electronic barrier programme, particularly in terms of how it was used to bridge the considerable gaps between the particular and the general; from the isolated observations of a Roadwatch team or an aerial reconnaissance plane to the charts and graphs that set out monthly and seasonal trends in traffic. As a remote distributed system of sensors, the electronic barrier served as another prolific data source for analysis—an immense generator of information that translated ground tremors into evidence of presences. It did not remove uncertainty from the chain of intelligence production, however. Rather, as was admitted by defence researchers in subsequent years, it introduced a whole array of new uncertainties which were supported and legitimised through the ‘expert’ composition of heterogeneous streams of evidence.

## 5.3 Part II: IGLOO WHITE

### 5.3.1 A Game of Measures and Countermeasures

In the late summer of 1966, a group of physicists were commissioned to examine the preliminary sketches of a barrier programme previously outlined by SAG analysts, and explore how such a strategy would 'help to isolate the South Vietnam battlefield from North Vietnam' (Deitchman et al. 1966, ii). The JASON Division had been active albeit highly secretive contributors to defence research: as Weinberger (2017, 93–96) details in her book *Imagineers of War*, this group of physicists had been proponents of highly experimental, and often fantastical, technical weapons and defence systems since the early 1960s. Many of these were produced during their annual 'summer studies'—ruminative planning and report-writing sessions organised around a specific military problem. While many of the JASON Division's ideas generated across these summer studies were only confined to the speculative recommendations in their concluding reports, the barrier concept explored in the 1966 study was met with a deeper sense of urgency.

The resulting document, titled *Air-Supported Anti-Infiltration Barrier* and classified 'confidential', was published in August that year. It offered a lengthy analysis that detailed the 'infiltration system', the technical functionality and estimated costs of their barrier system, its spatial arrangements, and the tactical countermeasures which the NVA would likely introduce (Deitchman et al. 1966, 1). The report set out details on two connected systems: a physical fence, referred to as the 'anti-troop infiltration system', which stretched across the DMZ from the South China Sea in the east to the Laotian border in the west; and a second 'anti-vehicle system' designed for the Ho Chi Minh trail region. The latter system—the elaboration of which I discuss below—the report's authors proposed that acoustic sensors could be 'seeded' from the air alongside trails known to be active, providing ‘quasi-clandestine, all-weather, day and night performance’ (1966, 29). Figure 5.6 depicts the sensor layout proposed in the document, tracing the meanders of trail routes in one-mile intervals. Multiple different sensor types were introduced in the deployed barrier over subsequent years. The JASONs, however, focused on ‘off the shelf equipment’ with the aim to have the barrier operational within approximately one year (1966, 1).

The JASON report set out for the first time the possibility and assumed strategic benefits of a sensor-based barrier at length and in detail. Although schematic, the barrier ‘system’ proposed in this report served as the functional template for the barrier and its various components as it was eventually deployed and elaborated from late 1967 up until its eventual deactivation in early 1973. In its speculative but highly specific attempts to quantify and delineate its proposals, the discursive characteristics of the report invoke the stylistic propensities of operations research and systems analysis. Given that both knowledge practices had originally emerged to meet the planning demands of strategic bombing and the design of large technical systems—both of which were often formative domains in the careers of many Cold War defence researchers—these resonances might be unsurprising.

The JASON Division were prescriptive in their assertions, developing models to itemise, quantify, and cost the resources needed every month to reproduce the barrier; to determine the ‘kill probabilities’ of various weapons and bombing procedures; and to ascertain the precise types of aircraft required to sustain the coherency of the barrier. In addition, they noted that the barrier’s success depended on a parallel effort to observe it; to evaluate its effectiveness and constantly seek out possibilities to extend, elaborate, and strengthen its technical and operational functionality in the face of NVA attempts to subvert and undermine it.

The system as imagined in the JASON report offered a readily deployable alternative to the strategic bombing campaigns (codenamed ROLLING THUNDER)

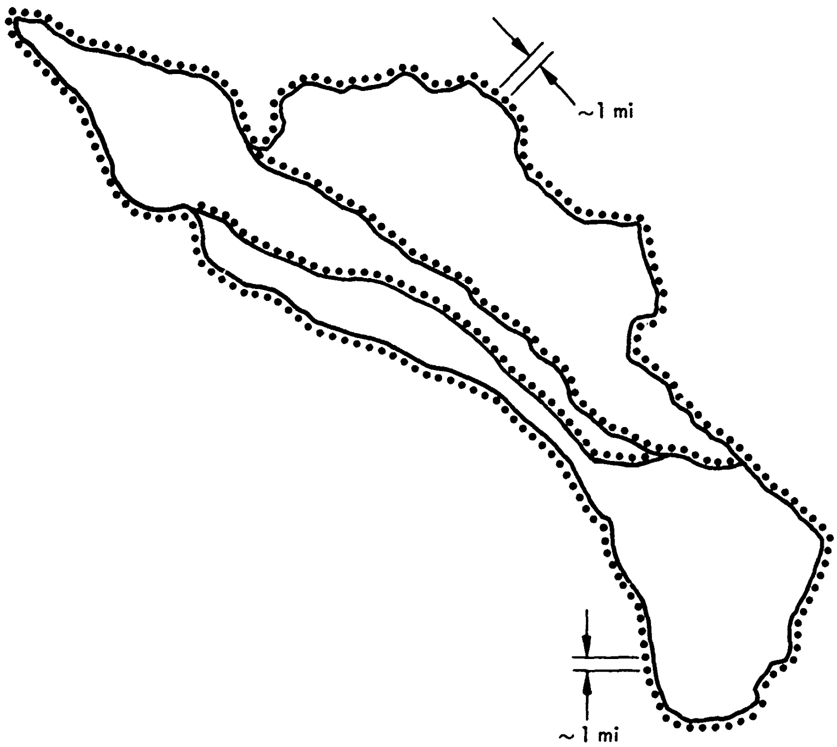



Figure 5.6: Sensor distribution schematic in JASON report (1966, 43).

conducted against North Vietnam which, by 1966, Secretary of Defense Robert McNamara begun to admit had failed (Twomey 1999, 242). The central strategic assumptions and imperatives of ROLLING THUNDER were rooted in McNamara's favoured forms of expert knowledge: operations research and systems analysis. However, the acknowledged failure of ROLLING THUNDER did not precipitate a major revision of the signature forms of expert knowledge and their methodological assumptions at the OSA. The particular type of strategic planning, rooted in the uneasy convergence of intuitive speculation of experts and a quantitative empirical objectivity, had not met its objectives. The barrier as proposed by Deitchman et al. (1966) subscribed to the same quantitative rationality informed by the cost-benefit perspective of systems analysis. For instance, later in the document the discussion shifts to the optimal interplay between a set of criteria to maximise the 'kill probability' of pedestrian and truck traffic: the most cost-effective arrangement of sensors, bombing patterns, use of mines, in relation to the previously recorded estimates of daily traffic rhythms and the likely distances between isolated trucks in a convoy, were considered by the authors of the report (1966, 36–44).

For the JASON Division, this analytic approach supported a variety of political, economic, tactical, and strategic imperatives that made the use of sensors a more attractive proposition than deploying more human observers. Sturdevant (1964) had already estimated in his report for RAND that a physical barrier or sieve would impose a prohibitively large demand on military personnel. He wrote that 'between 15 and 38 divisions' would be required 'depending on the degree of seal', and as such, the application of such a measure would be an impossibility 'unless very large augmentations of both materiel and manpower' by the United States or another force (1964, 16). In the intervening years between Sturdevant's report and the JASON study, the United States had officially initiated the ground war, mobilising tens of thousands of troops and committing vast military resources to the conflict across Southeast Asia. As Deitchman et al. (1966) saw it, even with this rapidly growing availability of personnel and material resources, constructing a physical barrier had its own array of issues and uncertainties. A parallel study into the viability of a physical manned barrier concluded that, due to the lengthy construction time, the risk of continuous ambushes, the difficulties of the terrain, and the additional troops required, a manned physical barrier was ‘a less desirable option’ than a sensor-based system (1966, 11).

The spatial configuration of the Ho Chi Minh Trail, frequently described in commentaries on the interdiction strategy as a ‘network’ (see for instance Deitchman et al. 1966; Gatlin 1968), demanded that ‘interdiction technique’ had to function over a greater territorial scale. The JASONs wrote: ‘the degree of redundancy and flexibility in the system is so great that only an interdiction technique applied over sizable areas is likely to be effective’ (Deitchman et al. 1966, 2). The option to send troops into Laos to seize control of the roadways was said to be ‘constrained’ by political considerations. The JASONs wrote:

> 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. (1966, 25–26, emphasis mine)

Despite the extensive activity in Laotian territory over the previous 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’ (1966, 26). For the JASON Division, the possibility of using sensors as a discreet, distributed array of observers would allow for a ‘cost-effective’ increase in surveillance (1966, 52–54), the real-time generation of quantitative information to conduct interceptions, and the more prolific production of knowledge about the shifting configuration of the trails. 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, politically justifiable—vertical distance (1966, 24–26).

The whole objective of the anti-infiltration barrier concept was not to *impose* the full force of American military power over the region in the form of an infallible, immutable, impermeable blockade. Rather, the JASON Division sought to counter the 'networked' configuration of the trail infrastructure by developing a 'modular' programme that would slow down, penalise, and complicate the NVA's logistics and border-crossing efforts. They wrote that, for the barrier to be effective, 'men who do get through have a much tougher time of it'; it should 'impose severe logistic, military, economic, political and morale penalties'; and finally, it should complicate and impede enemy efforts to introduce subversive countermeasures long enough to ensure that American forces held the 'continuing initiative' (1966, 26–27). To sustain this distributed 'barrier', the JASON Division anticipated that a vast coordinated effort in aerial-logistics would be required on the part of the Americans—one estimated to cost about $800 million annually. This figure was only partial, as it excluded 'sunk' costs in buildings, aircraft, and aircraft attrition (1966, 1). 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 (1966, 46). The design of the barrier system meant that, if it was 'successful', the system would destroy itself. The mass-bombing of any section of road following a sensor activation would have the likely effect of destroying other mines and sensors in the area, and consequently, sensors and minefields would have to be continuously 'reseeded' (1966, 13).

The anti-infiltration barrier envisaged by the JASON Division would not function through the precision targeting of detected activity. The physicists made it clear in their report that the barrier would not be able to accurately pinpoint trucks detected by the sensors, but proposed a number of measures to account for this. For instance, the JASONs estimated—correctly as it turned out—that the accuracy of aerial emplacement of sensors was likely to be relatively poor (1966, 32). To 'compensate for uncertainties in target location', wide-area SADEYE bombs fitted with a special 'jungle-penetration fuse' developed by ARPA were designated the ' "canonical" weapon for all attack applications'. A series of these bombs, each of which dispersed a circular arrangement of bombs 800 feet in diameter with a '400 foot "hole" at centre', would then be released in succession with 'appropriate overlap' to counter the imprecise locatability of the convoy. A flash of presence detected by a sensor would not trigger an expeditious pinpoint interception, but a devastating, aggressive, and broad attack that deliberately targeted a great, approximate area to alleviate the myriad ambiguities in the sensor emplacement and targeting process, and consequently raise 'kill probabilities' (Deitchman et al. 1966, 32).

A key SAG study from 1967, carried out by the Operations Analysis department, sought to map out AAA locations, trace aircraft attrition patterns, and construct a systems analysis-style inquiry to predict future attrition rates (Linsenmayer and Thompson 1967). The report notes that aircraft attrition during sensor emplacement was a significant concern for military strategists. It is important to note here, however, that such 'attritions' were typically rendered in terms of their financial and strategic rather than human costs. The study's authors, Linsenmayer and Thompson, aimed to construct a 'threat model' and a series of 'kill probability' matrixes and curves for US sensor emplacement sorties, displaying graphically the interplay between factors that included their aircraft type, altitude, and speed of travel; time of day; type of anti-aircraft artillery; and the density of enemy defences in the specific region in question. They noted that 'the expected attrition rates are several times higher than overall experience rates' documented elsewhere in South Vietnam (Linsenmayer and Thompson 1967). Out of an estimated six hundred helicopter sensor-emplacement sorties during the first six months of the barrier programme, they anticipated a loss of precisely 31.8 aircraft during the day, and 16.2 at night (1967, 4).

In the opening pages of their report, Deitchman et al. (1966) emphasised that, given the technology then available to them, the effectiveness of their proposed barrier system would be short-lived. They wrote: 'we anticipate that the North Vietnamese Army would learn to cope with a barrier built this way after some period of time which we cannot estimate, but which we fear may be short' (1966, 3). The NVA personnel who used and supported the trail were characterised as 'highly determined and ingenious human beings' who would quickly improvise and adapt a range of countermeasures to neutralise and subvert the barrier. The JASON Division anticipated, amongst other options, that the NVA would redirect the flow of supplies to unwatched territories; that they would shift activity to after nightfall or take advantage of cloudy weather; or that they would introduce more complex tactical shifts that would target the technical functionality of the barrier and render it redundant (1966, 45–46).

According to the JASONs, any barrier system had to facilitate a continuous elaboration to account for these tactical developments, posing new obstacles and anticipating new exploitations. This mutual exploitation of emergent weaknesses, what the physicists described as a 'complicated game of measures and countermeasures' (1966, 13), meant that the objective for the Americans was not to construct an infallible, monolithic barrier. The operational logic of the system incorporated a modular arrangement of reconfigurable, replaceable components, all monitored continuously to quickly ascertain vulnerabilities and produce new technical developments or operational shifts. As such, the proposed barrier system not only involved mapping real-time incursions, designating attack zones, and dispatching strike aircraft to bomb the area; it also required the continued analysis of its own performance. The barrier programme had to incorporate speculations regarding the range of possible actions directed against it and how they might be neutralised: 'Counter-countermeasures must be an integral part of the development', they wrote (1966, 7).

Although the JASON Division envisaged possibilities to automate the interpretation of sensor data with 'information processing' and 'pattern recognition' techniques, they make it clear that a substantial amount of manual analysis would still be required to support their barrier system (1966, 53). Photo interpretation would remain central to mapping out the shifting geographies of the trail and the introduction of countermeasures. 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' to build up intelligence 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. (1966, 44)

The sensors then were not at all a replacement for the immense task of photo interpretation; rather it created an increased 'need' for such work to confirm whether sensor activations actually signalled truck presence, or whether they were 'noisy' activations. 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 automate and mechanise aspects of the interdiction programme over the following years, photo interpretation and its tacit analytic processes proved to be one of the prime tasks that could not be delegated to a machine. Photo interpretation demanded a tacit knowledge, a mode of looking grounded in the practice of examining nuances of differentiation in light and shade. This mode of looking could not then be algorithmically configured: it involved the identification of indicative patterns and traces of presences in soil and vegetation; the ability to distinguish between different types of flatbed truck; an understanding of the explosive imprint of different types of ordnance; and a capacity to examine and annotate damage in imagery capturing the aftermath of a violent attack on a convoy.

Of prime importance in the JASON study was an observational apparatus that operated across two time scales: firstly, an immediate one that operated in minutes and hours, which had the objective of rapidly analysing and interdicting NVA traffic along the trails in order to produce coordinates for attack; and a second effort, which operated over weeks and months, taking the barrier system itself as its object of analysis in order to continuously gauge its performance and seek out opportunities to adapt it, introducing counter-countermeasures in response to the tactical adaptations instigated by NVA forces. There were many unresolved problems with the system as the JASONs had conceptualised it, not least of which was the conundrum of how to establish whether it was an effective contribution to the interdiction effort. The JASON scientists speculated on two ‘possibilities of failure’:

> The system will work but its long time constant will discourage us from persisting with it because of lack of visible effect; or the enemy will gradually exploit other alternatives, to the same time scale, without making it obvious. We would then not react to his alternative system until it is well emplaced and therefore much more difficult to dislodge. (1966, 60)

The sensor-based barrier aimed to translate what had proved to be an unmanageably vast system of roadways into a real-time picture of activity, a morphing map of routes in the 'trail network' that could be adeptly intercepted and bombed from the air. This live image of activity was unstable, however: its efficacy was subject to the range of countermeasures that could be introduced by the NVA. As such, the JASONs knew that their barrier system could not only take this 'network' as its object of observation; it had to also be the object of a parallel analysis, a meta-assessment that continuously sought out new opportunities to 'keep the North Vietnamese off-balance' (1966, 3). In their conceptualisation of the barrier, military control of the region was not asserted through the hard physical blockade of space nor through the precision detection and interception of every truck, but by escalating the penalties incurred by the NVA in the process of infiltration.

Over the following year, oversight for the nascent barrier programme was handed over to the newly established (and vaguely-titled) Defense Communications Planning Group (DCPG). Directly reporting to Robert McNamara and with complete control over the barrier's development, a congressional subcommittee investigating the so-called 'electronic battlefield' later stated that the DCPG had 'unprecedented authority' (Electronic Battlefield Subcommittee 1971, 2). This becomes clear in the proliferation of 'tasking memorandums' issued by the DCPG in 1967, ordering trials of new technologies and investigations into environmental factors. A 1966 tasking memo requested that 'increased emphasis be placed upon the development of improved faster acting defoliants', estimating that 'the barrier area to be defoliated could total an estimated 250 square miles every 3 1/2 months' (Starbird 1966). A tasking memo from 1967 called for plans to account for 'ecological problem areas', or more specifically, 'false alarms' caused by animal interference with the sensors: 'Rodents might be interested in the dropped items, possibly moving or examining them', the author noted, and 'monkeys might swing on or play with the acoubuoys hanging in the canopy' (1967c, 1967a). Another memo from the same year requested the testing of an 'ultraviolet intrusion detector' system, in which capsules with an ultra-violet sensitive dye could be dispensed from aircraft, and leave trails detectable by aircraft equipped with a special sensor if walked through by NVA personnel (1967b).

While the ultraviolet system goes unmentioned in subsequent reporting on the trail, these tasking memos do highlight a concerted effort to broaden the scope of the surveillance capacity of the barrier, cutting through environmental factors and managing uncertainty. The operational logic of the barrier system was duly elaborated and extended, accruing various subsystems and new experimental sensor types. Simultaneously, the corresponding regime of practices, configured in a way that amplified the quantitative predilections of its proponents, provided a system of observation and measurement that provided enormous quantities of data to defence researchers at the OSA, RAND, the SAG, and the IDA. The effect was the cultivation of a militarised knowledge of eastern Laos and the strategic rhythms and features of the Ho Chi Minh Trail (HQ 7th Air Force 1970, i; Thayer 1975b, 25–27).

### 5.3.2 Information Management

While the JASON report outlined a schematic operational logic for the electronic barrier system, it took another 12 months to define the more intricate details of its functioning. The technical novelty of the system, and the immense scale and urgency of its deployment, meant that the development of the barrier was also identified as a significant 'live' case study for defence researchers and military planners desperate to glean insights into what might count as a militarily 'successful' counterinsurgency strategy.

> The counterinsurgency and unconventional warfare environment of Southeast Asia has resulted in the employment of USAF's airpower to meet a multitude of requirements. The varied applications of airpower have involved the full spectrum of USAF aerospace vehicles,

> support equipment, and manpower. As a result, there has been an accumulation of operational data and experience that, as a priority, must be collected, documented, and analysed as to current and future impact upon USAF policies, concepts, and doctrine. (Shields 1971, ii)

The above paragraph served as the opening contextualising statement for a prolific series of reports produced by the Directorate of Tactical Evaluation, Pacific Air Forces (PACAF), during the Vietnam War. Beginning in the early 1960s, 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 documents were often assigned a classification status of 'Secret', and were circulated broadly across the military services, the DOD, and the State Department in an effort to share insights gleaned from ongoing operations and apply them to future Air Force programmes. Over 250 CHECO reports were published between 1961-1975, covering diverse subjects from the herbicide programme (Collins 1967) to night interdiction (Porter 1966). The barrier programme was also 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), and also as a secondary subject in reports by Burch (1969), Porter (1966), and Colwell (1971). These documents were intended to serve as internal institutional 'on-going' histories, and as such, they are inevitably entangled with the institutional politics, concerns, and interests of the Air Force. Yet, what is evident from the aforementioned documents on the anti-infiltration barrier is that the system was not simply lauded by all its commentators. In fact, a number of critical failings and shortcomings were diagnosed in the early CHECO report.

