The London School of Economics and Political Science

Innovation, technology and security: the emergence of Unmanned Aerial Vehicles before and after 9/11

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Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

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Abstract

This thesis addresses the relationship between military technological innovation and evolving practices of security before and after 9/11 through the case of unmanned aerial vehicle (UAV) technology and particularly the UAV lineage associated with the General Atomics Predator system.

Through the case of UAV development the thesis contributes to wider theoretical debates regarding military innovation and weapons acquisition processes. The case illustrates that rather than a moment, innovation is better understood as a process. Rather than linear, however, the process is uncertain, involving complex interactions between institutional pressures, technological development and external events.

The thesis presents UAV development in terms of 'statuses' of marginality, emergence and assimilation. Establishing the long UAV development history in the US, the thesis explores military innovation theory to consider the reasons for their long Cold War marginality, despite repeated efforts. It then considers the emergence of UAVs in the early post-Cold war period, focusing particularly on the design iterations that yielded the Predator and the bureaucratic political processes through which that system was fielded. Thirdly, the progressive assimilation of Predator is addressed in relation to the growing threat of terrorist networks, and the post-9/11 attempt to reorient existing military and intelligence capabilities to counter terrorism and counter insurgency operations. This raises the question of the relation between technological innovation and the security 'pathways' opened up after 9/11, the extent that 9/11 provided a window of opportunity for drone assimilation, and the role of drones in shaping the emergence of a technologically-enabled, remote approach to counter terrorism and military intervention.

Table of Contents

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Acronyms

A2/AD – Anti-access/Area Denial

ABM – Anti-Ballistic Missile Treaty

ACC – Air Combat Command, US Air Force

ACTD – Advanced Concept Technology Demonstration

AFMC – Air Force Materiel Command

AFRICOM – United States Africa Command

AFSOC – Air Force Special Operations Command

AI – Artificial Intelligence

ARSP – Airborne Reconnaissance Support Program

APKWS – Advanced Precision Kill Weapon System

APL – Applied Physics Lab (Johns Hopkins University)

AQ – al Qaeda

AQAP – al Qaeda in the Arabian Peninsula

AQI – al Qaeda in Iraq

ARPA – Advanced Research Projects Agency (subsequently DARPA)

ARSP – Airborne Reconnaissance Support Program

ASW – Anti-Submarine Warfare

AV – Air Vehicle

AVSCOM – Aviation Command (US Army)

B-2 – manned stealthy long range bomber

BDA – Battle Damage Assessment

BLACS – Barometric Low Altitude Control System

CAOC – Combined Air Operations Center

CAP – Combat Air Patrol

CENTCOM – United States Central Command

CEO – Chief Executive Officer

C4ISR – Command, control, communications, computers, information, surveillance and reconnaissance

CIA – Central Intelligence Agency

CNAS – Center for a New American Security

COIN – Counter-insurgency

COMINT – Communications intelligence

COMSAT – Communications Satellite

CONOPS – Concept of Operations

COTS – Commercial off-the-shelf

CR – Close Range (UAV)

CSG – Counterterrorism Security Group

CT – Counter Terrorism

CTC – Counter Terrorism Center (at the CIA)

CTOL – Conventional Take-off and Landing

DAB – Defense Acquisition Board

DAIP – Defense Acquisition Improvement Program

DARO – Defense Airborne Reconnaissance Office

DARPA – Defense Advanced Research Projects Agency

DCGS – Distributed Common Ground System

DDO – Deputy Director of Operations (CIA)

DDR&E – Director of Defense for Research and Engineering

DEAD – Destruction of Enemy Air Defences

DIA – Defense Intelligence Agency

DMZ – Demilitarized Zone (Vietnam)

DoD – Department of Defense

DSARC – Defense Systems Acquisition Review Council

DSB – Defense Science Board

DTIC – Defense Technical Information Center

EAIS – Expeditionary Air Intelligence Squadron

ECM – Electronic Countermeasures

ELINT – Electronic Intelligence

ELTAS – Elevated Target Acquisition System

EO – Electro-optical

EO – Executive Order

ERADCOM CSTA – Electronics Research and Development Command Combat Surveillance and Target Acquisition (US Army)

ESM – Electronic Support Measures

FAC – Forward Air Controller

F3EAD – Find, Fix, Finish, Exploit, Analyze, Disseminate

FAC – Forward Air Controller

FATA – Federally Administered Tribal Areas (Pakistan)

FBM – Fleet Ballistic Missiles

FLIR – Forward Looking Infrared

FLOT – Forward Line of Own Troops

FMV – Full motion video

FOIA – Freedom of Information Act

FSD – Full Scale Development

FY – Fiscal Year

GA – General Atomics

GA-ASI – General Atomics Aeronautical System Incorporated

GAO – General Accounting Office

GCS – Ground Control Station

GPS – Global Positioning System

GWOT – Global War on Terrorism

HAE – High Altitude Endurance

HALE – High Altitude Long Endurance

HD – High Definition

HUMINT – Human Intelligence

HVI – High Value Individual

HVT – High Value Target

IAI – Israeli Aircraft Industries

ICBM – Intercontinental Ballistic Missile

IMINT – Image intelligence

INF – Intermediate-Range Nuclear Forces Treaty

INS – Inertial Navigation System

ISI – Inter Services Intelligence (Pakistani intelligence agency)

ISR – Intelligence, Surveillance and Reconnaissance

IR – International Relations

JCS – Joint Chiefs of Staff

JDAM – Joint Direct Attack Munition

JFACC – Joint Forces Air Component Commander

JIEDDO – Joint Improvised Explosive Device Defeat Organization

JPEL – Joint Prioritized Effects List

JPO – Joint Projects Office

JPSD – Joint Precision Strike Demonstration

JROC – Joint Requirements Oversight Council

JSOC – Joint Special Operations Command

J-STARS – Joint Surveillance and Target Attack Radar System

LAMPS – Light Airborne Multi-Purpose System

LANDSS – Lightweight Advanced Night/Day Surveillance System

LARS – Laser Aided Rocket System

LRE – launch and recovery element

LSI – Leading Systems, Inc.

MACS – Multiple Altitude Control System

MAE – Medium Altitude Endurance

MALE – Medium Altitude Long Endurance

MANPRINT – Manpower and Personnel Integration (US Army human systems integration in acquisition)

MARS – Mid Air Retrieval System

MICNS - Modular Integrated Communications and Navigation System

MICOM – Missile Command (United States Army)

MLRS – Multiple Launch Rocket System

MNS – Mission Needs Statement

MOA – Memorandum of Agreement

MON – Memorandum of Notification

MOOTW – Military Operations Other Than War

MR – Medium Range (UAV)

MRAP – Mine Resistant Ambush Protected

MTI – Moving Target Indicator

MTS – Multi-Spectral Targeting System

NASA – National Aeronautics and Space Administration

NATO – North Atlantic Treaty Organisation

NAVAIR – Naval Air Systems Command

NAVSTAR – Navigation System using Timing and Ranging (see GPS)

NCTC – National Counter Terrorism Center

NGO – Non-Governmental Organisation

NIIRS – National Imagery Interpretability Rating Scale

NIMA - National Imagery and Mapping Agency

NRO – National Reconnaissance Office

NSA – National Security Agency

NSC – National Security Council

OEF – Operation Enduring Freedom

OIF – Operation Iraqi Freedom

OOTW – Operations Other Than War

OSD – Office of the Secretary of Defense

OTH – Over the Horizon

PED – Processing, Exploitation and Dissemination

PDD – Presidential Decision Directive

PLSS – Precision Locator Strike System

PPBS – Planning, Programming and Budgeting System

PSS – Persistent Surveillance Systems (company)

R&D – Research and Development

RDT&E – Research, Development, Test and Evaluation

ROVER – Remotely Operated Video Enhanced Receiver

RPA – Remotely Piloted Aircraft

RPAODS – Remotely Piloted Aerial Observation Designation System

RPV – Remotely Piloted Vehicle

RSO – Remote Split Operations

RSTA – Reconnaissance, Surveillance and Target Acquisition

SAC - Strategic Air Command

SALT – Strategic Arms Limitation Talks

SAR – Synthetic Aperture Radar

SATCOM – Satellite communications

SAM – Surface to Air Missile

SEAD – Suppression of Enemy Air Defences

SIGINT – Signals Intelligence

SOCOM – Special Operations Command

SOF – Special Operations Forces

SOUTHCOM – United States Southern Command

SPO – System Program Office

SR – Short Range (UAV)

SSB – Small Smart Bomb

STAR – Shipborne Tactical Aerial Reconnaissance system

STD – System Technology Demonstrator

STS – Science, Technology and Society Studies

TAC – Tactical Air Command (Air Force)

TARS – Target Acquisition Requirements Study (1969 US Army review)

TEOTA – The Eyes of the Army (1953 Army review of reconnaissance needs)

TRA – Teledyne Ryan Aeronautical

TRADOC – Training and Doctrine Command (US Army)

U-2 – Manned Spyplane

UAS – Unmanned Aircraft System

UAV – Unmanned Aerial Vehicle

UCAV – Unmanned Combat Aerial Vehicle

UHF – Ultra High Frequency

UN – United Nations

USAF – United States Air Force

USAFE – United States Air Forces Europe

USCS – United States Customs Service

USD/A – Under Secretary of Defense (Acquisition)

USMC – United States Marine Corps

USN – United States Navy

USSR – Union of Soviet Socialist Republics

VHF – Very High Frequency

VTOL – Vertical Take off and Landing

V/STOL – Vertical and/or short take off and landing

WMD – Weapons of Mass Destruction

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Page 93- image

1. Introduction

Diverse and far-reaching changes to US security practices were set in motion following the attacks of September 11th 2001, and the political imperative, articulated in response, to make war on terror. Many of these practices fit uneasily with earlier and still prevalent understandings of the character (if not nature) of war, who wages it, by what means and according to what territorial, legal and ethical limits. The war on terror has opened fundamental debates about the proper legal and moral limits upon state power to invade and occupy, surveil, detain and interrogate, and to hunt and kill. In the post-9/11 period, moreover, US political leaders have routinely adopted positions on these issues that were unthinkable on September 10th 2001. Amongst these far-reaching changes, the MQ-1 Predator unmanned aerial vehicle (and its larger more capable successor, the MQ-9 Reaper), and more precisely particular ways that this vehicle has been employed to hunt and kill suspected terrorists and insurgents, has been the subject of intense public debate and controversy. Meanwhile, some experts have suggested that the true significance of these vehicles lies less in their particular applications in the war on terror than in heralding the advent of a new era of unmanned military technology, and believe that unmanned systems are now set to start replacing manned systems – fighters and bombers in the air, boats and submarines at sea, and then land-based systems (Singer 2009). This thesis sets out to explain why and how the Predator lineage of systems developed and successfully advanced from experimental settings to operational use and came to be assimilated into military and intelligence organisations and their practices after 9/11.

Following the decision to declare a war on terror, the Bush administration found that its military was not only not optimised to respond to this political imperative, but simply had not been designed or built for such a task, and was conceptually, organisationally, technologically and culturally unprepared to make such a war. It may seem counter-intuitive to make such a claim given the expulsion of the Taliban regime from power in Afghanistan in the winter of 2001-2002 and the 2003 invasion of Iraq, both justified as campaigns in the war on terror and both making convincing claims to have been highly innovative in quite different ways. The war in Afghanistan entailed an unconventional combination of Central Intelligence Agency (CIA) and Special Forces personnel, the mobilisation of local opponents of the Taliban and provision of air support – an approach that has since been dubbed the

'Afghan model' (Biddle 2005; Andres et al 2006).[1] In comparison with Afghanistan, Iraq in 2003 (albeit crippled by sanctions) possessed a more conventional military apparatus modelled on western lines and equipped with expensive and sophisticated military hardware. Here the sweeping success of the United States-led invasion was initially and widely seen as showcasing the decisive advantages (at least for the purposes of defeating conventional state forces) of the military technological advances of the past decade, strengthening the hand of Defense Secretary Rumsfeld (although he was not its architect) and proponents of defense transformation.[2]

Yet, as critics pointed out at the time, neither war fully gained traction over al Qaeda, the enemy directly responsible for 9/11. Although there seems little dispute that al Qaeda sustained severe losses during the invasion of Afghanistan, Taliban and al Qaeda succeeded in slipping across the Durand line into the Pakistani Federally Administered Tribal Areas where, as is now well known, they then regrouped.[3] In the case of Iraq, no link was ever established between Saddam Hussein and his regime and al Qaeda, and the Anglo-American claim to have discovered evidence of a renewed Iraqi Weapons of Mass Destruction (WMD) program turned out to be, at best, incorrect. What is more, in the ensuing insurgency in Iraq there emerged a new and dangerous al Qaeda affiliate. While the invasions of Afghanistan and Iraq can be (and are being) productively studied in terms of the military innovation they demonstrated, they were both primarily interstate wars whose logic drove towards regime change and occupation. While perhaps reassuring American

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[1] Importantly, Mazzetti notes that although Defense Secretary Rumsfeld would receive public credit for the innovative war plan that dislodged the Taliban from Afghanistan's cities by December 2001, 'the invasion was, at its inception, conceived and led by the CIA with the U.S. military in a supporting role' (Mazetti 2013: 19). Schroen (2005) provides a first-hand account of his experience leading the first CIA team (codenamed JAWBREAKER), which he reports arrived in Afghanistan on 26 September 2001.

[2] Biddle provides detailed references for the claims made by defence transformation advocates about the implications of Operation Iraqi Freedom (Biddle 2007: 5 fn 5). Biddle's important critique sought to correct a then-dominant narrative that focused on American strengths but screened out Iraqi weakness. Instead, he suggests 'an interaction effect between Iraqi choices, Iraqi military shortcomings, and Coalition strengths' and counsels against restructuring the US military by reducing numbers of troops and relying on speed and precision (Biddle 2007: 39).

[3] Naylor points out that their escape into Pakistan was facilitated by the light footprint approach to the invasion. 'Reluctant to put too many American troops on the ground,' he writes, 'U.S. commanders had relied on their Afghan allies backed up by Special Forces to snare Osama bin Laden and his henchmen. But this time the Americans' faith in their militia allies was misplaced, and a failure to block escape routes into Pakistan from Tora Bora meant bin Laden and hundreds of Al Qaida's most hardened fighters had slipped the net' (Naylor 2005: 70). Bergen (2009) calls Tora Bora 'one of the greatest military blunders in recent U.S. history' (Bergen 2009).

citizens that their government was acting decisively, this was primarily interstate war rather than war on al Qaeda.

Nevertheless, over subsequent years and in the long shadows cast by these two post-9/11 invasions (and their consequences), another set of security capabilities has come into being to meet the post-9/11 imperative to make war on terror. Rather than being oriented to interstate warfighting, these capabilities are tightly focused on the tasks of identifying, locating, tracking, and killing or capturing members of non-state terrorist and insurgent groups. In the post-9/11 period the US and its allies have developed a number of inter-related ways to perform these activities in different contexts. These different contexts include countries that are or were effectively directly occupied by the United States and its allies (such as Iraq 2003-2011) and countries from which the US and its allies have largely withdrawn but where they maintain considerable military capabilities (such as Afghanistan at present). They also refer to areas of countries where the official state authority is unable or unwilling to eliminate non-state terrorist or insurgent groups that the US considers endanger its security or interests. In such locations a range of options is available, from intelligence collaboration, to training and equipping police, military and intelligence organisations in the relevant state, to undertaking joint operations, to undertaking kill or capture operations directly. Depending on where state organisations sit on the 'unable-unwilling' spectrum in relation to a given group at a given point in time, kill or capture operations have been undertaken on the basis of some form of general agreement with the relevant state political leadership, a discrete authorisation for a particular operation, or without informing the relevant government of the operation (as in the 2011 raid on Osama bin Laden's hideout in Abbottabad, Pakistan). A qualitatively new military-intelligence counter-terrorism apparatus and set of practices, scarcely conceivable in the pre-9/11 world, has developed and consolidated to the extent that it is now described as 'the only game in town' in the fight against al Qaeda and other terrorist networks, according to then CIA Director Panetta (quoted in Shactman 2009).

There can be few more potent symbols of these post-9/11 capabilities than the sleek silhouettes and macabre names of the MQ-1 Predator and MQ-9 Reaper unmanned aerial vehicles (UAVs). These 'drones', as they are known in contemporary public discussion, have captured the imagination of the public and of policymakers alike. They provide a combination of capabilities that did not exist before. First, although typically needing to be launched, recovered and maintained from airfields relatively close to the intended area of use, control via satellite relay enables a drone flying over Afghanistan or Yemen to be piloted from Nevada, and allows video and other data gathered from the drone to be streamed around the world in close to real time. Second, air vehicles specially designed to provide 'long endurance' can remain aloft for a day or more at a time, while teams of pilots and sensor operators on the ground can work in shifts.[4] This adds up to a loitering surveillance capability – flying CCTV that can in principle be sent anywhere on earth. Not only is the drone freed from the human constraint of needing rest but removing personnel from the cockpit means that rather than putting people in harm's way they can work on secure bases inside the United States – and even (virtually) 'commute' from their homes and families to warzones anywhere on earth on a daily basis.

Satellites provide episodic coverage since in their orbits of the earth they pass fleetingly over particular spots. Drones, enabled by satellite infrastructure, in contrast provide 'persistent' presence over a selected region and the long endurance of a single vehicle can be made near-permanent by means of drone 'orbits' (of a quite different kind to the satellites). Drone orbits are created by organising rotas for teams of vehicles. These rotas ensure a vehicle that is 'on station' will be relieved by the arrival of a fresh vehicle before the fuel-depleted vehicle is forced to make the journey back to the airfield. In this way long endurance can be turned into a constant presence over a given area, relaying whatever data is generated by the onboard sensor suites back to bases potentially thousands of miles away. As both the quality of video feed and the means to transmit, store and analyse it improve, drones are creating vast banks of data. A single ARGUS wide area surveillance camera, for example, reportedly gathers a million terabytes of video data per day (equivalent to 5000 hours of HD video footage).[5] Video is only one form of data that can be gathered using sensor suites that can be carried by drones. The data being generated is imposing downstream pressures, particularly for more advanced data analysis techniques. Indeed, Air Force Lt General Shanahan has observed that '[e]very day, US spy planes and satellites collect more raw data than the Defense Department could analyze even if its

[4] According to the manufacturer, General Atomics Aeronautical Systems (GA-ASI) the MQ-9 Reaper can remain aloft for 'over' 27 hours. See http://www.ga-asi.com/predator-b

[5] These figures are taken from an interview with BAE Systems Engineer Yiannis Antoniades, on the PBS Documentary *Rise of the Drones* (first aired 23 January 2013).

whole workforce spent their entire lives on it.'[6] In addition to these burgeoning surveillance capabilities, by adding a laser designator and Hellfire missiles (and potentially also smart bombs in the case of the Reaper) to the drone, it became possible to 'paint' targets that could then either be attacked from other platforms or attacked directly using munitions on board. The decision to arm drones, again, yielded fundamentally new capabilities.

The Predator and Reaper unmanned aerial vehicles – both of which can carry and fire precision guided munitions (PGMs) - have become 'weapons of choice' in the ongoing war on terror. If 9/11 demonstrated al Qaeda's ability to mount mass casualty terrorist attacks on the United States mainland from a safe haven in Afghanistan, drones express the development of the means to reach into such territories and hunt and attack suspected enemies with precision weapons. These drones embody a qualitatively new set of capabilities and make possible – technically as well as politically – sets of practices that did not exist before 9/11.

Although this form of drone technology is integral to the practices of hunting and killing terrorists and insurgents, the development of these capabilities entails much more than the 'mere' development of new technological artefacts, or systems comprising combinations of technologies. Rather, as this hunter-killer role has developed, these drones have become integral parts of an emergent global infrastructure that is less visible, less tangible, far larger (but also diffuse) and (despite being the subject of intensive public discussion and debate) shrouded in secrecy. From this perspective, the significance of drones is that they constitute the most tangible and visible tip of an iceberg that belies a much larger architecture that is less visible, widely distributed and (despite being the subject of intensive discussion and debate) officially secret. While it would be quite possible to design a study more narrowly focused as a case study in weapon system development (a strategy with a long track record), this larger whole, of which the UAV-as-artefact is an integral component, also needs to be analysed as such. The innovation in question, therefore, has important technological dimensions, but also entails heterogeneous combinations of innovation and adaptation that are conceptual, organisational, legal, ethical and cultural in character.

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[6] The volumes of data are such that DoD envisages that effective exploitation requires the development and application of artificial intelligence. This is being addressed under the Algorithmic Warfare Cross-Functional Team – better known as Project Maven (Allen 2017).

This thesis sets out to determine the nature and scope of this particularly dramatic and important contemporary case of military innovation. It concerns the processes by which technological change interacted with a range of other factors – including beliefs about the strategic environment, organisational process and bureaucratic politics – to produce a qualitatively new set of security capabilities. It seeks to demonstrate the heterogeneous processes involved in creating these qualitatively new security capabilities. It seeks to show how weapons acquisition programmes and existing technologies shaped and were shaped by the process of seeking to articulate such new capabilities.

Research Objective and Research Questions

Research Objectives

The over-arching aim of this research is to explain how and why the Predator drone developed and came to occupy a position at the centre of a new, post-9/11 security apparatus and set of practices, and to understand the processes of innovation that drove this development. The thesis seeks to explain a specific case of military technological innovation and the process by which it became incorporated into a new set of security practices, explaining these capabilities and practices and the combining of various heterogeneous technical and other components in their formulation. The research objective is to describe and explain not only the development of a particular technical artefact or lineage of unmanned aerial vehicle, but the *co-evolution* of this lineage and its underpinning technologies, particular practices of 'drone warfare' and the wider organisational apparatus and infrastructure without which the practices would not be possible. In this thesis 'drone warfare' is narrowly defined in terms of the counter-terrorism/counter-insurgency activities of surveillance, and hunting and killing people suspected of being members of terrorist and insurgent organisations, both in declared theatres of war and beyond them. Yet it is also stressed that employment in this way, and embeddedness in the apparatus of these operations represents but a fraction of the ways in which the Predator has been used and incorporated in the post-9/11 contingencies. Indeed, their great utility in *multiple* roles in these contingencies has driven enormous demand from multiple 'customers', and it is this demand that has driven the dramatic expansion of Predator since 9/11. This thesis is interested in how and why this class of military technology as a whole remained marginal for so long, and why a particular and relatively flimsy and unassuming incarnation of this class then came to emerge at the centre of a new security response in the wake of 9/11. In so doing, this thesis examines what Predator's progress along the innovation pathway to assimilation and integration tells us more broadly about innovation processes, what gives rise to 'major' or 'revolutionary' innovation, and the interplay between technological possibility and potential usage that drives this.

To pursue these objectives, the thesis draws upon and combines strands of different fields of existing research. The first, military innovation studies, largely engages debates in international relations theory in an effort to explain a bewildering variety of cases of military innovation. It is concerned with explaining how and why militaries make major changes, such as to their doctrines, in the ways that they are organised, and perhaps above all in the way they fight (Farrell and Terriff 2002). A subset of this research concerns explaining military technological innovation, mainly although not exclusively focused on the development of particular weapons, weapons programmes and weapons systems. International relations often draws on ideas developed elsewhere, and military innovation studies has particularly engaged organisations theory in its probing of the way military organisations and other sub-state entities handle innovation. When it comes to technology, some research on military innovation has been grounded more in the sociology of technology (Science, Technology and Society studies), particularly the tradition known as the social shaping of technology, but is widely cited in the military innovation scholarship (eg MacKenzie 1990, Spinardi 1994). This literature, developed in part to challenge technologically determinist assumptions, emphasises that technology is 'a social product, patterned by the conditions of its creation and use' (Williams and Edge 1996: 866). A related and overlapping literature, innovation studies, is also highly relevant to the study of military innovation. In particular, a cluster of approaches geared to identifying and analysing the emergence and development of 'large technical systems' is identified as a promising way to investigate the co-evolution of drone technology and drone warfare. This thesis seeks to demonstrate the potential in building closer links between these fields, as set out in the conceptual framework (chapter 2).

Research Questions

An attempt to explain why and how the Predator emerged at the heart of a new security apparatus and set of practices in the post-September 11th period, and to understand the interplay between technological innovation processes and other factors in making this possible, implies two potential directions of inquiry. If the starting point is UAV technology, the questions that come into focus centre on how the 9/11 conjuncture opened up a new development pathway, encouraging adaptation of a particular lineage of the technology and enabling it to achieve more 'assimilated' status. If the starting point is the recognition of a new threat and the decision to respond with a declaration of war on terror, the central questions are instead about the processes by which US officials and organisations went about developing new capabilities dedicated to the war on terror imperative, and why and how they settled upon a particular configuration involving armed drones in hunter-killer roles. To explain the *co-evolution* of a particular configuration of drone technology and a particular apparatus of counter-terrorism drone warfare, the analysis attempts to consider both sides of the question, working, as it were, from the inside out and from the outside in. It therefore asks questions about the R&D processes that yielded the technology but also the impact of external circumstances, and the way Predator's development trajectory was reshaped as the US government sought to define and formulate new security capabilities. This thesis is therefore driven by the following research questions:

1. Why did military UAVs stay so marginal for so long?

2. Why did the Predator lineage finally emerge, as and how it did?

3. Why is Predator seen as revolutionary (and is it revolutionary)? What explains the creation of a truly new capability?

4. What does the case of Predator suggest about what military innovation entails and how military innovation occurs?

Policy and Scholarly Relevance of Research Questions

Why these research questions? A thesis about the development of drone warfare is readily justified both on grounds of policy significance and in more academic terms. As noted, drone warfare is at the heart of some of the most pressing foreign policy and national security issues presently confronting the United States and its allies. What is to be done about terrorist networks capable of mounting attacks such as those of September 11th 2001 remains a compelling question and there is plenty of scope to recommend alterations – even sweeping changes - to what is currently being done. It therefore readily meets the first criteria of social science research as stipulated by King et al (1994: 15) in being 'consequential for political, social, or economic life, for understanding something that significantly affects many people's lives, or for understanding and predicting events that might be harmful or beneficial'.