The 'contemporary historical' framing of the CHECO documents which detail IGLOO WHITE, written from within the programme as it unfurled, provide a strong sense of the experimental urgency of the system: it was rapidly deployed in a live warzone following a notably brief research and development period, and as

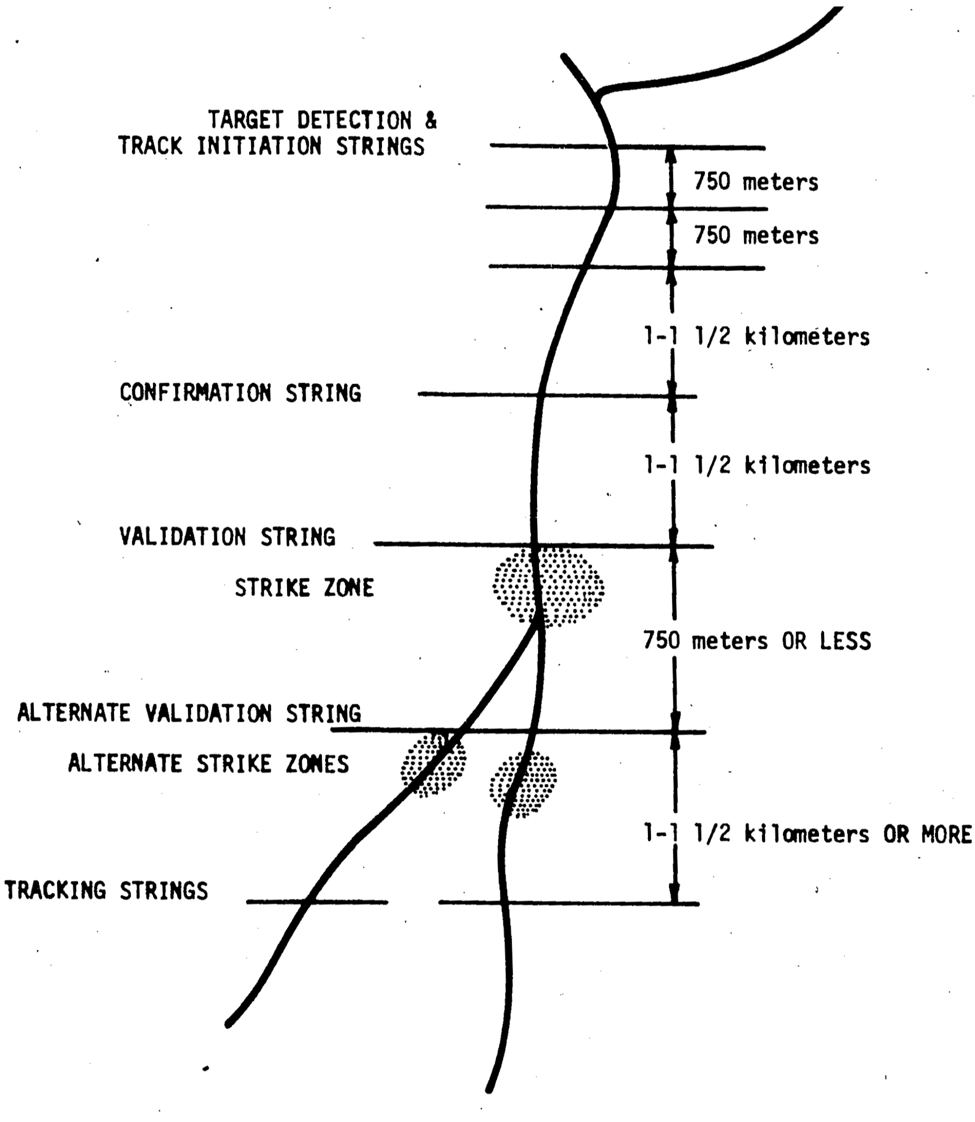



Figure 5.7: Diagram of sensor string used in MUD RIVER area, from Gatlin (1968, 12).

such, its first six months were beleaguered with a range of technical and operational issues. Over this period, as the Air Force grappled with the immensity of the barrier programme, the Laotian jungle was transformed into an open testing ground where various configurations of sensors, mines, bombs, and communications procedures were trialled and assessed. The three primary reports on IGLOO WHITE document this elaboration, describing performance data and capabilities for different generations of sensors, noting their failures and inconsistencies (Gatlin 1968, 26–29); explaining the technical functionality of the data-processing equipment (Shields 1971, 105–10); and documenting operational progress through extensive arrays of explicatory documentation, including annotated maps and photographs, information-flow diagrams, forecast graphs, statistical charts and matrices (Caine 1970). These three CHECO reports offer perspectives on the barrier which imply 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 manage, process, and coordinate this information at the requisite speed.

In their study, Deitchman et al. (1966) had only examined the possible form an 'air-supported anti-infiltration barrier' could take, given the fiscal, technological, and military resources available at the time. The precise relationship between their barrier proposal and the pre-existing interdiction effort discussed in the previous chapter was not afforded any detailed discussion. The first CHECO report, published in the summer of 1968 and covering the first four months of the programme, clarified how the Air Force envisaged the strategic utility of the system. Gatlin (1968, 6) stated that the barrier programme 'should not be viewed as a panacea or a final solution to the interdiction problem', but should 'augment' existing efforts. It was 'expected to *produce information* on the enemy vehicular and personnel movements reliably enough and quickly enough to be used for directing immediate strikes against these targets as they were identified and located' (1968, 5, emphasis mine). It was to act as a '*real-time* intelligence source', providing '*another set of eyes* to supplement those visual and mechanised means already used to detect and strike enemy infiltration' (1968, 5–6, emphasis mine). The principle was to identify and 'cut' key 'lines of communication'—conduits through which the NVA could package and transmit personnel, materiel, and messages to support the insurgency in the south through the Ho Chi Minh Trail infrastructure (Caine 1970, 11).

When the JASON Division wrote in their report that 'the system as we conceive it is very simple in the sense that it has few components', they spoke only of the technical dimension of the barrier, ignoring for the most part the points where the technical devices and the personnel interacted (1966, 27). Gatlin (1968, vi) however, writing from a vantage point within the live programme, opened his report by emphasising that the system was in fact 'extraordinarily costly and complex'. This complexity traversed the technical, operational, and bureaucratic domains—the latter becoming especially clear when trying to navigate the wealth of codenames ascribed to the programme in the first months of its deployment. Ignoring the many informal, sometimes derisory, monikers attributed to it by the military and the press, the following served as formal codes for different barrier 'systems' and 'subsystems' at various points in its lifetime: PRACTICE NINE (1966-1967); ILLINOIS CITY (1967); DYE MARKER (1967); MUSCLE SHOALS (1967-1968), which was split into sub-systems titled MUD RIVER (anti-vehicular area in Laos) and DUMP TRUCK (anti-personnel area in the demilitarised zone); and finally, the comparatively long-lived IGLOO WHITE, which referred to operations in Laos between 1968 until its eventual slow demobilisation in early 1973. While this rapid succession of codenames is at least partially attributable to the details of this fledgling top secret programme being leaked to the press (1968, 1–2), it also points to problems with how the programme was organised bureaucratically: subdivided into components, the lines of command and control were often ambiguous, if not incoherent.

Gatlin stated that the strategic and operational configuration of their proposed barrier programme had to be quickly determined in the development phase, and to a significant extent, *during* the first year of its active deployment:

> The command and control of these strike forces and of those aircraft needed to implant and monitor sensing devices and related munitions were not clearly spelled out in the initial plan, and became the subject of debate and concern among those charged with operating the system in the field. (1968, 3–4)

The operational logic of the system, visualised in the diagram in Figure 5.8, incorporated the organisational relations and information flows between the multiple military units, technical components, and administrative processes involved in IGLOO WHITE. Such 'information flow' diagrams were common features in institutional reporting on the programme. The diagram pictured here, published in the 1968 CHECO report, makes a distinction between flows of information (dotted lines) and control (solid lines). It's important to note here, such was the rate of the technical and bureaucratic elaboration of the programme, that this diagram can only be considered as a snapshot, representative of a brief period of time in early 1968. The locus of information processing is represented here by the box labelled '7AF TFA'—Seventh Air Force, Task Force Alpha—at the Infiltration Surveillance Centre (ISC). The centrality of the ISC in the system is reflected in Gatlin's choice of descriptive terms: he refers to it as the 'brain' of the programme, a 'nerve centre', and the 'crucial focal point' (1968, 4):

> Here the raw data obtained from the sensing devices was assembled, analysed, and stored. Here decisions were made on the validity of sensor data and the information to be passed to strike forces. (1968, 4)

The work carried out by TFA personnel at the ISC, as Gatlin suggests here, revolved around assessing whether the sensor data suggested the presence of an

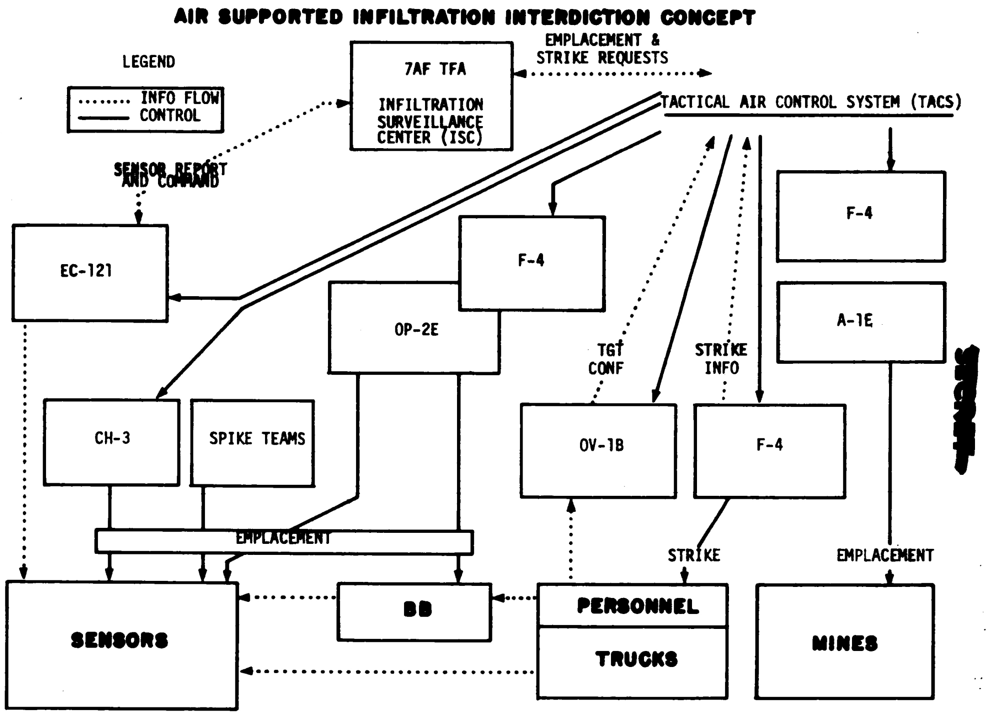



Figure 5.8: IGLOO WHITE, information flow diagram in 1968 CHECO Report.

enemy convoy. The Airborne Battlefield Command and Control Centre (ABCCC, referred to as EC-121 in the diagram) functioned as a second key relay and processor of information. The ABCCC loitered thousands of feet over the sensor field, receiving activation data and relaying it to the ISC. Control, on the other hand, emanates unidirectionally from the Tactical Air Control System (TACS). The TACS was a command post located at Tan Son Nhut airbase outside Saigon, which coordinated both strike and sensor emplacement sorties in support of the barrier programme.

The operational logic of the system, as depicted in this information flow diagram, is characterised in terms of a large feedback loop that runs between information gathering from distributed sensors which produce the coordinates for strikes, which in turn necessitate the 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 the crews and technical devices in the various aircraft and command stations, but the vibrations and sounds of the trucks and personnel on the trail and also visual observations from reconnaissance planes. All pertinent activity captured by the barrier system was rendered as a component—be it a transmitter, receptor, or processor of information or an issuer of control. 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, outmoded, or further developed in order 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 drone aircraft which assisted in relaying sensor data. In a contradiction that is perhaps exemplary of IGLOO WHITE more broadly, these 'remotely piloted' drones were in fact typically 'manned' due to recurrent technical problems with the aircraft (1971, 70–75).

This diagram is a theoretical representation of how the system functioned: the lines between individual discrete functional units were clearly delineated and codified as either flows of control or information. In practice, however, these flows were beset with a range of uncertainties which modulated and impeded transmissions, lengthening the temporality of the purportedly 'real-time' feedback loop between the detection of activity and the designation of zones of destruction.

Diplomatic problems, for instance, disrupted the sensor emplacement process. Every sensor string had to be formally authorised and coordinated with the US Embassy in Vientiane to satisfy Thai and Laotian governments, taking anywhere from a few days up to a couple of weeks for each request to be sanctioned (1968, 10–13). Concerns about the impact of NVA anti-aircraft fire on the operation had also proven to be well-founded: crews could only emplace sensors along 'the relatively safe areas along the western sector' of the barrier area—implying that these would be the very areas that were of less importance to the NVA (1968, 14). Furthermore, pilots were 'instructed to make one pass only over the target' (Gatlin 1968, 14). In addition, accurately logging the locations of sensors dropped over the jungle necessitated additional photographic analysis: at the point of release, the aircraft automatically took a photograph of the terrain, which then had to be manually geographically correlated with maps of the 'enemy lines of communication' by interpreters back at the ISC. Because data from sensors deployed in the same string were used to calculate truck traffic vectors, errors in geographically locating emplaced sensors introduced additional uncertainties into the speed, direction, and coordinates of detected activity. The commander who oversaw proceedings at the ISC is noted by Gatlin to have remarked that the delivery of sensors was 'the most pressing single problem facing the entire [...] operation' (1968, 15).

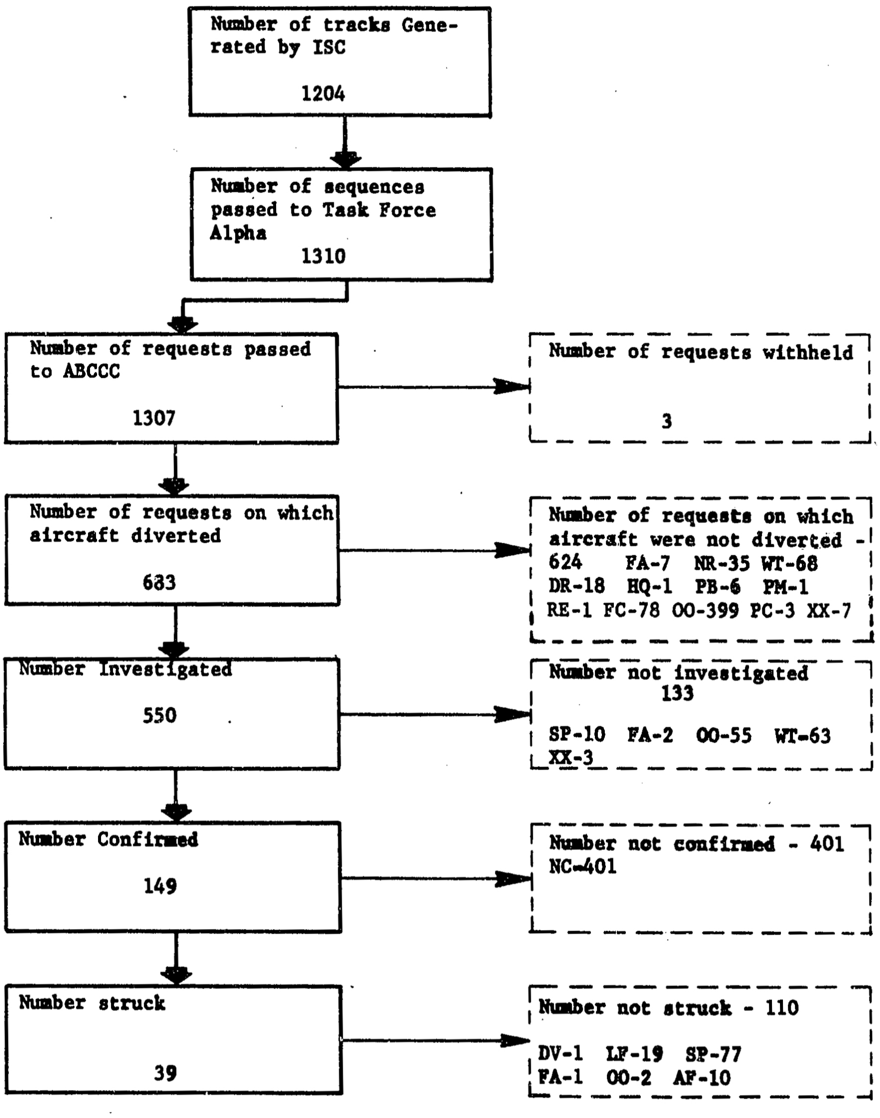



Figure 5.9: MUD RIVER Sequence of Events, March 1968 (Schwartz 1968, Exhibit 8).

Managing sensors that had been successfully delivered into the trail area was made awkward due to their technical unreliability, whether it was 'hyperactively' producing noisy data, or their batteries cutting out prematurely. The central technique of distributed sensors which had defined the novel technical functionality and strategic utility—that is, facilitating the 'real-time' production of information and designation of strike zones—was also a prevalent source of complications and uncertainties.

Greater insight into the factors that modulated the flow of information and control across the barrier system in its first operational months can be found in a 'sequence of events' diagram included in a March 1968 working paper prepared by the Office of Operations Analysis (Schwartz 1968, exhibit 8). Focusing on the MUD RIVER (antivehicular) region in Laos over a one-month period, the diagram (see Figure 5.9) enumerated the so-called 'disposition of sequences'—that is, how suspected convoy 'tracks' generated by the sensors were processed by the ISC and subsequently moved through a series of administrative and tactical 'actions'. The sequence of boxes on the left were referred to as the 'positive actions', which at each step quantified the number of tracks that resulted in information being passed on for further action. The branches on the right were 'negative actions', which quantified and categorised the number of tracks which were not acted on. A table included in the document explained the various abbreviations used in the graph. In themselves, these categories are revealing of the myriad uncertainties which introduced operational limitations into the series of actions which comprised the anti-infiltration barrier. Familiar factors such as weather, foliage, or trucks which appeared to simply vanish are included in the list of categories. In addition, a number of problems pertaining to command and control feature prominently.

Table 5.4: List of abbreviations referred to in Figure 5.9.

| | |
|---|---|
| DR | Excessive defensive reaction |
| FA | Strike forces unavailable |

Table 5.4: List of abbreviations referred to in Figure 5.9.

| | |
|---|---|
| FC | All FACs committed to other targets |
| HQ | Request withdrawn by a higher headquarters |
| OO | Other Operations being conducted in the area |
| WT | Weather over the target |
| XX | Aircraft lost in the area |
| RE | Rules of engagement |
| SP | Strikes in progress |
| NC | No visual contact |
| DV | Aircraft diverted to more lucrative target |
| LF | Target lost in [foliage] |
| AF | Target lost after flaring |
| PC | Passed to Cricket (ABCCC) |
| PM | Passed to the USMC |
| PB | Passed to Moonbeam (ABCCC) |
| NR | No report submitted |

The diagram shows that a gross total of 1204 tracks were identified at the ISC in March 1968 and, including subsequent updates on these tracks, 1310 were passed on for target assessment at TFA. At every following point of action, however, this gross total is diminished. Almost all were passed on to the ABCCC to coordinate strikes, but only just under 700 were assigned aircraft. The disparity here was partially explained by poor weather and lack of available aircraft, but the primary reason was the category 'other operations being conducted in the area'. 550 tracks were actually investigated by diverted aircraft, and in 401 cases, there was no visual contact. Ultimately, of the total of 1310 suspected tracks generated in the system, 39 were reportedly struck. In 77 cases, strikes were already in progress by other units by the time the convoy was confirmed, and 19 were 'lost in foliage'.