The second criteria stipulated by King et al is that 'a research project should make a specific contribution to an identifiable scholarly literature by increasing our collective ability to construct verified scientific explanations of some aspect of the world' (ibid.). Contributing to a scholarly literature requires 'locating a research design within the framework of the existing social scientific literature'. This thesis seeks to make a contribution by combining theories and evidence from the military innovation studies literature and science, technology and society studies and innovation studies. The evolution of military innovation studies has always reflected underlying theoretical debates and trends in IR and related disciplines. The field was shaped and in a certain sense inaugurated by a book that sought to weigh the relative explanatory power of internal versus external determinants of state behaviour in international relations (Posen 1984). This subsequently gave way to a generation of organisational/bureaucratic politics research exploring the relative importance of different kinds of internal factors in explaining innovation/non-innovation, and from the 1990s, military innovation scholars have increasingly investigated the potential of constructivist/culturalist explanations and the methodological difficulties of investigating them.

Framed in terms of the field of military innovation studies, this instance of military innovation immediately seems of great interest because of the way this literature prizes cases of 'major', 'discontinuous' innovations. During the war on terror period, this field has increasingly focused on wartime adaptation, bottom-up innovation and the institutionalisation of wartime learning (Griffin 2017). It seems reasonable to see the emergence of drone warfare as one of the most far-reaching shifts in US security practices at least since the end of the Cold War. Such a stark and dramatic example of innovation involving a qualitatively novel weapon system (the armed endurance UAV) and widespread claims to the effect that this lineage of systems affords 'revolutionary' capabilities makes it an apparently important case meriting the attention of military innovation scholars.

Research Design

Introduction to Research Design

Rather than beginning with an already-identified literature or setting out to test the merit of an already-identified theory or theories, this thesis began with a pressing topic of policy concern. Topic selection, literature, research questions and conceptual framework emerged iteratively and in large part through participation in two related research programmes at LSE as part of my PhD: the *Security in Transition* research programme (the ERC advance grant for this programme funded the research) and an ESRC research collaboration between LSE and a team from the Science Policy Research Unit (SPRU) at Sussex University (called 'Strategic Governance of Science and Technology Pathways to Security' and part of the wider ESRC *Global Uncertainties* programme). These research programmes both explored the co-evolutionary relationship between technology and security, connecting to a literature that is increasingly described as 'military innovation studies'. In collaborating with SPRU I was simultaneously drawn into the science and technology studies and innovation studies literatures. My research within these programmes became focused on US efforts to develop the means to wage a war on terror and the emergence of a set of technologies, capabilities and practices that, in public discussion, was increasingly labelled 'drone warfare'. The multi-disciplinary, topic-driven character of the research, a function of the exploratory nature of the wider research programmes, required the research design, questions, theory and argument to emerge in the course of the research process through an ongoing dialogue between the existing literatures on military innovation and innovation more broadly, and the data assembled from disparate sources about drone technology, drone warfare and the global war on terror.

Historical Case Study

Unit of analysis

This thesis understands technology as a 'complex whole' (Rip and Kemp 1998: 330). Research on technology in military innovation has mainly taken weapon systems or weapons development programmes as the subject of enquiry. Yet technology plays all sorts of other roles in military affairs, and weapons systems are but one possible unit of analysis. Artefacts such as weapons systems nest downwards into sub-assemblies and components and upwards into larger systems (Walker et al. 1987). The study of technology and of innovation more broadly is multidisciplinary since each discipline necessarily takes slices of this complex whole. No hard and fast boundary demarcates the 'technical'; technology and technique co-evolve and numerous 'components' interact with technology in a complex system that Hughes calls a 'seamless web' (Hughes 1986).

Setting out to study a complex whole such as this presents an analyst with some basic choices about how best to establish the boundaries of their work. While the observer is free to 'choose as his system any cluster of phenomena from the most minute organism to the universe itself, such choice cannot be merely a function of whim or caprice, habit or familiarity' (Singer 1961: 77). Much of the work on military technological innovation has focused on a particular weapons system or weapons development program or has adopted a framework comparing a small number of such cases. Farrell (1997) selected four cases of weapons acquisition in the United States, subjecting each to the same questions according to the method of structured, focused comparison (George 1979, George and Bennett 2005). Individual case studies provide space for 'detailed investigation of the decisions surrounding the development and deployment' of particular systems (MacKenzie 1990: 7-8). This approach is not well attuned to understanding the long-run impact of a gradually changing enabling technology on a range of weapons systems. For this reason, MacKenzie opted to focus on the development of inertial guidance technology over the course of the late nineteenth and twentieth centuries (ibid.). Evangelista's (1988) comparative study of how the US and Soviet Union developed new military technologies, meanwhile, is notable for identifying potentially important variation between the military innovation processes of different states. Evangelista developed models of innovation in the United States and Soviet Union with each process divided into characteristic stages. Spinardi (1994), meanwhile, focused on something like a technical 'trajectory' of development (Dosi 1982) in opting to study the development of United States Fleet Ballistic Missiles (FBM) across 'generations' of development spanning a period of more than thirty years.

In contrast to research designed to focus on a particular weapons system or program, compare the development of selected weapons systems or programmes, or reveal long-term development of an enabling technology across a variety of programmes, this thesis sets out to explain the emergence of a broader 'apparatus' and a novel set of security practices, of which a weapon system lineage – the Predator and Reaper drones – is an integral part. In this it reflects an understanding of military innovation as (i) a broad phenomenon, specific instances of which may not be reducible to a single dimension (such as doctrine or technology) but (ii) always distinguished by practical change of some kind, in the Schumpeterian senses of doing something differently or doing different things. The majority of writing on innovation in general concerns not only cases of 'success' (understood as 'those which succeed in diffusing') but that subset of those successes that produce 'discontinuous changes', those which turn out 'big and radical' (Edgerton 1999: 123-124). The relative lack of interest in those which did not succeed (or which did not produce particularly dramatic or important change, however this is defined) tends to produce a distorted picture of innovation that neglects the fact that 'societies have long thrown up many more [technological] innovations than have actually been used, or probably could be used' and therefore that 'the majority of technologies were "resisted", and had to be' (Edgerton 1999: 123). From a technology perspective, one major question that leaps out is why and under what conditions technologies may 'graduate' from the Schumpeterian stages of invention and innovation – which from this perspective is the lot of the vast majority of would-be innovations - to become 'successes'.

One kind of answer proffered to this question is 'maturity'. This kind of answer fits with an understanding of technological innovation as following a 'life cycle' from birth, immaturity, to 'adulthood' and eventually, retirement and old age. In this view technology develops along a path and only the technical tasks of making it work 'well enough' hold it back from being widely adopted and used. Once the technology 'works', or works 'well enough' it comes of age. An alternative view sees the technological innovation process not as unfolding according to its own immanent logic but as an at least partly open-ended process of discovery involving a creative process of connecting technological possibilities to potential uses or functions. It is helpful to see technologies as '"multiply realisable" with many technical choices available to fulfil a given function and many functional uses possible for a particular form' (Nightingale 2014: 7). Rather than thinking in terms of a linear process moving assuredly from invention-innovation-diffusion/use, from this perspective technology develops in a branching pattern, in which technologies and envisaged uses co-evolve. Developments in underlying or related technologies constitute one set of variables affecting how inventors try to make connections between advancing technological possibilities and possible roles. However, changes in the landscape of possible roles can also 'open up' possible pathways along which the status of a technology may change from invention to innovation to diffusion.

There is a need to balance the entirely understandable real-world research interest in understanding cases of 'success' (marked by doing different things or doing things differently) with the need to recognise the distorted picture of innovation created by neglecting the vast majority of inventions and related innovations that do not succeed in developing further. If technological innovation is marked by a process in which inventors pursue multiple possible applications of emerging technology (and combinations of technology), it is likely that a given case of 'success' is likely to emerge not from 'out of the blue' but from a kind of primordial soup of related endeavours. One option in designing research is to set a case of 'success' against the backdrop of a universe of related non-innovations. Building up an understanding of why related efforts did not become successful innovations can help build a stock of knowledge about the different ways that prospective military technological innovations may fail. This is valuable in itself but also creates a powerful baseline against which to consider what is different about a closely related case that does become an innovation.

In this thesis, chapter **3** sets out the main UAV development programmes and systems of the Cold War and post-Cold War periods, explaining how far each advanced and delving into the reasons that they did not advance further along the innovation continuum. This enables comparison between the most closely related systems (and the reasons that they advanced only so far) and the system of interest, helping to discern the variables of importance from a complicated mass of empirical information, to attempt to suggest possible chains of causation that fit the available evidence, and to evaluate the plausibility of different accounts.

Drone warfare as I have begun to describe it in this introduction is not reducible to the Predator and Reaper weapons systems. These systems are rather parts of a larger, complex whole. Following the work of technology historian Thomas P. Hughes and his colleagues, and drawing on related traditions in innovation studies, the development of drone warfare is conceptualised as a specific military case of the development of a 'large technical system' (Hughes 1983). Such systems, Hughes argued, are made up of heterogeneous 'components' including material artefacts but also organisations, and scientific and legislative artefacts. Hughes shares the perspective of sociologists of technology who view technology as shaped by society while also shaping society. Bijker, for example, conceptualises technology as 'technology ensembles' that are made up of physical artefacts, the techniques for their use, and an associated regime of norms and regulations governing such use (Bijker 1995: 273-275). In Hughes' work, technology ensembles can themselves become incorporated as components of larger systems. This much better fits the case of drone technology and drone warfare than does conceptualisation as a 'weapons system'.

To rise to the level of a military innovation, as that term is understood in the military innovation literature, a new technology must not only advance through invention and innovation but must be implicated in changes in practice. A number of students of technology and innovation point out that analysis often dwells too much on invention and innovation and fails to follow through to use, even though what is relevant is adoption and use (Edgerton 1999). In moving from weapons system to the formulation of a large technical system that both incorporated Predator and reshaped its development trajectory, my aim is to open up to scrutiny the interaction between research and development and technological development processes and strategic level processes of formulating 'responses' to 'threats'. In this sense military technological innovation is not merely about inventive activity but the way that available technologies figure in organisational efforts to identify promising avenues to pursue in developing responses. It is also about the ways in which processes of searching for and fleshing out new responses can redirect ongoing development efforts along new pathways that may enable the technology in question to advance further along the invention-diffusion continuum. Since technological development and the formulation of ways to do different things co-evolve, shaping one another while being shaped by one another, their relation cannot be expressed in terms of an independent and a dependent variable. Rather, their co-evolution has to be cast as a process unfolding over time (Pierson 2004).

Historical Case Study Approach

Framing the research within military innovation studies draws attention to a broad tradition that has typically designed research around detailed studies of historical cases. The weapon system case study, the main approach used in the scholarship on military technological innovation, is too narrowly bounded by particular programmes and weapons to capture the entirety of the military innovation of which the Predator-Reaper drone lineage is such a vital component. The large technical systems perspective provides the conceptual means to maintain focus both on numerous onboard and offboard technologies besides the flying vehicles, and on the important changes in practice regarding the use of force associated with drone technology in the war on terror. In short, it enables thinking about innovation in terms of heterogeneous components. The model for research in the LTS tradition is the historical case study, epitomised by Hughes' seminal *Networks of Power* (1983), an historical study that traces the development of electric power networks in the United States, Germany and the United Kingdom between 1880-1930.

The case study has emerged not only intact but strengthened from a period of intense methodological scrutiny and debate stimulated by dialogue with statistical research methods. George and Bennett understand case study research as 'the detailed examination of an aspect of a historical episode to develop or test historical explanations that may be generalizable to other events' (George and Bennett 2005: 5). In this sense a case is a particular 'instance of a class of events' whether that class be 'revolutions, types of governmental regimes, kinds of economic systems, or personality types'. Case study research is undertaken with a view to 'developing theory (or "generic knowledge") regarding the causes of similarities or differences among instances (cases) of that class of events' (George and Bennett 2005: 17-18). As an approach, George and Bennett stress 'their potential for achieving high conceptual validity; their strong procedures for fostering new hypotheses; their value as a useful means to closely examine the hypothesized role of causal mechanisms in the context of individual cases; and their capacity for addressing causal complexity' (George and Bennett 2005: 19).

Process Tracing

Process tracing is 'perhaps the tool of causal inference that first comes to mind when one thinks of qualitative methodology in political science' (Mahoney 2010: 123). Collier et al define process tracing as 'the examination of diagnostic pieces of evidence, commonly evaluated in a specific temporal sequence, with the goal of supporting or overturning alternative explanatory hypotheses' (Collier et al 2010: 201). Bennett usefully explains process tracing as akin to the way a detective seeks to solve a crime or a Doctor seeks to diagnose an illness - involving:

> 'the examination of ''diagnostic'' pieces of evidence within a case that contribute to supporting or overturning alternative explanatory hypotheses. A central concern is with sequences and mechanisms in the unfolding of hypothesized causal processes. The researcher looks for the observable implications of hypothesized explanations, often examining evidence at a finer level of detail or a lower level of analysis than that initially posited in the relevant theory. The goal is to establish whether the events or processes within the case fit those predicted by alternative explanations.' (Bennett 2010: 208)

Despite its prominence in the work of qualitative social scientists, methodology textbooks present quite different understandings of how this approach works and what it can be made to do. Read through the prism of the quantitative template advanced by King, Keohane and Verba in their highly influential *Designing Social Inquiry* (1994), process tracing is seen as the hunt for intervening variables nestled between independent and dependent variables. In this view process tracing is a rather weak basis for making causal inferences, merely enabling 'descriptive generalizations' that might 'prepare the way for causal inference' (King et al 1994: 227-28, quoted in Mahoney 2010: 123). Investigating the causal steps linking chains of causation, it is argued, can lead to 'infinite regress'. Drawing again on statistical methodology, it is also argued that 'the number of cases in a data set must be far greater than the number of variables in a model', since the large number of variables being handled in a small number of cases introduces the 'degrees of freedom' problem.

Bennett (2010) asserts that the answer to these concerns flows from recognising that 'that not all data are created equal', that 'not all information is of equal probative value in discriminating between alternative explanations, and a researcher does not need to examine every line of evidence in equal detail.' Rather, '[i]t is possible for one piece of evidence to strongly affirm one explanation and/or disconfirm others, while at the same time numerous other pieces of evidence might not discriminate among explanations at all. What matters is not the amount of evidence, but its contribution to adjudicating among alternative hypotheses.' In similar vein, George and Bennett dismiss the view that process-tracing simply helps increase the number of observable implications of a theory, arguing that it is 'fundamentally different from statistical analysis because it focuses on sequential processes within a particular historical case, not on correlations of data across cases.' This distinction matters because 'a single unexpected piece of process-tracing evidence can require altering the historical interpretation and theoretical significance of a case, whereas several such cases may not greatly alter the findings concerning statistical estimates of parameters for a large population' (George and Bennett 2005: 13).

Collier et al, meanwhile, argue that the low esteem in which some methodologists hold process tracing is based on confusion between 'dataset observations' (DSOs) and 'causal process observations' (CPOs). Where CPOs 'are pieces of data that provide information about context, process, or mechanism and contribute distinctive leverage in causal inference', DSOs 'correspond to the familiar rectangular data set of quantitative researchers' (Collier et al. 2010: 201-202).

Data Collection

Data was collected on the historical development of unmanned aerial vehicles technology, the development of the Predator lineage in particular, and – within the limits of official secrecy – the development of the apparatus and practices of counter-terrorism drone warfare. At the outset, it seemed that the veil of secrecy surrounding drone use, particularly beyond 'declared' battlefields such as Afghanistan and Iraq, would present a formidable obstacle. In fact, early research revealed an existing literature on historical efforts to create military useful aircraft that did not carry a pilot on board. During the research period, corresponding to President Obama's second term, the Predator UAV was a subject of intense public discussion and debate. Despite official secrecy, an enormous amount of information was already in the public domain from a range of sources, while the administration was beginning to try explain its use of the Predator and Reaper around the world. A great deal of information about historical drone programmes is readily available via the internet, and several good books provide information about various important drone development efforts in the United States. To supplement and seek to assess the veracity of the voluminous information in the public domain, two rounds of interviews were conducted in London, Washington, D.C. and New York.

In developing an understanding of the history of drone development efforts in the United States the best sources by far are existing PhD studies of the history of drone development in the United States. Thomas P. Ehrhard's *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation* (2000) and Jon J. Rosenwasser's *Governance Structure and Weapon Innovation: The Case of Unmanned Aerial Vehicles* (2004) stand out as particularly important. Both are readily available online via the ProQuest Dissertations and Theses service. Parts of Ehrhard's thesis are also published in a publicly available Mitchell Institute report, also available through the Defense Technical Information Center. Both studies make important arguments about drone development in relation to military innovation studies. Both also reflect an admirable knowledge of an enormous range of sources in relation to a range of drone development programmes. Ehrhard's thesis compares how the differently structured armed services went about developing UAVs, and demonstrates unparalleled command of the history of dozens of programmes. His story covers the period almost to the end of the post-Cold War period. Rosenwasser is similarly concerned with the impact of 'governance structure' on innovation, and focuses more on the period from the 1986 Goldwater-Nichols Act and Packard Commission reforms to 2004, meaning that his study also just begins to address post-9/11 drone development. Both Ehrhard and Rosenwasser provided detailed references to a wealth of publicly available sources including numerous official reports, supplemented by archival research and extensive interviews. Thanks to the growing reach of the internet, numerous official reports on drone technology – including the vast majority that were referenced by Ehrhard and Rosenwasser, are readily available via the internet, notably via the Defense Technical Information Center (www.dtic.mil). Both scholars supplemented their research with extensive programmes of interviews.

There is considerable cross-over between drones in the US military conducting missions such as intelligence, surveillance and reconnaissance and providing overwatch and close air support, and the more secretive activities of targeted killing beyond so-called 'declared' battlefields. This means that a good deal of information is available about the development of the technology, how it works and has evolved, illuminating a good deal of the history of the innovation. Whittle's study of the Predator is the first published development history of this system, with numerous other studies of the rise of drone warfare providing additional detail. A large amount of information is available and accessible through the Defense Technical Information Center. Trade journals also provide a good deal of contemporary reporting useful in piecing together historical narrative. Aviation Week & Space Technology in particular maintains a complete online archive of past editions.

Despite the secretive nature of some parts of the historical development and contemporary operations relating to drone technology, even on these aspects a great deal of information can be assembled. Numerous memoirs, drawn upon in this study, informatively describe involvement in the development of drone technology and drone warfare. Like all sources, they should be handled with care since they are often subject to inaccuracies whether arising from the decay of memories, subjective perceptions, or from deliberate distortions. A sense of balance can only be achieved by weighing the evidence from a range of sources and taking care to distinguish subjective opinion from facts. Where possible, as with other sources, data points have been cross-referenced. Points of difference between sources, similarly, can help identify areas of controversy and to suggest where to look more closely. In addition, a number of people involved in the development of drone technology and associated programmes have engaged in numerous public interviews, and have made public statements and offered comments in public meetings. Many transcripts and video recordings of this kind are available via the internet. Thinktanks and universities, in particular, have hosted numerous conversations with current and former participants in the development of drone warfare.

In addition, national security and investigative journalists continually unearthed important information about contemporary drone operations during the time that this thesis was in preparation. Relatedly, whistleblowers from within the US government have often been a vital source of disclosures about activities and procedures. *The Intercept* has been particularly active in sifting and making available much of this information. For example, the Intercept's online publication of 'The Drone Papers', which led to a book, *The Assassination Complex* (Scahill et al 2016), was built on secret documents, shared by a whistleblower from inside the drone programme. In recent years, the names of Edward Snowden and Private Manning stand out for the decisions they made to leak information about classified activities undertaken by parts of United States government in the name of national security. Wikileaks, indeed, has been an important source of information about drone operations. Former participants in the drone programmes – including Brandon Bryant, Cian Westmoreland, Heather Linebaugh, Lisa Ling and 'Daniel', who all spoke about their respective involvement in US drone operations in the documentary, *National Bird* (Kennebeck 2016) have provided valuable insights into drone operations. All have been deeply affected by their experiences and believe that the government should provide the American public with much more information about these operations. These beliefs and motivations inevitably influence their views.

The Obama election campaign had been deeply critical of many aspects of the Bush administration's war on terror, especially enhanced interrogations and the detention facilities at Guantanamo. Yet, as has been widely discussed, the Obama team 'doubled down' on the use of drones in the war on terror (e.g. Sanger 2012, Savage 2015). In adopting this posture the administration sought to 'normalise' targeted killing and, in a controlled way, sought to make some information about these activities public. The intense and wide-ranging international discussion about drones and drone warfare in the course of the Obama administration helped generate a good deal more information about the development of nominally secret activities. As the Obama administration sought to justify and normalise its use of drones, for instance, it made very strong claims regarding the numbers of civilian casualties caused by its use of hunter-killer drones against terrorists and insurgents (CSPAN 2011). Several monitoring organisations sprang up to try to assess exactly who was being killed in drone strikes in Pakistan, Yemen and beyond, including the New America Foundation, the Bureau of Investigative Journalism (in the UK), the Long War Journal and more recently airwars.org, and reached very different conclusions (e.g. Woods 2011).

Two rounds of interviews were conducted in Washington D.C. with a variety of informants with knowledge of the development of drone technology. The first round of interviews in the United States, undertaken early in my PhD, included the American Enterprise Institute, Institute for Policy Studies, German Marshall Fund, United States Institute for Peace, the Brookings Institution, the Stimson Center and the State Department (in Washington, D.C.) and the Rockfeller Brothers Fund (in New York). The second research visit in November 2017 included interviews at the Project on Government Oversight, the Center for a New American Security, the New America Foundation, RAND as well as with independent journalists and researchers.

Limitations

Military innovation studies, as its name suggests, tends to focus on innovations grounded in military organisations. Although much of the research focuses on historical cases where once-secret information has been declassified, there is plenty of work dealing with contemporary cases where potential problems of access and secrecy have been overcome. Such research is enabled in part by the desire of military organisations to better understand innovation processes. It is also facilitated by the fact that many students of military innovation are to some extent 'insiders' – such as serving or former members of military organisations or defence-affiliated think tanks and research organisations. Nevertheless, it is important to bear in mind when surveying this literature that a sizeable proportion of overall US spending on defence R&D goes on work that is kept secret, preserving military advantage against potential adversaries by concealing capabilities and making counter-innovation as hard as possible. Defence journalist Tim Weiner (1991) reported that during the 1980s the Pentagon's 'black' budget (which he claimed also financed 'most' of the CIA and two larger intelligence agencies – the National Reconnaissance Office (NRO) and National Security Agency (NSA)) had mushroomed.[7] More recently, Priest and Arkin have given some sense of the massive scaling up of what they call 'top secret America' since 9/11 (2011).

[7] He notes that in April 1986, the then-House Armed Services Committee chairman, Les Aspin 'put out a terse statement saying the black *weapons* budget had gone up 800 percent since 1981' (Weiner 1991: 17) [my italics].

This difficulty, however, must be balanced against the real-world importance of the subject-matter. The Air Force 'black' budget alone is reputedly some $50 billion a year. Ascertaining just how much can be found out about secretive but consequential programmes and activities is a worthwhile and legitimate endeavour, provided that the inherent limitations are identified and confronted. In any case, even though information about secret programmes in the US is admittedly more restricted, they nevertheless can be – and are being – studied. In the aerospace field, such activities have long come with a cottage industry of journalists and a wider community of knowledgeable amateurs and therefore also an abundant literature – including newspaper articles and books (often replete with photos and artist's impressions) and trade publications. With the advent of the internet, the issue is less the volume of available data and more adjudicating its veracity. In the field of Intelligence Studies, meanwhile, basic sources such as Richelson (2002, 2012), Jacobsen (2015), Aid (2009, 2012) and Bamford (2008) provide only limited detail on the already-limited number of programmes they can disclose. There are limits to how much outsiders can discover, and this necessarily constrains the kinds of claims they can reasonably make.

It might be expected that more detailed work on the technology development in classified programmes from a military innovation studies perspective would be harder to find. The F-117 Nighthawk and B-2 Spirit, planes that make use of so-called 'stealth technology' (actually a combination of technologies intended to make air vehicles harder to detect by radar), are good examples of a weapons on which enormous amounts have been spent but where information about development has lagged behind. Yet even in such cases, secrecy is not necessarily an insurmountable barrier. Farrell (1996) was able to amass enough information about development of the B-2 to make it one of five cases compared in his study. MacKenzie was able to unearth an enormous amount of technical detail about the development of inertial guidance technology used to guide ballistic missiles, relying to a large extent on interviewees. Although certain technical details were withheld, MacKenzie found that interviewees 'were able to discuss in considerable technical depth not just missile guidance in general but the specifics of particular systems and their components', and that they were quite free to discuss 'the processes, technical and social, that lead to the selection and design of these systems and components' (MacKenzie 1993: 12). In their study of the Single Integrated Operational Plan (SIOP) – the United States plan for nuclear war against the Soviet Union – Pringle and Arkin (1983), meanwhile, found that they were able to construct an account of the evolution of the plan from a skeleton of publicly available documentary evidence, supplemented by interviewees who, again, proved surprisingly willing to discuss their work. These examples suggest that although secretive subject matter does create difficulties and obstacles for a researcher, and is likely to mean that the account developed may contain gaps, such research is, within limits, doable. Moreover, the difficulties involved in researching certain topics and the limitations that these difficulties may impose on the final product must be balanced against the public importance of the topic in question. Under such circumstances, it is possible to attempt to make a useful contribution without claiming to have had the last word.

Military organisations are not the only ones engaging in technological innovations relevant to military innovation studies. The NRO has been heavily involved in the development and operation of many of the US satellite systems as well as in other forms of overhead reconnaissance, including UAV development efforts, working in partnership with the US Air Force. The CIA, meanwhile, has long had an in-house technological development division, the Directorate of Science and Technology, and so can have hardware of its own built (Richelson 2002). The CIA has also worked closely with the Air Force, including on the U-2 program, and has also been involved in the development and operation of satellite technology. Indeed, this thesis seeks to show the intimate connections between the CIA and Predator development, and it is now widely reported that the Air Force maintains dedicated Predator and Reaper squadrons on behalf of the CIA (Woods 2015a). Compared with the military services, however, much less has been written about how the CIA innovates either specifically to develop new technology or more generally in terms of performing existing functions in new ways or performing altogether new functions.