The successive reduction in information passed along from one action to the next was not a process of filtering and honing the data in order to carefully assess its veracity, but was largely a consequence of environmental factors and, in particular, problems with the managerial dimensions of command and control.

The implications of this confused, *unsystematic*, command and control configuration, amidst the proliferation of targets generated by IGLOO WHITE and the various other missions in operation over Laotian territory, was remarked on by Porter in a 1969 CHECO report. Titled *Control of Airstrikes*, the report emphasised the prevalence of over-crowding in the airspace:

> Little doubt existed that one of the most vexing, hazardous, and difficult-to-solve problem areas lay in airspace saturation of congested and confined target areas. Lucrative targets were not scattered at random around the 90,000 square miles of Laos, but tended to be located in clusters around fairly well-defined lines of communication, areas of conflict, and centres of enemy strength (Porter 1969, 40).

The diagram that describes the 'disposition of sequences' might give the impression that the barrier was an inconsequential element in the bombing campaigns directed against the Ho Chi Minh trail. As the above quote makes clear, many of these operational issues that halted the investigation of a suspected convoy were in actuality a consequence of prolific ongoing activities over Laos, generated and conducted external to the IGLOO WHITE system.

Gatlin concluded his CHECO report by saying that the document 'covers only the stone age of what may be a long era of development' (Gatlin 1968, 38). Although he implied that the programme was somewhat primitive and set out at length its many failings and shortcomings, this is not to say that the programme was considered to be an outright failure. In this highly experimental, unstable phase, IGLOO WHITE nevertheless realised the schematic that the JASON Division had proposed: their experiment in distributing fields of electronic sensors was productive in that it prolifically generated coordinates for aerial bombardment, converting an 'impenetrable' landscape into zones of quantifiable activity. Rather than abandon the programme due to the myriad uncertainties that dogged this abundant data, however, the Air Force opted to expand and extend the IGLOO WHITE system. Over the following four years, they furnished it with more administrative resources and tackled the systemic ambiguity of the programme through the creation of new operational procedures, the delineation of new chains of command, and further technical development of the sensors.

### 5.3.3 Interpreting Documents

IGLOO WHITE's 'long era of development' was shaped by an effort to better manage the massive quantities of information produced by the sensor system and direct it toward the primary objective: cutting off the North from the South through the effort of raising the 'costs' of infiltration by, to refer to the institutional parlance of the time, 'killing trucks'. Central to this effort was the schematisation of sensor data that allowed for the development of a knowledge of the Ho Chi Minh Trail that functioned across different temporal scales: the tactical (near) real-time designation of strike zones, and the strategic longer-term analysis of rhythms and their correlations with a range of environmental and strategic factors. These two time scales of analysis were inscribed in a proliferation of documents, generated both by humans and machines. The former, furnished with an embodied, tacit knowledge that gave them an epistemic authority within the regime, could clarify ambiguities generated by the latter. To function as 'evidence' of presences or of 'truck kills'—and by extension to legitimise bombing sorties and the further extension and elaboration of the barrier system—the role of the human operator as an interpreter of data was pivotal.

**Minutes/Hours**

In the first phase of IGLOO WHITE, a team of four Target Assessment Officers

(TAO) at the ISC 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' (1968, 18). The printouts were a matrix of sensor activity: each column was a specific sensor, and each row quantified their minute-by-minute activations. It was not a simple case of reading instructions from these sheets; they had to be interpreted and scrutinised by trained personnel capable of discerning activations with the signature patterns of a convoy from those which signified so-called 'random activity'—this being extraneous noise. '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. The TAOs were trained at Eglin Air Force Base in Florida before being assigned to the ISC, but Gatlin explains that a tacit knowledge of the sensors, which could only be developed through experience of their 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. (1968, 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, automatic 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 make a decision whether to formally designate it as an enemy convoy—referred to as a 'mover'—and assign a strike aircraft to bomb the area. Those charged with the assessment of sensor data were commanded to actively *interpret* it. At least in theory, an experienced TAO could discern a convoy's direction and speed of travel, its length, and judge its likely location by comparing their knowledge of the sensor locations and their activation patterns. In addition to the 'random activations', the uncertainties and inaccuracies in the sensor emplacement process introduced a corresponding 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.

In later phases of IGLOO WHITE, these printouts became more sophisticated. The tables pictured in Figure 5.10, titled CONFIRM sheets (COiNcidence Filtering Intelligence Reporting Medium), were included in the appendices of the final CHECO report on IGLOO WHITE to demonstrate the visual appearance of various categories of activation patterns. 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 denotes the assumed 'reliability' code for each sensor, indicating how much confidence the analyst should have in the data it reports. 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' (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 (1971, 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 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

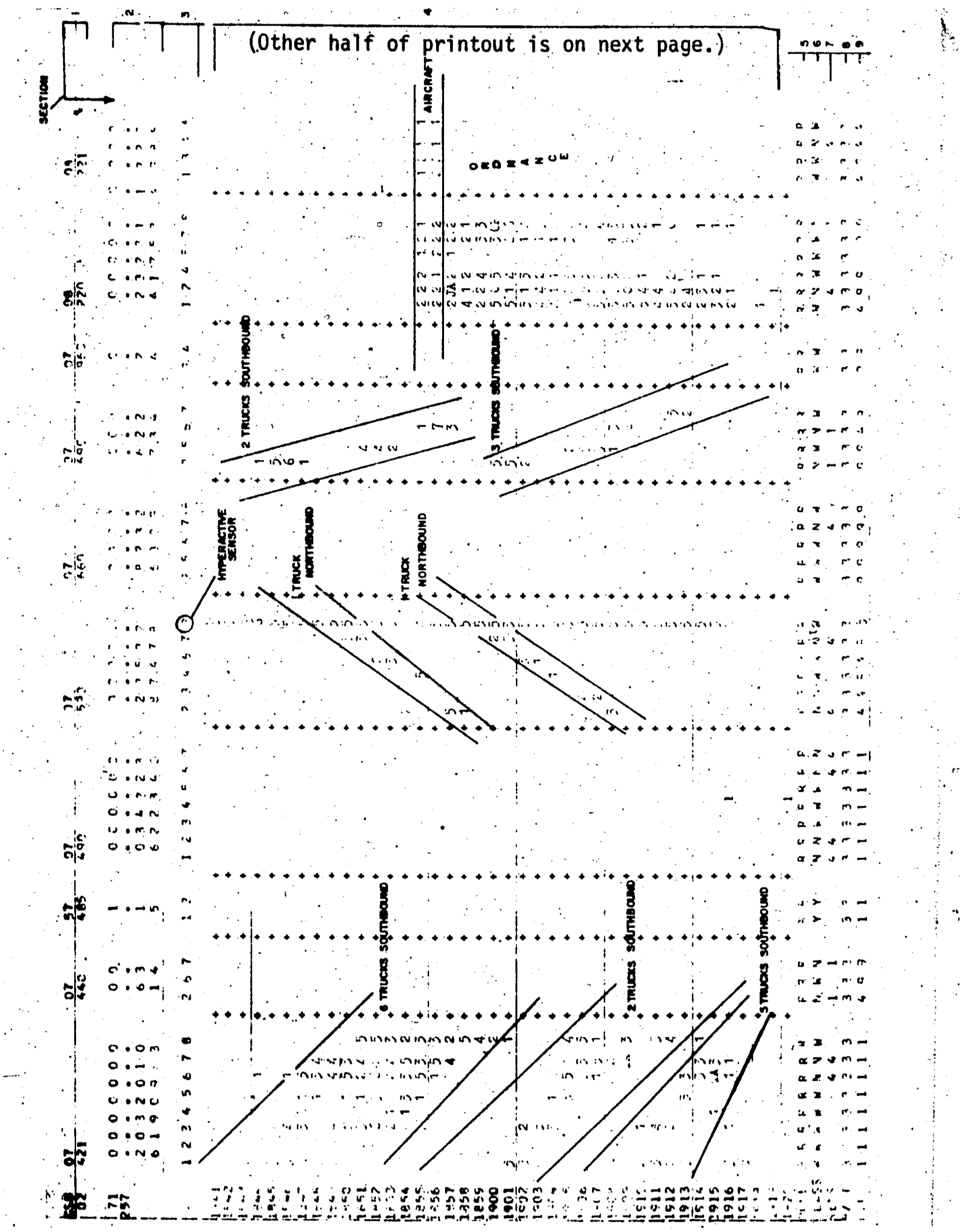



Figure 5.10: CONFIRM sheet sample from 1971 CHECO Report on IGLOO WHITE.

sensors themselves had been destroyed in the explosions.

The CONFIRM sheets were not the only documents which visualised and quantified sensor data. Devices called X-T Plotters were installed on the ABCCCs assigned orbits at the southern extremities of the trail system, beyond the radio coverage of the ISC (1971, 27). The X-T Plotter functioned in a similar way to CONFIRM, but provided 'information of a more "real-time" nature', marking a continuously unspooling roll of paper with electro-static charges when an activation was received from a sensor (1971, 26). With this device, teams of on-board analysts could monitor activity on the ground below, calling in airstrikes without looping in the ISC. 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) here 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 (1971, 4). With COLOSSYS, instead of printing sensor data onto paper, the matrix of quantified activations were displayed on a computer screen, updated in one-minute intervals.

This system automated aspects of the target assessment process, although it still relied on some human expertise. Suspect patterns for instance were passed over to a radio operator to conduct an audio-visual assessment of signals transmitted by nearby acoustic sensors, matching the waveforms with the signature oscillatory characteristics of truck engines (Caine 1970, 21). If it was determined to be a 'mover', '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' (1971, 25).

The COLOSSYS was also capable of rendering sensor activations on computer monitors as a spatio-temporal graphical representation, computing sensor activations along a string and rendering the convoy on an electronic map of the route under scrutiny. The convoy, referred to as 'the worm', was animated in real-time, 'mov[ing] 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 chaotic command and control of aerial interdiction was also reportedly streamlined through new interception protocols. Rather than dispatch aircraft to the convoy, analysts would refer pilots to intercept at one of the many Designated Mean Points of Impact (DMPI)—predetermined, fixed coordinates distributed across the trails. The 'worm' display automatically calculated estimated times of arrival at various DMPIs. To account for inaccuracy and uncertainty, strike aircraft drop cluster bombs 'cover[ing] an area 3000 feet long and 1100 feet on either side of the target' (1970, 18).

Given that the sensors could be activated by events as variable as the weather, the fact that a quiet string of sensors suddenly flashed into action could not be taken for granted as evidence of a convoy. This evidence was produced through an instituted process of analysis, and shaped by the personal development of an intuitive, tacit knowledge of the peculiarities and uncertainties 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 automated over the course of the programme, analysts necessarily had to continue playing a vital role in interpreting the incoming data, translating it into evidence of activity, and designating actionable zones of attack. The human operator thus played a crucial role in the translation of quantitative data into an explicit knowledge that could travel across the institution and, in aggregate, inform longer term strategic priorities.

**Weeks/Months**

'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 line graphs, were the subject of generous commentary in reporting on the COMMANDO HUNT series of operations. Running twice yearly beginning in 1969 until 1973, the performance of the COMMANDO HUNT interdiction campaigns were evaluated by defence researchers and military strategists. The 'style' of systems analysis also permeated in these accounts of the programme, with a 'cost-benefit' lens applied to the aggressive bombing campaigns along key routes in the Ho Chi Minh Trail. The imperative was to maximise the cost to the NVA while trying to identify and measure opportunities to increase their own efficiency to intercept truck traffic. In a report for COMMANDO HUNT III, the objectives of the programme were articulated as 'to increase the cost to North Vietnam' of supporting and supplying the war in the south and 'to make logistics movements as expensive as possible' (1970, i, p. 70). Although not the only intelligence source in the campaigns, IGLOO WHITE was nevertheless an 'integral' component (1970, 157). But just as the interdiction programme before the introduction of sensors had produced a broad range of measurements to assess performance in the absence of any observable coherent narrative, in COMMANDO HUNT we see a similar proliferation of metrics. The sensor fields provided the data to detect and attack NVA convoys, but an overarching parallel initiative to quantify every truck 'killed' in each campaign required a separate analytic process, central to which was aerial photography.

The capacity for a photo interpreter to examine the aftermath of a strike on a convoy—a task referred to as Bomb Damage Assessment (BDA)—in order to

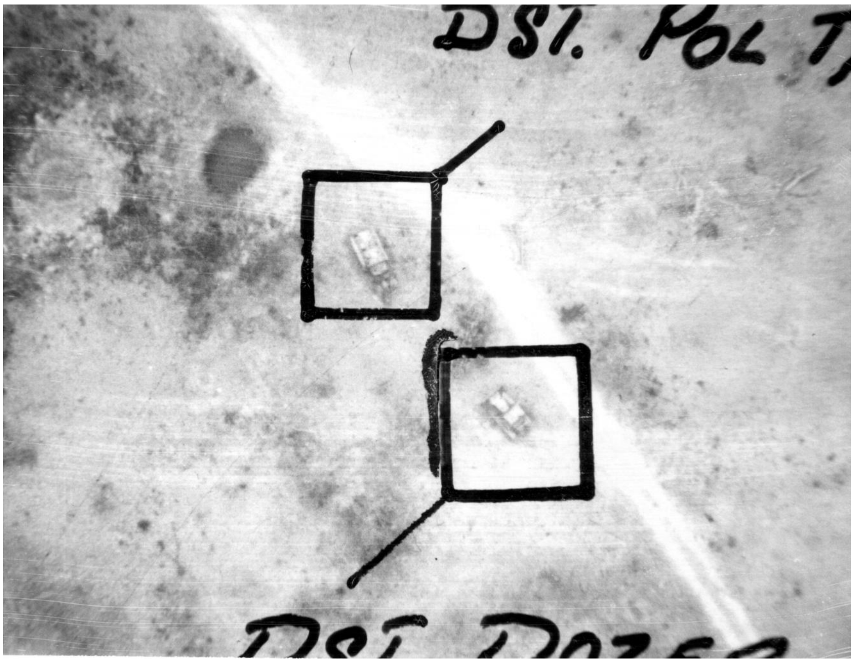



Figure 5.11: Aerial photograph of bombing location with two annotations identifying destroyed vehicles, from Task Force Alpha at the ISC (TFA n.d.).

accurately quantify truck kills was fundamentally shaped by the same range of uncertainties discussed in *Part I* of this case study: weather, foliage, camouflaging activity, and delays in surveying the area contributed to a widely-remarked on uncertainties in the resultant data. Disparities between number of strikes and the number of trucks deemed damaged or destroyed following a BDA was explained by suggestions that the NVA 'removed or camouflaged' trucks hit by bombs (HQ 7th Air Force 1970, 50). The report on COMMANDO HUNT III stated that 'results were hard to observe because of poor weather, dust, smoke, and foliage over the target', and 'not observed for 35 per cent of the total sorties flown' (1970, 68). One year later, the conclusions that could be drawn from BDA were still limited. A CIA memo addressed to Henry Kissinger, then National Security Advisor for the Nixon administration, commented on the effectiveness of the COMMANDO HUNT IV campaign. The author of the memo stated that

> the methodologies currently used to convert BDA results to supply losses involve a number of questionable, though necessarily arbitrary,

> assumptions yielding results which are at odds with other intelligence. (CIA 1970)

The author of a report documenting the events of the following COMMANDO HUNT campaign also noted problems with BDA: ‘in many cases the strike crews were not sure of the exact location of their strikes’, they wrote, and concluded that ‘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).

The analyses contained in the COMMANDO HUNT reports, predicated as they were on two clearly defined objectives, served as an explicit attempt to quantify the extent to which the barrier programme could be considered militarily successful. Bruce Layton, an experienced ‘systems analyst’ with a background in mathematics and operations research, chronicled the sixth iteration of the campaign (Layton 1972, ix). With regard to stated objective of maximising cost of infiltration, he wrote that ‘attempts to quantify the impact of truck losses on the enemy were hampered by a lack of definite information on the enemy’s capability and intent’ (1972, 18). This issue, which had been present in US efforts to observe infiltration in the early 1960s, was the obsessive drive to measure despite the obvious incoherencies involved in the process. The progress of the programme—and thus the continued justification for the bombing of Laotian territory—was described through a set of metrics whereby gaps in the data were patched up with accessible correlations: the measurement of ‘truck kills’ was represented as a ratio with another variable for which a value was known. For example, the number of trucks destroyed or damaged was graphed in relation to the number of sorties; or to the number of trucks observed; or to the type of aircraft which conducted the strikes; or to the total number of bombs dropped over the trail (see Figure 5.12). Acknowledging this reflexivity, the author of the COMMANDO HUNT III report wrote: ‘the total of sensor detected trucks should not, therefore, be viewed in an

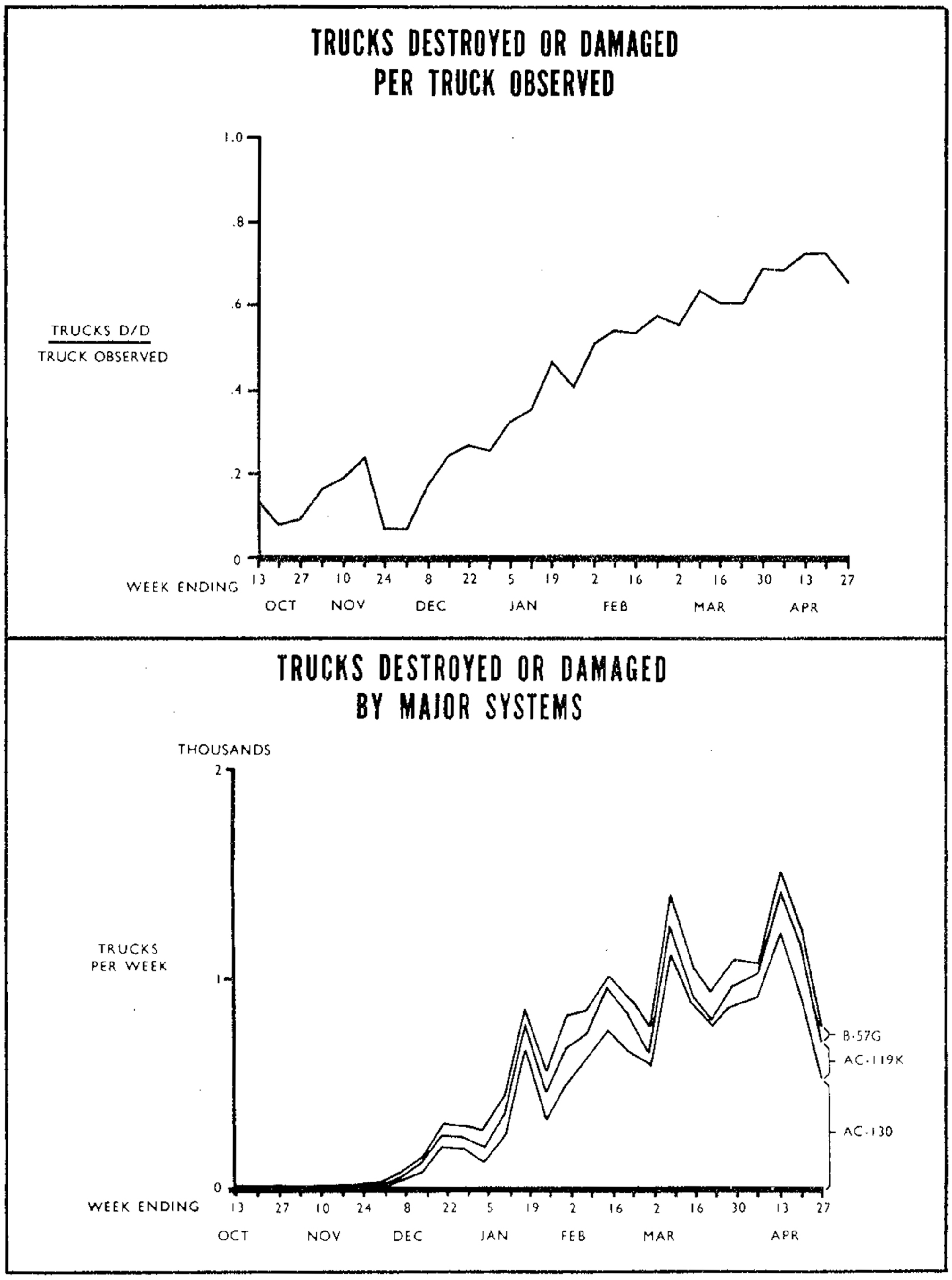



Figure 5.12: Two graphs depicting relation rates of trucks destroyed or damaged ('D/D') against trucks observed (top), and by aircraft (bottom). From study of COMMANDO HUNT V (1971, p. 53).

absolute sense, but rather as a measure of changes and trends in enemy activity over a period' (HQ 7th Air Force 1970, 72–73).