One of the most important notional applications for unmanned aerial vehicles is in the field of 'national' intelligence, surveillance and reconnaissance. During the time of writing various reports surfaced about the existence of a stealthy, high altitude reconnaissance drone called the RQ-170. Not surprisingly given its suspected role, information about this system is fairly sketchy (some leaked out as a result of coverage of the operation that killed bin Laden in Abbottabad and the purported capture in December 2011 of such a system by Iran) and no interviewees were willing to confirm or deny reports about a suspected successor system described in a leading aerospace journal. More has been written about the other major US reconnaissance drone, the Global Hawk, which to some extent fulfils functions performed by the famed U-2 high altitude reconnaissance plane (Thomas 2015). Owing to the significance it has taken on in the war on terror, the Predator lineage has been the subject of a great deal of scrutiny and its development is the subject of a well-researched history (Whittle 2014a). In all three cases – and the same is true for satellites, the U-2 and other reconnaissance systems – information about their payloads remains vague. By contrast with 'national' strategic reconnaissance, however, the Predator's development history is largely open to investigation even if some details remain to some extent vague. CIA involvement both sustained the program at key moments and was responsible for some crucial technical advances. The Defense Advanced Research Projects Agency (DARPA), which develops technology with a view to equipping both the military and the intelligence world, also played an important role. The Army, Navy and Air Force were all also involved at different points in the development of this system.

When it comes to the missions implemented using the Predator, the picture is more mixed. The Air Force maintains fleets of MQ-1 Predators and MQ-9 Reapers. The army's Task Force ODIN also operates the MQ-1C Gray Eagle (a Predator variant). Where these systems are being used in what the US military describes as conventional battlespaces, their use, even where weapons are employed, is seen simply as 'an extension of conventional warfare' (Mayer 2009). Greater complexity arises, however, where drones are employed in the war on terror beyond such allegedly conventional warzones, especially in armed roles. These operations are 'classified as covert, and the [central] intelligence agency declines to provide any information to the public about where it operates, how it selects targets, who is in charge, or how many people have been killed' (ibid.). Joint Special Operations Command (JSOC) also has a drone program outside of conventional battlefields, possibly 'to allow the plausible deniability of CIA strikes' (Zenko 2013).[8]

Official secrecy regarding covert operations using armed drones outside of declared battlefields might be expected to firmly rule out the possibility of scholarly examination. Yet official secrecy belies a rather different situation in which a substantial amount of

[8] Within the Air Force Special Operations Command (AFSOC), the MQ-1 Predator and MQ-9 Reaper drones are reportedly flown by the 3rd and 33rd Special Operations Squadrons which are based at Cannon Air Force Base in New Mexico, and the 2nd Special Operations Squadron which is based at Hurlburt Field in Florida (Gettinger 2015).

information is publicly available. Drone warfare is an ‘open secret’ – technically classified by the US government covert but incessantly discussed and debated throughout both terms of the Obama administration. Nor is it a poorly kept secret by accident. Several commentators point out that the Obama administration was not simply managing a situation in which a secret had slipped out. Rather, as some commentators have noted, it sought to make political use of the condition of open secrecy, engaging in a ‘theatrical performance of… faux secrecy’ (Tahir 2012), ‘in which the veil of official secrecy is deliberately let slip… [by] unnamed spokesmen “speaking on condition of anonymity” because they are “not authorised to speak on the record”’ (Gregory 2012: 23). Jameel Jaffer, Deputy Legal Director of the American Civil Liberties Union (ACLU) Foundation and instrumental in bringing Freedom of Information Act (FOIA) litigation aimed at forcing the government to release basic documentation about drone warfare, argues that ‘the fiction of secrecy has a function: it decouples transparency from accountability. It saves the government from having to answer — to the public, to the courts — for facts that are publicly known’ (Jaffer 2013).

The challenge involved in researching this subject is not that there is not enough material in the public domain, as one might expect of ‘secret’ programmes. Rather, there is a glut of information about the development of drone warfare, even if important gaps and ambiguities remain. The difficulties of empirical research on this subject turn more on building, to the extent possible, an accurate account from fragments of data derived from a variety of sources. Piecing together data on this subject raises numerous questions about the reliability of information and informants. Factual inaccuracies, whatever their cause, are normally handled by seeking corroboration of information across multiple sources. When handling data, particularly in a politicised context in which officials (whether speaking on the record or anonymously) actively seek to shape public perception, the possible motivations of differently situated sources must be taken into account.

Chapter Structure

This thesis is organised around the research questions set out above. In Chapter 2 - the Conceptual Framework – I situate my research at the intersection of military innovation studies, science and technology studies (STS) and innovation studies, summarising the contribution of these three extremely large literatures to thinking around technology, military innovation and innovation more broadly. On technology, the chapter demonstrates the limits to thinking of drones as 'artefacts' or even as 'weapons systems' in the sense that that term is defined by the US Department of Defense. In addition to being made up of subsidiary technologies, drones are increasingly bound into much larger socio-technical systems and it is through this embeddedness that they are endowed with some of their most important capabilities. These systems are made up of other 'technical' hardware (such as satellites), software, as well as various disparate elements, including, for example organisational adaptation and new organisational relations, tactics, legal frameworks and shifting normative claims. The full significance of contemporary drone technology begins to come into view only once it is recognised that drone warfare, at least as that term is understood in this thesis, is made possible not simply by Predator drones narrowly conceived but by the construction of something akin to what Hughes (1983) conceptualises as a 'large technical system'. On innovation, this chapter emphasises that rather than a moment, innovation is a process that can be investigated in terms of a continuum, and that rather than being linear, innovation processes are uncertain, involving complex interactions at each stage between institutional pressures, technological development and external events. Advancing along the innovation continuum from marginality through to assimilation is highly reversible; marginality remains the norm for the vast majority of nascent technologies.

Third, this chapter also considers dominant thinking in the literature around the effects of 'peacetime' and 'wartime' conditions on the trajectories of military innovation. I suggest reconceptualizing this distinction as the tension between innovative activity oriented by future war scenarios and the requirements thrown up in actual contingencies. This thesis is particularly concerned with the way that incipient technological development pathways marginalized by 'peacetime' understandings of requirements may be afforded new opportunities by external shocks and actual contingencies, potentially opening up quite different and unforeseen technological development pathways associated with different security practices.

Finally, this chapter sets out a framework for thinking about the military technological innovation processes and the way that connections are established between shifting technical possibilities and military operational applications and uses. In so doing I suggest framing technological innovation processes in terms of the changing status of a given technology in relation to organizational sponsors and users. Those few technologies that successfully advance to become fully incorporated into military organisations and practuces, I argue , pass through 'statuses' that I characterise as 'marginality', 'emergence' and 'assimilation'.

Chapter 3 – Marginality - seeks to place the development of the Predator lineage in the historical context of a long and rich history of efforts to transform unmanned flight from an idea into a technology that was useful to military and intelligence organisations in the United States. This chapter serves to counteract a widespread and entirely misplaced contemporary perception that the Predator somehow was thrown together from scratch in response to 9/11. It also suggests something of the scale of effort invested in this technology class during the Cold War, describes in each case just how far the system advanced along the invention-adoption spectrum, and explains why each advanced only so far, but no further. The chapter charts the historical process of technological and conceptual differentiation as the research and development community explored potential applications with users over several decades. This underscores that drones were envisaged for a growing number of roles in pursuit of which new capabilities were explored that, over time, changed their essential capabilities and thereby in a sense what they *were*. Additionally, while insufficient technology does constitute an important part of the answer to why drones did not progress from R&D to become firmly established in any of the military services, this is not the only explanatory factor in play. With the passage of time, core technological constraints were progressively relaxed, and by the early 1980s, a range of other factors come to the fore in explaining why drone technology still failed to cross the threshold from R&D to meaningful and sustained service adoption.

Finally, focusing particularly on the Lightning Bug and DASH drone lineages, the chapter demonstrates how in an earlier period the trajectory of drone development was profoundly interrupted and redirected by a transition from the 'peacetime' of the Cold War to the actual contingency of the Vietnam War. It then relates the fate of these systems following the US withdrawal from that conflict and the resumption of a 'peacetime' innovation environment.

Chapter 4 - Emergence - zeros in on the programmatic development history of the Predator lineage, seeking to explain how and why this system in particular succeeded in overcoming the range of inhibitors that undid other programmes. The empirical record is detailed and convoluted yet the interaction of a few key factors proves to be strikingly important. First, rather than the product of a 'prime' contractor, the Predator lineage developed in the garage of an 'inventor-entrepreneur' in the Hughesian sense. He committed himself to a drone development programme that identified and assiduously pursued two core performance attributes in a way that seemingly transcended evolving thinking about specific real-world contexts: endurance and reliability.

Second, although bankrupted after the would-be service adopter of his development programme pulled out amidst a wider Congressionally-mandated shakeup of US drone development initiatives, a new entrant in the defence industry bought out the collapsed business, revived development and demonstrated considerable ability to build a coalition of high-level support for the technology. Although the services had rejected the design, the CIA remained particularly interested. Amidst momentous Congressional efforts to reform the defence acquisition system, a network of civilian leaders, appointed to key Pentagon and CIA positions during the Clinton administration, set about reintroducing the endurance drone. With Congressional support, they embarked on a novel, risky and experimental acquisition strategy to rapidly prototype and develop the drone through a series of iterations and ongoing modifications driven by experience in real-life operations and feedback from operational commanders. This strategy helped generate an internal support constituency across the services among a cadre of high-level 'believers' while also having the effect of provoking a sense of inter-service rivalry that motivated the Air Force to stand up drone squadrons and seize ownership of the capability. Despite the Air Force formally adopting the system, however, when the civilian Pentagon network moved on a range of internal resistance forces slowed development. It is conceivable that the Air Force Predator may have remained formally adopted but not substantively embraced but for a series of wartime engagements. These served to maintain the Predator's position and succeeded in stimulating a series of further innovations that led to important qualitative shifts in its technical capability and thereby also its organisational status within the Air Force.

Chapter 5 – the Bin Laden problem – then explores the emerging and thorny policy problem presented by Osama bin Laden and his sanctuary inside Afghanistan. Over the course of several years, this problem drove a wide-ranging search process that exposed a dearth of available options and motivated efforts to generate new possibilities. In the course of attempting to formulate new options, a connection was made between the 'bin

Laden problem' and the Predator UAV, a connection that in turn drove further innovation in the existing Predator system. First, it provoked innovation in the mechanism of long-range control and data relay, enabling real-time surveillance of Kandahar to be viewed in Langley. The excitement generated by this mission was coupled with the realisation that, having located him, the means to act on this knowledge was still lacking. A further effort to add options to the table stimulated the fast-tracking of armament efforts and further innovation in the system of remote control that yielded, in embryonic form, the Predator capability that would subsequently become so important in the post-9/11 period. Although this technical capability was being actively tested on the eve of 9/11, however, the normative and legal basis for using this system for the narrow and specific purpose of hunting and killing Osama bin Laden remained heavily contested and controversial.

Chapter 6 – Assimilation – examines the profound impact of 9/11, and the global war on terror developed in response, on the trajectory of Predator innovation. On 9/11 the basic technical elements of the system that subsequently came to such prominence were already in place. 9/11 transformed the domestic political situation in the US creating conditions in which the President was able to establish a new regulatory basis for the use of the CIA's armed drone, not only against bin Laden, but a list of senior leaders of al Qaeda and the Taliban regime who had provided them with sanctuary. In the course of operations in Afghanistan and Iraq the CIA and the Joint Special Operations Command developed techniques for using the armed Predator to hunt al Qaeda leaders and other 'low-contrast foes'. Meanwhile, however, the Air Force learned to use the Predator in a variety of other ways in support of military operations, particularly in post-invasion conditions where air supremacy was established, conventional military opposition was defeated but where US forces struggled to control mounting violence and insurgency. Though before 9/11 the future war scenarios had seemed to suggest Predator's lack of military utility, and though some senior Air Force officials continued to stress Predator's lack of utility in a 'real' war, in the decades of post-9/11 military intervention, its value in ISR provision, armed reconnaissance and close air support generated enormous demand from military users, other 'customers', and political leaders that drove a dramatic expansion of the Predator in the US arsenal.

While important technical changes – not least the acquisition of a larger, more capable follow-on system, the MQ-9 Reaper – followed 9/11, post-9/11 Predator innovation has been less about technical invention or modification yielding different-in-kind capabilities, and more refinement and consolidation along a trajectory established in the pre-9/11 months. The character of post-9/11 Predator innovation has been much more concerned with the development and refinement of tactics and techniques for employing the platform in a variety of ways, and the incorporation of that system into a mosaic of larger socio-technical systems, reflecting Air Force ISR and close air support provision, and CIA and JSOC efforts to build collaborative cross-governmental networks capable of cuing drones and special forces operators against terrorist and insurgent networks.

The strategic surprise of 9/11 radically redirected Predator innovation, less at the technology platform level and more in terms of the purposes in which it was employed and the binding of the system into the wider organisational and technical apparatuses necessary to perform new tasks that profoundly changed how the US military and intelligence organisations operated in the '9/11 wars'. In enabling the US not just to 'do things differently', but to 'do different things', the Predator, despite its flimsy, propeller-driven and somewhat low-tech appearance, has had far-reaching consequences for security practice.

2. Conceptual Framework

Introduction

This chapter conceptualises military technological innovation as a contingent, contested, and reversible process that fundamentally involves making and institutionalising connections between shifting technical possibilities and military operational applications and users. Rather than thinking of technology as developing according to an inner logic of immanent technological possibility, the innovation literature has shown the value in interpreting it instead as developing along particular *trajectories* established by technological *paradigms* that are periodically upended by the advent of innovations that instantiate a new paradigm (Dosi 1982).

In the military innovation literature, meanwhile, wartime and peacetime are typically treated as two starkly different conditions that produce different patterns of innovation, with 'peacetime' in particular being characterised by efforts to forecast the character of future wars and to create the capabilities to prevail therein (Rosen 1991). There is, however, a widely observed mismatch between the character of future war as envisaged by planners and the conflicts in which the US has actually become embroiled since 1945. For this reason I reconceptualise the peacetime/wartime distinction as the distinction between the *imagined scenarios* defined by planners and the *actual contingencies* and security crises in which the US has been engaged. The imagined scenarios, I argue, have established and justified the military organisational division of labour in terms of roles and missions. At the same time, by directing basic and applied R&D resources in particular directions and not others the imagined scenarios contribute to the survival of dominant military technological paradigms. Within the established paradigm, relations between the imagined scenarios, the established roles and missions and the existing military technological platforms, weapons and systems are mutually reinforcing. These relations structure the *selection environment* that incipient technological possibilities must survive if they are to be adopted and employed by military users.

The central argument of this thesis is about the way that actual contingencies can interrupt and redirect the trajectories of technological development established by visions of future war, providing windows of opportunity for developing technologies to be used in operational settings. When actual contingencies reveal capability shortfalls, military organisations – possibly with prompting from civilians – may embark upon search processes to try to address them (Allison 1971). Search processes relating to technology may begin by considering modifications to systems already in the field, but may also reach into the pool of technologies then confined to experimental and developmental settings. If technology located in these settings appears to provide a way to address an urgently needed capability gap, it may be fielded in provisional and experimental ways despite limitations. Fast-tracking like this can put technology in the R&D pipeline into use settings, demonstrating the potential (though also the flaws) to users and also providing potentially valuable feedback from which developers can learn in order to address problems and better match the technology to user needs. Contingencies can open up incipient trajectories of technological development, although they may not persist once the contingency has passed and the imagined scenarios reassert themselves. I argue that it takes a major external shock to shift existing trajectories and establish a new military-technological paradigm.

This chapter proceeds by charting three relatively distinct bodies of literature concerned with innovation and technology and suggests how the study of military innovation might profit from closer interaction between them. It then turns to examine how these literatures inform the way 'innovation' and 'technology' are understood in this thesis. I then set out the distinction between peacetime and wartime as it appears in much of the international relations literature and in military innovation studies and, building on critiques emphasising the blurriness of this distinction, I suggest reconceptualising it as one between imagined scenarios and actual contingencies. I then present military innovation as a process of making and institutionalising connections between shifting technical possibilities and military operational applications and users. Finally I frame this process in terms of three statuses, which I characterise as 'marginality', 'emergence' and 'assimilation'.

The Innovation Literature

Innovation is 'one of those words that suddenly seems to be on everybody's lips' whose importance is a fundamental assumption of contemporary public discourse (Fagerberg and Verspagen 2009: 218). Firms see innovation as essential to their success, and fear being swept aside by the innovations of their rivals. Governments see innovation as essential to a thriving economy and seek to promote it through appropriate public policy measures and investments. In the military sphere meanwhile, just as in the commercial, innovation is prized for its ability to create competitive advantage. Yet the study of innovation has developed in parallel within a number of fields, each with their own empirical and theoretical concerns and with somewhat patchy connections between them.

Prior to 1960, academic publications on innovation were 'few and far between' (Fagerberg 2004, Fagerberg and Verspagen 2009: 220). The work of Joseph Schumpeter (1883-1950), stands as the towering exception. Schumpeter placed innovation firmly at the centre of his conception of capitalism, his critique of the neoclassical economic theory emerging around him, and his efforts to formulate a theoretical alternative. When he died in 1950, it was Keynesian rather than Schumpeterian thought that was coming to dominate research programmes in economics, yet his ideas later enjoyed a renaissance and have come to exert a profound influence in contemporary thinking about innovation just as, as his biographer notes, 'today's thinking about capitalism is in large part his' (McCraw 2007: ix). Schumpeter is probably most closely associated with the notion of 'creative destruction' (derived from his reading of Marx), the idea that innovation simultaneously involves the creation of the new while also destroying what already exists (Schumpeter 1942: ch. 7). We sense the continuing influence of Schumpeter's conception of innovation in the way the contemporary business literature explores both the benefits accruing to successful innovators and the capacity of innovation to sweep aside established firms and to 'disrupt' entire industries. We may also find Schumpeter's view of innovation as creative destruction echoed in the way the defence literature simultaneously positions innovation as a force bestowing military advantage whilst threatening to destroy the value of existing capabilities – the fruits of yesterday's innovators.

While the number of academic publications directly concerned with innovation rose from about 1960, no single academic discipline existed to undertake systematic investigation of the full range of phenomena that could be labelled as innovations. Rather, scholars from a variety of disciplines across the social sciences began to write about innovation through the lenses and problematiques of their respective scholarly traditions. Some economists, influenced by Schumpeter, viewed innovation as central to developing an alternative economics that interpreted the economy as a complex evolving system (Dosi 2013). The field of science policy (sometimes called research policy) emerged with a particular focus on informing public policy as it related to innovation. Some academic departments, such as the Science Policy Research Unit at Sussex University, became important sites at which scholars from different disciplines fruitfully congregated. Martin notes that in the early 1960s '"science" was broadly interpreted as including "technology" and even "innovation". The emphasis on "science" at that stage reflected the key role that science was then assumed to play in relation to the development of technology and innovation', while '"policy" was taken to include wider issues relating to the *management* of science, technology and innovation (in particular the firm) and to the *economics* of science, technology and innovation' (Martin 2012: 2). As it became clear that 'science is only one among several ingredients in successful innovation', 'science policy' increasingly became a misnomer and researchers began to speak of 'science policy and innovation studies' (SPIS), or simply 'innovation studies' (ibid., Fagerberg 2004: 2).

Meanwhile, the sociology of science and of technology grew into an important branch of sociology (Science and Technology Studies – STS) that began to develop its own schools with distinctive perspectives and interests (Martin et al 2012: 1183). In parallel, historians of science and increasingly of technology began to study innovation processes, and through the 1980s and 1990s some bridges were established between historians and social scientists working in these areas (Bijker et al 1987, Roland 1992). Business schools, for their part, studied and developed a rich literature on innovation management, although innovation only rose to the top of the agenda in early 2000s (Nelson 2013, Tomes 2007: 23).

From the 1960s, then, both the emerging sociological field of science and technology studies and the field that has come to be known as innovation studies began to emerge as distinct scholarly fields that were centrally concerned with innovation. Strikingly, however, and with some important exceptions, neither field developed a particularly rich literature devoted to specifically *military* aspects of innovation. In 1986 MacKenzie (whose study of the development of inertial guidance systems is among the most important contributions from STS on military technological innovation) lamented what he saw as the general failure of his field to address the relationship between science and the military or 'to gain intellectual purchase on this *wholly fundamental* aspect' (MacKenzie 1986: 363).[9] More than

[9] MacKenzie suggests the perceived difficulties of research access may have contributed to this gap but in his discussion of his approach to studying 'secret' technology he suggests this concern is misplaced (MacKenzie 1990: 12-14).

twenty years later, the situation seemed little improved. In the third edition of the *Handbook of Science and Technology Studies* (Hackett et al 2008), for example, Balmer et al observed that 'only a few writers have addressed the post-9/11 situation through the lenses of STS', that 'the changing security and military landscape… remains a rather peripheral concern of the STS community' and commented that the 'limited interrelationships between STS and other fields concerned with the military and security remains unfortunate' (Balmer et al 2008: 730-732).

The field of innovation studies, similarly, has devoted relatively scant attention to military questions (again with some important exceptions), despite widespread acknowledgement of the enormous influence of military funding, interests and actors in shaping the directions of technological innovation as a whole and the size of the defense industry in the largest economies.[10] In an important contribution to this field, for example, Kline and Rosenberg stick strictly to 'commercial' innovation since, they state, military innovations have 'certain distinctly different characteristics' (Kline and Rosenberg 1986: 275). This situation is perhaps the more surprising given that some of the most important early work in science policy and innovation studies was produced through United States Air Force sponsorship via the RAND Corporation.[11] Those investments were made because 'the US leadership was well aware of the fact that the country's global dominance rested on technological supremacy and that the factors underpinning it needed to be catered for' (Fagerberg and Verspagen 2009: 220).

The relative scholarly neglect of the military sphere in innovation studies, despite ready acknowledgement of its importance for innovation, is difficult to explain. It may be - in part - because innovation studies, like the business and management literature, works with models and assumptions that fit uneasily with the situation in the military sphere. For example, large 'mission-oriented R&D' investments are the norm in this sector, often justified by the 'market failure' rationale as set forth by Nelson (1959) and Arrow (1962),

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[10] Mazzucato (2013), for example, points to the vital role of defense R&D in several of the underlying technologies that contributed to the iPhone, including GPS, the internet, touchscreen technology and later the voice-activated smartphone assistant Siri.

[11] Kenneth Arrow, Burton H. Klein, Richard R. Nelson and Sidney Winter, each of whom made fundamental contributions to innovation studies, were all associated with RAND (Hounsell 2000). Mowery notes of military mission R&D that 'this class of R&D is largely overlooked by the welfare economics of R&D developed by (among others) scholars whose research originally was inspired or supported directly by military R&D programs' (Mowery 2010: 1221).

although such failure underpins less than 50% of such investments across OECD economies (Mowery 2010: 1222-1223). Such investments frequently do not resemble the 'ideal' of scientists as set forth in the seminal 1945 report *Science: The Endless Frontier*, produced by Vannevar Bush, since investments are often selected by policymakers pursuing specific agency missions rather than by scientists as per the Bush model. Thus, Mowery concludes, the science and technology policy literature 'provides no framework for considering the reasons for such large-scale investments of public funds or for comparing and evaluating the design and effects of such programs' (Mowery 2010: 1224). Specifically *military* innovation is awkward for innovation studies in a number of other obvious ways, not least of which is that the 'value' of a military innovation cannot be established in a 'marketplace' as it is in the for-profit sector.[12] Nonetheless, there are calls from within innovation studies to address this situation. In a recent survey, for example, Lundvall specifically identifies 'the process of developing new weapons that make it possible to kill remotely at a distance' as a priority for future research. He calls for research 'that looks into how the collaboration between industry, defence departments, and the military influences the development of new technologies' to help clarify 'how new technological trajectories are shaped' (Lundvall 2013: 206).

The majority of work on military innovation developed in parallel among historians and, more and more influentially, in political science, international relations and cognate fields such as strategic studies and security studies. Among historians, as noted by Grissom, innovation (and stagnation) had been 'important themes since the earliest writings on warfare, dating at least to Thucydides' description of a proto-flamethrower employed by the Boetians in 423 BC' (Grissom 2006: 905). Yet in the 20th Century it took time for links to develop between military historians and historians of science and technology. As observed by Roland, 'military history has been studied often but not well; the history of science has been studied well but not often' and 'compelling syntheses of these topics' were lacking (Roland 1985: 247). The 1980s, however, witnessed an 'unprecedented flowering' of historical scholarship on technological innovation and war (Roland 1993: 117, Roland 1995:

[12] Alic captures some of these differences when he observes that whilst '[b]usiness routines flourish in stable environments that support repeatable production of standardized goods and services', in contrast 'the stock-in-trade of military organizations is the destabilization of operating environments—those of the enemy—through violence, death, and destruction' (Alic 2008: 5-6).

S84).[13] Military historians did not confine themselves to the macro-historical impact of technological innovation but also laboured to produce studies grounded in the detail of particular cases of innovation (and, conversely, non-innovation) in technology. Nor did they limit themselves to technical change narrowly defined but examined a broad spectrum of ways in which military entities had sought to change. Doctrinal changes were a particular focus of study, as were changes in organisational arrangements.

From the 1980s, however, some of the most influential scholarship on military innovation tackled the subject through the lens of international relations and positivist social science, with Posen's 1984 study of *The Sources of Military Doctrine* in the vanguard (Farrell and Terriff 2002: 3, Grissom 2006: 906). Posen's work is today often seen as having inaugurated a new sub-field, and it is this that is increasingly described as 'military innovation studies' (Grissom 2006, Griffin 2017). Work on military innovation grounded in political science and IR has tended to reflect the preoccupations (the kinds of questions scholars are likely to find interesting) and evolving theoretical approaches in these fields. In particular, political science literature on military innovation has tended to engage evolving debates about the relative explanatory power of neo-realist, organisational process and bureaucratic politics, and latterly constructivist and culturalist approaches. Although heavily grounded in IR theory and reflecting the evolution of the underlying theoretical debates in this discipline and political science more broadly, military innovation studies has also imported ideas from organisational sociology (in common with other political scientists and IR scholars) and science and technology studies (particularly work in the 'social shaping of technology' school) while also retaining close ties with military historians. Some military innovation scholars are beginning to introduce insights from the business and management literature, despite the acknowledged difficulties in importing concepts from beyond the military sphere (for example, Pierce 2004 and Tomes 2007). Yet despite these interdisciplinary leanings, one military innovation scholar reviewing the current state of the field has expressed concern that 'the influence of military innovation scholarship is minimal

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[13] Roland specifically highlights several works, including: McNeill, W.H. (1982) *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000* Chicago: University of Chicago Press, van Creveld, M. (1989) *Technology and War: From 2000 B.C. to the Present* New York: Free Press, O'Connell, R. (1990) *Of Arms and Men: A History of War, Weapons and Aggression* New York: Oxford University Press, Parker, G. (1988) *The Military Revolution: Military Innovation and the Rise of West, 1500-1800* New York: Cambridge University Press.

outside of a very specific scholar-practitioner community' and suggested that a fresh round of interdisciplinary effort may provide the means to further enrichment (Griffin 2017: 196).