In parallel to this attempt to assess bomb damage and quantify 'truck kills' was a continued effort to conduct regression analyses on the correlations between various environmental factors and the patterns in US observations, detections, and strikes on truck traffic. This technique, in which statistical 'cause and effect' models are constructed as 'aids in identifying the individual influences of separate variables' was used throughout the COMMANDO HUNT III report (1970, 225). In the regression analyses that were conducted, the number of trucks observed over time were considered the dependent variable in relationship to a range of parallel measurements—for instance, height of cloud ceilings, time of day, and type of reconnaissance aircraft. The obsessive quantification of environmental factors expanded to the point where even the correlation between the moon's luminescence and the capability to observe trucks was drawn into their statistical model of the battlefield (see also Henry 1970, 26–27; HQ 7th Air Force 1971, 225–28).

> A regression analysis of the influence of the moon phase on visual observation revealed that as lunar illumination increased from 0 to 100 percent, 39 fewer trucks were observed. This reduction was probably a consequence of the enemy operating his trucks without lights when the moon was high (1970, 77).

The long-term function of the IGLOO WHITE programme was to construct a coherent strategic knowledge of the Ho Chi Minh Trail out of fragmentary, contradictory observations and sensor activations. This knowledge of the region was then used in the effort to predict areas of activity. By identifying 'patterns' and 'trends', operators referred to as 'Targeteers' drew on this to devise 'target lists' ordered by their estimated 'lucrativity' (TFA 1972, 56–57). Other systems which supported the construction of this strategic knowledge of the region included the so-called 'KEYWORD file', an 'automated data file which served as a central depository for multiple source intelligence data' (Caine 1970, 34). KEYWORD allowed operators to query the dataset for particular times of day, locations, or time periods. Another programme, termed Traffic Analysis and Prediction (TRAP), reportedly assisted operators in the tasks of ‘target development’, identifying route construction and storage areas, and determining the effectiveness of a strike (Caine 1970, 34).

The quantity of truck kills was but one metric that comprised a greater criterion termed ‘force effectiveness’ (1970, 84). In accounts of COMMANDO HUNT campaigns, force effectiveness constituted a generalised assessment of the level of disruption caused US Air Force bombing sorties over the trail. Calculating this, however, relied on the persistent problem of aerial surveillance: Layton (1972, 29), writing on the penultimate COMMANDO HUNT campaign in 1972, noted that ‘weather, darkness, smoke, and foliage [...] affected visibility’. Layton (1972, 29–30) also listed a set of criteria which determined whether a truck had been ‘destroyed’:

1. No longer visible after a direct hit.
2. Observed to be aflame.
3. Observed to be a mass of twisted metal after a strike, or
4. Rendered unusable and irreparable after a strike.

These efforts to systematically measure the devastation of their campaigns were complicated by the fact that the objects being measured were also targets for destruction: the complete absence of a truck could become evidence of a ‘successful’ strike. As had been the case in the interdiction programme prior to the introduction of the electronic barrier, overall measurements of ‘force effectiveness’ resulted in an unpredictable variability, expressing an uneven and uncertain account of the extent that IGLOO WHITE played in the interdiction effort and, more broadly, the US military involvement in Vietnam.

### 5.3.4 A Memorandum on the Subject of Killing Trucks

The operational logic of the IGLOO WHITE system was elaborated with additional elements which, in the minds of the defence researchers, would allow for a greater knowledge of and attacks on the trail 'network'. However, the underlying uncertainties in the technical practices of measurement persisted, and even proliferated, due to the increase in 'data' collected by the sensors. The construction of other metrics, rendered through discursive and graphical modes which incorporated key qualities of systems analysis as a discourse, provided a set of techniques to reframe streams of numbers into narratives of 'progress' and cost-benefit tables. The charting of sortie-strike ratios, the number of confirmed truck kills, and the monthly tonnage 'throughput' all converged on the question of whether the 'costs' of resupply were increasing for the enemy. In late 1971, the Director of the Office of Defense Research Leonard Sullivan sent a file to Georges Duval, a scientific advisor at Military Assistance Command which outlined his effort to '[rework] the truck-kill business' (Sullivan 1971). 'OASD/SA's view of the US interdiction effort as an exchange of costs is a valid one', he wrote, 'however the conclusions drawn oversimplifies the methods and objectives of the US effort against the enemy logistics system' (Sullivan 1971). Written during one of the final COMMANDO HUNT campaigns, the enclosed memoranda indicate a continued effort to demonstrate and assert the strategic legitimacy of the sensor data collected by the IGLOO WHITE system.

Interdiction 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 '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). Sullivan noted this entrenched, generalised scepticism of the statistics produced within 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]. (Sullivan 1971, 1)

For Sullivan himself, 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' (1971).

The obvious problems with the data did not give cause for any substantial reconfiguration of the electronic barrier programme, however. Sullivan suggested, rather, that the consequence of this glaring contradiction between two information sources—the photograph and the systems analysis—should be a shift in metric. Truck kills should no longer be the core statistic cited to express and evaluate the operational efficacy of the anti-infiltration programme, he proposed: a more accurate criterion was to measure the quantity of supplies in tonnes that entered the Ho Chi Minh Trail region from North Vietnam, and again quantify the supplies that entered South Vietnam, with the difference between the two indicating the measure of efficacy of US interdiction efforts.

The ways in which sensor 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. Contextualised within this sphere of discourse, Sullivan's memo is not particularly remarkable, but it is precisely for that reason that I invoke it here. The proposition to reframe the data collection process is emblematic of the general politics of truth of the regime of practices that shaped the elaboration of the barrier programme. Indications of some system breakdown, where contradictions in the chains of 'evidence' between the electronic measurement of vibrations in the ground to the corresponding aerial photographs of bomb sites initiated a shift from 'killing trucks' to 'supplies destroyed'. The capacity for the operational elements of the system, from the photo interpreters to those who scanned the CONFIRM reports, to produce authentic data about the region was taken for granted. What persisted in the electronic barrier from the earlier 'manual' phase of the anti-infiltration programme was the idea that the correct analytic metric could cut through the uncertainties in the dataset, despite considerable internal discussion which contradicted this. The central strategic problem which initiated the whole effort to use electronic sensors and computers to detect traffic and manage the information remained: a question of compositing data from a multiplicity of interpretive sources in order to construct and scaffold a knowledge of the region that, despite the myriad uncertainties involved, could still be mobilised to legitimise the continued, immense bombing intensities—whether it measured in terms of 'truck kills' or 'supplies destroyed'.

## 5.4 Conclusion: A Photograph

The image in Figure 5.13 is taken from a report describing operations in the COMMANDO HUNT III anti-infiltration campaign (HQ 7th Air Force 1970). It is a 'vertical aerial photograph', the camera lens pointed perpendicular to the landscape. It shows a blanched, cratered earth and scorched tree trunks; a road arcs from top-middle out to the left of frame. A truck, a type often used by north Vietnamese supply forces, is visible on the roadway. What might be smoke rises from the truck—a dense, cloudy white patch drifts leftward and diffuses over darker terrain. In the bottom right of the image, the silhouette of the aircraft taking the photo is visible.

This chapter has examined the respective roles played by electronic instruments and human operators in the construction of claims and assertions made about the trail region, and how, in aggregation, these statements contributed to an institutionally-sanctioned strategic knowledge that shaped and legitimised the anti-infiltration programme. The operational logic described in diagrams such as that in Figure 5.8 presents a picture of the electronic barrier system as flows of information and control. Contrasted with the 'Sequence of Events' diagram (Figure 5.9) which illustrates the successive complications and uncertainties which mediated data flows from the sensors, the extent of the involvement of human operators in managing these 'information flows' amidst emergent ambiguities becomes abundantly clear. Despite the extraordinary push for increased systemic 'efficiency' through automation and the quantification of the trail region, a huge amount of manual work still characterised the system, necessitating particular practices of interpreting and analysing great quantities of data.

While IGLOO WHITE does indeed represent an irruption in remote, electronic warfare, what is crucial to highlight here is how the introduction of sensors and computers did not simply remove the human from the loop. Tacit practices of

Figure 5.13: Aerial photograph from COMMANDO HUNT III report, 1970.

interpretation and analysis were integral to the development of this knowledge. Indeed, such forms of tacit knowledge only became more important as the system was increasingly computerised. The documents cited in the above discussion provide a series of 'grey' perspectives on the electronic barrier. In this vast domain of administrative media, the extensive roles played by human operators in the elaboration and evaluation of the programme becomes abundantly clear.

The centrality of photographic interpretation is expressed repeatedly in documents produced throughout the deployment of the anti-infiltration programme. As a particular type of expert practice instituted within a broader regime of practices, it was an instrumental source in the construction of a strategic knowledge of the Ho Chi Minh Trail which recharacterised the environment as a militarised landscape of environmental agents. In this discourse, the canopy became 'camouflage', the topology of the valleys became obstructions to radio communications, the trail infrastructure became a 'network', the seasonal monsoons became cover for NVA operations, and the fullness of the moon became an analogue of 'vehicular activity' levels. As such, the production of this knowledge about the logistics of the trail was conditioned by a set of emergent countertactics and institutional contingencies, which required further supports to sustain its intended effects.

IGLOO WHITE represents an early experiment in a military concept that has become increasingly integrated within the discourse of defence research since the end of the Cold War. Human-computer systems that can simultaneously detect, surveil, and attack across micro and macro scales have been a prominent feature of the so-called 'Revolution in Military Affairs' in the United States' Armed Forces. For example, the concept of battlespace, emerging in the aftermath of the first Gulf War, is indicative of how the principles of IGLOO WHITE endure in the present. In his article 'Bombing at the Speed of Thought', Cullather (2003, 144) writes: 'Casting aside these hard-earned doubts, battlespace resurrects the dream of total clarity, total coordination, along with the founders' promise of an end to bureaucratic conflict'. Invoking IGLOO WHITE as a forebear of battlespace, Cullather describes how the disciplinary frame of systems analysis 'conditioned military planners to translate the lessons of new technologies into requisitions for new technologies' (2003, 146).

The operational logic of battlespace is not radically new, but rather represents an intensification of the techno-strategic doctrines experimentally explored and deployed in both domestic air defence and in Vietnam. Cullather's summation of battlespace, where 'anything not shown on its flat-panel display is presumptively not worth seeing' (2003, 142), would perhaps have been a familiar one to operators of both SAGE's Direction Centres and the IGLOO WHITE's Target Assessment Officers stationed at Nakhon Phanom. What might also have been familiar to these operators was the necessary work involved in the manual processing of imagery. Cullather writes: 'Once "Desert Storm" was underway, operations moved with unprecedented speed but battle damage assessment advanced at the deliberate pace of satellite tasking and photo interpretation' (2003, 146).

Focusing on photo interpretation here demonstrates how technologies designed to automate the business of war are scaffolded by types of 'interpretive' work carried out by human operators. These configurations contributed to the rationalisation of new scales and distributions of violence. The introduction of electronic sensors to replace 'human operators' produced arrays of additional tasks which could only be carried out by trained analysts familiar with the system, the environment, and the emergent countertactical inventions of the NVA. In the move to systematically expand the scale and accelerate the pace of interdiction, the need for these necessarily manual practices only expanded. The introduction of the computer, which represented the movements of detected convoys as a 'glowing white worm' on a cathode ray tube thousands of miles away at the ISC, did not simply replace manual interpretive work. Rather, it introduced new elements into the system, creating additional demands for the various operators distributed across the process.

The proliferation of sensors corresponded to an immense increase in the amount of 'data' being produced. While some of those who reported and evaluated the barrier system struggled to make this data cohere with the aerial photography of the trail, the data that did exist also served to legitimise the allocation of further resources—in aircraft, bombs, interpreters, and analysts.

# Chapter 6

# Conclusion: The Limits of Command and Control

## 6.1 'Machine, Here is a Problem'

> It would be nice to have a machine to which one could say, 'Machine, here is a problem; I've written it out in longhand for you and I'm sure that although you have never done this problem nor anything like it before, you can figure out a way to do it. Call me at home when you're through.' It would be nice indeed to have this machine. But we don't, and it is not likely that we ever will. (Ware 1954, 10)

Willis Ware, a computing researcher and a chronicler of RAND's corporate history, speculated on the future of such machines in a paper presented to an audience of radio engineers in 1954. Titled *The Digital Computer: Where Does It Go From Here?*, the paper was an effort to explain the technical principals and prevailing problems of computing to a non-specialist audience, and to relay some of what Ware considered to be its possible future applications. He suggested that the problem of imbuing the computer with creative problem-solving capabilities would be a long-standing one: handing over complex problems for the machine to devise its own approach toward a solution could not, he estimated, be achieved without some process of translating real world conditions into a machine-readable algorithm. Nevertheless, Ware suggested that the digital computer would be enormously beneficial, if not critical, in a wide range of future contexts, and in particular the office and laboratory environment, largely due to what he saw as the increase in data-processing efficiencies, an unprecedented 'freedom from error', and that machines would be cheaper than the manual systems which they replace (1954, 13). For him, this future of efficiency and accuracy was not inevitable, however. He signed off his paper with the following caveat:

> It is clear that machines will gradually relieve man of a great burden of routine clerical drudgery and simpler mental tasks. In doing so there will be made available large amounts of time for intellectual activity and thought. This can result in either of two things: this time is squandered in useless and unproductive directions, or this time is devoted to a more rapid advance of the sciences and the humanities. (Ware 1954, 16–17)

The more optimistic take sketched out here was that the computer, by virtue of its automative capabilities, could free the human from dull, repetitive work and allow for a concerted attention on more complex and 'creative' problems. A 'mental revolution' was coming, Ware proposed, but it was up to those working in the specialist field of computing research to ensure that the 'time dividend given to us by these information handling machine systems' was put to optimum use (1954, 17).

Ware's remarks express a set of tensions concerning the potentials and limits of computing systems which played out in the discourses of defence research during the 1950s and 1960s. With the distinctly humanistic stance that Ware adopts in the above-mentioned paper, the obvious military contexts and implications of the digital computer were for the most part discursively marginalised. Besides a mention of ENIAC's role in solving a 'very nasty' field of problems in 'nuclear research' and the near-future applications in air traffic surveillance (perhaps a nod to the then-experimental SAGE system which dominated RAND's research and development effort at the time), there was no speculation on how this time dividend might impact the nation's biggest sponsor of computing research: the Department of Defense. Nevertheless, the central theme of his paper—how computers might facilitate novel efficiencies in practices of management and administration—was also a recurring theme in documents arguing for the development of digital, networked command and control systems. During this period, countless reports, memoranda, and studies authored by defence researchers were dedicated to speculations about what implications the computer held for the conduct of war in the near-future. The timely processing of vast quantities of information to support decision-making was a general principle that motivated the dedication of vast resources to the digitisation of command and control systems.

This preoccupation with casting war as information and the use of computers to expedite information-processing have featured frequently across the documents examined throughout this thesis. They have been present in the ADSEC reports which proposed the schematics of the SAGE project and in the Systems Research Laboratory's human-machine experiments; the RAND Corporation's extensive catalogue of memoranda on systems analysis and wargaming; and they recurred again and again in the reporting that aimed to quantify 'truck kills' in Operation IGLOO WHITE. Precisely *how much time* was required was, of course, a quantity subject to extensive discussion and revision by defence researchers. I have used the term *operational logic* throughout my case study analyses in reference to the imagined relations between humans and machines as rendered in the administrative documentation of these systems. What we find in this operational logic is a tension between the assumed potentials and limits of the role the computer in command and control systems—a tension that also informed the reconceptualisation of the human operator as a manager of information.

## 6.2 Administrative Regimes

Over the previous two chapters, I have examined two historically significant command and control systems which involved unprecedented efforts to automate a pre-existing arrangement of largely manual operational practices. As I set out in the introduction to this thesis, I proposed to investigate the discursive context of these shifts, largely focusing on how the role of the human was framed, rather than on the automative qualities of the technologies themselves.

Civilian defence researchers, considerably more so than military commanders, were the primary proponents and architects of these systems. The pre-established configuration of manual practices were understood by defence researchers to be ineffective, and they subsequently constructed an argument to convince military commanders that 'advanced' systems were strategically necessary. Given that both systems were highly experimental and unproven, and from the outset expected to require enormous budgets (ultimately costing billions of US dollars in each instance), this task of convincing was by no means a foregone conclusion. There was also a second implication: this shift in the locus of strategy-formulation to civilian-led think tanks—most notably RAND in this research project—and the reframing of war in scientistic terms has been discussed at length in existing scholarship. Terms closely associated with cybernetics and information theory do appear frequently as descriptors for enemy behaviour and the management of war. However, in both case studies they were applied in a more open and intuitive way than is typically accounted for in this scholarship. Defence researchers in question here were, in internal lines of communication, quite alert to the critical problem of uncertainty and the speculative dimension of their imagined command and control systems.

Despite the public-facing discourse espoused by military and governmental officials which celebrated the 'advanced' qualities of the computers at the kernel of these systems, the human was positioned as essential to facilitating adaptivity. In the case of domestic air defence, the human operator was a malleable 'factor' of the system with a unique capability to learn to continuously self-optimise and counteract enemy countermeasures (Chapman et al. 1952). In the latter, the operator was a 'component' that could clarify ambiguities in the sensor system, and quantify its overall efficacy (Deitchman et al. 1966, 3). The intention of both system designs was to use the computer to automate much of the hitherto manual information processing, and consequently leave certain types of decision-making and interpretive work to the human operator. The output of computational processing was also understood to possess an inherent authoritative function, a capacity to provide evidential support or legitimise a particular strategic plan.

In the second part of each case study, I examined the role of the operator amidst the digital, networked command and control system once it was deployed, as documented in administrative materials produced by and about the respective systems. The operational logic expressed through these materials presupposed that the battlefield could be abstracted into streams of information with clear and standardised structures—in other words, that events of war could be optimally sensed and recorded in a way that was in principle *computable*. What becomes clear from my analysis of these discursive contexts is that a significant amount of manual work was required in order to facilitate this. The computer, introduced to automate existing manual processes thought to be inefficient, did not simply *replace* manual operational work. Rather, it moved it to other parts of the system, often lodging it in the grey areas between the technical, human, and institutional components of the system. This emergent work was distinctly administrative, often involving the production and management of paperwork and the structuring of extensive quantities of information. The number of interpretive tasks required to support the operability of these systems was far greater than had been initially schematised in their operational logics.

By adopting an expanded notion of 'system' to incorporate these administrative supports, the extent to which manual operations still defined command and control becomes apparent. My analysis of the greyer domains of defence research—material such as daily reports, classified studies, memoranda, and technical manuals—reveals that the human operator frequently had to act to shore up contingencies, to patch ruptures in information flows, to translate data incompatibilities, and to read that which remained illegible to the machine. J.C.R. Licklider's reflection of these human-machine systems, in which he characterised the operators as being there 'to help more than be helped', was therefore not inaccurate (1960). However, this is not a simple subordination of the human to the machine, a relegation to a passive observer who only intervenes sporadically while computers manage the core actions which comprise command and control. We should understand the role of the human operator as vital, active, ongoing, and continuously subject to elaboration.