In these ways, STS, innovation studies and military innovation studies have all been heavily preoccupied with questions relating to innovation – working to understand and explain its causes, drivers, inhibitors and dynamics, types, as well as with its consequences and the possibilities for making recommendations on how to innovate more successfully. Yet their respective research programmes have developed largely (though again, not entirely) in parallel. STS and innovation studies both readily acknowledge the importance of the military sphere for science, technology and innovation as a whole but scholars in both disciplines lament the limited contributions from their fields. Military innovation scholars, meanwhile, recognise that the innovation studies and STS scholarship have the potential to enrich and advance the debate. In short, and notwithstanding the difficulties in translating between military and non-military spheres, there is plenty of room for further productive exchange between military innovation studies, STS, and innovation studies on questions of military innovation. One of the underlying ideas of this thesis is that re-engagement between these fields might yield a richer understanding of the historical evolution of UAV technology, the emergence of forms of violence often dubbed 'drone warfare', and of the processes of innovation in the military sphere.

What is innovation, what is technology?

Innovation and technology are closely associated terms. Indeed, innovation is sometimes too narrowly equated with the development and introduction of new technology. Technology, in turn, is often narrowly understood to mean artefacts and devices – as 'gadgets and gizmos' (Rip and Kemp 1998: 329). Upon closer inspection, however, the term is used in such a wide variety of ways that rather than seeking to arrive at a single definition, scholars instead seek to clarify the different registers in which the term is used (Rip and Kemp 1998, Nightingale 2014). These two terms, so central to this enquiry, merit further reflection.

Innovation, wrote perhaps its greatest student, involves '[t]he doing of new things or the doing of things that are already done in a new way' (Schumpeter 1947: 151). The 'things' in question vary widely, in proportion with humanity's capacity for ingenuity and creativity. In practice technological innovation is an enormously important aspect of innovation, yet innovation need not involve technology at all. Schumpeter distinguished five types of innovation: new products, new methods of production, new sources of supply, the exploitation of new markets, and new ways to organise business (Fagerberg 2004: 6-7). None is inherently about technology. Within military innovation studies, arguably the main current of research has followed Posen's lead in focusing not on technology but on innovative doctrine (Posen 1984).[14] Doctrinal innovation need not involve technical change. Meanwhile Rosen, who did not confine himself to doctrine, examined twenty-one cases of military innovation, but considered only seven of these as being specifically about the development and introduction of new technology.[15] Most of the other cases involved technology, but were primarily about new ways of fighting, by employing technology in new ways. Others, such as the development of jungle warfare and counter-insurgency, were innovations respecting the concepts underpinning the use of force. Rosen proposed distinguishing three different kinds of innovation: 'a change in one of the primary combat arms of a service in the way it fights' or 'the creation of a new combat arm', or 'the creation of new technologies' (Rosen 1991: 6-8).

Although a great deal of the military innovation literature has concentrated on doctrinal innovation, military innovation is no more reducible to doctrinal innovation than it is to technology. Posen focused on innovation (or 'stagnation') in doctrine because he saw it as the vital link connecting military means to grand strategic objectives (Posen 1984). Yet exclusive focus on doctrine has since been criticised on a number of grounds, while numerous other scholars have pointed out that military innovation can occur in the absence

[14] Posen defined military doctrine as 'the subcomponent of grand strategy that deals explicitly with military means' (1984: 1). Those following in Posen's footsteps in focusing on doctrinal innovation include Snyder (1984), Zisk (1993), Avant (1994), Kier (1995, 1997) and Cote (1996).

[15] Rosen studied cases drawn from the US and UK (Rosen 1991: 6). In the US he classified Amphibious warfare (1905-1940), Carrier Aviation (1918-1943), Helicopter airmobility (1944-1965), Counter-insurgency (1960-1967) as 'peacetime' cases and Jungle warfare (1942-1943), Strategic bomber targeting (1941-1944), Submarine warfare (1941-1945) and Long-range escort fighter (1940-1944) as 'wartime' cases. His specifically technological cases were Guided missiles (1918-1956), Proximity fuse (1941-1944), Electronics warfare (1921-1945), Centimeter wave radar (1930-1942), and Ordnance (1918-1945). For the UK, Carrier Aviation (1918-1940) and Air defense (1916-1940) were classified as 'peacetime', Jungle warfare (1939-1944), Amphibious warfare (1914-1915), Strategic bomber targeting (1939-1945), and the tank (1914-1918) as 'wartime' cases, while Electronics warfare (1938-1945), and Centimeter wave radar (1938-1942) were treated as 'technological' cases. Clearly, several of the cases analysed in terms of 'peacetime' or 'wartime' dynamics involved technological change.

of doctrinal change.[16] Taken as a whole the military innovation scholarship suggests the need for an expansive conception of innovation and what being innovative involves, in order to reflect the observation that militaries can and do change in multiple ways.

Rosen's definition of innovation reflects his practical but insightful recognition that innovation involves and demands much more than formal agreement (though this may be important) at the level of language or written documents; but 'means actually doing something differently' and therefore has to entail substantive change in practice (Rosen 1991: 4).[17] He therefore defines major military innovation as 'a change in one of the primary combat arms of a service and the way it fights or alternatively, the creation of a new combat arm' (Rosen 1991: 7). He adds that such innovation involves 'a change in the concepts of operation of that combat arm, that is, the ideas governing the ways it uses its forces to win a campaign' in contrast to mere 'tactical innovation' which is 'a change in the way individual weapons are applied to the target and environment in battle' (ibid.).[18] Military innovation then can be doctrinal (provided it does produce a change in practice) or it can be defined as some change in the concepts underpinning the way an existing combat arm operates, or the creation of a new one to perform a new kind of military task. While Rosen also deals with technological innovation, he treats it as a separate category 'concerned with building machines' (although he does acknowledge that this has a 'political component') (Rosen 1991: 40). He does not explicitly establish the criteria of change in concepts of operation

[16] Farrell and Terriff summarise the criticisms of exclusive focus on doctrine: not all states have doctrine, doctrine means different things in different states and at different points in time, changes in doctrine may not always translate into changes in the way military organisations actually operate, and doctrine may be developed for political reasons as much as from strategic or operational concerns (Farrell and Terriff 2002: 4-5). Rosen cites the argument that formal doctrinal shift of the US Army from the Pentomic structure to Active Defense to Airland Battle did not change the Army's central combat function. In this view these doctrinal shifts would not meet the threshold of innovation (Rosen 1991: 8). Rosen refers to Kevin Patrick Sheehan, "Preparing for an Imaginary War: Examining Peacetime Functions and Changes of Army Doctrine" (Ph.D diss., Harvard University, 1988), pp. 352-56. Vennesson argues that '[t]he widespread belief in the importance of military doctrine is exaggerated', pointing to 'a wide gap between doctrine and the policies actually implemented in peacetime and wartime' and noting that doctrine is not universal (Vennesson 1995: 39-40).

[17] Grissom makes 'a change in operational praxis that produces a significant increase in military effectiveness' a basic criteria of military innovation (Grissom 2006: 907). Tomes also defines innovations as 'qualitative improvements in *military* effectiveness that yield a comparative advantage over other militaries, creating opportunities for increasing a nation's overall *strategic* effectiveness' and as 'large-scale, historically noteworthy change that over time shifts military effectiveness' (Tomes 2007: 10-11).

[18] Farrell and Terriff point out that this definition 'appears to rule out changes in the objectives of military operations, which are taken together to be "winning the war"', such as the US adoption of peacekeeping missions in the post-Cold War world (Farrell and Terriff 2002: 5).

and the way a combat arm fights as a marker of innovation; his treatment of technology is concerned with its 'creation' rather than use or battlefield implications. In Rosen's hands the addition of new technology counts as innovation even if it does 'not involve behavioural changes in the organization' (ibid. 8).

Students of innovation have long wrestled with the question of why certain innovations prove to be more consequential than others, with what if anything distinguishes different 'degrees' of innovativeness. This difficulty is reflected in military innovation studies, where a great deal of attention has been devoted to the concept of 'revolutions in military affairs', which are often closely associated with technological 'breakthroughs'. Military innovation scholars are often particularly interested in 'major' forms of military innovation, both because they seem less likely and therefore more interesting, and 'because, quite simply, minor military change is less important' (Farrell and Terriff 2002: 6). What constitutes 'major', though is harder to define. Tomes views 'major' innovation as 'large-scale, historically noteworthy change that over time shifts military effectiveness' (Tomes 2007: 11). Major innovation tends to be understood as change that turns out to yield major improvements in battlefield performance. Grissom argues this kind of 'consequentialist' definition of major innovation forms part of a tacit consensus across the literature about the meaning of military innovation (Grissom 2006: 906-907).

Evangelista, Rosen and Farrell and Terriff all understand innovation in terms of major consequences, but define it less in terms of battlefield improvement than in terms of impact on and between the affected organisations. In this view innovations are those changes in one domain that necessitate changes to other parts of the military whole. Seemingly against Rosen's view of technological innovation as 'building machines', Evangelista argued that an innovative weapon would have to lead to 'significant changes – for example, in the realm of strategy, in the organization of military forces, or in the distribution of resources among services' (Evangelista 1988: 51). With the exception of his discussion of technology, however, Rosen shares this view of 'major' innovation as that which cannot simply be added to the existing organisational structures but has knock-on effects. Major change in a combat arm would mean changing its 'concepts of operation', which is to say 'the ideas governing the ways it uses forces' as opposed to tactical innovation (defined as 'a change in the way individual weapons are applied to the target and environment in battle'). Major innovation changes the relation of a combat arm to others and produces 'a downgrading or abandoning of older concepts of operation and possibly a formerly dominant weapon' (Rosen 1991: 7-8). Farrell and Terriff see major change leading to 'new organizational goals, strategies, and structures' (Farrell and Terriff 2002: 6). Thus, these military innovation scholars define innovations as those changes that cannot simply be plugged into the existing intellectual and organisational constructs, but require potentially significant adjustments to be made in order to accommodate them. This suggests the Schumpeterian sense of the simultaneously creative and destructive character of innovation. In his study of innovative doctrine, Cote takes an explicitly Schumpeterian view of military innovation as 'more than an increase or improvement in efficiency', that 'exploits radically new weapons and/or new beliefs about how to fight, *and destroys old, outmoded doctrine*' [my italics] (Cote 1996: 8-9)'.[19]

In the innovation literature, it is recognised that the preoccupation with apparently major and very visible innovations needs to be balanced against an appreciation of longer running and less visible cumulative improvements. These less visible, apparently less dramatic processes may prove 'vastly more important, economically' than the initial invention, and indeed 'may, and often do, totally transform their economic significance' (Kline and Rosenberg 1986: 282-283). Military innovation scholars have recently begun to criticise the focus on 'major' change to the exclusion of incremental 'adaptation' processes. They point out that refining and modifying existing tactics, techniques and procedures, or making adjustments to existing technology can lead to significant improvement in battlefield effectiveness.[20] Farrell and Terriff (2002) had earlier made this point, defining innovation as one of three routes to military change, with adaptation and emulation the others. Farrell (2010) maintains the distinction between innovation and adaptation by arguing that any new tactics or techniques adopted during operations may afterwards be abandoned. If such adaptations become institutionalised, however, they may cross the threshold into innovation. From this perspective the focus on major and relatively sudden innovations needs to be balanced by an appreciation of the important increases in military effectiveness that can be achieved by organisations capable of accumulating and incorporating numerous adjustments.

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[19] Cote explicitly invokes Schumpeter's notion of 'creative destruction', which he then uses to develop his concept of radical innovation (Cote 1996: 62).

[20] Examples of recent work on military adaptation, typically during war, include Farrell (2010), Farrell, Osinga and Russell (2011), Foley et al (2011), Jungdahl and MacDonald (2015), Kollars (2015), Russell (2010), Marcus (2014, 2017), Murray (2011), Serena (2011).

The distinction between adaptation and innovation mirrors the distinction that is often made in innovation studies between incremental and radical change. In innovation studies, gradual improvements to existing products are often described as 'incremental' innovations whereas 'radical' innovations are held to be those that introduce a new concept that departs significantly from existing practice (Henderson and Clark 1990). For example, as Freeman and Perez note, '[t]here is no way in which nylon could have emerged from improving the production process in rayon plants or the woollen industry. Nor could nuclear power have emerged from incremental improvements to coal or oil-fired power stations' (Freeman and Perez 1988: 46).

Technology

Technology is often understood as artefacts and the knowledge to make and use them (Pavitt 1987: 182, Alic et al 1992: 29). All technologies also have a crucial aspect of 'intentionality'. What a technology 'is' is defined not by intrinsic physics, but in relation to desired functions that are imposed by people and that form a yardstick against which it is judged to work or not. Technologies often depend on other technologies and bodies of knowledge, and 'often require a wider social and physical environment of complementary devices, systems, institutions, rules and norms to operate'. This perspective points to 'dynamic processes where technological artefacts, understanding, and their environments co-evolve'. Rather than 'a one way process of changing the world to match an idea, or something determined by static social structures… [new technology] is generated by a distributed, often contested, co-evolutionary process that involves incremental improvements and radically new combinations, in which understanding and artefacts both change in a complex combination of deliberate design and unintended outcomes' (Nightingale 2014: 7).

Technologies, however, typically encompass numerous different things that often have a nested relation to one another. This means that technological units of analysis can be bounded in different ways. This typically 'stratified' character suggests that technology can be thought of as being 'composed of materials and components, combined into devices and linkages that, in their turn, are combined into an overall working system' (Rip and Kemp 1998: 330). Walker et al impose some conceptual order on military technology by providing a vertical hierarchy, with materials at the bottom and components, sub-assemblies, sub-systems, complete weapons and communication kits, weapons platforms and communications systems, nesting upwards into integrated weapon and information systems (Walker et al: 1987). The 'system of interest may be a subsystem as well as one encompassing its own subsystems', and this nestedness and complexity creates 'countless opportunities for isolating subsystems and calling them systems for purposes of comprehension and analysis' (Hughes 1987: 55).

The integrated weapon and information systems described by Walker et al, and the development programmes from which they emerge, have been the focus of the majority of the military innovation scholarship concerned with technology. And indeed, the different branches of military services do tend to be organised around given platforms or weapons systems (Grissom 2006). As noted by MacKenzie, however, this approach tends to screen out the effects of changes in enabling sub-units across successive iterations of larger units (MacKenzie 1990). By studying the development of a subsidiary enabling technology (inertial guidance) across successive generations of intercontinental ballistic missiles, MacKenzie was able to show the effects of developments in a critical sub-system technology across multiple weapons development programmes. Such change is harder to capture when the study is confined to a particular weapons system case study. Critical bottlenecks in subsidiary and enabling technologies can impose rather firm constraints on what a given technology making use of such technologies can be made to do. Similarly, incremental change in a given subsidiary technology can lead to dramatic differences in the possible applications of systems in which it is integrated. Understanding the historical syncopation of change in subsidiary technologies is vital in understanding how the timing and combinations of such changes can alter the parameters of military technological possibility, sometimes dramatically so.

The United States military introduced the term 'weapon system' in the early 1950s to help manage the increasingly complex tasks of integrating different technologies and managing the work of different contractors on joint programmes. The language of 'systems' reflected an attitude toward weapons acquisition and an aspiration to improve the research and development process by making sure that it encompassed not just a weapon but everything needed to build and maintain it. The term persists in military language today and is now defined in JP 1-02, the US Department of Defense dictionary as '[a] combination of one or more weapons with all related equipment, materials, services, personnel, and means of delivery and deployment (if applicable) required for self-sufficiency' (DOD 2010). Having been coined to articulate (and help tame) the increasing complexity of mid-Twentieth Century technology, the term sits increasingly uneasily with contemporary developments in information and communications technologies. These technologies make it increasingly difficult to continue to think in terms of large discrete platforms that draw mainly on their own organic capabilities when they are increasingly networked into wider infrastructures through which they both feed, and draw from capabilities distributed across the network (Dombrowski and Gholz 2006: 9). Thus military platforms can be conceptualised as nesting into larger systems still, sometimes discussed in terms of 'systems of systems' (e.g. Owens 1996).

Some sociologists and historians of technology had meanwhile employed terms such as 'large technical systems' (Hughes 1987), 'socio-technical systems' (Geels 2004a, Smith et al 2005) or simply 'infrastructures' (Edwards 2003) to capture the way artefacts become enmeshed in larger wholes. The emphasis in this literature is less on the hierarchies through which technologies relate to one another, and more on the 'societal embedding of a technology in concrete societal contexts as part of the development of technology': these systems are not technical but socio-technical in nature (Rip and Kemp 1998: 331). The large technical systems tradition in STS emphasises that large systems are comprised not only of interconnected technical artefacts, but also encompass heterogeneous elements including 'organizations, such as manufacturing firms, utility companies, and investment banks', and beyond to such domains as the scientific and legislative (Hughes 1987: 51). These heterogeneous elements are interconnected because their individual operations and interactions all contribute to the system goal and, since they are interconnected, changes in one component can have consequences for other parts of the system.

In Hughes' view large technical systems are built by particular kinds of people, whom he labels 'system builders'. While one such person may build an entire system it is more common for different people to act as system builders during different periods or aspects of a system's evolution. System builders 'construct or force unity from diversity, centralization in the face of pluralism, and coherence from chaos' (Hughes 1987: 52). The environment in which a large technical system exists may be said to be all those elements that are not under the control of the system. Systems tend progressively to 'incorporate environment into the system' since they seek control and predictability. The freedom and unpredictability of individual people working within a large technical system tend to be controlled by bureaucracy, deskilling and routinization. Technological systems are thus 'bounded by the limits of control' (Hughes 1987: 53-54). Although he calls it a 'pattern' rather than a model or theory, Hughes suggests that large technical systems may tend to evolve through a number of phases: invention, development, innovation, transfer and growth, competition, and consolidation. He qualifies this by allowing that phases may overlap and backtrack, with more invention potentially occurring throughout, transfer possibly occurring at different moments, and so on. Hughes further suggests that a certain kind of system builder tends to be 'most active as a maker of critical decisions' in each phase. For example, inventor-entrepreneurs are associated with invention and development, manager-entrepreneurs tend to come to the fore during innovation, competition and growth, and financier-entrepreneurs and consultant engineers are associated with consolidation and rationalization (Hughes 1987: 57).

Parallel to the concept of large technical systems is the notion of a technological paradigm. Dosi, who wrote the classic article on technological paradigms, suggested that clusters of related technologies tended to emerge over time.[21] 'Given some generic technological tasks… such as, for example, those of transporting commodities and passengers, producing chemical compounds with certain properties or switching and amplifying electrical signals, certain specific technologies emerged, with their own "solutions" to those problems' (Dosi 1982: 153). Dosi extended the definition of technology to encompass not only devices and equipment but also a specific set of knowledge and experience that contained within it 'the "perception" of a limited set of possible technological alternatives and of notional future developments' (Dosi 1982: 152). Dosi argued that those working on established technologies or technology clusters typically share a sense of what the relevant problems are, what 'progress' will look like, and the principles and materials to be drawn on to proceed. By analogy with Kuhn's work on scientific

[21] Marx had noted the tendency of innovations to cluster in time and space, which he interpreted in terms of the tendency of competitors to imitate one another's innovations. Schumpeter modified the Marxian position, emphasising the likely room to improve upon the early versions of an innovation, and the potential for it to be applied in initially unrecognised areas and ways, so that an initial innovation would tend to 'induce' a chain of related innovations. Schumpeter believed that the clustering of innovations in time and space was connected to business cycles and 'long waves' of world economic development (Fagerberg 2004: 6, 14-15).

paradigms Dosi referred to these technology clusters as 'technological paradigms.' A paradigm is thus 'an "outlook", a set of procedures, a definition of the "relevant" problems and of the specific knowledge related to their solution'; it 'determines the field of enquiry, the problems, the procedures and the tasks'.

These characteristics mean that each paradigm defines 'its own concept of "progress" based on its specific technological and economic trade-offs.' Technological paradigms therefore direct technological development along particular paths that are defined by a shared understanding of the relevant problems and the means to solve them. This in-built sense of direction of technological change produced within a given paradigm Dosi calls a 'technological trajectory' (Dosi 1982). Trajectories direct development efforts in particular directions but they also entail the 'exclusion of other notionally possible ones', focusing the minds and energies of engineers 'in rather precise directions while they are, so to speak, "blind" with respect to other possibilities' (Dosi 1982: 151). It is a '"model" and a "pattern" of solution of *selected* technological problems based on *selected* principles derived from natural sciences and on *selected* material technologies.' Technological trajectories of development have a cumulative character in that 'the more they are adopted, the more experience is gained with them, and the more they are improved' (Arthur 1989: 116).[22] Typically 'crude and primitive' in their early stages, subsequent slow, incremental, low-visibility change along established trajectories often 'transforms a mere novelty to a device of great economic significance' (Kline and Rosenberg 1986: 283-284). Technological innovation processes, therefore, appear to be subject to self-reinforcing dynamics and even 'lock-in' (David 1985).[23]

In this thesis, I understand innovation to be – along Schumpeter's lines – doing things differently, or doing different things, i.e. new roles and missions, or doing existing roles and missions in new ways. As military innovation and innovation scholars alike have considered, innovation can be disruptive (major), or incremental (cumulative). Major forms

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[22] Arthur suggests five drivers of increasing returns: '(i) learning by using: the more a technology is used, the more is learned about it, the more it is improved; (ii) network externalities: the more a technology is used by other users, the larger the availability and variety of (related) products that become available and are adapted to the product; (iii) scale economies in production, allowing the price per unit to go down; (iv) informational increasing returns: the more a technology is used, the more is known by users; (v) technological inter-relatedness: the more a technology is used, the more complementary technologies are developed' (Arthur 1988: 591, cited in Geels 2004a: 22).

[23] Cairns (2014) provides a useful overview of the debates surrounding the concept of lock-in.

of innovation involve not only changes in technology, understood as artefacts and the knowledge needed to produce them, but changes to the wider systems in which technological artefacts are embedded and the institutions, doctrine and structures governing their use by the military. Such significant changes are normally accompanied by a change in the security environment, shaping the conditions under which military planning occurs (more on this below). Incremental innovation also plays an important role in changing the parameters of technical possibility over time, and positioning and testing new technologies. This becomes clear only through historical enquiry into how certain technologies have evolved over time.

As stated above, technology cannot be reduced to 'artefact': it must be seen within the wider whole in which it is embedded. I borrow Hughes' term 'large technical system' from the STS literature, applying this to the military sphere to denote how military technologies are embedded not only as part of wider 'weapons systems', but within broader socio-technical systems comprising institutions, user groups and governing rules, and which evolve over time. I use the term 'military technological paradigm', meanwhile (building on Dosi's interest in technological paradigms), to denote technological clusters which define the scope of certain military procedures, behaviours and goals. The dominant paradigm will have a conditioning effect on how technological systems are able to evolve.

From the Wartime/Peacetime Distinction to Imagined Scenarios versus Actual Contingencies

The distinction between peace and war constitutes a deep-seated and enduring assumption of western political thought; indeed, the distinction as we understand it is bound up with the emergence of the modern state and the Westphalian order (Kaldor 2007). Like technology, wars are often used to periodise history, with one occasional and relatively brief period of war marking the end of one typically longer period of peacetime and the beginning of another (Dudziak 2012, Gray 2005). International law rests upon this distinction, with a specific body of law (international humanitarian law) applicable during war.

The wartime/peacetime distinction has been used to great effect by military innovation scholars. In addition to dividing their subject by domains or degrees, some of these scholars have identified important differences between military innovation processes in these two different contexts. The differences between peacetime and wartime innovation, as they are depicted in the literature, can be well summarised as the differences between the challenges of anticipating and preparing for a future war and the challenges of organisational learning and adaption whilst actually immersed in 'the malevolent, violent chaos of war' (Rosen 1991: 23). Thus peacetime innovation becomes a question of how to get bureaucracies to innovate in the absence of a clear external stimulus and in large part the ensuing debate is one about motive forces and conditions under which military organisations do prove capable of innovation in the absence of a clear threat. In wartime, meanwhile, the discussion has turned on the problem of wartime learning, and particularly how militaries can recognise and respond to situations in which their existing capabilities cannot result in victory, however much they are improved upon (Rosen 1991).

The literature on peacetime military innovation raises two major issues. The first issue is primarily a problem of theory. Even those accounts of military innovation that emphasise neo-realist theory and therefore systemic constraints and incentives (which today is a minority position) tend to allow that in peacetime, organisational and bureaucratic dynamics are often allowed to 'flourish' (Posen 1984: 27-28). Yet if organisational process and bureaucratic politics are the used as the frame of reference, the challenge becomes to explain why innovation would take place at all, if the premium organisations place upon predictability, stability and certainty is 'inimical to innovation'.[24] Indeed, organisational resistance to innovation is a major theme of the literature (for example, Ellis 1973, Hacker 1974, Holley 1953).

The second issue concerns the fundamental dilemma of how to prepare for future wars 'that may or may not occur' in the face of multiple forms of uncertainty: who the enemy may be, their objectives and strategy, and the forces, weapons and tactics they may employ (Rosen 1991: 8). Drawing from the organisations literature, Allison suggests that in common with other types of large organisation, military organisations abhor uncertainty and characteristically seek to manage it by developing 'a set of *standard scenarios* that

[24] Rosen, similarly, remarked that '[a]lmost everything we know about large bureaucracies suggests not only that they are hard to change but that they are *designed not to change*'. For him '[t]he particular problem facing men and women involved in the study and practice of modern politics is how to get bureaucracies to innovate', yet '[n]o good explanation of bureaucratic innovation exists' (Rosen 1991:1-4).

constitute the contingencies for which they prepare' (Allison 1971: 84). Allison argues that because effective organisational action involves successfully orchestrating the behaviour of numerous individuals, '[a]ssured performance requires sets of rehearsed [standard operating procedures]' that are clustered into programmes (Allison 1971: 83). Due to the difficulty in achieving assured performances, organisations can only maintain a limited number of programmes. The programmes actually developed constitute the effective range of responses that a given organisation can enact in a given situation. The missions that military organisations prepare themselves to perform, and that establish the basic suite of military options available in response to any given situation flow from the way the future conflict scenarios are imagined and defined. Allison argues that these scenarios have an important influence upon the way the US military services have undertaken technological innovation. As an example, he claims that 'the standard scenario for Tactical Air Command of the U.S. Air Force involves combat with enemy aircraft' (Allison 1971: 84). The relevant performance characteristics orienting aircraft development, as well as the way pilots are trained, in this view, flow from the way the scenario is defined.