Contrary to the general speculations expressed by defence researchers about a possible 'time dividend' brought about by the automation of repetitive clerical work, there was a proliferation of precisely these routine tasks which, in the initial schematic design of these systems, were anticipated to be elided by the computer. It was because of the particular *types* of 'information'—spoken words and images—that suddenly proliferated which meant that it had to manually administrated. One of the central arguments of this thesis then is that these command and control systems, understood in a broad holistic sense, are substantially *administrative systems* which, although built in principal to more optimally manage information, ended up producing their own problems of information overload.

By focusing on the figure of the operator as discussed in the grey media of defence research, the struggle to optimise the operational logic of command and control systems amidst emerging contingencies and countermeasures features as a recurrent point of discussion. Developing from Fuller and Goffey (2012), the 'recessive' power of grey media has been a crucial theoretical frame for this research project. This field of media is of course not at all unusual in historical enquiries into institutions. The approach I have adopted here is not to refer to such material as sources through which to chart a narrative of technological progress or the roles of individual figures, but to examine it in terms of the effects it has on structuring and standardising specific operational practices. In a Foucauldian sense, this has meant examining the discourse of defence research in terms of the way in which it takes certain propositions for granted and self-evident, and how forms of knowledge congeal in institutionally-encoded relations between individuals, technologies, and practices.

Grey media, as formal expressions and records produced within a particular institution, are imbued with a capacity to *authorise* and *validate*, and thus to differentiate what processes can 'produce' knowledge. A manual, for instance, is not merely a description of how to operate a given object, but it also sets expectations and standards of its intended reader. Whether or not the instructions delineated in a manual are ever actually followed in the day-to-day realities of the institution has been largely beside the point here; what has mattered in my analysis is the idea that grey media is embroiled with, and thus indicative of, the regimes of power and knowledge from which it emerges. Manuals are particularly explicit in this regard, but they are only one of many 'genres' of document that I have studied in the course of this research project. What has emerged over the course of analysing the wealth of archival material collected during this project is a tension in the relation between alternate, but sometimes overlapping, subdomains of defence research. On one hand, there are the prescriptive documents which propose the 'operational logic' of human-machine systems by defining the specific configuration of instruments and individuals involved in formal terms. On the other, there are the routine inquiries which continuously observe and revise this operational logic across regular programmes of reports, studies, and memoranda.

This tension is a reflection of the unfinished, unstable states of the command and control systems I have examined: research and development were synchronous, mutually integrated, and often in conflict with one another.

To conduct an analysis on the basis of the 'positivities' of grey media means to engage with them on the level of *what is said*, rather than attempting to extract from them a buried potential or 'hidden stratum' of meaning. The implications of this theoretical approach for how we think human-machine systems is further enriched and deepened by understanding that the 'positivities' of discourse not only encompass the written words, but also the adjacent informational structures and explicatory diagrams, the metaphors and models drawn on, and even the formal qualities of the documents and the ways in which they were published. Throughout the discussion of the case studies, I discussed these qualities at length. In this regard, the headings of a table of data matter at least as much as the actual data contained within, in that the headings tell us something about how the battlefield was understood to be interpretable and quantifiable; on an information flow diagram, the question of what the lines *between* operational boxes abstract out of visibility become vital, because they represent points of translation between what are understood to be system components; and the numerical coding and publication format of a document becomes of critical importance, as it expresses how the object it describes functions within an overarching system of reporting, codification, and administration. The aesthetics of grey media thus play an integral part in scaffolding their capacity to authorise and validate.

While his optimistic hopes of a 'time dividend' clearly proved to be rather more complicated in reality, Willis Ware was more accurate when he suggested that 'personnel training may well become a process of essentially playing a game with a machine' (1954, 15). In the first case study, with any actual aerial invasion of Soviet nuclear jet bombers decidedly *absent*, the role of the operator within the system was delineated and inscribed through a series of training simulations, whereby enemy flight trajectories were computer-generated to form a 'defence problem'. Throughout the 1960s, these training simulations were continuously extended to take into account new possible evasive tactics that could be deployed to disrupt the omniscience of SAGE's continental perimeter of surveillance: a continuously unfurling negotiation of, in military parlance, 'electronic countermeasures' (ECM) and 'electronic counter-countermeasures' (ECCM). Scenarios had to be scripted and programmed to tape to test the capabilities of the crews to respond, while teams of analysts struggled to examine the immense amounts of information produced during a training exercise. As Chapman et al. (1959, 263) speculated, 'literally hundreds of very pretty hypotheses' about human-machine systems were lost in it. The paradox here related to how the limits of the system were conceptualised: it was considered to be better to train the collective, alongside the myriad appendages, but to do so would be to produce more information that could only go unanalysed. Meanwhile, the institutional functioning of the system faltered due to bureaucratic and administrative contingencies such as the regularised routines of personnel rotation and crew turnover.

In the latter case of IGLOO WHITE, the attempts to discern the strategic efficacy of the 'electronic barrier' were substantially hampered by a lack of evidence of 'successful' strikes. The nature of the work of the photo analyst, in particular their unique capability to *interpret* an image and construct the 'hard fact' of a confirmed wreckage from the blurred edges of a smoke cloud, precluded it from automation. The veracity of a fact in this context had a great deal to do with a specific type of tacit, expert process of interpretation that involved the translation of statements from one form to another. On a much broader temporal scale, this data was aggregated and presented in various visual forms which purported to distil the most pertinent facets of the programme into legible, quantitative expressions. Data represented in a table might in another instance appear as a bar chart comparing trucks destroyed across two seasons, a graph contrasting sortie and strike rates, or a textual summary of activities conducted by a particular squadron. The ambiguity of an image is lost in the structure of the information graphic mobilised to convey 'progress', and the need to further invest in and extend the system. The practice of systems analysis, somewhere between 'art' and 'science' according to its proponents, was but one practice that structured this data, extracting from it the justification for further technical elaborations of the barrier programme.

As I have emphasised above, the shortcomings of these systems—often, their distinct lack of *systematicity*—were not lost on the defence researchers who reported on them. The cautiously optimistic forecasts about the digital computer espoused by defence researchers such as Ware in the early 1950s dampened somewhat by the end of the decade—a level of circumspection whose attribution is difficult to separate from the widely discussed problems of the SAGE project. Reviewing RAND memoranda dating from the late 1950s, we readily encounter substantial debates around the ways in which contemporaneous efforts to automate had not quite delivered the anticipated efficiencies. The management theorist Norman Dalkey—an inventor of the Delphi technique of decision-making—authored an analysis of the potentialities of command and control systems. In this memo, titled *Command and Control: A Glance at the Future* and prepared for a presentation for SAGE's umbrella corporation MITRE, he was candid in his acknowledgement of the shortcomings of existing command and control systems:

> Complete automation of current procedures has turned out to be much more difficult than was thought, and without something close to automation, gains in speed are overcome by the complexities of man-machine interaction. (Dalkey 1962, 2)

Indeed, the problem of system complexity is echoed in Licklider's articles of the early 1960s referred to in the introduction to this thesis. The source of much of this burdensome administrative work was the need to continuously monitor the performance of the command and control system, as the defence researchers themselves could not otherwise be sure of whether the system was 'helping' militarily. In Licklider's jargon, this effort was termed 'the system system'. In contrast to the 'object system'—which he suggests could be the arrangement of humans and technical fixtures in a satellite network or a combat operations centre—the system system was 'the organising force to make coherent and harmonise the many facet phases of the network or the centre' (Licklider 1963, 633). Propositions for an operational logic such as this, however, beg the question of how many meta-systems are required to ensure each is functioning effectively.

Despite the reflections around the function and potentials of the digital, networked computer that followed SAGE, what we find in IGLOO WHITE is a recurrence of a field of problems which, in a general sense, are largely familiar in scope to those of the earlier system: administrative needs rapidly expanded, largely in the immense task of 'preparing' unstructured information so that it can be processed computationally. The day-to-day functionality of the system relied on this domain of administrative operations, a 'regime of practices' formally inscribed in masses of reports, manuals, working papers, and studies, all in a continuous process of being superseded, appended, and rescinded.

In both cases, this proliferation of grey media was both an effort to produce and reinforce coherency, while also standardising the conditions in which the human operator performed their role. Yet, these efforts quite clearly fell down when operational needs continuously developed, countermeasures elaborated, institutional resources expanded and contracted, and computer systems fell short of their original designs required further ad-hoc operational support. As the sinuous elaborations of measures, countermeasures, and counter-countermeasures shows, this domain of discourse very much continued to what it meant to 'operate' these systems throughout their lifetimes. The limits of command and control arise in the administrative tensions between the diagrammatic operational logic of the system and regime of practices which arise to support and codify the ‘knowledge’ it produces. Research and development did not mean a linear pathway from ideation of a system to its material realisation and deployment, but proceeded simultaneously in an attempt to cultivate systemic stability and optimisation. An underperforming or failing technical element was appended with another to shore up contingency. Systems accumulated subsystems and automatic processes accrued manual operational supports.

## 6.3 From C2 to C4I2

An early plan for this research project was to conduct a genealogy of command and control that would include an analysis of Operations Desert Shield and Desert Storm in the Gulf War in 1990-91, and also the contemporary use of Ground Control Systems from which attack and reconnaissance drones are remotely piloted. By opting to narrow the historical scope of this research project, I have been able to focus in detail on the discursive contexts of command and control systems and inquire into the figuration of the human as an element of such systems. This narrow scope, however, has also been a limitation: I have not drawn any explicit conclusions in my case studies about theories of defence research and the role of the human operator in contemporary weapons systems. Yet, by understanding the preceding chapters as a ‘history of the present’, the conclusions set out above open up an array of contingent lines of inquiry, and also highlight some focal points which have gone underexamined in contemporary scholarship on war and technology.

A great deal of the contemporary transdisciplinary scholarship that can be broadly understood under the domain of ‘critical military studies’ foregrounds the transformations which technologies undergo, without necessarily following the broader implications for the systems which these technologies sit within. One of the crucial points I have emphasised here is that, for all the prominent discussions of machines taking command, examinations of the more prosaic, everyday dimensions of these systems reveals that humans tend to remain very much 'in the loop'. In writing critical studies of purportedly 'advanced' military computing systems deployed today, or indeed accounts of key historical systems such as SAGE and IGLOO WHITE, it is important to be able to identify the ways in which these technologies shift the field of possibility in which the management and conduct of warfare takes place, without occluding the ways in which humans still have to act and operate within them. Overemphasising the roles that computers play in the formulation of strategy and the management of military operations displaces the centre of decision-making away from individuals, and risks mythologising these systems as omniscient and hyperrational configurations of 'thinking' machines. Furthermore, such emphases contribute to a normalisation of the promise of the next update, legitimising the ongoing production of new and more expensive military technologies. A study of the discourse of defence research—and particularly from greyer, institutional sources—reveals the blind spots and contingencies that modulate and delimit the operational dimensions of these systems, and problematise the assumed 'logic' and 'accuracy' which computational systems are often imbued with.

Following on from this point, a discussion of these systems should also be sensitive to their incoherencies and forms of resistance which, often to large degrees, characterise their operational functionality. In particular, by paying attention to their tendency to continuously expand and accumulate subsystems, we can open up a possibility for a critique of command and control systems that emphasises its continuous problems with contingency and shifting conceptualisations of the battlefield. Demonstrative of this is the way in which the term 'command and control' has itself accrued various terminological modifications since the early days of SAGE. As Hables Gray (1997, 39–40) has noted, from the 1950s to the present, we have gone from C2 to C4I2; a complication of command and control to a configuration that additionally encompasses ‘communications’, ‘computers’, ‘intelligence’ and ‘interoperability’. This broadening of the operational scope was an incremental but uneven process. In the aftermath of the First Gulf War, the term C4I2 has become prominent. This terminological adjustment reflects a parallel complication in the domains over which command and control functions, incorporating more and more subsystems and, at least purportedly, allowing for the more rapid and effective coordination of joint operations between the Armed Services. Digital, networked computers have clearly played an important role in precipitating this shift, and the shifts in the field of possibility in military human-machine systems they have brought about require critical scrutiny. However, we should also seek out the pervasive incoherencies, contradictions, and forms of resistance which modulate command and control systems, and draw into question their purported frictionlessness, their surgical accuracy, and their apparent efficiency.

A recent experiment in command and control conducted at Al-Udeid Air Base in Qatar highlights the need for such studies. For over a decade, the base had served as the US Air Force’s primary command post staffed by hundreds of personnel overseeing operations in West Asia-North Africa—a region that has been a particularly obvious focal point in US military interventions. An article in the *Washington Post* noted that over a 24-hour period in late September 2019, the room sat empty while ‘300 planes were in the air in key areas such as Syria, Afghanistan and the gulf’ (Taylor 2019). Command and control had in fact been handed over to another air base in South Carolina. This was a major trial: as the article notes, it was the ‘first time US command and control had been moved out of the region since the centre was established in Saudi Arabia during the 1991 Persian Gulf War’ (Taylor 2019). Yet what was especially striking about the article was a comment by the centre’s Commander, Frederick Coleman. Clearly excited by the possibilities of a new agile modalities of command and control facilitated by real-time digital networks, Coleman remarked that he would like to be able to work from his iPad, adding ‘eventually, I’d like to be able to do this from Starbucks’.

## 6.4 Postscript: Automating/Operating

Coleman’s irreverent comment about an imaginary command and control system that can be run on an iPad does reflect a widely observed long-standing desire to untether decision-making from the immediacy of the battlefield. Certainly, developments in networked, digital computing spurred on by extensive military investment have repeatedly presented very real shifts in the continuous distancing of warfare—a theme which has been central to the work of Paul Virilio for more than four decades (2005, 2009; 2006). In his essay ‘A Travelling Shot Over Eighty Years’, Virilio argues that a sequence of technological irruptions in war has culminated in what he calls ‘a subliminal light of incomparable transparency, where technology finally exposes the whole world’ (2009, 111). For Virilio, in facilitating such prosthetic omniscience, digital and network technologies also contribute a shift in the type of problems that structure and mediate strategic planning. He remarks that the emergent problem that faced military decision makers over the course of the Cold War was one ‘of ubiquitousness, of handling simultaneous data in a global but unstable environment where the image is the most concentrated, but also the most stable, form of information’ (2009, 90).

Stable, yes; but as we have seen, this stability requires a corresponding set of interpretive and analytic practices reliant on stable notions of expertise and knowledge. In both SAGE and IGLOO WHITE, various forms of interpretive work remained central to the conversion of imagery into computable data: the rapid, calculated comparison of potential enemies with commercial flights during a SAGE System Training Mission; the scrutiny of a glowing white worm to distinguish between signature patterns of animal behaviour, thunderstorms, cluster bombing, and enemy convoy movement. Maintaining a focus on the tacit practices that persisted in these systems, both SAGE and IGLOO WHITE remain as valuable case studies: they provide a bevy of administrative media that document in minute detail how operational decision-making, conceptualised as the management of information, consistently encountered the limits of command and control. These encounters were most firmly felt at points of semantic and representational ambiguity—notably, where the tacit knowledge involved in acts of coding speech to measure collective organisation and categorising aerial photography was instrumental. SAGE and IGLOO WHITE are instructive case studies in that they highlight how tacit operational practices persist despite, and even as a consequence of, explicit efforts to dispel uncertainty through the addition of more advanced software and more omniscient sensors.

In mapping out the legacies of both SAGE and IGLOO WHITE are felt in the present, the question arises of how more contemporary networked computing—many orders of magnitude more powerful than those discussed in the case studies earlier in this thesis—might further reconfigure the positionality of the 'operator' as an element of a command and control system. This research project proceeded against a background of a new wave of AI research whose proponents argue represents a qualitatively new, even mysterious, field of computational possibility (Lee 2018; Campolo and Crawford 2020). One of the most visible applications of this has been natural language processing and computer vision. Undoubtedly, the contemporary technical requirements of such applications is radically different to those of the Cold War. No longer purely the domain of specialist researchers with access to experimental supercomputers, both of these computational processes can now be routinely performed using a consumer smartphone app or a simple web browser to a relatively high degree of sophistication. In other words, the software itself is now much more mobile, and the wireless infrastructures which permit its functionality much more pervasive, than ever before.

The US military has been both an obvious benefactor and driver of such technological advancements for decades. Indeed, various defence agencies have been sponsors of such research in its formative stages since the early years of the Cold War. This history is intertwined with my case studies. Allen Newell, co-founder of the Systems Research Laboratory, developed the landmark AI program 'The Logic Theorist' with the economist and defence strategist Herb Simon in 1956. SAGE's software and training managers, the Systems Development Corporation, also carried out research in natural language processing in the 1960s (Simmons 1965). Given the extensive part played by verbal communication despite the unprecedented use of graphical interfaces on SAGE's computer, it is not difficult to see why the automatic translation of language into computable forms might have been of interest to the SDC's researchers.

Likewise, the operational focal point in my discussion of IGLOO WHITE—the photo interpreter—performed a specific type of analytic work which today can be, and indeed in certain domains *is already*, augmented by computer vision algorithms. Such is the scope and rhythm of planetary-scale surveillance imaging that at least part of its interpretation must, as an apparent matter of strategic necessity for military and intelligence agencies, be handed over to predictive models trained to algorithmically detect specific signature patterns of enemy activity. How might the limits of the operational logic of command and control systems be reconfigured by greater processing power, faster networks, and planetary-scale information-sharing infrastructures? What regimes arise amidst these renewed strategic obsessions of more automated, and increasingly remote, warfare?

Particularly over the last decade, one of the prevailing focal points for scholars, artists, activists, and humanitarian organisations investigating the human-machine configurations of contemporary warfare has been the drone. In recent years, and thanks in no small part to the *Campaign to Stop Killer Robots* (2020), debates around these ethical questions have taken up considerable column inches and airtime in the news media. Spearheaded by a coalition of NGOs including Amnesty International and Human Rights Watch, the campaign claims that autonomous weapons systems cross a 'moral threshold', disrupt lines of accountability, and potentially lead to greater civilian casualties. In response, the campaign proposes a prohibition of autonomous weapons, and call for an assurance that humans remain 'in the loop'. 'Machines', according to the campaign's website, 'would lack the inherently human characteristics such as compassion that are necessary to make complex ethical choices'.

In order to mount an effective critique of the extreme violence which is both the effect and objective of war, however, we must first detach ourselves from takes for granted the exceptional status of the warrior-operator (Qaurooni and Ekbia 2017). Nevertheless, *Stop Killer Robots* sensational claims that war might soon be waged by algorithms was leant further credence in 2018. Details of Google's highly secretive artificial intelligence project, codenamed 'Project Maven', were leaked to the press. The objective of Project Maven was to deploy Google's considerable expertise and powerful computer vision models to aid armed drones to automatically designate and target enemy combatants (Cameron and Conger 2018; Shane and Wakabayashi 2018). While the news served as yet more evidence that the tech giant's erstwhile signature motto 'don't be evil' had been definitively retired (Crofts and van Rijswijk 2020), there is of course nothing surprising about such collaborations. Seen in the long tradition of defence research in the United States, Google are acting completely predictably: the Pentagon, faced with crippling problems of information overload amidst a rapidly proliferating regime of imagery, recruit a corporate behemoth to devise a system that promises to delegate more decisions to machines.

As in the cases of SAGE and IGLOO WHITE, we should adopt a circumspect attitude to the claims about the 'autonomy' and 'automatic' credentials of weapons systems, while also acknowledging any shifts in the field of possibility . Critiques of new generations of weapons technologies which overstate the purported 'autonomy' of such systems are unhelpful in that they tend to mystify the way such systems are developed, deployed, and maintained. In doing so, they both obscure the real human agency involved in their design and operation, and fail to take into account how operators might be displaced and redeployed at other crucial points of the system. The most insightful of scholarly inquiries into drone warfare provide an account that emphasises its organisational heterogeneity: reconnaissance and attack drones are not singular objects, but rely on a complex assemblage of sensory subsystems, network infrastructures, and civilian and military operational positions (Gregory 2011; Packer and Reeves 2013; Chamayou 2015). Any critical intervention in the operational logic of drone warfare should take into account the regimes from which it emerges: the relations between discursive spheres of defence research, the emergent strategic imperatives, and the institutionally-inscribed 'general politics of truth' that delimit and legitimise the operational positions of humans and machines in the system.