If the organisational process perspective interprets the scenarios of future war as products of efforts to manage uncertainty, bureaucratic politics perspectives stress that the way the scenarios are defined has important implications for power and influence between national security organisations and between branches within those organisations. This approach points more to processes of political contestation and compromise and tends to portray the scenarios more as reflections of bureaucratic interests. In strong form, this perspective sees the way future war scenarios are defined as reflections of organisational and bureaucratic interests. Ideas about future war that suggest existing capabilities are redundant would be filtered out in favour of ideas that enhance the influence and resources of an organisation, its roles, missions and capabilities. In the same way, the formal requirements used to justify funding for large acquisition programmes, sometimes appear to have been facades.[25] From these

[25] Alic cites numerous examples, including Getting, a participant in the B-1 bomber programme, who stated afterwards "'there had to be a strategic role for the long-range strategic combat aircraft and that was where the imprecisely located target concept came in… The result of that study was that the B-1 received revived respectability"' (Alic 2008: 89). Art's study of the TFX (which became the F-111) aircraft argues that while paying lipservice to the air support role, Tactical Air Command actually sought a plane that could deliver nuclear weapons against the Soviet Union, thus seizing influence from Strategic Air Command (Art 1968).

different perspectives, rather than outright innovation resistance in 'peacetime', we might instead consider how the future war scenarios channel innovative efforts in certain directions while excluding others.

Peacetime scenarios developed by military organisations represent the building blocks of the dominant military-technological paradigm and have the effect of directing 'the efforts and the technological imagination of engineers and of the organizations they are in' in 'rather precise directions', while rendering them '"blind"' to other options (Dosi 1982: 153). Seen this way, these scenarios have selective or 'focussing' effects upon military innovation, directing innovative activities along particular 'trajectories' rather than others.[26] By the same token, the 'relevance' of technological inventions bubbling up from R&D efforts would be judged through the lens of the established scenarios. To advance along the invention-innovation-adoption continuum, a prospective innovation would have to be seen to 'fit'. Dosi himself seems to allow for this. The pathways of technological change actually selected, he argues, are likely to be heavily influenced by economic, institutional and social forces such as 'the economic interests of the organizations involved in R&D', while at the same time he also points out that the paths historically selected by military organisations have often established trajectories of wider significance (Dosi particularly cites the examples of semi-conductors and computers) (Dosi 1982: 155).

The development of military innovation research along the lines of peacetime/wartime scenarios continued to unfold during the 1990s and 2000s. At the same time, however, a growing chorus of scholars and professionals began to argue that the wartime/peacetime distinction was breaking down. The advent of nuclear weapons coupled with intercontinental delivery systems, it was argued, effectively precluded large-scale war between states armed with these weapons. '[T]he effect of nuclear weapons, unforeseen and perhaps unforeseeable', argues Van Creveld, 'has been to push conventional war into the nooks and crannies of the international system' (Van Creveld 1991: 11). Rupert Smith believes 'war as cognitively known to most non-combatants, war as battle in a field between men and machinery, war as a massive deciding event in a dispute in international affairs: such war no longer exists' (Smith 2006: 1). This is not to say that the use of organised

[26] Similar ideas are conveyed by the concepts of 'inducement mechanisms' (Hirschman 1958) and 'inducement mechanisms and focusing devices' (Rosenberg 1969).

violence for political purposes has been consigned to history. Rather, scholars making this argument shared the view that different kinds of war were coming to the fore. They often added that the awesome and expensive military capabilities acquired by the United States and others might be of limited ‘utility’ in these forms of conflict. Others argued that the established mental models for thinking about war were inhibiting clear thinking about the character of contemporary conflicts and likely character of future wars (Kaldor 2007). Dudziak points to a ‘disconnect between the way we imagine wartime, and the practice of American wars’ (Dudziak 2012: 8).

This perspective hints at the difficulties with calling the Cold War and post-Cold War periods ‘peacetime’. Such a characterisation is misplaced for two reasons. First, while the United States has not actually fought the kinds of large-scale conventional, existential war for which it has been constantly preparing since the end of the Second World War, nor did it demobilise as it had in previous post-war periods. Rather the period since 1945 has been characterised by continuous and large-scale US investment in military capabilities, channelled by the scenarios of future war. Secondly, throughout these periods, in the shadow of the image of future war that dominated the thinking of the DoD, the US military has been repeatedly and indeed almost continuously engaged in a series of ‘other’ military operations, often described as ‘contingency operations’.

As has been widely recognised, the actual contingencies in which the US has become engaged often involved applying capabilities designed for imagined future conflict to a range of conflicts that proved markedly different. This mismatch can have two broad kinds of impacts on technological innovation. First, peripheral conflicts have sometimes demonstrated the dangers posed by systems available to adversaries, engendering sustained counter-innovation efforts. For example, direct experience of Soviet-made air defence systems and fighters during the Vietnam War and observation of the 1973 Yom Kippur war were recognised to have profound implications – above all for the way a possible direct confrontation was imagined between the US and USSR in Europe. These experiences fed sustained efforts at technological innovation in a number of related areas as well as sustained and interlinked efforts at doctrinal and organisational change throughout the 1970s and 1980s (Kagan 2006, Tomes 2007). The results became visible in the 1991 Gulf War and were widely heralded as a ‘revolution in military affairs’.

Second, military organisations may seek to change the way they fight in response to difficulties experienced in the course of involvement in actual contingencies. Much of the literature on 'wartime' military change adopts the prevailing view of 'war' as relatively short, high intensity, conventional fighting. Rosen argues that because of this, rather than decades-long timelines, any such innovations 'must be thought through and implemented within two or three years if they are to be any use' (Rosen 1991: 22). For this reason, wartime innovation research often stresses more incremental, pragmatic adaptation of existing capabilities under time pressure (Kollars 2014). Yet in practice the contingencies have sometimes departed from the notion of war as a relatively short and bounded phenomenon, stretching across a decade or more. Such time spans, in principle, open up the possibility of developing and fielding military technology tailored to specific conflicts.

In this thesis, to overcome some of the limitations raised above, I rearticulate the wartime/peacetime division as imagined war versus real contingency. In so doing, I demonstrate how actual contingencies are vital in allowing for a shift in trajectory, albeit sometimes temporary: it is the combination of external shock or crisis and sustained involvement in new types of contingency that makes possible an opening in or departure from dominant peacetime or 'future war' planning scenarios, and occasioning a shift in military-technological paradigm.

Military Technological Innovation as a Process

Understanding how new technologies can be positioned to capitalise on such openings in the dominant ways of conceptualising and doing warfare requires an understanding of how technologies move along the innovation pathway, i.e. the *process* of innovation. As explained above, this process is highly contingent and reversible, and involves the evolving interplay between technological possibilities at a given time, with the strategic environment and potential user groups and usages to which the technology might be aligned.

Innovation is often understood as a process that can be divided into stages. Efforts to model innovation as a process are normally developed from the Schumpeterian distinction between invention and innovation. In this view 'invention' encompasses the generation of ideas ('the first occurrence of a new idea for a new product or process') whereas ‘innovation’ involves turning ideas into marketable products (‘the first attempt to carry it out into practice’) (Fagerberg et al 2013: 1135, Fagerberg 2004: 4).[27] The invention/innovation distinction helps emphasise that it is one thing to invent something and quite another to see it ‘adopted and embedded’ in productive processes (Edgerton 1999, quoting Rosenberg 1982). This invention/innovation distinction reflects that only a small proportion of new ideas will be successfully carried out into practice, helps focus attention on the difference between the first glimmerings of a new idea and the successful incorporation of that idea in practice, and draws attention to what is involved in turning the former into the latter. Indeed, the skills associated with invention are not identical to those needed to implement an idea – history being ‘replete with cases in which the inventor of major technological advances fails to reap the profits from his breakthroughs’ (Fagerberg 2004: 5).[28] The literature also often refers to a ‘Schumpeterian’ third stage, often labelled ‘diffusion’ (particularly associated with Everett Rogers (2003)), in which the novelty is imitated by competitors and spreads across the market, although Schumpeter wrote comparatively little about this (Freeman 1994: 480).[29] The term ‘innovation’ is thus used sometimes to designate an overall process and sometimes to refer to a particular phase in that overall process, distinct from ‘invention’.[30]

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[27] Innovation scholars often attribute the distinction to Schumpeter without providing citations. In *Business Cycles*, Schumpeter points out that invention is not a necessary precondition for innovation and that where innovation does develop from invention (‘where innovation consists in giving effect, by business action, to a particular invention’), ‘the making of the invention and the carrying out of the corresponding innovation are two entirely different things’ (Schumpeter 1939: 85-86). Rogers, however, found the same distinction drawn by Ogburn (1922) and Linton (1936), while Godin identifies the same idea in the work of Jeremy Bentham, Lester Ward and Joseph Stamp (Godin 2014: 23-24, fn.18).

[28] In addition, innovation increasingly tends to arise from collective efforts of organisations and networks of organisations, rather than only from inspired individuals. Where Schumpeter initially assigned special importance to individual entrepreneurs in generating innovation, his later work (sometimes known as Schumpeter Mark II), and subsequent scholarship, has particularly emphasised the role of firms. Mazzucato has observed that this focus on firms in turn has tended to encourage narratives that obscure the often crucial role of public (and frequently military) investments in basic and applied research and development, pointing out, for example, that some of the key technologies that make the iphone a ‘smartphone’ - the internet, GPS and touchscreens - all directly and substantially emerged from military research programs (Mazzucato 2015). This suggests that innovation scholarship could benefit from more work on such investments in overall innovation processes (Martin 2016: 437), although the military innovation literature does include substantial work on spin-off (e.g. Alic et al 1992) and ‘mission R&D’ (Mowery 2010).

[29] The term ‘diffusion’ is closely associated with the work of Everett Rogers (2003).

[30] The literature reveals numerous versions of the basic idea that it is helpful to conceptualise innovation as a process. Brozen (1951) suggested invention-innovation-imitation, Mansfield (1968) invention-innovation-imitation-diffusion, and Staudenmeier (1985) characterised the literature as exhibiting a shared ‘tripartite’ mental model invention-development-innovation (see Godin 2014: 23-24). Rip and Kemp distinguish between the ‘introduction of novelty’ and the ‘adoption of novelty’ (Rip and Kemp 1998: 338). Everett Rogers described an ‘innovation-development process’, which he understood to encompass ‘all the decisions, activities, and

This model of innovation balances concern with invention (which often receives disproportionate attention) against recognition that any invention takes on its significance when it enters into use (Edgerton 1999). Military innovation studies, similarly, makes change in practice the marker of innovation – it 'means actually doing something differently' (Rosen 1991: 4). In commercial settings, 'diffusion' typically means the spread of a technology throughout a market. In the military context, diffusion often means the spread of a technology 'throughout the international system' and perhaps especially into the hands of adversaries (Eliason and Goldman 2003: 7). This thesis is not concerned with diffusion in this sense, although there is growing policy and academic interest in the diffusion of drones beyond the United States and its allies, and the pursuit of UAV technology by China, Russia, Iran and others, especially non-state actors. Rather than diffusion, the focus in this thesis is instead upon the process by which a technology moved from idea to use *within* the United States military context. This part of military technological innovation processes is described with a variety of terms, such as 'adoption', 'integration' or 'assimilation'.

A central insight and point of departure in the military innovation literature is that in the modern era, war has been prepared for and conducted by large bureaucratic organisations (e.g. Farrell and Terriff 2002, Grissom 2006, Nielson 2010, Posen 1984: 26, Rosen 1991: 2). For this reason, an essential feature of successful advancement of technology along the innovation continuum is increasing incorporation of a prospective military innovation into a military organisation, its structure, plans, routines and, ultimately, its operations. Much more than new ideas, military innovation therefore concerns the processes by which those ideas are actualised in practice, the barriers to such actualisation, and the means by which or conditions under which such barriers may be overcome. Since the marker of innovation is change in practice - as Schumpeter argued, *doing* something differently or *doing* different things – the introduction of new technology can be described as innovative only when organisations start using the technology in ways that mean they are doing things differently or doing different things in practice.

The invention-innovation-diffusion framework is sometimes taken to suggest a unilinear, sequential, deterministic progression, in which research leads to development to

their impacts that occur from recognition of a need or a problem, through research, development, and commercialization of an innovation, through diffusion and adoption of the innovation by users, to its consequences' (Rogers 2003: 405).

production to marketing, each 'flowing smoothly down a one-way street' (Kline and Rosenberg 1986: 285). The most common variant of the 'linear model', in which innovation is presented as proceeding from scientific discovery, is a frequent target of scholarly derision, although it is difficult to find proponents of this view and the critics have in turn been criticised for attacking straw men.[31] Besides the important point that there are plenty of examples of innovations that do not originate in scientific discovery (and indeed 'plenty of instances where technology appeared before the science that explains it' (Nightingale 2014: 3)), the problem with a linear innovation model is simply that innovation does not unfold as an orderly progression of steps.[32] In practice, science is often an important part of technological innovation but rather than the 'initiating step' the 'linkage from science to innovation… rather extends all through the process' (Kline and Rosenberg 1986: 290-291). Moreover, technology also feeds back into science in profound ways.[33] Thinking of technological innovation as a succession of stages, each involving a discrete set of activities, tends to screen out feedbacks from 'later' stages: 'crucial innovations take place both at the design and at the implementation stages, and are continually fed back into future rounds of technological change' (Williams and Edge 1996: 874-875).

Another criticism levelled at linear models is their treatment of innovation as emanating from a single source. While the 'linear' model most commonly invoked locates the fundamental impetus for (technological) innovation in scientific discovery, an alternative model instead points to technological discovery processes and the technical communities driving those processes. Both these variants of the linear model locate the impetus for new technology in forces of 'supply' (science or technology, respectively). From this point of view technological innovation is conceptualised as being 'pushed'. In his comparative study of

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[31] Freeman defines the linear model as the 'notion that innovation begins with a discovery in "basic science," proceeds with an application or invention derived from this fundamental work ("applied science"), and ends with the development of a new product or process (an "innovation")' (Freeman 1996: 27). Edgerton convincingly argues that the 'linear model' is a creation of innovation scholars of the 1980s 'to describe what is taken to be the standard or traditional position'. He shows that academic specialists from earlier generations had adopted far richer positions and argues that such a model did not in fact drive postwar innovation policy or science in the US or UK (Edgerton 2004).

[32] For example, even though science has become increasingly important to innovation over time, '[w]hile the initial synthesis of nylon and the demonstration of a working laser each marked the culmination of a lengthy process of scientific exploration, the microprocessor was the outcome of a pure exercise in engineering design' (Alic 2007: 109-110). Kline and Rosenberg argue that '[h]ad the idea been true that science is the initiating step in innovation, we would never have invented the bicycle' (Kline and Rosenberg 1986: 288).

[33] As Kline and Rosenberg argue, '[w]ithout the microscope, one does not have the work of Pasteur, and without that work there is no modern medicine' (Kline and Rosenberg 1986: 293).

military technological innovation in the US and the Soviet Union, for example, Evangelista proposed an avowedly supply-push account of the US case, arguing that the invention of new weapons in the US has little to do with external factors such as threats (or the perception of threats). Rather, he writes, 'impetus for innovation in weapons technology comes from the bottom – from scientists in government or private laboratories and the military officials with whom they are in close contact. The new proposal is pushed up through the bureaucracy until it attracts the attention of supporters in the Congress and the Executive. In this respect, a new weapon starts with a technological idea rather than as a response to a specific threat or as a means to fulfil a long-standing mission' (Evangelista 1988: X).[34] MacKenzie and Spinardi, by contrast, both found that although there is an important sense in which new military technology originates in the ideas and work of technical communities, and although technologists do indeed try to 'push' their concepts, they do not have it all their own way (MacKenzie 1990: 390, Spinardi 1997). Military decision-makers are unlikely to sponsor the development of technical concepts that do not, in a variety of senses, 'fit'. Spinardi points out that for the technologists-out-of-control thesis to be confirmed, evidence would have to be found of technologists transforming the goals and interests of the military user (Spinardi 1994: 172).

If Evangelista overstates the importance of technologist-push in technological innovation, his conceptualisation of innovation as a process is nonetheless helpful. It enables him to concentrate attention on the combinations of actors involved at each stage, and to present the innovation process as one of gathering support.

An alternative theory of innovation, focused particularly on technology and based in classical economics, may also be said to be linear but inverts the direction of causality in seeing 'demand' (typically market forces) as a prime mover that 'pulls' innovation along the

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[34] Evangelista's supply-push model of US military technological innovation characterises the process in terms of the following stages:

1. Technocratic initiative: discovery of new technical possibilities; scientists advocate military applications
2. Consensus Building: Scientists and military associates generate interest in new technology within military-technological community
3. Promotion: Scientific, military, and industrial "entrepreneurs" promote new weapon proposals within military services, Congress, and Executive
4. Open Windows: External threats serve as windows of opportunity for military to push a new weapon into production
5. High-Level Endorsement: Pentagon officials gain congressional support for mass production of a new weapon, justified with more specific reference to an external threat (Evangelista 1988: 52).

innovation process. Applied to military technology, this view echoes the ‘politics in command’ perspective, and captures the way that the weapons acquisition process is formally depicted by the US government. As MacKenzie puts it, in this view leaders first ‘assess the threats to the security of their nations and alliances. They then select amongst the technologies available, or provide resources for the creation of new technologies, in order to meet these threats rationally. Strategic goals come first; technology follows’ (MacKenzie 1989: 162). This view corresponds to the ‘mere tools’ understanding of technology. New military technologies are understood as products of ‘political decision-making’ – a process that is ‘typically characterized as based on a rational assessment of national security “requirements”’ (Spinardi 1994: 9). ‘In essence, national elites decide what nuclear weapons are needed - for example, to deter a potential enemy - and then the technologists are directed to design and build them’ (Spinardi 1997: 549). This kind of approach sees ‘a nation’s arsenal of weapons… as the product of government choices’ and in this view ‘[w]eapons are the result of national strategic choice; governmental leaders select specific weapons and total force posture on the basis of precise calculations about national objectives, perceived threats, and strategic doctrine within the constraints of technology and budget’ (Allison & Morris 1975: 101-103). Yet as Van Creveld has argued, in the Twentieth Century ‘none of the important devices that have transformed war – from the airplane through the tank, the jet engine, radar, the helicopter, the atom bomb and so on all the way down to the electronic computer – owed its origins to a doctrinal requirement laid down by people in uniform’ (Van Creveld 1989: 220).

The selection environment described by Dosi, when discussing the emergence of a technological paradigm, consists of both economic demand forces, as well as ‘institutional and social factors’ (Dosi 1982: 155). Since multiple pathways may still be possible based on general criteria such as feasibility, marketability and profitability, he argues, more specific variables must explain why a particular new path is taken. Dosi therefore points to a much richer range of factors in accounting for the establishment of particular technological paradigms. He especially emphasised the importance of the ‘economic interests of the organizations involved in R&D’, their ‘technological history’ and existing expertise (echoing Rosenberg), and especially the role of public ‘political’ forces, pointing to mission R&D such as military and space programmes as an important factor in the establishment of new technological paradigms. Mission R&D, he points out, historically had the clout to define ‘technological targets, while at the same time providing financial support to R&D and guaranteeing public procurement’ in particular directions (Dosi 1982: 154).

A similar kind of selection environment needs to be elaborated in the military sphere. In the United States, as elsewhere, different constellations of actors are associated with research and development and with operational use (Kaldor 1986, Rosen 1991). Movement along the innovation spectrum is therefore also characterised by a shift in an incipient technology’s organisational centre of gravity – generally from settings associated with research and development to more operational settings associated with use. An incipient technology’s status in a military organisation changes as the locus of organisational activity and responsibility shifts. Because of this, movement along the innovation continuum can be conceptualised in terms of the technology’s changing ‘status’ in relation to a military organisation and its practices over time. In this thesis I suggest that the changing organisational status of an incipient technology can be used to conceptualise the military technological innovation process. Whereas the idea of stages implies a linear process, statuses are reversible and contingent. Each status involves elements or shaping factors that represent a complex interconnected combination of both demand-pull and supply-push.

Marginality, Emergence, Assimilation

In this thesis the term ***marginality*** describes the status of any technology that is actively being developed in R&D settings, but has not (yet) found ways to become embedded in user organisations and their operations. Development efforts may well involve support or interest from a prospective end-user/s, although research and development actors may instead seek to garner interest for what they see as promising concepts by pitching them to prospective users. Marginality is not synonymous with ‘invention’, but includes all attempts to translate an idea into reality that do not (yet) yield a change in practice. Most ideas will not advance beyond this point. As noted by Kline and Rosenberg of inventions in general, ‘the overwhelming majority of the inventions recorded at the U.S. Patent Office were never introduced on a commercial basis’ (Kline and Rosenberg 1986: 276). The ‘majority of technologies were “resisted”, and had to be’ (Edgerton 1999: 123).

Technology that is under development but that remains militarily marginal may face two broad kinds of barriers to movement along the innovation continuum. On the one hand, technological constraints in one or more areas create gaps between actual and envisaged performance attributes. Since complex technologies are typically made up of nested subsidiary technologies, ostensibly a single technology or technological development programme may have to overcome multiple imposing technical constraints. A single constraint, similarly, may bedevil multiple development programmes. It is not a binary case of technology 'working' or 'not working', however. All technologies have a crucial aspect of 'intentionality' – the desired and subjective functions that people impose (Nightingale 2014: 5). In the military context, the assessment of military 'needs', and the way the threat environment is defined form the yardstick against which judgments about technological 'adequacy' are made.

On the other hand, movement along the innovation continuum also requires that the technology perform tasks that a military user regards as important. Those tasks are defined by the established, imagined scenarios that frame the way military organisations seek to prepare to fight the wars of the future. These imagined scenarios have tended to envisage large-scale warfare against similarly technologically capable state adversaries, and therefore extremely exacting battlefield conditions. The imagined scenarios thereby tend to set a high and ever-rising bar in terms of what it would mean for a technology to work 'well enough'. The established roles and missions, moreover, tend to be accompanied by incumbent platforms and weapons systems that are embedded in established organisational structures and routines, as well as in norms and values. Those incumbents have typically benefitted from rounds of technological refinement along established trajectories supported by close user feedback (Rosenberg 1969).[35] As Rosenberg observed, 'inventions, in their early stages, are typically very crude and primitive and do not even begin to approach the performance characteristics or productivity levels that are attained later on' (Rosenberg 1969: 283-284). This presents a dilemma for new technological innovations that may in principle eventually prove superior, but may only be able to achieve those improvements once they have benefitted from the feedback learning that they can only enjoy once they begin to be used.

[35] One important way that feedback learning in military technological development differs from civilian settings reflects that commercial technology faces the test of the market continuously, whereas '[m]ilitary systems and equipment confront the environment for which they have been designed only in wartime and then only in wars fought against capable and determined adversaries' (Alic 2008: 6). Military feedback learning therefore tends to be 'sparse and spotty, learning and unlearning discontinuous and error-prone.'

Opportunities for entry into use may be afforded to technologies that can be applied to missions that are acknowledged to be needed but that are neglected because they constitute grey areas of responsibility in relation to established military divisions of labour. Technology applied to such roles risks being neglected for the same reasons. Alternatively, marginal technology may find opportunities to move along the innovation continuum in a context in which an actual contingency leads to the identification of a new need and for which existing capabilities prove inadequate. Where gaps in existing capabilities are exposed by military contingencies, end users can be provoked to undertake search processes. Exploration of novel capabilities may often begin with an unconventional user such as an intelligence agency or part of the special operations community. Contingencies often have an urgent character, meaning that users cannot start from scratch. Allison follows Cyert and March in arguing that ‘where situations cannot be construed as standard, organizations engage in search’ processes that are largely determined by existing routines (Allison 1971: 84).[36] This means that having exhausted the options in existing repertoires of the relevant organisations, the search may widen to R&D programmes at ‘sufficiently’ advanced stages of development. Certain urgent tasks may provoke ‘crash’ development programmes. Contingencies can provide unexpected opportunities for developing technology to be put into operational settings. The urgency of actual contingencies, additionally, may alter the risk tolerance of leaders so that technology may be applied by users in operations long before it would have been deemed sufficiently mature under ‘normal’ conditions. Such situations can begin to provide the kind of user feedback and learning that is needed to refine early stage technology, and can begin to build constituencies on the user side that begin to ‘pull’ the technology along the innovation continuum.

Actual contingencies can open up incipient roles for which there are as yet no incumbents and for which marginal technology may appear particularly suitable – thereby opening up unforeseen opportunities for use. In times of urgent need, financial resources may become more abundant. The sense of urgency can create impetus behind the

[36] Allison portrays search processes as ‘simple-minded: the neighbourhood of the symptom is searched first, then the neighbourhood of the current alternative. Patterns of search reveal biases that reflect factors such as specialized training, experience of various parts of the organization, and patterns of communication within the organization’ (Allison 1971: 84-85).

technology sufficient to override objections that hold in 'normal' times. Technologies can find themselves fielded despite significant technological limitations. Such technologies show signs of shedding their marginal status through fast-tracked operational use. Yet requirements thrown up in contingencies may not survive their passing, and therefore the status of technology turned to in time of urgent need is far from assured during the period that follows. The imagined scenarios of future war seem to reassert themselves, with resources redirected to performance improvements for incumbent systems along established trajectories. Contingencies can act as important incubators of marginal technology and can pass it to users under operational conditions, but they are still no guarantee of a permanent shift in the technology's status.

'Marginality' thus describes the status of technology at various stages of R&D but that has not yet advanced to a permanent home with operational users. The organisational centre of gravity of marginal technology is with the R&D communities. Military services and other security agencies may express interest, provide R&D funding, offer small exploratory contracts but are far from believing in or committing to the technology. Most technical ideas and incipient innovations never make it from the margins.

Emergence describes the innovation journey from development towards organisational adoption and use, and concerns the processes by which a technology navigates this journey. Rather than a single route, emergence is perhaps better understood in terms of many potential ways though a labyrinth. Innovation processes are fraught with uncertainty and contingency; rather than the 'execution of a plan', innovation often entails setbacks along the way (Rip and Kemp 1998: 347). Adoption and incorporation by users is by no means assured, and what seems like progress towards user adoption can be reversible.

An important condition for a technology to emerge is the lifting of technical constraints on desired performance. The innovation literature identifies an important explanation of lags between invention and innovation in the need for complementary technologies to become available (Fagerberg 2004: 5). At the same time, however, emergence entails the alignment of the developing technology with one or more capabilities or missions that are needed by a user. To find a niche in the military user landscape the emerging technology must afford at least the makings of a capability that is perceived to be relevant. This could mean competing with incumbent technology for an established role. It could also mean seeking to gain a foothold by providing a solution to a neglected mission. In this case, however, whatever drives neglect of the mission is likely to translate into a weak organisational base for the technology. Alternatively, trends in the evolving security environment may create new 'needs' even if these are not at first clearly perceived. In this way new footholds may appear, and if the emerging technology affords capabilities relevant to the emerging issue, this may provide a route along which the technology can begin to emerge. The technological development trajectory may be altered through efforts to tailor the developing technology to the emerging trend.

Emergence involves efforts to apply and experiment with the technology. Useful learning can be derived from test or exercise settings but opportunities for use in real world settings are vital in developing the technology. User feedback is essential for learning. Use can expose technical problems that then become sites at which technical communities congregate. Use can indicate ways to adapt the technology so as to make it more suited to user needs and thus suggest further directions of development. Such use is also an important part of building a constituency of support for the new technology. In the case of the drone, a technological development was steered through labyrinthine process involving an outsider network of inventors, entrepreneurs and unconventional users. But this process is tentative and opposed not least because of prevailing norms and values. And it was the actual contingencies of the Vietnam and Bosnia wars that allowed for introduction into use and the associated learning process, even if these gains were, in both cases, reversible once the wars were over.

'Emergence' is a half way house status. Emergence is marked by systems being fielded in actual military operations but in experimental and provisional ways. The technology is actively employed but it is not really embedded in the organisational structure, not tied to careers and roles, not integrated into the way the wider nested structure of military entities are set up to operate. The organisational centre of gravity is shifting between the R&D communities and the user communities and marked by efforts among supporters of a technology to broaden and strengthen its constituency of support. Emergence is a tentative and reversible status.

Assimilation describes the move from tentative and experimental use to more permanent incorporation of the technology into military organisations, their doctrine, their training and career structures, their operations and maintenance programmes, their budgets, and above all the way they actually conduct military missions.

Much of the technology that is developed through US military R&D is conceived and shaped so as to fit into, and enhance, existing doctrine and organisation as well as the existing capital stock of platforms, weapons and systems, or their planned successors. Following Christensen such innovations can be described as 'sustaining' in that they uphold and reinforce established capabilities. Although '[e]very act of technology adoption… involves certain transformations and is thus innovation in itself', sustaining technological innovations can be largely accommodated without necessitating upheaval to existing doctrine and organisation (Rip and Kemp 1998: 347). Technological innovation that tends to enhance existing roles and missions and associated weapons, platforms or systems (or their 'follow-on' successors) may be readily accommodated. 'Disruptive' technological innovations are those whose potential capabilities cannot be exploited through 'grafting' onto established doctrinal and organisational arrangements but instead require, or strongly indicate the need for wider change to doctrine and organisational structure. In order to exploit their military potential, technology, doctrine and organisation have to be melded to one another. This melding process entails changing the organisational and doctrinal landscape, and patterns the technology. Such technology is harder to accommodate. In the absence of some critical juncture sufficient to unsettle these established and self-reinforcing patterns, such technologies, it has been argued, either 'are made to fit, like the odd-shaped piece in a child's puzzle, or they simply fall between the cracks' (Allison and Morris 1977, cited in Kaldor 1981: 175).

Technology can be assimilated within existing roles and missions, but it can also play a central part in the creation of new roles and missions. The mutually reinforcing relations between the established scenarios of future war and the existing roles and missions make the latter comparatively rare, though perhaps not impossible, under 'peacetime' or 'imagined war' conditions. Often, however, some form of crisis is needed to provoke the kind of institutional fluidity within which new roles can be established and major innovation can take place. Milton Friedman, mentor to Rumsfeld and Cheney, wrote in 1982, '[o]nly a crisis – actual or perceived – produces real change'. 'When that crisis occurs', he continued, 'the actions that are taken depend on the ideas that are lying around' (Friedman 2002: xiv).

Conclusion

Military innovation can apply to doctrine, technology, organisational structure or any combination of these. It is always marked, however, by a change in practice. Innovation can be both disruptive, occasioning significant changes in practice, or incremental, i.e. evolving and adapting over time. In this thesis, I use the term 'military-technological paradigm' as the equivalent in the military sphere of the term 'technological paradigm' widely used in Science and Technology Studies. Technology, meanwhile, must be understood as nested within larger technical systems, whose emergence and use is shaped by the dominant military technological paradigm.

In the military innovation literature, a distinction is drawn between peacetime and wartime innovation. In peacetime, military services and bureaucracies are assumed to be resistant to change but in wartime, new needs arise and emergency resources are provided. I reconceptualise this distinction as one between imagined scenarios and actual contingencies. For most of the period since the end of World War II, the United States has envisaged a war with a peer competitor. Imagined scenarios of future war have shaped the thinking of the military services and determined the trajectories of change within the dominant military-technological paradigm, locking out other possible directions of change. Actual contingencies arising during this 'peacetime' period, like the wars in Vietnam, Bosnia, Iraq or Afghanistan, have generated new requirements and new experiments, illustrating the role contingency plays in shaping innovation pathways.

Innovation is a process and has often been depicted as linear, passing through stages of invention, innovation, and sometimes diffusion. Among those who develop such linear models, there is a debate about whether innovation is pushed by supply factors such as new ideas, corporate interests, or the enthusiasms of engineers and scientists, or pulled by demand factors, that is to say, in the military context, strategic requirements. I use the term 'status' rather than stage to illustrate the way in which innovation processes are not always linear, and are often reversible. I argue that supply and demand factors are often difficult to distinguish and are mutually shaping, with military technological innovation arising in the interplay between 'supply' factors – technological possibilities at any one time – and 'demand' factors – imagined scenarios or actual contingencies.

I define three statuses. *Marginality* is similar to invention. It is the stage of incomplete technological development, which tends to be blocked by the trajectories of the dominant military-technological paradigm, shaped by imagined scenarios. The organisational centre of gravity is the R&D communities. *Emergence* marks the moment that the technology is sufficiently developed to be adopted by some user communities, mainly as a consequence of actual contingencies, and this entails feedback learning – further contributing to technological development. Emergence is a reversible status, where continuing imagined scenarios often block new utilities developed in actual contingencies. The organisational centre gravity shifts uneasily between user and R&D communities. *Assimilation* involves the adoption and integration of innovation into new and existing roles and organisations. This may necessarily mean a shift of military-technological paradigm. Assimilation may require an external shock and can only come about through sustained actual practice over a long period of time. The organisational centre of gravity is firmly in the user community.

In the remainder of this thesis, I use these ideas to explain the emergence along the innovation pathway and eventual assimilation of the Predator lineage of UAVs. I argue that the Predator UAV lineage has, in the post 9/11 context, been incorporated into a new military-technological paradigm at the centre of the Global War on Terror, characterised by new roles, missions, goals, doctrine, coalitions of actors and norms. This is a departure from the military-technological paradigm at the centre of the classic 'imagined war' scenario, conceptualising the future war as between state adversaries based on conventional arsenals, which has dominated military planning since the end of the Second World War. The two following chapters describe the marginality and emergence statuses respectively. I then describe the pathway to and crisis of 9/11, and, in the assimilation chapter, how this served to open up a new military technological paradigm, to be consolidated and built-upon through the Global War on Terror, with the Predator drone playing a central, multi-faceted, and previously unforeseen role. This has involved the steady incorporation of the drone into existing roles and missions, as well as entirely new roles and missions. The long run emergence and assimilation of the Predator demonstrates the fragile and contingent nature of innovation, the important role played by contingency in providing opportunities and openings for Predator to advance along the spectrum, and the incremental as well as disruptive innovation processes involved in its breakthrough.

3. The Long Marginality of military UAVs in the United States

Introduction

Public awareness of and concern about drones really arose during the course of President Obama's first term, as journalists and others increasingly came to recognise and report on the increasingly prominent role being played by armed Predators in the war on terror (McKelvey 2013). Rather than having emerged in a flash of invention, however, these drones and their various subsidiary and enabling technologies represent the cumulative achievements of decades of research and development across multiple research programmes that cost billions of dollars. Although drones became a subject of interest due to the notoriety of the Predator during the course of the war on terror, these drones emerged from within a rich ecosystem of UAV development efforts within the United States (with parallel efforts in a number of other countries), stretching back through the World Wars to the earliest experiments with flying machines. The history of drone technology encompasses numerous research and development initiatives undertaken by each of the military services as well as combinations of those services, and intelligence agencies including the NRO, CIA and NSA.[37] It involved the efforts of numerous defense contractors of different sizes as well as DARPA and defence research laboratories such as Johns Hopkins Applied Physics Lab (APL) – a 1988 compendium lists 55 distinct entities then actively pursuing UAV research in the United States (Munson 1988).

This history is largely a story in which dozens of drone development efforts were explored in research and development but did not yield systems that became integrated into military and intelligence practices and did not translate into military innovations. Although a few of these systems advanced quite far along the military and intelligence equivalents of the Schumpeterian invention-innovation continuum, none became firmly established to the extent that Predator appears to have done since 9/11. Moreover, the advances that were made by certain systems proved fragile and highly reversible. As late as 2000, one of the foremost scholars of US military UAV technology wrote of their historically 'indeterminate status', the way they had 'teetered on the brink of breakthrough and

[37] NASA also sponsored a number of UAV research efforts.

washout for over 40 years'. Having still not 'achieved consistent success as a system', they remained 'trapped in the odyssey a weapon system takes when it challenges convention' (Ehrhard 2000: 16). In the summer of 2000 even to close observers, they seemed condemned to remain confined to the marginal position they had occupied for the past 50 years.

This chapter seeks to explain the puzzle of why historical drone development did not yield any systems that became firmly integrated into military or intelligence organisations or operations, much less culminate in military innovation in the full sense of that term. In doing so it performs a number of functions in relation to the central research questions and wider arguments developed in this thesis. Since the history of UAV development is not well known despite such intense recent interest in this technology, this chapter sets out to demonstrate just how extensive and wide-ranging these efforts were.[38] Contrary to the more simplistic of contemporary narratives about the novelty of the Predator system, establishing the earlier history and the richness of the development landscape from which the Predator emerged helps place this system in its proper context and in perspective. It demonstrates that the

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[38] Several good studies recount overlapping parts of the overall history of drone development. Ehrhard's (2000) PhD dissertation remains the most comprehensive and is available online through the ProQuest dissertation facility, while large sections of it are also reproduced in a 2010 Mitchell Institute study that is freely available online (see bibliography). Ehrhard's thesis is extremely rich empirically, combining archival research with 85 interviews with figures involved in UAV development in the US. Ehrhard's research was designed to compare differences between military services in the way they acquire new weapons, focusing on drone technology, but his study discusses more than 40 UAVs developed during the Cold War and the 1990s. Rosenwasser (2004) focused his PhD (also available via ProQuest) on tactical UAV development from 1987-2002, taking the Goldwater-Nichols Act and Packard Commission reforms and their impact on UAV acquisition efforts as its point of departure. Rosenwasser's study encompasses development of *Pioneer*, *Hunter*, *Predator*, *Outrider*, *Shadow* and *Fire Scout*. Ehrhard and Rosenwasser both present an enormous volume of empirical detail (Erhard's thesis runs to 724 pages and Rosenwasser's to 445). Other important existing contributions to the history of drone development include Blom (2010), Clark's (1999) thesis (also available online), Hirschberg (2003, 2010), Kakaes (2015), Knox (1994) (an electronic copy of which was made available upon request from the United States Army War College Library) , McDaid and Oliver (1997), Munson (1988), Newcome (2004), Peebles (1995), Sullivan (2006), Van Atta et al (2003), Wagner (1982), Wagner and Sloan (1992), Werrell (1985), Yenne (2004) and Zaloga (2008). Many of the more recent books on the rise of drone warfare also touch on the history (for example, Benjamin and Ehrenreich (2013), Rogers and Hill (2014)) but tend to present the history in narrative form without delving into why historical programs only advanced so far or what the answer suggests about what enabled Predator's progress. While some of these studies do explicitly reflect on the question of why drone technology historically did not advance further than it did, the sheer number of programmes and volume of empirical detail make it difficult to distil the causal factors that were at work. This chapter seeks to make its contribution by synthesising the existing literature, distilling from it and then presenting the causal factors that were at work across this range of programmes. While recognising that the reliability of secondary sources cannot be assumed, the fairly wide range of available sources allows this difficulty to be managed by comparing the findings of different authors on particular points, and judging the strength of analysis by scrutinising the supporting evidence and sources. This approach, although still time-consuming, allowed an enormous amount of ground to be covered comparatively efficiently.

Predator is not *sui generis*, but emerged from a landscape of earlier and ongoing efforts, building on and learning from incremental advances over this long history. As such it is part of a 'technological domain', understood as 'coherent wholes, families of devices, methods, and practices, whose coming into being and development have a character that differs from that of individual technologies' (Arthur 2009: 145).

Such perspective is a prerequisite to evaluating what, if anything, is novel about the Predator in technological terms and that marks it out from other systems, and particularly to assessing claims about how, if at all, it can be characterized as 'revolutionary' (as it often has been). Part of the problem with efforts to 'define' drone technology's essence stems from the way technical change over time transforms what the technology can be made to do and therefore, in a sense, what it *is.* Whether or not a technical change is judged revolutionary is a question of its dramatic social effects and consequences in practice rather than the extent to which it represents a novel or discontinuous technical change per se. The latter may or may not lead to the former in a given instance. But dramatic social effects can, and often do, also result from the accretion of technical change over time (Fagerberg 2004: 8). To identify the combination of technical advances that set the Predator apart we need to understand the inhibitors to earlier systems.

The historical record also demonstrates that technological limitations are far from the only constraining (or, conversely, enabling) factors. Drone development programmes were shaped – and in some cases, felled – by a range of factors that might be loosely framed as 'social' rather than technical. Indeed, even apparently 'technical' limitations turn out on closer inspection to be socio-technical in character. Although, generalising across different historical programmes, technical constraints became less severe over time and with the accumulation of experience and knowledge, even with the earliest systems technical bottlenecks were not absolutes. Rather, various solutions were developed that were judged 'successful' or 'unsuccessful' to a greater or lesser extent. Recalling the 'mind dependent' aspect of technology (Nightingale 2014: 4) – judgments about whether a given drone system 'worked' well, or well enough, depended on the roles for which it was intended and the envisaged character of the operating environment and adversary. While technology did constrain the horizon of possibility, and although how it did so shifted over time as the horizons of technological possibility changed, that 'technological' horizon was never an asocial absolute.

Examining the record of historical drone development efforts allows us to clarify the range of factors that prevented particular systems from progressing, and strongly suggests where to look when evaluating what marked out the Predator's development history. As observed, innovation needs to be approached as a process, and attention focused on what is involved in moving along the continuum of invention-assimilation. Whereas studies of technological innovation often concentrate on invention and innovation, a more complete picture requires recognizing that these are still only aspects of what must take place before a promising technology really becomes embedded in the structure, routines and operations of military and intelligence organisations. As noted by Tomes, 'there can be no successful innovation if the advantage proffered by the proposed new capability never enters service' (Tomes 2007: 13). Following Schumpeter and James Q. Wilson, I argue that military innovation means doing things differently or doing different things; new technology that does not become connected with change in practice does not meet this threshold. For this reason, studies of military technological innovation have to follow the technological innovation in question from invention through to use (or as far as it advances along this spectrum and the reasons for it not advancing further).

The history of drone development efforts reveals that progress along this continuum is far from inevitable, and is highly reversible. As this chapter reveals, certain systems did appear to have advanced through basic and applied research, and development and testing, to the point that users established dedicated units for their operation and fielded them in real-world operations. The Vietnam War, in particular, had the effect of opening up new pathways and possibilities for the Lightning Bug drone lineage as well as the Drone Anti-Submarine Helicopter (DASH), and contemporaries could have been forgiven for thinking that the Lightning Bugs might have established a permanent place for themselves – to have become integrated through wartime. This proved not to be the case – 'five years after Viet-Nam the USA had not one single operational RPV in its inventory' (Munson 1988: 7), and when Wagner was eventually cleared to publish his history of the Lightning Bugs in late 1981 his Editor observed '[a]s this book comes off the press, not one U.S. remotely piloted vehicle is operational' (Schemmer, in Foreword to Wagner 1981). Throughout the Cold War period, drones existed in the United States in a kind of limbo – neither truly adopted nor decisively rejected. They repeatedly seemed on the cusp of advancing, without becoming truly established. Despite genuine interest and repeated rounds of investment by all the military services as well as major intelligence agencies such as CIA, NRO and NSA, they persisted at the margins, never fully integrated into organisational structures, routines, plans and operations. In explaining why this was and identifying the range of factors at work, this chapter thus plays a necessary part in the wider tasks not simply of explaining the rise of the Predator but of clarifying what it means to break through, why *that* system did when others did not, and why it broke through when it did.

This chapter draws upon case histories of a multitude of historical drone development efforts (summarised below). It traces the different paths taken by drones, from their early origins, through the First and Second World Wars, and through the Cold War and post-Cold War periods. By examining the historical development of this class of technology in terms of the most important of numerous development programmes, it becomes apparent that there was great variation in the extent to which evolving thinking about applications was translated into functional (much less truly 'integrated') systems. Different systems advanced to different extents. Moreover, they did not advance further than they did not because of a single underlying factor but for a variety of reasons that combined in different ways in different specific cases. This chapter groups the most important underlying causal factors that acted as obstacles to further advancement of historical drones under five headings: (i) technology, (ii) 'strategic' considerations, (iii) organisational process and bureaucratic politics, (iv) norms and culture and (v) problems of operability. Before doing so, it provides a brief overview of the US drone programmes up to the end of the Cold War showing the branching or differentiation of development paths, as different possible applications were imagined and pursued.

Overview of US Drone programmes up to the end of the Cold War

The following table presents the most important of the United States drone development programmes, listing each programme specifically identified in Blom (2010), Clarke (1999), Ehrhard (2000), Hirschberg (2003, 2010), McDaid and Oliver (1997), Newcome (2004), Rosenwasser (2004), Wagner (1982), Wagner and Sloan (1992), and Werrell (1985). These development efforts followed a branching pattern in which evolving thinking about different potential applications led to air vehicles with quite different physical appearances and capabilities developing along different development pathways.

This branching of development paths is discussed and then summarised in diagram form. The impact of each of the different sets of factors that inhibited greater progression of historical drone technology is then examined in turn, drawing supporting evidence from the range of historical cases.

Selection of Historical Drone Programmes in the United States

Program Name, Drone Name (Manufacturer)	Dates	Description	Number built (approx.)
Curtiss/Sperry 'Flying Bomb'	1915	Experimental demonstrator	5
Kettering Bug (Liberty Eagle)	1918	Experimental aerial torpedo	20-45
Operations Aphrodite and Anvil	1943-1945	Old bombers used as radio-controlled divebombers	-
Navy TDRs	1940s	'Assault drone'	200
OQ-1 target drone series (Radioplane then Northrup)	1940-1984	Target drone, propeller driven 15,374 built to train AA gunners in WWII, more thereafter	17,000
Q-2 Firebee (Ryan)	1948-present	Target drone, jet propelled	7,000 +
USD-1 Observer/Falconer (Radioplane)	1955	'Interim' propeller-driven battlefield reconnaissance drone based on Radioplane OQ-19 Shelduck/RP-71	1,500
USD-2 Overseer (Aerojet)	1957	Fast, propeller driven, 45 min endurance army drone	35
USD-3 Sky Spy (Republic) (Snooper/Peeping Tom)	1957	Short range army reconnaissance drone	50
USD-4 Swallow (Republic)	1960	Higher echelon battlefield recce subsonic, delta wing, turbojet	0
USD-5 Osprey (Fairchild)	1960	Higher altitude battlefield recce – derived from Air Force Bull Goose long range decoy programme. Subsonic, delta wing, turbojet	15
Bikini (Republic)	1959-1967	Tactical battlefield surveillance drone (Marines)	50
DASH (Gyrodyne)	1958-1966 extended	Antisubmarine warfare coaxial helicopter, subsequently modified for a range of missions	750+
147 Series (Ryan)	1962-	28 different variations, mainly reconnaissance drone based on Firebee target drone	thousands
D-21 (Lockheed)	1962-1971	Mach 3+ ramjet stealthy long range recce	38
154 Compass Arrow (Ryan)	1966-	High altitude long range recce	28
Aquiline (Douglass)	1965	CIA strategic reconnaissance mini drone	Unknown
DARPA Mini-RPV series (various)	Early 1970s	Including Prairie (I and II), Calere (I and II), Axillary, RPAODS, STAR/Manta Ray	various

Aquila (Lockheed)	Early 1970s-1987	Army battlefield reconnaissance and target acquisition	Unknown
Compass Dwell 845A (Martin Marietta)	c. 1968-1973	Prototype endurance reconnaissance and relay	2
Compass Dwell XQM-93 (E-Systems)	c. 1968-1973	Prototype endurance reconnaissance and relay	2
Compass Cope B Gull (Boeing)	1971	High altitude endurance sensor platform	2
Compass Cope R Tern (Ryan)	1971	High altitude endurance sensor platform	2
Teal Rain Amber (Leading Systems)	1984-1990	Medium altitude endurance	7
Teal Rain Condor (Boeing)	1980s	High altitude endurance	2
AARS (Lockheed Quartz)	Late 1970s-1992	Stealthy, penetrating, loitering reconnaissance	unknown
Medium Range UAV (Ryan)	1985-1993	Fast reconnaissance, Suppression of Enemy Air Defences (SEAD)	6
Pioneer (Mastiff III) (Tadiran/IAI)	1983-2007	Navy reconnaissance, artillery spotting	175

Efforts to build remotely piloted aerial vehicles are as old as flight itself. Newcome notes the concept 'had its beginnings with the models built and flown by Cayley, Stringfellow, Du Temple and other aviation pioneers as precursors to their attempts at manned flight in the first half of the nineteenth century,' while McDaid and Oliver point out that '[t]he first heavier-than-air, powered, sustained, controlled flight was achieved by a pilotless aircraft named "Aerodrome No. 5"' – which flew for over a minute in 1896 (the Wrights made their famous first flight in 1903) (Newcome 2004: 1, McDaid and Oliver 1997: 10). The history of UAV development efforts in the United States reveals a process of differentiation marked by evolving thinking about how UAVs might be applied to practical tasks of military and intelligence organisations and the situations in which they could prove superior to manned alternatives. Originating in radio-controlled (unmanned) dive-bomber experiments of the Second World War, and the development of 'target drones' for military training purposes, Newcome argues that the 'concept of using a robotic aircraft for reconnaissance *evolved naturally* during the mid-1950s from the cruise missile and target decoy roles' (Newcome 2004: 71, my italics). A number of claims have made about the origins of ideas for new technologies. Kellerstraus (1973), for instance, suggests that ideas for drone applications may be traced to interwar science fiction writing (quoted in Kakaes

2015: 363) and Singer (2009), similarly, devotes a chapter of *Wired for War* to exploring the significance of science fiction in technological development. Bottom-up reviews undertaken by military organisations (such as the Army's 1953 The Eyes of the Army review and 1969 Target Acquisition Requirements Study) also contributed to realisation and exploration of potential applications, while arguments advanced by technical communities that the enabling technology was within reach also played a role.[39] The direct experience of combat, moreover, acted as a further vital stimulus that led to the exploration of different potential applications. During the Vietnam War, for example, the Lightning Bug series was repeatedly modified to explore 'virtually every sub-task of intelligence collection, as well as branching into leaflet dropping and chaff dispensing' (Newcome 2004: 91).

Over time the process of differentiation opened up a number of pathways of UAV development corresponding to various envisaged missions, notably battlefield reconnaissance, anti-submarine warfare, strategic reconnaissance, electronic intelligence, and the suppression of enemy air defences (SEAD) (Kakaes points out that speculation about reconnaissance and SEAD application dates to the 1940s (Kakaes 2015: 366)). Different kinds of missions strongly suggest distinctive combinations of technical properties, and these in turn suggested particular trajectories of development in various subsystems, and contributed to the identification of additional technical possibilities and problems. In this sense, just as UAV technology as a whole brought with it certain core technology problems that were the focus of attention of generations of UAV technologists, the different contemplated missions implied different technology requirements. Of these, some would turn out to be more achievable than others in relation to the various technical constraints at given points in time.

Although much of the history of drone development proceeded incrementally by modifying existing systems, new pathways could also be opened up apparently at the behest of well-placed individuals with strong ideas about desirable ways forward. Notably, in 1971 Dr John Stuart Foster Jr apparently used his position as Director of Defense Research and Engineering to set in motion a new mini-RPV research program at DARPA (Hirschberg 2010: 5, Kaplan 2013, van Atta et al 2003b: VI-7). Foster argued that rather than

[39] Although the latter (TARS-75) remains classified, TEOTA can be accessed online via DTIC. See Clements et al (1953).

complicated and expensive platforms, DARPA should concentrate on using lightweight, rugged and inexpensive drones to carry the more capable payloads then becoming possible due to 'the development of the electronic digital computer, progressive miniaturization of components, and other related developments in the 1960s and 1970s' (Stewart et al 1989: 1). This research trajectory became the basis for a number of important successors, some of which remain classified (Van Atta et al 2003b VI-6).