The lessons of STS, discussed in Chapter 2 earlier, provide valuable tools for us to investigate this heterogeneous constitution and the various social forces involved. John Law's (2002) account of the multiplicities of the TSR2 jet, although specifically grounded in a historical political context, provides a set of theoretical implements with which we might deconstruct contemporary semi-autonomous systems such as the Reaper drone or indeed the Joint Strike Fighter. As Elish (2017, 1101) notes, 'critical histories of technological development demonstrate that far from any teleological trajectory, technologies develop through anticipated and unanticipated alliances and contestations that are historically and socially contingent'. For Elish, in the logic of drone operations is the embedded strategic imperatives shaped by the exigencies of prior conflicts, including the wars in

Vietnam in the 1960s and the Persian Gulf in the 1990s. Given these historical provenances, she argues 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).

The decidedly ‘grey’ memorandum issued by the Vice Secretary of Defense announcing the ‘Algorithmic Warfare Cross Functional Team’ (AWCFT)—that is, Project Maven by a greyer title—already indicated how part of this reconfiguration implicated human operators:

> AWCFT will: 1) organise a data-labeling effort, and develop, acquire, and/or modify algorithms to accomplish key tasks; 2) identify required computational resources and identify a path to fielding that infrastructure; and 3) integrate algorithmic-based technology with Programs ofRecord in 90-day sprints. (Work 2017)

The autonomous targeting system envisaged by Project Maven’s team of defence researchers fundamentally depended on a vast ‘data-labelling’ effort where teams of photo interpreters labelled features on aerial imagery gathered by drones. For Suchman (2020, 182), this ‘overwhelmingly begs the question of the criteria by which “objects” are identified as imminent threats’. Embedded within this question are problems of institutionalised definitions, operational protocols, and tacit forms of interpretative work. The practices involved in this process thus delimit what counts as a ‘successful’ or ‘legitimate’ strike, and who counts as an ‘enemy combatant’ or ‘civilian’.

Suchman’s remark that ‘the ability to accumulate massive amounts of data is accompanied, however, by the debilitating challenge of rendering data into “actionable” information’ evokes those issues of indigestion and ambiguity explored earlier. The questions of who is involved in the classification of ‘information’ and the practices involved in making it ‘actionable’ have been central to the discussions of both SAGE and IGLOO WHITE. Should we read both case studies against the present framing of remote controlled, networked, and digital warfare, then we would treat the idea that the operator has entirely vanished from such contemporary systems with scepticism. What becomes increasingly important in the present, where spectacular claims about the automative and autonomous qualities of remote weapons systems are abundant, is to retain a critical sense of how the technical limits of such systems reconfigure and displace the operator, and are productive of new kinds of operational practices. This requires an expanded understanding of the operational positions in command and control systems, taking into account the institutional regimes which codify and prescribe the knowledge practices that inform their configuration. We should pinpoint and forensically examine those embodied, tacit, interpretive practices which could not be previously delegated to the machine in the past, to build a foundation which permits the critical examination of unfurling efforts to encode them as software in the present.

SAGE and IGLOO WHITE may be technologically distant ancestors of contemporary human-machine command and control systems. As expressions of efforts to further negotiate the the roles of operators, however, they serve as case studies through which we can map out the contradictions in these regimes where the drawing up of strategy requires the administration of information. Far from being seamless and orderly processors of information orchestrated by machines, command and control systems have myriad grey areas where the recessive, shifting role of operators remains instrumental.

# Bibliography


7th Air Force. 1972. “LOC Status and Logistics Flow, Laos and Cambodia (Jul 1972).” Record Group 472: Records of the U.S. Forces in Southeast Asia, 1950 - 1976; Series: Secret Classified Registered Documents Regarding Orders of Battle in Southeast Asia 8/1965 - 1/1973 (Box 1). National Archives at College Park, College Park, MD.

81st Congress. 1951. *Public Law 920: Federal Civil Defense Act of 1950.* https://www.hsdl.org/?abstract&did=.

Abbate, Janet. 1999. *Inventing the Internet.* Inside Technology. Cambridge, MA: MIT Press. https://ebookcentral.proquest.com/lib/nottingham/detail.action?docID=3338844.

———. 2012. *Recoding Gender: Women’s Changing Participation in Computing.* Cambridge, MA: MIT Press.

Abello, Alex. 2008. *Soldiers of Reason: The RAND Corporation and the Rise of the American Empire.* Orlando: Houghton Mifflin Harcourt.

ADSEC. 1950a. “ADSEC, Progress Report 1 May 1950.” http://archive.org/details/ADSECProgressReport1May1950.

———. 1950b. “ADSEC, Final Report 24 October 1950.” http://archive.org/details/ADSECFinalReport24October1950.

Aerospace Defense Command. 1976. “SAGE Operational Specifications, Volume 8: Displays.” Technical Memorandum TM (ADCOM) 637/008/01. SAGE Operational Specifications. Ent Air Force Base, Colorado: Department of the Air Force. Record Group 333: Records of International Military Agencies, 1941-2003; Series: Records Relating to the Semi-Automatic Ground Environment/Backup Intercept Control System (SAGE/BUIC), 1961-1981 (Box 1); File: TM (ADCOM) - 637-008/01, 14 June 76, SAGE Operational Specifications, Volume 8, Displays (Chapters 1-2). National Archives at College Park.

Agar, Jon. 2003. *The Government Machine: A Revolutionary History of the Computer.* Cambridge, MA: MIT Press.

Air Defense Command. 1955. “System Training Program Procedures and Techniques.” Manual ADCM 50-15. Ent Air Force Base, Colorado: Air Defense Command, United States Air Force. CBI 90, Burroughs System Development Corporation (Box 22, Folder 15). Charles Babbage Institute, University of Minneapolis.

———. 1957. “Staff Study - Implementation of SAGE System Training Program.” Ent Air Force Base, Colorado: Air Defense Command, United States Air Force. CBI 90, Burroughs System Development Corporation (Box 19, Folder 21). Charles Babbage Institute, University of Minneapolis.

Akrich, Madeleine. 1992. “The de-Scription of Technical Objects.” In *Shaping Technology/Build-*

*ing Society: Studies in Sociotechnical Change*, edited by John Law and Wiebe E Bijker. Inside Technology. Cambridge, MA: MIT Press.

Alexander, L. T., J. D. Ford, B. T. Jensen, and M. S. Rogers. 1959. "Problems Encountered in Developing and Maintaining a Field System Training Program." SP-107. Santa Monica, California: System Development Corporation. http://www.dtic.mil/docs/citations/AD0297443.

Astrahan, M. M., and J. F. Jacobs. 1983. "History of the Design of the SAGE Computer-the AN/FSQ-7." *Annals of the History of Computing* 5 (4): 340–49. https://doi.org/10.1109/MAHC.1983.10098.

Auger, Peter. 1998. *Information Sources in Grey Literature*. Berlin/Boston, Germany: Walter de Gruyter GmbH. http://ebookcentral.proquest.com/lib/nottingham/detail.action?docID=5156167.

Bales, Robert F. 1950. "A Set of Categories for the Analysis of Small Group Interaction." *American Sociological Review* 15 (2): 257–63. https://doi.org/10.2307/2086790.

———. 1954. "Social Interaction." Paper P-587. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/papers/P587.html.

Bales, Robert F., and Ned A. Flanders. 1954. "Planning an Observation Room and Group Laboratory." *American Sociological Review* 19 (6): 771–81. https://doi.org/10.2307/2087925.

Baran, Paul. 1960. "On a Distributed Command and Control System Configuration." Memorandum RM-2632. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/research_memoranda/RM2632.html.

Basham, Victoria M., Aaron Belkin, and Jess Gifkins. 2015. "What Is Critical Military Studies?" *Critical Military Studies* 1 (1): 1–2. https://doi.org/10.1080/23337486.2015.1006879.

Baum, Claude. 1981. *The System Builders: The Story of SDC*. Santa Monica, California: System Development Corp.

Bessner, Daniel. 2015. "Organizing Complexity: The Hopeful Dreams and Harsh Realities of Interdisciplinary Collaboration at the Rand Corporation in the Early Cold War." *Journal of the History of the Behavioral Sciences* 51 (1): 31–53. https://doi.org/10.1002/jhbs.21699.

Biel, W.C. 1967. "Psychological Research in National Defense Today." In *Psychological Research in National Defense Today*, edited by J. E. Uhlaner, 279–86. S-1. Washington: U.S. Army Beheavioral Science Research Academy. http://hdl.handle.net/2027/mdp.39015031996989.

Biggs, David Andrew. 2018. *Footprints of War: Militarized Landscapes in Vietnam*. Seattle: University of Washington Press.

Bijker, Wiebe E. 1992. "The Social Construction of Flourescent Lighting, or How an Artifact Was Invented in Its Diffusion Stage." In *Shaping Technology/Building Society: Studies in Sociotechnical Change*, edited by John Law and Wiebe E Bijker. Inside Technology. Cambridge, MA: MIT Press.

Bijker, Wiebe E., and John Law, eds. 1992. *Shaping Technology/Building Society: Studies in Sociotechnical Change*. Inside Technology. Cambridge, MA: MIT Press.

Bishop, Ryan. 2015. "Smart Dust and Remote SensingThe Political Subject in Autonomous Systems." *Cultural Politics* 11 (1): 100–110. https://doi.org/10.1215/17432197-2842445.

Bousquet, Antoine. 2008. "Cyberneticizing the American War Machine: Science and Computers in the Cold War." *Cold War History* 8 (1): 77–102. https://doi.org/10.1080/14682740701791359.

———. 2018. *The Eye of War: Military Perception from the Telescope to the Drone*. Minneapolis:

Univ Of Minnesota Press.

Bowker, Geof. 1992. "What's in a Patent?" In *Shaping Technology/Building Society: Studies in Sociotechnical Change*, edited by John Law and Wiebe E Bijker. Inside Technology. Cambridge, MA: MIT Press.

———. 1993. "How to Be Universal: Some Cybernetic Strategies, 1943-70." *Social Studies of Science* 23 (1): 107–27. https://doi.org/10.1177/030631293023001004.

Bowker, Geoffrey C. 2010. "The Archive." *Communication and Critical/Cultural Studies* 7 (2): 212–14. https://doi.org/10.1080/14791421003775733.

Burch, Lt Col Robert M. 1969. "Command and Control, 1966-1968 - Continuing Report." 75. Project CHECO. HQ PACAF, Directorate, Tactical Evaluation, CHECO Division. Contemporary Historical Examination of Current Operations (CHECO) Reports of Southeast Asia, 1961-1975 (Box 2, Folder 8). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/114247.

Burroughs, William S. 1993. "The Limits of Control." In *The Adding Machine: Selected Essays*. Arcade Publishing.

Caine, Maj. Philip D. 1970. "Continuing Report: Igloo White July 1968-December 1969." 118. Project CHECO. HQ PACAF, Directorate, Tactical Evaluation, CHECO Division. Contemporary Historical Examination of Current Operations (CHECO) Reports of Southeast Asia, 1961-1975s (Box 16, Folder 5). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/545215.

Callon, Michel. 1986. "The Sociology of an Actor-Network: The Case of the Electric Vehicle." In *Mapping the Dynamics of Science and Technology*, edited by John Law, Arie Rip, and Michel Callon. Hampshire; London: Macmillan Press.

Cameron, Dell, and Kate Conger. 2018. "Google Is Helping the Pentagon Build AI for Drones." Gizmodo. June 3, 2018. https://gizmodo.com/google-is-helping-the -pentagon-build-ai-for-drones-1823464533.

Campbell-Kelly, Martin, William Aspray, Nathan Ensmenger, and Jeffrey R Yost. 2016. *Computer: A History of the Information Machine*.

Campolo, Alexander, and Kate Crawford. 2020. "Enchanted Determinism: Power Without Responsibility in Artificial Intelligence." *Engaging Science, Technology, and Society* 6 (0): 1–19. https://doi.org/10.17351/ests2020.277.

Carter, Launor F. 1966. "SDC Training Activities and Plans." Technical Memorandum TM(L)-3074/000/00. Santa Monica, California: System Development Corporation. CBI 90, Burroughs System Development Corporation (Box 22, Folder 18). Charles Babbage Institute, University of Minneapolis.

Ceruzzi, Paul E., William Aspray, and Thomas J. Misa. 2003. *A History of Modern Computing*. Cambridge, MA; London, England: MIT Press.

Chamayou, Grégoire. 2015. *Drone Theory*. London: Penguin.

Chapman, Robert L. 1956. "A Theory of Organizational Behavior Deriving from Systems Research Laboratory Studies." RAND/P-802. Santa Monica, California: RAND Corporation. http://www.dtic.mil/docs/citations/AD0605003.

———. 1957. "Simulation in RAND's Systems Research Laboratory." RAND/P-1074. Santa Monica, California: RAND Corporation. http://www.dtic.mil/docs/citations/AD0606372.

Chapman, Robert L., W.C. Biel, J.L. Kennedy, and A Newell. 1952. "The Systems Research

Laboratory and Its Program.” RM-890. Santa Monica, California: U.S. Air Force, Project RAND. https://www.rand.org/pubs/research_memoranda/RM890.html.

Chapman, Robert L., John L. Kennedy, Allen Newell, and William C. Biel. 1959. “The Systems Research Laboratory’s Air Defense Experiments.” *Management Science* 5 (3): 250–69. https://doi.org/10.1287/mnsc.5.3.250.

Chapman, Robert L., and Milton G. Weiner. 1957. “The History, Purpose and Script of Cogwheel.” P-1105. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/papers/P1105.html.

Chun, Wendy Hui Kyong. 2004. “On Software, or the Persistence of Visual Knowledge.” *Grey Room*, no. 18 (December): 26–51.

CIA. 1962. “Inside the CIA’s National Photographic Interpretation Center (NPIC), Washington D.C., 1962.” National Security Archive, Washington D.C. https://nsarchive2.gwu.edu/nsa/cuba_mis_cri/7.jpg.

———. 1964a. “Vehicular Traffic Towards South Vietnam.” https://www.cia.gov/library/readingroom/document/cia-rdp78t05439a000300280038-1.

———. 1964b. “Analysis of Truck Traffic on Selected Routes in North Vietnam and Laos.” Intelligence Memorandum 64-31. Office of Research and Reports, Central Intelligence Agency. https://www.cia.gov/library/readingroom/document/cia-rdp78t02095r000800070101-2.

———. 1965. “Interdiction of Communist Infiltration Routes in Vietnam.” Intelligence Memorandum 04966/65. Virginia: Central Intelligence Agency. CIA Research Reports: Vietnam and Southeast Asia, 1946-1976 (Box 2, Folder 873). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/581623.

———. 1970. “Logistics Impact of Interdiction Operations in South Laos.” Intelligence Memorandum. Central Intelligence Agency. CIA-RDP78T02095R000600230001-7. CIA FOIA Reading Room. https://www.cia.gov/library/readingroom/document/cia-rdp78t02095r000600230001-7.

Clymer, Kenton. 2013. “The Ground Observer Corps: Public Relations and the Cold War in the 1950s.” *Journal of Cold War Studies* 15 (1): 34–52. https://doi.org/10.1162/JCWS_a_00307.

Cohen-Cole, Jamie. 2014. *The Open Mind: Cold War Politics and the Sciences of Human Nature.* University of Chicago Press.

Cohn, Carol. 1987. “Sex and Death in the Rational World of Defense Intellectuals.” *Signs* 12 (4): 687–718. http://www.jstor.org/stable/3174209.

Collins, Capt. Charles. 1967. “Herbicide Operations in Southeast Asia, July 1961-June 1967 - Special Report, Volume 1.” 115. Project CHECO. HQ PACAF, Directorate, Tactical Evaluation, CHECO Division. Contemporary Historical Examination of Current Operations (CHECO) Reports of Southeast Asia, 1961-1975 (Box 02, Folder 11). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/114258.

Colwell, Robert F. 1971. “Project CHECO Southeast Asia Report. USAF Tactical Reconnaissance in Southeast Asia, July 69-June 71. Part 3.” PACAF Hickam AFB HI CHECO Division. https://apps.dtic.mil/docs/citations/ADA486459.

COMIREX. 1968. “Overhead Imagery Reconnaissance of North Vietnam During a Truce.” CIA-RDP79B01709A002300040008-6. CIA FOIA Reading Room. https://www.cia.gov/library/readingroom/document/cia-rdp79b01709a002300040008-6.

Comptroller General of the United States. 1962. “Review of Programming and Procurement of Selected Operational Equipment and Communication Services and the Utilization of Certain Technical Personnel by the Department of the Air Force in the Semi-Automatic Ground Environment System (SAGE).” Washington, D.C.: United States General Accounting Office. UG610.U5147. Library of Congress. https://lccn.loc.gov/62060861.

Cooperband, A. S., L. T. Alexander, and H. S. Schmitz. 1963. “Test Results of the Terminal Air Traffic Control Laboratory System.” Santa Monica, California: System Development Corporation. https://apps.dtic.mil/seo/citations/AD0422853.

Cortada, James W. 2008. *The Digital Hand*. Vol. 3. 3 vol. Oxford: Oxford University Press. http://www.oxfordscholarship.com/oso/public/content/management/9780195165869/toc.html.

———. 2012. *The Digital Flood: The Diffusion of Information Technology Across the U.S., Europe, and Asia*. Oxford; New York: OUP USA.

Crofts, Penny, and Honni van Rijswijk. 2020. “Negotiating ‘Evil’: Google, Project Maven and the Corporate Form.” *Law, Technology and Humans* 2 (1): 75–90. https://doi.org/10.5204/lthj.v2i1.1313.

Crowther-Heyck, H. 2008. “Defining the Computer: Herbert Simon and the Bureaucratic Mind–Part 1.” *IEEE Annals of the History of Computing* 30 (2): 42–51. https://doi.org/10.1109/MAHC.2008.18.

Crowther-Heyck, Hunter. 2006. “Patrons of the Revolution: Ideals and Institutions in Postwar Behavioral Science.” *Isis* 97 (3): 420–46. https://doi.org/10.1086/508075.

———. 2014. “The Organizational Revolution and the Human Sciences.” *Isis* 105 (1): 1–31. https://doi.org/10.1086/675549.

———. 2015. *Age of System: Understanding the Development of Modern Social Science*. https://ebookcentral.proquest.com/lib/nottingham/detail.action?docID=3433438.

Cullather, Nick. 2003. “Bombing at the Speed of Thought: Intelligence in the Coming Age of Cyberwar.” *Intelligence and National Security* 18 (4): 141–54. https://doi.org/10.1080/02684520310001688907.

Dalkey, Norman Crolee. 1962. “Command and Control: A Glance at the Future.” Paper P-2675. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/papers/P2675.html.

Day, Ronald E. 2014. *Indexing It All: The Subject in the Age of Documentation, Information, and Data*. History and Foundations of Information Science. Cambridge, MA; London, England: The MIT Press. https://ebookcentral.proquest.com/lib/nottingham/detail.action?docID=3339867.

Dayé, Christian. 2016. “‘A Fiction of Long Standing’: Techniques of Prospection and the Role of Positivism in US Cold War Social Science, 1950–65.” *History of the Human Sciences* 29 (4-5): 35–58. https://doi.org/10.1177/0952695116664838.

Deitchman, Seymour, V. Fitch, M. Gell-Mann, H. Kendall, and L. Lederman. 1966. “Air-Supported Anti-Infiltration Barrier.” IDA-S-255. Institute for Defense Analyses, JASON Division. http://www.dtic.mil/docs/citations/ADB954899.

Deitchman, Seymour J. 2008. “The ‘Electronic Battlefield’ in the Vietnam War.” *The Journal of Military History* 72 (3): 869–87. https://doi.org/10.1353/jmh.0.0024.

DeLanda, Manuel. 1991. *War in the Age of Intelligent Machines*. Swerve Editions. New York: Zone Books.

Deleuze, Gilles. 2006. *Foucault*. London: Continuum.

Department of the Air Force. 1951. “Ground Observers’ Guide.” Manual 50-12. Washington:

Department of the Air Force. http://archive.org/details/AirForceUFO.

Deutsch, Karl W. 1951. "Mechanism, Organism, and Society: Some Models in Natural and Social Science." *Philosophy of Science* 18 (3): 230–52. https://doi.org/10.1086/287157.

Dickson, Paul. 1977. *The Electronic Battlefield*. Open Forum. London: Marion Boyars.

Dreyfus, Hubert L, and Paul Rabinow. 2016. *Michel Foucault, Beyond Structuralism and Hermeneutics*. http://www.tandfebooks.com/isbn/9781315835259.

Edwards, Paul. 1997. *The Closed World: Computers and the Politics of Discourse in Cold War America*. Cambridge, MA: MIT Press.

Eisenhower, Dwight D. 1961. "Military Industrial Complex Speech." Avalon Project. https://avalon.law.yale.edu/20th_century/eisenhower001.asp.

Electronic Battlefield Subcommittee. 1971. *Investigation into Electronic Battlefield Program: Report of the Electronic Battlefield Subcommittee of the Preparedness Investigating Subcommittee of the Committee on Armed Services, United States Senate, Ninety-Second Congress, First Session*. Washington, D.C.: U.S. Government Printing Office.

Elish, M. C. 2017. "Remote Split: A History of US Drone Operations and the Distributed Labor of War." *Science, Technology, & Human Values* 42 (6): 1100–1131. https://doi.org/10.1177/0162243917731523.

Ensmenger, Nathan. 2012. *The Computer Boys Take over: Computers, Programmers, and the Politics of Technical Expertise*. Cambridge, MA; London, England: MIT Press.

Erickson, Paul, Judy L. Klein, Lorraine Daston, Rebecca Lemov, Thomas Sturm, and Michael D. Gordin. 2013. *How Reason Almost Lost Its Mind: The Strange Career of Cold War Rationality*. University of Chicago Press.

Everett, R. R., C. A. Zraket, and H. D. Benington. 1983. "SAGE-A Data Processing System for Air Defense." *Annals of the History of Computing* 5 (4): 330–39. https://doi.org/10.1109/MAHC.1983.10096.

Farish, Matthew. 2010. *The Contours of America's Cold War*. Minneapolis: Univ Of Minnesota Press.

———. 2016. "The Ordinary Cold War: The Ground Observer Corps and Midcentury Militarization in the United States." *Journal of American History* 103 (3): 629–55. https://doi.org/10.1093/jahist/jaw327.

Fitts, Paul M. 1947. "Psychological Research on Equipment Designs in the AAF." *American Psychologist* 2 (3): 93–98.

Foucault, Michel. 1980. *Power Knowledge: Selected Interviews and Other Writings, 1972-77*. Harlow: Longman.

———. 1984. *The Foucault Reader*. Edited by Paul Rabinow. Pantheon Books.

———. 1991. *Discipline and Punish: The Birth of the Prison*. London: Penguin Books.

———. 2001a. *Madness and Civilization: A History of Insanity in the Age of Reason*. Psychology Press.

———. 2001b. *The Order of Things: Archaeology of the Human Sciences*. London: Routledge.

———. 2002a. *The Essential Works of Michel Foucault, 1954-1984. Volume Three*. Edited by Paul Rabinow.

———. 2002b. *Archaeology of Knowledge*. London ; New York: Routledge.

———. 2003. *The Birth of the Clinic: An Archaeology of Medical Perception*. Psychology Press.

———. 2007. *Security, Territory, Population*. Translated by Graham Burchell. Basingstoke: Palgrave Macmillan.

Franklin, Seb. 2015. *Control: Digitality as Cultural Logic*. Cambridge, MA: MIT Press.

Fuller, Matthew, and Andrew Goffey. 2012. *Evil Media*. Cambridge, MA; London, England: The MIT Press.

Galison, Peter. 1994. "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision." *Critical Inquiry* 21 (1): 228–66. http://www.jstor.org/stable/1343893.

———. 2001. "War Against the Center." *Grey Room*, no. 4: 7–33. http://www.jstor.org/stable/1262556.

Gaston, SSgt Alton G. 1968. "Side View of an CH-3E Helicopter Dropping an ADSID (Air Delivered Seismic Detection Sensor) Sensor over Laos." Record Group 342-B: Records of Air Force Commands, Activities, and Organisations; Series: Organisations/Projects: Igloo White (Box 1037); Photograph no. 342-10-057-2. National Archives at College Park.

Gatlin, Col. Jesse C. 1968. "Special Report: IGLOO WHITE (Initial Phase)." 117. Project CHECO. HQ PACAF, Directorate, Tactical Evaluation, CHECO Division. Vietnam Archive Collection, Box 0041, Folder 0008. F031100410008. The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/552373.

Ghamari-Tabrizi, Sharon. 2012. "Cognitive and Perceptual Training in the Cold War Man-Machine System." In *Uncertain Empire: American History and the Idea of the Cold War*, edited by Duncan Bell and Joel Isaac. Oxoford ; New York: Oxford University Press. https://ebookcentral.proquest.com/lib/nottingham/detail.action?docID=998940.

Gibson, James William. 2000. *The Perfect War: Technowar in Vietnam*. New York: Atlantic Monthly Press.

Gilbreth, Frank B., and Lillian Moller Gilbreth. 1915. "What Scientific Management Means to America's Industrial Position." *The Annals of the American Academy of Political and Social Science* 61: 208–16. http://www.jstor.org/stable/1013015.

Gitelman, Lisa. 2014. *Paper Knowledge: Toward a Media History of Documents*. Sign, Storage, Transmission. Durham ; London: Duke University Press.

Gregory, Derek. 2011. "From a View to a Kill: Drones and Late Modern War." *Theory, Culture & Society* 28 (7-8): 188–215. https://doi.org/10.1177/0263276411423027.

Grint, Keith. 1997. *The Machine at Work: Technology, Work and Organization*. Cambridge: Polity Press.

Grossman, Andrew D. 2001. *Neither Dead nor Red: Civilian Defense and American Political Development During the Early Cold War*. New York ; London: Routledge.

Guillory, John. 2004. "The Memo and Modernity." *Critical Inquiry* 31 (1): 108–32. https://doi.org/10.1086/427304.

Hables Gray, Chris. 1997. *Postmodern War: The New Politics of Conflict*. London: Routledge.

Hacking, Ian. 1979. "Michel Foucault's Immature Science." *Noûs* 13 (1): 39–51. https://doi.org/10.2307/2214794.

Halpern, Orit. 2015. *Beautiful Data: A History of Vision and Reason Since 1945*. Durham: Duke University Press Books.

Haraway, Donna. 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14 (3): 575–99. https://doi.org/10.2307/3178066.

Harding, Sandra. 1991. *Whose Science? Whose Knowledge?: Thinking from Women's Lives*. Ithaca, N.Y: Cornell University Press.

Hecht, Gabrielle, Ruth Oldenziel, Suzanne Moon, Donna C. Mehos, and Itty Abraham. 2011. *Entangled Geographies: Empire and Technopolitics in the Global Cold War*. Cambridge, MA: MIT Press.

Helmer-Hirschberg, Olaf. 1963. "The Systematic Use of Expert Judgment in Operations Research." RAND Paper P-2795. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/papers/P2795.html.

Henry, Lehman L. 1970. "Review of the First Half of Commando Hunt Operations 29 October Through 24 February 1970." Working Paper 2-70. San Francisco, California: Scientific Advisory Group. Record Group 38: Records of the Office of the Chief of Naval Operations, 1875 - 2008; Series: Technical Memoranda and Working Papers 1965-1974 (Box 1); File: "WP2-70: Review of the First Half of Commando Hunt III Operations, 29 Oct - 24 Feb 1970 (Mar 1970)". National Archives at College Park - Textual Reference(RDT2).

Hicks, Mar. 2018. *Programmed Inequality: How Britain Discarded Women Technologists and Lost Its Edge in Computing*. The MIT Press.

Hitch, Charles. 1960. "Uncertainties in Operations Research." P-1959. Santa Monica, California: RAND Corporation. https://apps.dtic.mil/docs/citations/AD0613003.

Hitch, Charles Johnston. 1955. "An Appreciation of Systems Analysis." Memorandum P699. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/papers/P699.html.

Hoag, Malcolm W. 1956. "An Introduction to Systems Analysis." Memorandum RM-1678-PR. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/research_memoranda/RM1678.html.

HQ 25th NORAD Region. 1962. "NORADR 25NR SUP 55-25(S). Operations: Kill Probability Factors." 55-25. McCord Air Force Base, Washington: United States Air Force. Record Group 334: Records of Interservice Agencies, 1916-2004; Series: General and Special Orders, Rescinded or Superseded Publications, and General Administrative Files, 1/30/1959-1/3/1966 (Box 7). National Archives at College Park.

HQ 7th Air Force. 1970. "Commando Hunt III." DOA 70-300. HQ 7th Air Force. Glenn Helm Collection, (Box 6, Folder 5). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/87642.

———. 1971. "Commando Hunt V." HQ 7th Air Force. Glenn Helm Collection, (Box 6, Folder 4). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/87127.

Hughes, Thomas P. 1979. "The Electrification of America: The System Builders." *Technology and Culture* 20 (1): 124–61. https://doi.org/10.2307/3103115.

———. 2000. *Rescuing Prometheus: Four Monumental Projects That Changed the Modern World*. New York: Vintage.

Hutchby, Ian. 2016. "Technologies, Texts and Affordances:" *Sociology*, July. https://doi.org/10.

1177/S0038038501000219.

Israel, D. R. 1965. “System Design and Engineering for Realtime Military Data Processing Systems.” Fort Belvoir, VA: Defense Technical Information Center. https://doi.org/10.21236/AD0610392.

Jacobs, J. F. 1983. “SAGE Overview.” *Annals of the History of Computing* 5 (4): 323–29. https://doi.org/10.1109/MAHC.1983.10101.

Johnston, John. 1999. “Machinic Vision.” *Critical Inquiry* 26 (1): 27–48. https://doi.org/10.1086/448951.

Jones-Imhotep, Edward. 2017. *The Unreliable Nation: Hostile Nature and Technological Failure in the Cold War*. Cambridge, Massachusetts: MIT Press.

Kafka, Ben. 2012. *The Demon of Writing: Powers and Failures of Paperwork*. New York: Zone Books - MIT.

Kahn, Herman. 1960. “The Nature and Feasibility of War and Deterrence.” Paper P-1888-RC. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/papers/P1888.html.

Kahn, Herman, and Irwin Mann. 1956. “Techniques of Systems Analysis.” Product Page. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/research_memoranda/RM1829-1.html.

———. 1957. “Ten Common Pitfalls.” RM-1937-PR. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/research_memoranda/RM1937.html.

Keller, Evelyn Fox. 1995. *Refiguring Life: Metaphors of Twentieth-Century Biology*. New York: Wellek Library lecture series at the University of California, Irvine.

Kennedy, John L. 1949. “Handbook of Human Engineering Data for Design Engineers.” Technical Report SDC 199-1-1. Medford, Mass.: Tufts College, Institute for Applied Experimental Psychology. http://hdl.handle.net/2027/mdp.39015082463335.

———. 1951. “Handbooks of Human Engineering Data.” *Annals of the New York Academy of Sciences* 51 (7): 1135–45. https://doi.org/10.1111/j.1749-6632.1951.tb27341.x.

———. 1952. “The Uses and Limitations of Mathematical Models, Game Theory and Systems Analysis in Planning and Problem Solution.” Address P-266. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/papers/P266.html.

Kennedy, John L., and Robert Chapman. 1955. “The Background and Implications of the Systems Research Laboratory Studies.” Memorandum p-740. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/papers/P740.html.

Kline, Ronald R. 2015. *The Cybernetics Moment, or, Why We Call Our Age the Information Age*. New Studies in American Intellectual and Cultural History. Baltimore, Maryland: Johns Hopkins University Press. http://site.ebrary.com/lib/uon/Doc?id=11062673.

Lambert, Col. Floyd A. 1949. “The Air Defense of the United States.” *The Antiaircraft Journal* 92 (5, September-October 1949). http://www.dtic.mil/dtic/tr/fulltext/u2/a509811.pdf.

Latour, Bruno. 1979. *Laboratory Life: The Social Construction of Scientific Facts*. Beverly Hills; London: Sage Publications.

———. 1988. “Mixing Humans with Non-Humans: Sociology of a Door-Closer.” *Social Problems* 35: 298–310. http://www.bruno-latour.fr/node/279.html.

———. 1991. "Technology Is Society Made Durable." In *A Sociology of Monsters: Essays on Power, Technology, and Domination*, edited by John Law. Routledge.

Law, John. 1987. "On the Social Explanation of Technical Change: The Case of the Portuguese Maritime Expansion." *Technology and Culture* 28 (2): 227–52. https://doi.org/10.2307/3105566.

———. 2002. *Aircraft Stories: Decentering the Object in Technoscience*. Durham, NC: Duke University Press.

———. 2007. "Actor Network Theory and Material Semiotics." http://www.heterogeneities.net/publications/Law2007ANTandMaterialSemiotics.pdf.

———. 2008. "On Sociology and STS." *The Sociological Review* 56 (4): 623–49. https://doi.org/10.1111/j.1467-954X.2008.00808.x.

Law, John, and Michel Callon. 1992. "The Life and Death of an Aircraft: A Network Analysis of Technical Change." In *Shaping Technology/Building Society: Studies in Sociotechnical Change*, edited by Wiebe E Bijker and John Law. Inside Technology. Cambridge, MA: MIT Press.

Layton, Bruce P. 1972. "Project CHECO Southeast Asia Report. Commando Hunt VI." Project CHECO. PACAF Hickam AFB HI CHECO Division. http://www.dtic.mil/docs/citations/ADA486568.

Lee, Min Kyung. 2018. "Understanding Perception of Algorithmic Decisions: Fairness, Trust, and Emotion in Response to Algorithmic Management." *Big Data & Society* 5 (1): 2053951718756684. https://doi.org/10.1177/2053951718756684.

Licklider, J. C. R. 1960. "Man-Computer Symbiosis." *Human Factors in Electronics, IRE Transactions on* HFE-1 (1): 4–11. https://doi.org/10.1109/THFE2.1960.4503259.

Licklider, J.C.R. 1963. "The System System." In *Human Factors in Technology*, edited by Edward M. Bennett. New York: McGraw Hill. http://archive.org/details/humanfactorsinte00benn.

Light, Jennifer S. 2003. *From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War America*. Baltimore, Md.; London: Johns Hopkins University Press. http://site.ebrary.com/lib/uon/Doc?id=10070308.

Linsenmayer, Roy F., and Charles E. Thompson. 1967. "Aircraft Attrition Estimates for Certain Proposed Operations." Study 8-67. San Francisco, California: Headquarters of the Commander in Chief Pacific, Scientific Advisory Group. Record Group 38: Records of the Office of the Chief of Naval Operations, 1875 - 2008; Series: Technical Memoranda and Working Papers 1965-1974 (Box 1); File: "SAGS8-67: Aircraft Attrition Estimates for Certain Proposed Operations (Jun 1967)". National Archives at College Park.

MacKenzie, Donald A. 1990. *Inventing Accuracy: An Historical Sociology of Nuclear Missile Guidance*. Inside Technology. Cambridge, MA; London, England: MIT Press.

Marzocco, F.N. 1956. "The Story of SDD." Internal History SD-1094. Some Documents of Historical Interest: A Part of SDC's History 1950-1957. Santa Monica, California: RAND Corporation. Bitsavers. http://bitsavers.informatik.uni-stuttgart.de/pdf/sdc/sage/SDC_Documents_1950-1957.pdf.

McEnaney, Laura. 2000. *Civil Defense Begins at Home: Militarization Meets Everyday Life in the Fifties*. Politics and Society in Twentieth-Century America. Princeton, N.J. ; Oxford: Princeton University Press.

McMullen, Richard F. 1965. "Command and Control Planning 1958-1965." Historical Study 35. Air Defense Command, United States Air Force. https://www.northcom.mil/Portals/28/Paper%20No%2035%20Command%20and%20Control%20Planning,%201958-1965%20Full%

20Release.pdf?ver=2017-03-16-115751-207.

Medina, Eden. 2011. *Cybernetic Revolutionaries: Technology and Politics in Allende's Chile*. Cambridge, MA: MIT Press.

Mindell, David A. 2002. *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics*. Johns Hopkins Studies in the History of Technology. Baltimore: Johns Hopkins University Press. http://site.ebrary.com/lib/uon/Doc?id=10021657.

Mirowski, Philip. 2002. *Machine Dreams: Economics Becomes a Cyborg Science*. Cambridge: Cambridge University Press.

National Security Council. 1950. "United States Objectives and Programs for National Security." NSC-68. Washington, D.C.: National Security Council. History and Public Policy Program Digital Archive, US National Archives. http://digitalarchive.wilsoncenter.org/document/116191.

Newlands, E., and G. L. Grace. 1963. "Computer-Based Methodology for System Development Site Production and Reduction System." Santa Monica, California: System Development Corporation. https://apps.dtic.mil/seo/citations/AD0403384.

Noble, David F. 2011. *Forces of Production: A Social History of Industrial Automation*. New Brunswick, N.J: Transaction Publishers.

NPIC. 1966. "Glossary of NPIC Terminology." Glossary NPIC/R-176/66. National Photographic Interpretation Centre, CIA. https://www.cia.gov/library/readingroom/document/cia-rdp78b04560a005200010063-2.

Packer, Jeremy. 2010. "What Is an Archive?: An Apparatus Model for Communications and Media History." *The Communication Review* 13 (1): 88–104. https://doi.org/10.1080/10714420903558720.

———. 2013. "Screens in the Sky: SAGE, Surveillance, and the Automation of Perceptual, Mnemonic, and Epistemological Labor." *Social Semiotics* 23 (2): 173–95. https://doi.org/10.1080/10350330.2013.777590.

———. 2016. "Abstract Materialism: Peter Galison Discusses Foucault, Kittler, and the History of Science and Technology," 14.

Packer, Jeremy, and Josh Reeves. 2013. "Romancing the Drone: Military Desire and Anthropophobia from SAGE to Swarm." *Canadian Journal of Communication* 38 (3). https://doi.org/10.22230/cjc.2013v38n3a2681.

Parks, Lisa, and Caren Kaplan, eds. 2017. *Life in the Age of Drone Warfare*. Durham; London: Duke University Press Books.

Parsons, Henry M., and William E. Perry. 1965. "Concepts for Command and Control Systems." Santa Monica, California: System Development Corporation. https://apps.dtic.mil/seo/citations/AD0479368.

Peters, Benjamin. 2016. *How Not to Network a Nation: The Uneasy History of the Soviet Internet*. Cambridge, MA: MIT Press.

Pinch, Trevor J., and Wiebe E. Bijker. 1984. "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science* 14 (3): 399–441. https://www.jstor.org/stable/285355.

Pollard, Tom, Marvin Reimer, David San, Arco Mul, Matthew Gwynfryn Thomas, Jakub Nowosad, Dennis Weissmann, and W. Caleb McDaniel. 2016. *Template for Writing a PhD Thesis in Markdown*. Zenodo. https://doi.org/10.5281/zenodo.58490.

Porter, Capt. Melvin F. 1966. “Night Interdiction in Southeast Asia - Continuing Report.” 154. Project CHECO Southeast Asia Report. HQ PACAF, Directorate, Tactical Evaluation, CHECO Division. Contemporary Historical Examination of Current Operations (CHECO) Reports of Southeast Asia, 1961-1975 (Box 46, Folder 462). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/553306.

Porter, Elias H. 1967. “A Paradigm for System Analysis of Comand and Control Functions.” In *Psychological Research in National Defense Today*, 279–86. S-1. Washington: U.S. Army Beheavioral Science Research Academy. http://hdl.handle.net/2027/mdp.39015031996989.

Porter, Melvin F. 1969. “Project CHECO Southeast Asia Continuing Report: Control of Airstrikes, January 1967-December 1968.” DOTEC-69-53. Project CHECO Southeast Asia Report. HQ PACAF, Directorate, Tactical Evaluation, CHECO Division. Jan Churchill Collection (Box 1, Folder 11). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/504081.