Speaking to the manner in which technical change over time can transform the capabilities of ostensibly the same technology, the process of drone differentiation did not flow from a singular master typology devised at the outset. Rather, developments in the technology, in ideas about potential applications, and in beliefs about the capabilities required by the shifting strategic environment all contributed to recognition of additional possibilities that in turn forced planners to rethink their mental models of what drones were and what they could be made to do. Like other technologies, drone technology is difficult to define once and for all because it is not static. Although we still tend to think of 'smart' phones as phones, the ability to place calls and send text messages scarcely begins to summarise what these devices can do.[40] The historical context in this chapter helps us to see that although Predator seems to represent a culmination of what went before, the current generation of drones may be, as Singer has put it, 'the Model T Fords, the Wright flyers, compared to what's coming soon' (Singer 2009).

The following diagram summarises the extent, diversity and branching of development pathways of US drones over time.

[40] Launching the iPhone in 2007, Apple CEO Steve Jobs described the product as consisting of three revolutionary products in one, explaining "The first one is a wide-screen iPod with touch controls. The second is a revolutionary mobile phone. And the third is a breakthrough internet communications device. An iPod, a phone, and an internet communicator… Are you getting it? These are not three separate devices; this is one device, and we are calling it iPhone"' (Quoted in Merchant 2017: 3). The App Store, opened the following year, further transformed what could be done with the iPhone.

Technological Limitations

Technology itself is a very important explanatory factor that affected every historical UAV effort. Certain core technology challenges affected each of the fundamental elements of the drone system, impeding efforts to translate ideas about the potential military applicability of unmanned flight into systems that could be said to 'work' or work 'well enough' in practice in relation to the imagined missions for which they were devised. These challenges acted as 'bottlenecks' (Rosenberg 1982) or 'reverse salients' (Hughes 1983) and became sites at which technical communities congregated. In general, it is possible to think of these salients being rolled back over time, partly as a result of learning gained in UAV R&D efforts and partly as UAV technical communities realised ways to use exogenous technological advances to address their particular technological challenges. The general advance of the frontiers of technological capability over time did not, however, result in straightforward advancement of drones along the invention-use continuum. As shown by Ehrhard (2000), the way technological change 'accrued' to different possible technology solutions to particular military and intelligence challenges changed over time. Reconnaissance missions dominated Cold War thinking about possible drone applications in the military and intelligence communities. During the 1950s and 1960s, however, satellite technology developed in ways that made them superior to drones for the most important strategic reconnaissance missions. In the 1990s, by contrast, satellites morphed from rivals to critical enablers of drones, becoming the means by which some of the thorniest drone technology challenges were overcome. Meanwhile, trends in adversary capabilities exposed the limitations of 'episodic' satellite coverage and strongly suggested the need for continuous forms of surveillance and the potential utility of drones.

The major technology bottlenecks that are important in explaining why, historically, drones struggled to advance can be summarised as (i) stable flight, (ii) remote control and data-links, (iii) launch and recovery, and (iv) location accuracy and navigation. Additional, more mission-specific, technology challenges affected particular classes of drone. For example, high altitude roles required attention to engine design. Longer aerial 'endurance' (the time a vehicle could spend aloft unrefuelled), similarly, required attention to engine performance but also to airframe design (for example, the use of high aspect wing ratios used on gliders and sailplanes). Drones intended to operate in defended airspace implied properties, such as reduced radar cross section, that reduce observability and make the drone more ‘survivable’. The payloads the drones were to carry are also associated with technology bottlenecks of their own (for example, being small and light enough to be carried, robust enough to survive wear and tear, and capable enough to be useful such as by seeing in enough detail, and through cloud cover and at night). Finally, (v) each particular drone posed challenges of systems integration – making all attributes and components function as parts of an integrated whole.

Automatically Stabilised flight

All aircraft – manned and unmanned – need to be able to achieve and maintain flight stability. A key contribution of the Wright Brothers was to move from efforts to build gliders with inherent longitudinal stability to building gliders with inherent but tolerable instability, and relying on pilots to compensate (Tomayko 2000: 4).[41] Subsequently, pilots learned to feel deviations in pitch, roll and yaw axes and to compensate by manipulating control surfaces. Although fixed wing vehicles can be designed to provide inherent aerodynamic stability, such designs entail performance tradeoffs, and unmanned vehicles still require some means to sense deviations when there is no human onboard to feel them, and an automatic mechanism to make appropriate adjustments in response. Elmer Sperry ingeniously provided the basis of a solution to this technology challenge as early as 1909, by applying gyroscopes to the problem. Two years later, in partnership with aviation pioneer Glenn Hammond Curtiss, Sperry used servomotors to attach three gyros – one each to detect changes in a plane’s pitch, roll and yaw – to the aeroplane controls (Newcome 2004: 16). In 1914 they demonstrated that this system enabled their aircraft ‘to fly a straight and level course without pilot intervention’ (Hirschberg 2003: 1). In 1915 the Navy backed Sperry and Curtiss in the development of an ‘aerial torpedo’, the Curtiss/Sperry ‘Flying Bomb’ (Werrell 1985: 8-12). Sperry’s patent described ‘a gyrostabilizer for level flight, a steering gyro for direction, a barometer for altitude, and an engine revolution counter to determine the distance by dead reckoning; once the engine had turned the determined number of times, the engine power would be cut and dive into its target’ (Hirschberg 2003: 1). The proposal was picked up by Charles Kettering, whose company set out to produce the

[41] Recalling the reciprocal relations between technology and science, flight experiments at this time were proceeding ahead of the aerodynamic theory to support them and inventors depended on trial and error (Werrell 1985).

Liberty Eagle in January 1918 using gyro-stabilization technology developed by Sperry and his son – 'one of the first automatic pilot systems' (Hirschberg 2003: 1). The Kettering Bug, as it became known, is a forerunner of both drones and cruise missiles. Sperry's gyroscopic autopilot provided the basic technological solution to the problem of automatic stabilization.

From the 1960s, the growing sophistication of anti-aircraft systems induced the pursuit of 'stealthier' vehicle designs. An important strand of work in this direction led to vehicles with smaller radar cross section (an important determinant of their visibility to radar) but such vehicles tended to become inherently less aerodynamically stable. This is true of manned aircraft such as the F-111 *Nighthawk* and B-2 *Spirit* but also of the Aquila battlefield drone and the lineage of high altitude penetrating loiterers such as the AARS/*Quartz* and the *DarkStar* UAVs developed in the 1980s and 1990s. Vehicles such as these depend increasingly heavily on computer software to maintain flight stability. A flight control software glitch was found to have caused a *DarkStar* to crash during testing in 1996 (McDaid and Oliver 1997: 121-129). So although stable flight could be achieved using early twentieth century technology, the application of wider advances in computing are vital to making controlled flight feasible in drones designed with less inherent aerodynamic stability.

Remote Control and Data-Links

Early drones were controlled using radio control, a technology that dates to the 1890s and experiments such as the 'teleautomaton' demonstrated by Nikola Tesla and work by Thomas Edison (Singer 2009: 86-87). In the interwar years the US Navy's Bureau of Aeronautics and the Radio Division of the Naval Research Laboratory developed this technology and in 1937 the first full-scale pilotless planes were flown (Hirschberg 2003: 2). By the 1940s it had become possible to add TV cameras to the drone and broadcast their imagery back to the controller, leading to a series of concepts in which a TV attached to the nose of the vehicle was used to assist the operator in directing the vehicle onto targets.

The need for a direct line of sight between controller and air vehicle imposed range constraints upon radio control – assuming a strong enough radio signal that line of sight is eventually blocked either by topographical features or by the curvature of the earth (i.e., the horizon). In the 1950s this constraint acted as a powerful brake on the Army's SD-5

Osprey (cancelled in 1963) – a drone intended to perform long range reconnaissance missions to provide targeting for tactical ballistic missiles (Newcome 2004: 75). The *Osprey* navigated beyond line of sight using pre-programmed instructions and location information ascertained from an onboard inertial navigation system, which was subject to 'drift'.[42] Data gathered beyond line of sight had to be stored and transmitted once the drone came back into line-of-sight range. The Ryan 147B reconnaissance drone and its successors used an autopilot to fly autonomous, pre-programmed, missions beyond line of sight.

Early experiments with radio control (including Operations Aphrodite and Anvil during the Second World War) had involved placing the remote operator in an accompanying aeroplane. Experiments to extend the range of the *DASH* helicopter made use of an intermediate drone or manned vehicle. An important source of impetus behind the *Compass Cope* research in the 1970s was that a high altitude, long endurance drone might be used to carry relay equipment that would allow other drones to fly beyond line of sight to their ground control stations below (Wagner and Sloan 1992: 111). In 1973 the Gull, developed by Boeing under *Compass Cope*, may have demonstrated the first ever control of a drone via satellite relay (Ehrhard 2000: 445). The further development of satellite data-links in the 1990s and 2000s constitutes an extremely important technological development, enabling remote control and transmission of sensor data over far greater distances than was possible for the historical systems.

The emergence of duplex data-links in the early 1970s enabled data to be sent and received simultaneously between craft and control station, at the same frequency. During the Vietnam War, the 'Buffalo Hunter' 147 *Lightning Bugs* were fitted with a 'Speedlink' data-link that reportedly had a 200 mile line-of-sight range. In addition to sending data to and from the existing instruments, 'SC/TV' drones could now send real-time video footage. This had obvious benefits for reconnaissance but it also assisted navigation as operators could now use a low resolution television image from the drone to help them. Following Vietnam as the Air Force assessed the high operations costs of the 147s, it was realised that duplex now held out the possibility of reliable runway landing, a much more cost-effective solution, provided it could be performed reliably. This technology was developed under

[42] On inertial guidance see Werrell (1985), MacKenzie (1990). Drift occurs with the accumulation of small measurement errors.

Compass Dwell (begun in 1970) and applied to the vehicles of both of the rival contractors in that programme.

As the data generated by sensor payloads increases, so does the need for data-links of sufficient bandwidth to allow the gathered information to be transmitted as quickly as possible. Data compression techniques facilitate this but jam-proofing the connection constrains the volume of data that can be transmitted (Fahlstrom and Gleasom 2012). This problem bedevilled the battlefield *Aquila* drone, and was an important source of delay and cost-escalation in that programme.

Launch and recovery

Launch and recovery have presented persistent problems for unmanned aerial vehicles. These manoeuvres typically are the riskiest moments during flight. Launch can be achieved in a number of different ways. During the Second World War, Operations *Aphrodite* and *Anvil* involved packing aging aircraft with explosives and trying to direct them onto hardened enemy targets (such as Submarine pens) using radio control from an accompanying aircraft. In this scheme, a crew boarded the explosives-filled aircraft and performed an initial runway take-off. Once airborne, a radio controller in an accompanying aircraft assumed control of the plane (whose controls had been specially modified for this procedure), at which point the onboard crew were supposed to parachute out. Aphrodite and Anvil proved dangerous and ineffective. Joseph Kennedy Jr (older brother of future President John F. Kennedy) was killed over England in 1944 when the volatile explosives packed into the PB4Y-1 Liberator that he was piloting as part of Operation Aphrodite exploded prematurely (Beschloss 2014, Kakaes 2015, Werrell 1985). Technically, in any case, these aircraft were more missiles than true drones, being one-way and non-returnable, although at this early stage such distinctions had yet to be developed.

Following the Second World War, Radioplane's target drones were launched from custom-made rail launchers. Ryan's jet-powered target drones could also be ground launched using a rail and a booster add-on, but were also configured to be launched from under the wing of larger manned aircraft, and released in flight like missiles. The ramjet engine used by the Mach 3+ *D-21* could only be started at very high speeds and the initial concept of operation was to launch from the back of a specially modified SR-71 *Blackbird* at supersonic speeds. When that proved too dangerous, an alternative scheme involved launching it from under the wing of a B-52H *Stratofortress*, attached to a boost phase rocket that would accelerate the drone to speeds at which its engine could be started.[43]

Retrieval, similarly, has been achieved in a number of more or less satisfactory ways. Reflecting the incremental modification of target drones (including the Radioplane *Shelduck* and the Ryan *Firebee*), which eschewed landing gear to save weight and cost, winged drones of the 1950s and 1960s did not perform conventional runway landing (even though converted (droned) manned planes could be runway landed by ground crews). One common recovery scheme involved flying the drone into a recovery area, cutting the engine and deploying a parachute so that the vehicle would fall to earth relatively gently. In the 1950s parachute landing was used for the SD-1 *Falconer* but this method resulted in deterioration of relatively sensitive parts such as gyros and vacuum tubes. During the Vietnam War, the Mid-Air Retrieval System (MARS) – developed for the Corona satellites – was applied to the 147 *Lightning Bug* drones (which did not have landing gear and iterations of which were getting heavier and subject to damage from landing). The Lightning Bugs were flown into a recovery area, their parachutes deployed, and specially adapted helicopters used to snare their parachutes and return them for maintenance and relaunch. This solution to the fundamental difficulty of retrieving drones once they had been launched radically drove up the overall cost of the Lightning Bug programme, a factor that contributed to the post-Vietnam demise of the Air Force 147 capability. Ryan's 154 *Compass Arrow* was retrieved in the same way and it was only with their *Compass Cope R* that Ryan introduced conventional runway landing into their drones – generally tricky for high aspect wing ratio designs such as those used by both Compass Cope teams. In the 1990s the advent of GPS, combined with ongoing advances in fly-by-wire technology, brought runway landing without human input into view, by providing real-time location accuracy in three dimensions. The difficulties of retrieving the Lockheed *D-21* intact were such that it was not designed to be recoverable. Instead it was designed to jettison its camera, film and avionics and then simply crash – again, an enormously expensive arrangement (Peebles 1995: 120).

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[43] When launched from an M-12 (a customized SR-71), the drone then had to punch through the shock wave being created by the mothership aeroplane's Mach 2 speed. Johnson called the D-21 launch 'the most dangerous maneuver in any airplane that I've ever worked on' (quoted in Rich and Janos 1995: 265). During a test flight in 1966 the drone rolled during launch, and collided with the M-12, which was travelling at Mach 3 at 80,000 feet (Peebles 1995: 125-126). One of the crew was killed and Johnson returned the money and shut down the program.

The CIA's *Aquiline* as well as some of the most significant outgrowths of DARPA's 1970s mini-RPV research, including the DARPA/Navy *Shipborne Tactical Airborne UAV* (STAR), which led to the Teledyne Ryan *Manta Ray*, and the Army's battlefield *Aquila*, were retrieved by flying them into specially designed recovery nets (Pedlow and Welzenbach 2016: Appendix E, Hirschberg 2010: 6-7). The Israeli *Mastiff* and *Scout* and the RQ-2 *Pioneer* (built with Israeli input) were also retrieved at sea using net recovery techniques. Helicopter designs, such as the DASH, avoided the problems of fixed wing retrieval since they could hover and land vertically.

Location accuracy and Navigation

The advent of aeroplanes acted as a major stimulus to innovation in the navigation sciences. Initially, pilots relied on 'celestial positioning (time consuming), dead reckoning (inaccurate), and "flying the iron compass," of following roads, rail lines, and other landmarks from the air' (Rip and Hasik 2002: 16-17). None of these was initially available for a drone. In the 1950s the Army's SD-1 *Observer* (derived from the Radioplane *Shelduck* target drone) – the world's first fielded reconnaissance drone – was guided beyond visual range by monitoring its radar beacon and through instruments, reporting its altitude, speed and distance from the ground station (Blom 2010: 50). The SD-1 used an 'antiquated, highly unreliable' radar set that was badly affected by clouds and ground clutter and was only appropriate for a range of five miles – when the drone's thirty minute endurance gave it a potential range of 25 miles (Ehrhard 2000: 230). This relatively poor radar contributed to difficulties with control and location accuracy, and also raised the issue of airspace de-confliction. The SD-2 *Overseer*, which was meant to replace the *Observer* but never reached operational service, pushed the state of the art by making use of the command data link to achieve location accuracy using a method called translateration (Newcome 2004: 74). Shortcomings in this system were an important factor in the decision to cancel the programme, although (as is described below) it was bureaucratic forces at work in the management of this programme that really explain its demise.

Location accuracy, particularly at longer ranges and over greater distances, presented a fundamental technological challenge to drone operations and one that was only really solved with the arrival of the Global Positioning System (GPS) in the 1990s. Until that system became available, drone developers (and others) attempted a number of other solutions that provided partial answers. Inertial guidance systems (which work by calculating position based on known starting point and precise measurement of the forces acting on the vehicle in flight) improved markedly but still suffered from the problem of drift, particularly over longer distances. In 1969 the Ryan 147 SC iteration used cross correlation Doppler radar and a digital programmer to improve location accuracy. Long Range Aid to Navigation (LORAN) was tested on the Ryan 147 series in 1972 but interfered with other systems.[44] In 1973 the Ryan 147 SD introduced a new radar altimeter and a new navigation system that reportedly reduced navigation error from 3% to 1.1% and the same year the 147 SDL successfully incorporated LORAN, although this perhaps was still a 'rather fragile answer' (Ehrhard 2000: 431). Terrain matching and computer star navigation were also attempted. Nonetheless, these incremental gains in the Vietnam War years did translate into increasing mission success for the Lightning Bugs over time. In the late 1960s the D-21, which was intended to fly right across China and the Soviet Union at 90,000ft+, employed a star-tracker in its navigation system, which one source describes as a 'complete shambles' (McDaid and Oliver 1997: 31). Anticipating a later episode involving Iran and a downed RQ-170, a KGB agent reportedly returned some of the wreckage of one to a CIA counterpart, years after Tupolev Design Bureau had reverse-engineered the wreckage and developed their *Voron* (Rich and Janos 1995, Peebles 1994: 134).

A further innovation involved exploring autonomous navigation. Among a range of advances demonstrated by the 200 ft wingspan long endurance Boeing *Condor* in the late 1980s was a state of the art flight control computer 'in which redundant, high-speed computers and sophisticated software algorithms flew the aircraft autonomously' and the software enabled the Condor to compensate for in-flight malfunctions (Ehrhard 2000: 177). Condor gave an early indication of the possibilities of not merely remotely piloted but *autonomous* operations. In the words of the Boeing promotional video, 'unlike remotely piloted vehicles, Condor is truly autonomous and robotic, flying a preprogrammed mission stored in its onboard computer.'[45] Condor flew pre-programmed waypoints which could be adjusted from the ground with the UAV in flight. The advent of such computer capabilities

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[44] Rip and Hasik provide a discussion of LORAN (Rip and Hasik 2002:59-63).

[45] Boeing promotional video for the Condor UAV, held at the Hiller Aviation Museum, San Carlos, California and available to view online (see for example https://www.youtube.com/watch?v=9qefhleVl_E&t=30s).

meant that if the vehicle lost contact with the controller it could operate according to predetermined instructions, albeit still affected by the problem of location accuracy.

The perennial problem of location accuracy was not truly overcome until the advent of GPS. Rather than establishing location by calculating differentials in signals received from different fixed point transmitters on land, GPS works by calculating differences in the time taken to receive radio signals from at least four of a constellation of orbiting satellites. Once in place, GPS made it possible for drones (and anything else with a GPS capable device) to cheaply establish reliable, near continuous, and relatively secure real-time location data. Initiated in 1973, when GPS became fully operational in 1995 it effectively lifted a key technical difficulty that had continued to dog drone development efforts right up until its introduction.

Systems Integration

The various sub-systems to be assembled on a given drone all have to be made to function as an integrated whole. Integration has often proven especially challenging in its own right, particularly where programmes have sought to stretch the technological frontier in one or more sub-systems. In the 1980s, integrating the Advanced Tactical Airborne Reconnaissance System (ATARS) sensor (which replaced wet film with digital storage) into the Medium Range UAV air vehicle and datalink proved 'far from trivial' (Rosenwasser 2004: 136). The Army's Aquila also exhibits the importance of systems integration, especially if sub-systems are pushing the frontiers of proven technologies. Serious difficulties can arise when the need to make changes in one component impacts on the design of other components in the system (Nelson 1982, Nightingale 2014: 12). The Aquila vehicles were both relatively small (length: 2.08m, wingspan: 3.88m) – placing constraints on the size and weight of components to be integrated within the vehicle – and of a stealthy flying wing design, requiring a very capable flight control system. Lockheed had overall integration responsibility but Developmental Sciences designed and built the airframes, Harris Corporation was responsible for the data-link (the Modular Integrated Communications and Navigation System (MICNS)), Westinghouse were making the sensor package and laser designator, Philco Ford built the Forward Looking Infra-Red (FLIR); this situation was complicated by the separate reporting channels for these various sub-contracts (Knox 1994: 13-14, Ehrhard 2000: 279). The data-link component (which was then pushing technical frontiers in pursuit of jam-resistance) in turn was supposed to serve two other programmes (Stand Off Target Acquisition System and Precision Emitter Location System). When it was delayed a placeholder system was installed, but later efforts to install the MICNS caused 'tremendous problems' (Know 1994: 15, Fahlstrom and Gleason (2012: 191-192).

The Influence of wider technological change

Wider technological advances contributed to relaxing some of the most severe technological constraints that impeded the advance of drones. Starting in the late 1970s, and accelerating during the 1980s and 1990s a series of enabling technologies developed that collectively transformed what it was possible to do with drones. Several of these were at least to some extent exogenous to drone development efforts – the microprocessor revolution (which impacted numerous fields including navigation and autopilot software, fly-by-wire, sensors, full-duplex data-links, data compression, encryption), the development of higher bandwidth datalinks and the advent of GPS. Miniaturisation and falling unit prices have been key enablers behind the advent of small and very capable drones. As noted by Kakaes (2015: 13), '[i]n place of Sperry's 30-pound gyrostabilizers, today's drones have autopilots that contain gyroscopes, accelerometers, magnetometers, and barometers, at a total weight of less than a tenth of a pound'. The Raspberry Pi chips used in contemporary hobby drones, similarly, are 'more advanced than the first Predator flight control system'.[46]

Strategic considerations

No explanation of the overall historical marginality of drones can ignore the influence of shifting constraints on what the available technology could be made to do. Nonetheless, 'insufficient technology' was not the sole factor at work. Individual drone programmes were always oriented by a strategic rationale and intended to perform specific associated tasks. But shifting perceptions of the strategic environment and the requirements imposed by that environment exerted a powerful, though contradictory,

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[46] DARPA Tactical Technology Office Director Brad Tousley makes this point in an interview for DefenseNews with Jill Aitoro (Defense News 2018). Tousley identifies the most important technical advance underpinning unmanned technological advancement over the last fifteen years as the exponential increase in microprocessing power.

causal force on drone development. On the one hand, the requirements that were perceived to be imposed by the strategic environment created openings for drone development efforts, stimulating some of the most ambitious and expensive research efforts. We have seen that some drone programmes ‘lost out’ to rival technology solutions when those solutions seemed superior. But on the other hand, in a number of cases, just as strategic ‘need’ opened a development pathway, the removal of strategic rationale could lead to its closing down. Strategic need could align with technology but such alignments were not necessarily enduring.

As set out in the Conceptual Framework, in the military innovation studies literature a distinction is commonly drawn between ‘peacetime’ and ‘wartime’ contexts, while ion parallel it is increasingly seen that the Cold War blurred this seemingly sharp distinction. Although not in a state of open war in relation to the Soviet Union, throughout the Cold War, US military innovation efforts were oriented by four key factors relating to the strategic environment, each of which both opened up and closed down drone development pathways. First, assessments of what a future war against the Soviet Union would be like largely oriented ‘peacetime’ innovation efforts around the task of preparing to fight under extremely technologically onerous conditions. These predicted conditions made drones seem attractive in a number of roles but simultaneously imposed technological performance thresholds that were prohibitively high.

Second, while there was a continuous need to gather information about adversary capabilities, the Cold War was punctuated by moments, such as the Cuban Missile Crisis and the Chinese nuclear program at Lop Nor, marked by quite specific and very urgent intelligence targets. These moments generated urgent requirements for strategic reconnaissance that directed innovation efforts characterised by rapidity and pragmatism – more ‘wartime’ than ‘peacetime’ innovation conditions as typically understood in the military innovation literature. While such moments opened pathways of development, their passing led to programmes being closed down.

Third, the United States remained fundamentally committed to the pursuit of military technological superiority to compensate for numerical inferiority. By far the most expensive Cold War drone development efforts deliberately set out to test and roll back the frontiers of technological possibility. Most of these programmes would be considered ‘failures’ by the yardstick of delivering fielded systems that were fully integrated into the repertoires of military and intelligence activities. Such efforts, alternatively, might be interpreted as part of a strategy for managing technological forms of uncertainty. Such 'Type II flexibility' involves 'buying information… about the relative costs and performance of new technologies by investing money into the development of many different weapons' (Rosen: 1991: 244-245). According to such a strategy, prototyping or building a few production systems without committing to full-scale production can buy information about technological possibilities (and horizons) and, in view of the US commitment to technological leadership, might be considered worth the investment. What was learned in such programmes usually carried over into successor programmes, suggesting trans-programme technology lineages and cumulative improvements in enabling technologies that discrete weapons programme case studies tend to screen out (MacKenzie 1990: 8).

Fourth, while the Cold War US innovation environment was largely oriented by preparing to fight a future war, setting almost unattainably high prevailing performance thresholds for drones, the concrete conditions of the Vietnam War exposed a wide variety of tasks that drones could actually undertake given available technology and given enemy capabilities. Given their flourishing during the course of that war, those involved in the drone operations could have been forgiven for thinking that drones might have gained a permanent place in US military plans. But as the US set about its post-Vietnam recovery and renaissance, which included a series of substantial investments in air power technology (Kagan 2006: 24-35), the drones were quickly abandoned – even as 'Air Force analysts with a deep and sincere opposition to RPVs… [were] nevertheless [supporting] other new technologies such as PGMs and other standoff armaments' (Hall 1978:43). As post-war funding cuts forced the services to prioritise, the future war scenarios that once again oriented defense innovation efforts worked to close down the incipient pathways that the Vietnam war had opened up. These strategic considerations and their contradictory impacts – sometimes opening up and sometimes closing down drone development pathways – are now considered in turn.