Project Charles. 1951. “Problems of Air Defense: Final Report of Project Charles, Volume I.” Cambridge, MA: Massachusetts Institute of Technology. http://www.dtic.mil/docs/citations/ADA800165.

Qaurooni, Danial, and Hamid Ekbia. 2017. “The ‘Enhanced’ Warrior: Drone Warfare and the Problematics of Separation.” *Phenomenology and the Cognitive Sciences* 16 (1): 53–73. https://doi.org/10.1007/s11097-016-9481-z.

Quinlan, Andrea. 2014. “Imagining a Feminist Actor-Network Theory.” *International Journal of Actor-Network Theory and Technological Innovation* 4 (August): 1–9. https://doi.org/10.4018/jantti.2012040101.

RAND. 1956. “RAND SDD Newsletters.” RAND Corporation. Bitsavers. http://www.bitsavers.org/pdf/sdc/sage/RAND_SDD_Newsletters_1956.pdf.

Rathjens, G. W., H. W. Bode, P. J. Schweitzer, J. C. Armstrong, A. L. Bottoms, and L Wainstein. 1966. “A Study of Data Related to Viet Cong/North Vietnamese Army Logistics and Manpower.” Institute for Defense Analyses. Larry Berman Collection (Presidential Archives Research) (Box 5, Folder 3). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/117993.

Redmond, Kent C, and Thomas M. Smith. 2000. *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer*. History of Computing. Cambridge, MA; London, England: MIT Press.

Renshaw, J. R., and Annette Heuston. 1957. “The Game Monopologs.” Product Page. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/research_memoranda/RM1917-1.html.

Rohde, Joy. 2013. *Armed with Expertise: The Militarization of American Social Research During the Cold War*. American Institutions and Society. Ithaca, NY: Cornell University Press.

Rome, Beatrice. 1961. “System Training and the System Training Operations Department.” Technical Memorandum TM-618. TM Series. Santa Monica, California: RAND Corporation. Record Group 333: Records of International Military Agencies, 1941-2003; Series: Records Relating to the Semi-Automatic Ground Environment/Backup Intercept Control System (SAGE/BUIC), 1961-1981 (Box 1); File: “TM - 618, 25 Apr 61, System Training and the System Training Operations Department”. National Archives at College Park.

Roper, John E. 1966a. “Effectiveness of Steel Tiger Program.” Working Paper 5-66. San Francisco, California: Headquarters of the Commander in Chief Pacific, Scientific Advisory Group. Record Group 38: Records of the Office of the Chief of Naval Operations, 1875 - 2008; Series: Technical Memoranda and Working Papers 1965-1974 (Box 1); File: “WP5-66: Effectiveness of

Steel Tiger Program (Jan 1966)". National Archives at College Park - Textual Reference(RDT2).

———. 1966b. "Real Time Air Interdiction System (RETAINS)." Working Paper 14-66. San Francisco, California: Headquarters of the Commander in Chief Pacific, Scientific Advisory Group. Record Group 38: Records of the Office of the Chief of Naval Operations, 1875 - 2008; Series: Technical Memoranda and Working Papers 1965-1974 (Box 1); File: "WP14-66: Real-Time Air Interdiction System (RETAINS) (May 1966)". National Archives at College Park.

Roper, John E., and Alfred V. Chow. 1966. "Real Time Reporting of Location of Vehicular Traffic." Working Paper 7-66. San Francisco, California: Headquarters of the Commander in Chief Pacific, Scientific Advisory Group. Record Group 38: Records of the Office of the Chief of Naval Operations, 1875 - 2008; Series: Technical Memoranda and Working Papers 1965-1974 (Box 1); File: "WP7-66: Real-Time Reporting of Location of Vehicular Traffic (Jan 1966)". National Archives at College Park.

Roper, John E., and Roy F. Linsenmayer. 1966. "Effectiveness of Barrel Roll/Steel Tiger October 1965 Through January 1966." Working Paper 9-66. San Francisco, California: Headquarters of the Commander in Chief Pacific, Scientific Advisory Group. Record Group 38: Records of the Office of the Chief of Naval Operations, 1875 - 2008; Series: Technical Memoranda and Working Papers 1965-1974 (Box 1); File: "WP9-66: Effectiveness of Barrel Roll and Steel Tiger, October 1965 through January 1966 (Feb 1966)". National Archives at College Park.

Schaffel, Kenneth. 1991. *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense, 1945-1960.* Office of Air Force History, United States Air Force.

Schlosser, Eric. 2013. *Command and Control.* Penguin Random House.

Schwartz, Dr. Robert. 1968. "Steel Tiger (Laos) Monthly Interdiction Analysis (Muscle Shoals)." Working Paper 68/1-3. Saigon, Vietnam: Office of Operations Analysis, HQ 7th Air Force. Contemporary Historical Examination of Current Operations (CHECO) Reports of Southeast Asia, 1961-1975 (Box 42, Folder 773). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/552715.

Schwartz-Cowan, Ruth. 1999. "How the Refrigerator Got Its Hum." In *The Social Shaping of Technology*, edited by Donald A. MacKenzie and Judy Wajcman. Buckingham: Open University Press.

Schweitzer, P. J. 1966. "Description of the Ho Chi Minh Trail." IHDA/HQ-STAFF STUDY-125. Alexandria, Virginia: Institute for Defense Analyses, Weapons Systems Evaluation Division. http://www.dtic.mil/docs/citations/ADC007412.

SDC. n.d. "Simulation of ECM/ECCM at SAGE Direction Centres (and Its Value in Training Air Defense Crews)." SPC Briefing 2396. System Development Corporation. Record Group 333: Records of International Military Agencies, 1941-2003; Series: Records Relating to the Semi-Automatic Ground Environment/Backup Intercept Control System (SAGE/BUIC), 1961-1981 (Box 11, Folder "SDC 2396 Briefing: Simulation of ECM/ECCM at SAGE Direction Centers"). National Archives at College Park.

SDD. 1957. "Implementation of SAGE System Training Program." Staff Study. Santa Monica, California: System Development Division, The RAND Corporation. CBI 90, Burroughs System Develoment Corporation (Box 19, Folder 21). Charles Babbage Institute, University of Minneapolis.

Shane, Scott, and Daisuke Wakabayashi. 2018. "'The Business of War': Google Employees Protest Work for the Pentagon." *The New York Times*, April 4, 2018, sec. Technology. https://www.nytimes.com/2018/04/04/technology/google-letter-ceo-pentagon-project.html.

Shannon, C. E. 2001. "A Mathematical Theory of Communication." *ACM SIGMOBILE Mobile Computing and Communications Review* 5 (1): 3. https://doi.org/10.1145/584091.584093.

Shaw, Ian G. R. 2016a. "Scorched Atmospheres: The Violent Geographies of the Vietnam War and the Rise of Drone Warfare." *Annals of the American Association of Geographers* 106 (3): 688–704. https://doi.org/10.1080/00045608.2015.1115333.

———. 2016b. *Predator Empire: Drone Warfare and Full Spectrum Dominance.* Minneapolis: Univ Of Minnesota Press.

Shields, Capt. Henry S. 1971. "Continuing Report: Igloo White - January 1970-September 1971." 119. Project CHECO. HQ PACAF, Directorate of Operations Analysis, CHECO/CORONA HARVEST DIVISION. Contemporary Historical Examination of Current Operations (CHECO) Reports of Southeast Asia, 1961-1975s (Box 16, Folder 94). The Vietnam Center and Archive, Texas Tech University. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/545222.

Simmons, R. F. 1965. "Natural Language Processing and the Timeshared Computer." Santa Monica, California: System Development Corporation. https://apps.dtic.mil/sti/citations/AD0618531.

Sismondo, Sergio. 2010. *An Introduction to Science and Technology Studies.* Chichester: Wiley-Blackwell. https://ebookcentral.proquest.com/lib/nottingham/detail.action?docID=470731.

Slayton, Rebecca. 2013. *Arguments That Count: Physics, Computing, and Missile Defense, 1949-2012.* Cambridge, MA: MIT Press. http://site.ebrary.com/lib/uon/Doc?id=10747530.

Starbird, Lt. Gen. Alfred D. 1966. "Memorandum for the Secretary of the Army: Request for Accomplishment of JTF 728 Task (C.) on Defoliant." Tasking Memorandum TM 200 - 4/7. Defense Communications Planning Group. Record Group 330: Defense Special Projects Group Files; Series: General Files of the Logistics Support Division, 1966-1972 (Box 1, Folder 17). National Archives at College Park.

———. 1967a. "Memorandum for the Secretary of the Army: Request for Accomplishment of JTF 728 Task (C.) (TM700A-1.2/4 Ecological Considerations)." Tasking Memorandum TM700A-1.2/4. Defense Communications Planning Group. Record Group 330: Defense Special Projects Group Files; Series: General Files of the Logistics Support Division, 1966-1972 (Box 1, Folder 7). National Archives at College Park.

———. 1967b. "Memorandum for the Secretary of the Army, Navy, and Air Force: Request for Accomplishment of JTF 728 Task (C.)." Tasking Memorandum TM700A-12/5. Defense Communications Planning Group. Record Group 330: Defense Special Projects Group Files; Series: General Files of the Logistics Support Division, 1966-1972 (Box 1, Folder 5). National Archives at College Park.

———. 1967c. "Memorandum for the Secretary of the Air Force: Change Order 'A' to Request for Accomplishment of JTF 728 Task (TM 200A-1.2.2/4 Surveillance Aircraft, Drone)(C)." Tasking Memorandum TM700A-1.2.2/4A. Defense Communications Planning Group. Record Group 330: Defense Special Projects Group Files; Series: General Files of the Logistics Support Division, 1966-1972 (Box 1, Folder 10). National Archives at College Park.

Steedman, Carolyn. 2001. *Dust.* Manchester University Press.

Stengers, Isabelle. 2000. *Invention of Modern Science.* Minneapolis: Univ Of Minnesota Press.

Stromquist, R., and L. Robertson. 1962. "Description of Automatic Umpiring." Note N-SW-114. Santa Monica, California: System Development Corporation. Record Group 333: Records of International Military Agencies, 1941-2003; Series: Records Relating to the Semi-Automatic Ground Environment/Backup Intercept Control System (SAGE/BUIC), 1961-1981 (Box 11); File: "NOTE - N-SW-114, 14 Dec 1962, Description of Auto-Umpiring". National Archives at College Park.

Sturdevant, C. V. 1964. "The Border Control Problem in South Vietnam." Memorandum

RM-3967-ARPA. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/research_memoranda/RM3967.html.

Sturm, T. A. 1967. "The USAF Scientific Advisory Board: Its First Twenty Years. 1944-1964." Washington D.C.: Scientific Advisory Board (Air Force). http://www.dtic.mil/docs/citations/ADA954527.

Suchman, Lucy. 1987. *Plans and Situated Actions: The Problem of Human-Machine Communication*. Cambridge University Press.

———. 2002. "Located Accountabilities in Technology Production." *Scandinavian Journal of Information Systems* 14 (2). https://aisel.aisnet.org/sjis/vol14/iss2/7.

———. 2020. "Algorithmic Warfare and the Reinvention of Accuracy." *Critical Studies on Security* 8 (2): 175–87. https://doi.org/10.1080/21624887.2020.1760587.

Sullivan, Leonard. 1971. "Truck 'Killing' in the U.S. Interdiction Campaign." Memorandum 71-3574. Washington, D.C.: Office of the Director of Defense Research and Engineering. Record Group 472: Records of the U.S. Forces in Southeast Asia, 1950 - 1976; Series: Secret Classified Registered Documents Regarding Orders of Battle in Southeast Asia 8/1965 - 1/1973 (Box 3); File: "502-02 MACDI 31-2 D3361/71 Commando Hunt VII". National Archives at College Park.

System Development Corporation. 1957. "News Release." RAND Corporation. Bitsavers. http://bitsavers.informatik.uni-stuttgart.de/pdf/sdc/sage/SDC_Documents_1950-1957.pdf.

Task Force Alpha. 1972. "LOC Status and Logistics Flow." Nakhon Phanom, Thailand: Task Force Alpha. Record Group 472: Records of the U.S. Forces in Southeast Asia, 1950 - 1976; Series: Secret Classified Registered Documents Regarding Orders of Battle in Southeast Asia 8/1965 - 1/1973 (Box 9); File: "502-02 MACDI 31-2 4058/72 LOC Status and Logistics Flow, Laos+ Cambodia". National Archives at College Park.

Taylor, Adam. 2019. "Amid Tension with Iran, U.S. Air Force Shifts Middle East Command Center from Qatar to South Carolina." Washington Post. September 29, 2019. https://www.washingtonpost.com/world/middle_east/amid-tension-with-iran-us-air-force-shifts-middle-east-command-center- from-qatar-to-south-carolina/2019/09/29/67d93834-e216-11e9-be7f-4cc85017c36f_story.html.

Taylor, Frederick Winslow. 2003. *The Principles of Scientific Management*. Mineola, N.Y.: Dover Publications.

TFA. 1972. "NVA Logistics System in Steel Tiger." Nakhon Phanom, Thailand: Task Force Alpha. Record Group 472: records of the U.S. Forces in Southeast Asia, 1950-1976. Series: Secret Classified Registered Documents Regarding Orders of Battle in Southeast Asia 8/1965-1/1973, (Box 11); File "502-02 MACDI 31-2 4739/72". National Archives at College Park.

———. n.d. "Aerial View–Working at Task Force Alpha and Planes on Bombing Runs on Ho Chi Minh Trail." Steve Umland Collection. VA067827. The Vietnam Center and Archive, Texas Tech University. Accessed July 27, 2020. https://vva.vietnam.ttu.edu/repositories/2/digital_objects/562086.

Thayer, Thomas C. 1975a. "A Systems Analysis View of the Vietnam War 1965 - 1972. Volume 3. Viet Cong - North Vietnamese Operations." Assistant Secretary of Defense (Systems Analysis). https://apps.dtic.mil/docs/citations/ADA039314.

———. 1975b. "A Systems Analysis View of the Vietnam War: 1965-1972. Volume 5. The Air War." 5. A Systems Analysis View of the Vietnam War: 1965-1972. Assistant Secretary of Defense (Systems Analysis). https://apps.dtic.mil/docs/citations/ADA051611.

The Campaign To Stop Killer Robots. 2020. "The Threat of Fully Autonomous Weapons." 2020.

https://www.stopkillerrobots.org/learn/.

Thomas, William. 2015. *Rational Action: The Sciences of Policy in Britain and America, 1940-1960*. Transformations: Studies in the History of Science and Technology. Cambridge, MA: Massachusetts Institute Technology. https://ebookcentral.proquest.com/lib/nottingham/detail.action?docID=3339970.

Thompson, Charles E. 1966. "Effectiveness of Laos Interdiction Programs December 1965 Through March 1966." Working Paper 13-66. San Francisco, California: Headquarters of the Commander in Chief Pacific, Scientific Advisory Group. Record Group 38: Records of the Office of the Chief of Naval Operations, 1875 - 2008; Series: Technical Memoranda and Working Papers 1965-1974 (Box 1); File: "WP13-66: Effectiveness of Laos Interdiction Programs December 1965 through March 1966 (April 1966)". National Archives at College Park.

Tropp, Henry S. 1983. "A Perspective on SAGE: Discussion." *Annals of the History of Computing* 5 (4): 375–98. https://doi.org/10.1109/MAHC.1983.10091.

Turner, Fred. 2008. *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism*. London: University of Chicago Press. https://fredturner.stanford.edu/books/from-counterculture-to-cyberculture/.

Twomey, Christopher P. 1999. "The McNamara Line and the Turning Point for Civilian Scientist-Advisers in American Defence Policy, 1966-1968." *Minerva* 37 (3): 235–58. https://doi.org/10.1023/A:1004741523654.

Ulmann, Bernd, Gerhard Pappert, and Ron Brunell. 2014. *ANFSQ-7: The Computer That Shaped the Cold War*. Munich, Germany: De Gruyter Oldenbourg. http://site.ebrary.com/id/11004480.

United States Air Force. 1964. "Project Forecast: Data Processing and Display Report." SCGF-64-11. Project Forecast. United States Air Force. Bernard A Schriever papers, 1931-2005; Series: Military Papers, 1931-1977 (Box 22, Folder 1). Library of Congress. https://lccn.loc.gov/mm2005085217.

Valley, Jr. 1985. "How the SAGE Development Began." *Annals of the History of Computing* 7 (3): 196–226. https://doi.org/10.1109/MAHC.1985.10030.

Van Vleck, Jenifer. 2013. *Empire of the Air: Aviation and the American Ascendancy*. https://ebookcentral.proquest.com/lib/nottingham/detail.action?docID=3301344.

Virilio, Paul. 2005. *Desert Screen: War at the Speed of Light*. London New York: Continuum.

———. 2009. *War and Cinema: The Logistics of Perception*. London New York: Verso Books.

Virilio, Paul, and Sylvère Lotringer. 2006. *Speed and Politics*. Los Angeles, CA: Semiotexte.

Wainstein, L, C.D. Cremeans, J.K. Moriarty, and J Ponturo. 1975. "The Evolution of U.S. Strategic Command and Control and Warning. 1945-1972." S-467. Virginia: Institute for Defense Analyses: International and Social Studies Division. Record Group 408, Nuclear Weapons Secrets (Chuck Hansen Collection), (Box 70). National Security Archive, Washington D.C.

Waldrop, M. Mitchell. 2018. *The Dream Machine*. Stripe Press.

"War Department Thinking on the Atomic Bomb." 1947. *Bulletin of the Atomic Scientists* 3 (6): 150–68. https://doi.org/10.1080/00963402.1947.11455876.

Ware, Willis H. 1954. "The Digital Computer: Where Does It Go from Here?" Paper P-608. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/papers/P608.html.

Washington Air Defense Sector. 1962. "Washington Air Defense Sector (WAADS) Regulation

11-2, Illustration Work Orders, 22 October 1964." Record Group 342: Records of U.S. Air Force Commands, Activities, and Organizations, 1900 - 2003; Series: Headquarters Publications Record Set, 11/12/1958 - 1/4/1966 (Box 1, Folder "WAADS Regulation 11-2 (1964)"). National Archives at College Park, College Park, MD.

Weinberger, Sharon. 2017. *The Imagineers of War.* New York: Penguin Random House.

Weiner, Milton G. 1959. "War Gaming Methodology." Memorandum RM-2413. Project SIERRA. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/research_memoranda/RM2413.html.

White, Hayden V. 1973. "Foucault Decoded: Notes from Underground." *History and Theory* 12 (1): 23–54. https://doi.org/10.2307/2504692.

Winner, Langdon. 1977. *Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought.* Cambridge, MA: MIT Press.

———. 1993. "Upon Opening the Black Box and Finding It Empty: Social Constructivism and the Philosophy of Technology." *Science, Technology, & Human Values* 18 (3): 362–78. https://www.jstor.org/stable/689726.

Wohlstetter, Roberta M. 1965. "Cuba and Pearl Harbor: Hindsight and Foresight." Memorandum RM-4328-ISA. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/research_memoranda/RM4328.html.

Work, Robert O. 2017. "Establishment of an Algorithmic Warfare Cross-Functional Team (Project Maven)." 1010 Defense Pentagon Washington, DC 20301-1010: Department of Defense. https://dodcio.defense.gov/Portals/0/Documents/Project%20Maven%20DSD%20Memo%2020170425.pdf.

Yates, JoAnne. 1990. *Control Through Communication : The Rise of System in American Management.* Series: Studies in Industry and Society. Baltimore, Md.: Johns Hopkins University Press.

Zasloff, Joseph Jeremiah. 1964. "The Role of North Vietnam in the Southern Insurgency." RM-4140-PR. Santa Monica, California: RAND Corporation. https://www.rand.org/pubs/research_memoranda/RM4140.html.

Zegart, Amy. 2012. "The Cuban Missile Crisis as Intelligence Failure." *Policy Review*, no. 175: 23–39. http://search.proquest.com/docview/1115478156/?pq-origsite=primo.