Future war

In the 'peacetime' innovation environment of the Cold War, technological development efforts were mainly oriented by the scenarios for future war envisaged by planners, and especially by what were seen as the gravest of those scenarios. Such scenarios, however, were shaped by a variety of factors and have an inherently subjective aspect. American innovation efforts in this period made assumptions about the nature of the future battlefield and the identity and capabilities of the most serious adversary (the Soviet Union).[47] These assumptions made drone technology highly desirable while suggesting extremely onerous technical capabilities. Following the Korean War, the US Army began to consider the implications of fighting with nuclear weapons and restructured according to the Pentomic structure (Bacevich 1986). The Eyes of the Army battlefield reconnaissance review of the early 1950s made clear that a family of drones might offer the means to furnish different echelons with timely, responsive battlefield reconnaissance (Clements et al 1953). To the inherent danger posed to crews of manned reconnaissance efforts against capable opponents, the prospect of operating on irradiated battlefields strongly suggested the utility of remotely piloted vehicles.

The projected future battlefield foreseen by US war planners drove the technical complexity of drone development towards, and often beyond, the limits of technical feasibility – at least within bounds of time and money. In a 13 May 1985 letter to Congressman Matthew J. Rinaldo, Under Secretary of the Army James R. Ambrose articulated the much more demanding technical implications of the future war scenario. '[I]t is obvious there are uses for low cost RPVs in low intensity conflicts or observations where little or no risk of survivability, data security or jamming exists', he wrote. By contrast, however, 'Aquila… in contrast to all other currently available systems, was designed for use in intense conflict in Central Europe' (quoted in Knox 1994: 30). Under Secretary Ambrose went on to outline the technical properties built into Aquila that were designed to enable it to perform in such a conflict. The question was therefore whether or not the capabilities being created were actually needed. The point here is that where future war scenarios in the US simultaneously made drones desirable while pushing them to the edge of technical possibility, other countries, with different and less technologically onerous strategic outlooks, found ways to make the drone technology of the day perform extremely useful

[47] Kagan, thinking particularly of the Vietnam War period and its aftermath, points out that the nature of Soviet threat to the US was understood to be 'multifarious' in itself. Observing that the Central Front in Europe was thought to be 'the most dangerous', however, Kagan argues that American strategists 'faced the problem of balancing threats in multiple theaters by accepting risk in what had been thought to be "the main theatre"' (Kagan 2006: 8).

functions. Israel, for example, relied heavily on drones in 1973 for surveillance, spotting and enemy air defence suppression.

Knox furnishes an excellent analysis of how projections about the future threat environment led to '*overspeccing*' – the imposition of unreasonable, even 'exotic', sub-system specifications – in the development of the Army's Aquila during the 1980s. The jamming threat, for example, was 'defined as the most powerful Soviet ground based tactical jammer operating directly across the FLOT [Forward Line of Own Troops] from the MICNS data link ground station. This jammer operated in the Megawatt power range and would be far closer to the ground station than the Aquila RPV would be operating.' In other words, writes Knox, the 'absolutely worst case scenario was being used for the baseline performance of the data link design… It would require the opposing forces to discover where the Aquila was positioned on the battlefield and to move a jammer directly across the FLOT from the ground station before the RPV flight took place.' He adds, '[t]o baseline the system design on that premise was absurd' and 'drove datalink cost through the roof as well as greatly slowing down the schedule' (Knox 1994: 14-15). Sharing this assessment, Ehrhard states, '[n]ot only did this one requirement add millions of dollars and years to the program, it produced a time lag in the imagery that disoriented soldiers in operational testing and complicated the integration of the infrared sensor critical to night operations' (Ehrhard 2000: 275).

Such 'overspeccing' was a problem in other areas. The demand for nuclear survivability led to the airframes being 'containerized in shock proof, crush proof, overpressure proof huge containers' that meant that it required two 5 ton trucks to transport a complement of 6 air vehicles (Knox 1994: 15). Despite this, the original idea that a vehicle could be lifted by four men led to an insistence on an air vehicle of 240 lbs. The program was able to yield a 280lb vehicle but it proved extremely expensive to shave the last 40 lbs off. In any case, in 1983 the concept was changed so that the vehicle could be launched from further back from rear areas with control then handed off to forward controllers. Therefore, the four-man lift specification was no longer necessarily so vital, but the weight requirements were never reviewed in light of the concept change. Major General Meloy, who joined the program in 1984, found the requirements more akin to a space program than an Army system (Knox 1994: 16).

Urgent intelligence requirements

The Cold War thirst for information about Soviet and Chinese military capabilities, particularly the state of their nuclear weapons and missiles programmes, drove the United States to invest heavily in strategic reconnaissance capabilities. Although drones largely lost out to competing solutions (manned aeroplanes and satellites) strategic reconnaissance still drove the most technologically ambitious – and expensive – US drone programmes of the Cold War. Several of these efforts, however, were characterised less by long-term and sustained efforts to nurture new capabilities than by short-term and acute demands driven by specific intelligence needs. While these needs opened up possibilities for development, with the passing of crisis such programmes were left vulnerable.

In the late 1950s the now-famous U-2, a high altitude, long range reconnaissance plane, became the workhorse for these US strategic reconnaissance efforts (Pedlow and Welzenbach 2016). When it was introduced it could fly at altitudes that put it beyond the reach of Soviet air defences, enabling it to return photographic intelligence from deep beyond the Iron Curtain. In response, the Soviet Union soon fielded a new anti-aircraft missile – the SA-2 – which could hit the U-2s, making their flights both increasingly dangerous for the pilots and politically risky for the White House. Aware that sooner or later U-2s would begin to be shot down, the US pursued three technology alternatives. First, more advanced manned spy-plane concepts were considered. This led to the CIA A-12/Air Force SR-71 *Blackbird*, designed to restore the US advantage over Soviet missile defence by flying higher and faster - more innovation to counter Soviet counter-innovation. Second, major investment was being made in satellite surveillance systems, embodied in the *Corona* programme. Finally, it was also suggested that unmanned vehicles might be devised to perform reconnaissance tasks. If they were shot down, no crew would be killed or taken prisoner and the political fallout would be much less embarrassing. In the early 1960s Ryan also argued that drones offered a number of advantages over manned competitors, including an ability to provide greater ground resolution than satellites and to return imagery more quickly (Wagner 1982: 19).

Efforts to apply drone technology to strategic reconnaissance got off to a faltering start. As the Army had done for the USD series of battlefield reconnaissance drones in the 1950s, strategic reconnaissance mission research began with experimental modifications to an existing target drone. Ryan Aeronautical, the manufacturer of the Q-2C *Firebee* target drone, was given a small contract to find ways to reduce radar cross section without redesigning the entire vehicle. The growing vulnerability of the U-2s crystallized on May Day 1960, when one was shot down en route from Pakistan to the Soviet Tyuratam missile test facility close to the Aral Sea. The pilot, Francis Gary Powers, survived, was captured and was then subjected to a very public trial in the USSR. Amidst the furore of Powers' capture the advantages of an unmanned reconnaissance plane were obvious. If in future the Soviet Union fielded new missiles capable of hitting the U-2 successor, at least an unmanned system would deny the Soviets the propaganda value and political leverage of a captured pilot. Two larger drone concepts, *Red Wagon*, and *Lucy Lee*, were initiated in the aftermath but quickly cancelled to concentrate funds on *OXCART*, the project that led to the CIA A-12/ Air Force SR-71 *Blackbird*, demonstrating the way that rival technology solutions could stifle drone development. The idea of a Ryan reconnaissance drone was then revived when the newly-established National Reconnaissance Office (NRO) began sponsoring drone research under its Program D. The NRO directed *Firebee* modification work through the Air Force Big Safari procurement system (Wagner 1982: 23).[48]

By the time of the Cuban Missile Crisis, the Ryan experiments had resulted in the 147A model, which proved promising. The drones were packed up and shipped to be ready to use over Cuba in November 1962. Civilians in DoD and the Air Force advocated their employment but General Curtis LeMay, the Chief of Staff, opposed the idea, wanting to 'save the capability for bigger things' (Wagner 1982: 42). U-2 pilot Major Anderson was killed when his plane was shot down over Cuba in 1962, an episode that helped provide support for work on a 147B model, which became perhaps the first true reconnaissance drone (it contained a more advanced Doppler radar, the ability to fly at higher altitudes and fly longer range missions). By this point other kinds of intelligence-gathering missions were

[48] Big Safari holds a very important place in the broad history of drone development, and in the specific case of the Predator (discussed in the next chapter). Big Safari is an Air Force acquisition office that specialises in quick reaction acquisition, modification, management and operation of special purpose weapons and communications systems, many of which are classified (Whittle 2011: 11, Grimes 2014: 2-3). In 1962 Big Safari provided the conduit to get around 'the old R&D Command – with all the approval chains' to get the 147 Lightning Bug underway after Red Wagon was cancelled, sending a detachment to work with Ryan (Wagner 1982: 23). It subsequently worked on ELINT drone modifications (United Effort), the MARS retrieval system for the 147s, and the low altitude modifications for the Buffalo Hunter programme. At the height of the Vietnam war, so many drones were being built that in 1968 the programme was transferred from Big Safari to Air Force Systems Command (Grimes 2014).

envisaged for the drones and when the crisis receded, rather than being closed down the program continued.

The Chinese nuclear program presented another major strategic reconnaissance challenge. Nuclear testing was carried out at Lop Nor, in south eastern Xinjiang province, due to its extremely remote location. Intelligence on Lop Nor was gathered by U-2s flown by Chinese 'Nationalist' (Taiwanese) pilots. The U-2s had the range for 4,000 mile round trip from Taiwan, but Soviet-supplied SA-2s continued to prove an effective threat (five U-2s were shot down on these missions). Lop Nor was beyond the range of the Lightning Bug programme. Two drone alternatives were stimulated by this problem, a fresh Ryan design that became the 154 *Compass Arrow*, and an altogether different offering pitched to the NRO by Lockheed's Skunk Works in 1962, which became the *Tagboard*/*Senior Bowl* D-21. Both programmes struggled against the technological frontiers of the day to produce a militarily viable solution. But both were largely undone not by limits in drone technology but by a combination of advances in satellites (the NRO's Big Bird Keyhole satellites) and President Nixon's political decision to try to reset Sino-American relations and visit to Beijing in February 1972. When Nixon pledged to cease the overflights these two programmes lost their animating purpose and were cancelled.

Testing the technology frontier

Given the inherent uncertainties surrounding technological change and the United States' commitment to maintaining military technological superiority, the pursuit of 'type II flexibility' – as discussed by Rosen (1991: 243-245) - would appear a sensible strategy. Several drone programmes set out to explore the frontiers of technological possibility, inspired by a sense of the possibilities being opened up by the new technologies of the day. Some such programmes set out to test several frontiers at once and did not result in fielded – much less fully integrated – systems. Having been cancelled, any technology advances that such technology-stretching programmes yielded tended to make their way into successor programmes. Of course, it is difficult to assess whether such programmes were motivated by a desire to 'buy information' or whether such information should be seen as a consolation prize for programmes that failed to yield the desired fielded systems.

Two programmes of the 1980s, *Condor* and the *Advanced Airborne Reconnaissance System* (AARS), exemplify the dynamics at work in technology-stretching programmes that never apparently yielded an operational product. Both were developed in pursuit of fairly clear, though technologically onerous, strategic logic. *Condor* was initiated in the late 1970s and was meant to serve as an 'outer air battle' sensing platform, capable of loitering 'for up to a week' and monitoring the Norwegian and Barents Seas for approaching Soviet Backfire bombers. When detected and located, *Condor* would cue long range, ramjet-powered missiles that would destroy the bombers before they could get close enough to US Naval forces to fire their anti-ship cruise missiles.

With its 200 ft wingspan (more than the Boeing 747 passenger jet), and driven by two turbo-charged, liquid-cooled Teledyne Continental engines, in 1989 Condor set a propeller aircraft altitude record of over 67,000 ft and demonstrated unrefueled endurance of over 51 hours at 55,000 ft and in 1989 flew for almost 60 hours (Newcome 2004: 105). As noted, the drone made other significant advances, demonstrating new composite technologies, a state of the art flight control computer capable of flying waypoints that could be adjusted in flight and compensating for inflight malfunctions, and runway take-off and landing. Despite these technological strides, the Cold War ended before *Condor* (or a successor) was ready to be deployed to scan NATO's borders, and the programme was closed down in the face of budget cuts and consolidation (discussed in the next chapter). The Boeing drone ended up at Lawrence Livermore Laboratories where it became 'part of their work on UAV-based boost-phase ballistic missile intercept' (Ehrhard 2000: 176).

AARS, developed in the same period as *Condor*, represents arguably the high watermark of Cold War drone development in terms of technological ambition and sophistication. Like *Condor* it was driven by a relatively clear strategic rationale within President Reagan's Strategic Defense Initiative. It was meant to respond to a particularly concerning trend in Soviet nuclear capability: the increasing mobility of Soviet nuclear launchers. During the early Cold War, the Soviet military infrastructure was very fixed. This favoured fast-pass reconnaissance photography of the sort that satellites and the U-2 and its successors readily provided. But as this balance shifted towards mobile missile systems (both for air defense and nuclear weapon delivery), not only did fast reconnaissance become more dangerous for the crews but the episodic imagery provided could no longer keep track of so many moving Soviet targets. Ehrhard (2000: 138) explains the implications of this critical shift as follows: '[t]he only militarily useful way to deal with the proliferation of critical mobile systems was to find and track them in real-time. Satellites provided only episodic coverage, so only a stealthy, data linked overhead system—an airborne system—could accomplish the "find and track" mission by filling the gaps between satellite overflights'. The Advanced Airborne Reconnaissance System set out to create a drone that could not only penetrate but also *loiter* in heavily defended airspace, in order to find and track mobile systems in real time. Importantly, AARS, the Milstar satellite program, and the B-2 stealth bomber were intended as inter-locking parts: AARS would hunt and track targets, Milstar would relay the information, and the B2 Stealth bomber would then be used to attack the mobile target. This combination of capabilities would resurface and recombine in subsequent years.

The funding to attempt such technologically ambitious work was afforded by the severe nature of the perceived threat, the political context of the Reagan defence build-up and the return of large black budgets to the drone development landscape. The National Reconnaissance Office had closed down its drone research in 1974, but finding that its satellites were no longer sufficient to keep up with mobile inter-continental ballistic missiles, returned to UAV work. At the same time, a series of technological innovations seemed to make this concept a technical possibility – albeit an enormous stretch. 'Stealthy' aircraft design, satellite data links, digital fly-by-wire autopilots, composite materials, and the prospect of GPS navigation all 'pointed toward the possibility of a UAV that could loiter so long, so high, and with such impunity that it would serve as an endo-atmospheric, geo-stationary satellite' (Ehrhard 2000: 134). The AARS programme led to the development of the Lockheed Quartz UAV, a very secret, high technology design that reportedly had the low-observable 'clam-shell' shape of the subsequently-built DarkStar UAV (but was significantly larger). The AARS technology push did not yield an operational UAV. It was formally cancelled in 1992 when it was estimated that its per unit cost would run to a billion dollars (Ehrhard 2000: 508). The end of the Cold War also played an important role, transforming the development environment from one of resource abundance to one of scarcity. Despite cancellation it had advanced the state of the art across a range of enabling technologies and laid the ground for what was known as 'Tier III' in the 1990s.

As noted, during the 1970s DARPA was involved in a string of mini-RPV designs that employed small, robust, expendable flying vehicles and focused on developing payloads and data-link technology. This work may have been influenced by the CIA *Aquiline*, which also used a small vehicle and dates to the mid 1960s, but also grew out of Air Force research on mini-RPVs (as they were then becoming known) (Klass 1973). DARPA initially worked with a series of Philco-Ford manufactured drones that could hold interchangeable modular payloads. *Praeirie* I reportedly carried a wide-angle non-stabilised camera for basic navigation and sensor pointing, and a narrow-angle stabilized daylight television and TWL-50 laser designator. *Calere* carried the same wide-angle camera plus a forward-looking infrared sensor and larger laser designator (Hirschberg 2010: 5). In summer 1973, *Praeire* successfully laser designated ground targets, anticipating hasty Big Safari modifications to the Predator during the Kosovo campaign some 26 years later. These experimental vehicles were supplanted by *Praeire*/*Calere II*, which switched to a pusher propeller configuration, and on which payloads were substantially smaller and more capable and which now included electronic warfare capabilities. *Praeire* IIB then demonstrated ‘an extended range version with a high performance data link’, some of which were sold to Israel in 1977 and whose technology was subsequently integrated into a new generation of Israeli battlefield drones (Van Atta et al 2003b VI-11). *Calere* III, which first flew in 1976 ‘featured a new, lighter FLIR/laser target designator combination, developed under the DARPA Lightweight Advanced Night/Day Surveillance System (LANDSS)’ (Hirschberg 2010: 6). The payloads developed for *Praeire*, *Calere* and *Aequare* fed into both the *Aquila* battlefield reconnaissance program and the Navy Shipborne Tactical Aerial Reconnaissance (STAR) system – which became the *Manta Ray*. Although these were ultimately cancelled, the technology also fed into what would become the first ‘smart’ precision-guided bombs as well as another of DARPA’s drone development projects, *Amber*, which became the direct forerunner to the Predator. *Aequare*, a further DARPA mini-RPV project connected to RPAODS (Remotely Piloted Aerial Observation Designation System), developed a system that could be launched from an F-4 Phantom aircraft into heavily defended territory and bad weather to find and designate targets. Lockheed Missiles and Space Company won the contract. A further effort tied to Army observation and target designation research, *Axillary*, developed an E-Systems E-45 as a test-bed that included work on a lightweight autopilot. One of the concepts was suppression of enemy air defenses (SEAD) using radar homing and a small explosive charge so that the drone could turn into a missile if it identified a target. These experiments led to the Harassment Drone Program, and in turn to the AGM-136 *Tacit Rainbow* (cancelled in 1991) (Hirschberg 2010: 7-8). *Axillary* was an offshoot of the CIA

Aquiline and became the basis for the *SkyEye* drone (Pedlow and Welzenbach 2016: Appendix E).

Actual contingencies

The United States entry into the Vietnam War substantially altered the innovation dynamic for drones. The army's SD-1, an interim system that had been kept on owing to delays with its intended successor, was left behind when the Army went to Vietnam. The Navy's DASH and the Ryan 147s, however, were taken. While the Ryan drones continued to provide a basis for work on strategic reconnaissance applications, the modification programme increasingly became oriented to meeting other requirements that had not previously been considered but were realized in the course of operations in Vietnam. In this way the war opened up new pathways that diverged from those established under peacetime conditions and the kinds of conflict and associated missions anticipated by planners. These concepts and drone designs were refined in the experience of operations, resulting in a mushrooming of drone tasks. The two main thrusts of wartime development – relating to Ryan 147 Lightning Bugs and the DASH – proceeded in quite different directions than had either branch of 'peacetime' work.

Deployed to Southeast Asia in August 1964, Lightning Bugs then flew continuously for the next 11 years, during which period 23 different models were developed in a mushrooming of operations and differentiation of attributes to suit different tasks. Between them the Ryan 147 derivatives explored 'virtually every subtask of intelligence collection' as well as various other applications (Newcome 2004: 91). Newcome states that between 1964 and 1975, the '23 versions of the Ryan AQM-34 Lightning Bug flew 3435 sorties in support of the Vietnam War' on missions ranging from imagery reconnaissance to 'electronic and communication intelligence (ELINT and COMINT) collection, decoy, and leaflet-dispensing… chaff and electronic countermeasures (ECM)' as well as experiments launching munitions' (Newcome 2004: 83). The program pushed technologies of recovery, guidance and control, sensors, data exploitation, relays and data links, and stimulated development of new operational concepts and a wealth of experience.

Lightning Bug 147Bs were sent to Okinawa in the wake of the 1964 Gulf of Tonkin incident, which provided the pretext for the US to undertake a major expansion of its involvement in Vietnam. The drones were tasked with reconnaissance missions to build a picture of Chinese military intentions and troop movements. The drones also undertook 'strategic' reconnaissance of the Chinese nuclear programme as well as air defences. A succession of Lightning Bug iterations began to flow (see table below). During the Cuban Missile Crisis three Ryan 147Cs had been modified to carry a CIA-developed 'SAM-sniffer' payload. Its job was to lure an SA-2 into attacking it, obtain important information about the incoming missile and relay that information to an RB-47 electronic warfare aircraft before the missile destroyed it. In Vietnam this idea was quickly and successfully revived in a programme called United Effort. Wagner reports that in February 1966, on the fourth mission of the Model 147E, the drone successfully relayed data on the SA-2's proximity fuze, its radar guidance after the fuze activated, and the blast overpressure that destroyed the drone. He states that Assistant Secretary of Defense for Research and Engineering (DDR&E), Dr. Eugene Fubini judged this mission 'the most significant contribution to electronic reconnaissance in the last 20 years' and that information gained on this one mission was worth the cost of the entire drone program up to that point (cited in Wagner 1982: 102).

Another important development pathway was dedicated to low altitude operations. High altitude photographic reconnaissance was threatened by the SA-2s and impeded by North Vietnam's cloudy skies, particularly during Monsoon season. If they could be made to fly at lower altitudes, the Lightning Bug could operate below cloud cover, too low to be caught by the high altitude SA-2 missile. Low altitude flight was much more technically demanding. When flying low, variations in terrain became important. Moreover, owing to limitations in navigation technology the Lightning Bugs had always tended to deviate from planned reconnaissance routes. Photographs taken from 50,000 feet tended to still capture targeted areas, but at lower levels navigational drift would make the drone photography more likely to miss its intended targets. Ryan responded by adding a barometric altitude control system (BLACS) and a dual camera system (one looking front and rear, the other left and right) (Peebles 1995: 98, Wagner 1982: 93-94). The modified system, listed as the 147J, arrived in March 1966, becoming the first in a new pathway of low altitude Lightning Bug reconnaissance.

From December 1967 a new 'family of low altitude drones' emerged that would become 'the backbone of the final years of 147 operations' (Peebles 1995: 102). In preparing a new, cheaper and more effective version, Ryan went back to the original airframe's shorter, cheaper wingspan which would enable sharper turns, and added a redesigned single camera that provided an 80% increase in coverage. Unit cost was 40% lower than the 147G and J. The 147S was built in blocks, each of which would provide additional proposed capabilities. The 147SA was succeeded by a B version that could make sharper turns and that bore a multiple altitude control system (MACS), giving flexibility and also making it less predictable to opponents. Subsequently, these were configured to fly at 500 knots at just 500 feet, to evade antiaircraft fire. SRE models were deployed for night photography. Peebles reports that of 304 drone missions in 1968, '205 were 147S drones, while only 67 were 147H high-altitude flights… The original concept of high-altitude, covert reconnaissance, similar to that of the CIA U-2 overflights, had been replaced by the much simpler low-altitude missions' (Peebles 1995: 105). The next version, the 147SC 'Buffalo Hunter' arrived with improved navigation and a Microwave Command Guidance System that enabled flight corrections to be made from the DC-130 launch craft (Elder 1973: 4-6). In 1969 307 out of 437 drone launches were SC drones (only 21 flights were high altitude 147H flights). These iterations show how the Vietnam War opened up new missions that led the existing drones to be modified in new and unforeseen ways. In the course of these wartime operations, the Lightning Bugs advanced considerably along the innovation spectrum. The Army's SD-1 had been provided a place in the organisational structure, and concepts of operation had been developed for its use. But the SD-1 was not truly accepted or adopted despite this formal status. The Lightning Bugs, by contrast, were deployed and in the course of combat experience, they became more effective.

<u>Vietnam War Iterations of the Ryan 147</u>

Model Number	Mission	Number Launched	Years operated
A	First recce demo		1962
B	Lightning Bug – big wing high altitude recce	78	1964-1965
C	Training and low altitude testing		1965
D	ELINT (from C)	2	1965
E	High altitude ELINT (from B)	4	1965-1966
F	Electronic countermeasures (ECM) (from B)		1966
G	Longer B, larger engine	83	1965-1967
H	High altitude photo – longer range	138	1967-1971
J	Low altitude day photo	94	1966-1967
N	Expendable decoy	9	1966
NX	Decoy and medium altitude day photo	13	1966-1967
NP	Interim low-altitude day photo	19	1967
NRE	First night photo (form NP)	7	1967
NQ	Low altitude NX; hand controlled	66	1968

NA/NC	Chaff and ECM		1968-1971
NC	Leaflet dropping	29	1972
NC (M1)	Interim low altitude day photo and training		
S/SA	Low altitude day photo	90	1967-1968
SB	Improved SA low altitude	159	1968-1969
SRE	Night photo SB	44	1968-1969
SC	Low altitude – main model	1651	1969-1973
SC/TV	SC with real time TV	121	1972
SD	Low altitude photo – real time data	183	1974-1975
SDL	SD with LORAN navigation	121	1972
SK	Aircraft carrier operations		1969-1970
T	Larger engine, high altitude, day photo	28	1969-1970
TE	High altitude; real time Comint	268	1970-1973
TF	Improved long-range TE	216	1973-1975

Adapted from Wagner (1982: 13)

Another drone that underwent substantial and historically important wartime modification was the Navy's Drone Anti-Submarine Helicopter (DASH). DASH was a coaxial helicopter built by Gyrodyne based on a manned vehicle developed for the Marines from 1955.[49] DASH was built for the Navy for a specific anti-submarine warfare (ASW) mission, created by a gap that emerged during the 1950s between 'the detection range of destroyer sonar systems (22 miles)' and 'the engagement range of their antisubmarine warfare (ASW) weapons (1-5 miles)' (Newcome 2004: 87). Capable of carrying 1000lb of weight, DASH was armable. When an enemy submarine was detected from the ship, the DASH, loaded with two anti-submarine Mark 44 homing torpedoes, would take off from the ship deck (the helicopter configuration removed the need for a runway) and was then directed towards the target using its radar return by means of radio control. The torpedoes could then be remotely dropped into the water to locate and attack the enemy submarine and the DASH remotely piloted back to the ship.[50] DASH represented 'the first time that a reusable UAV had been developed and operated for attack missions' (Hirschberg 2010: 2). The Navy/ARPA DESJEZ project afterwards equipped DASH QH-50Ds with long-range fuel tanks and sonubuoys (as well as torpedo), enabling them to search for and attack targets independent of the sonar of the ship from which it was launched. With DESJEZ, the drone 'became a hunter-killer platform and was not limited to the ships sonar detection range' (Hirschberg

[49] Coaxial helicopters employ two sets of rotorblades above the body of the vehicle which turn in opposite directions, counteracting one another's rotational forces and holding the vehicle steady while aloft rather than using the more familiar tail rotor arrangement.
[50] DASH was also slated to carry Lulu, a 5-10 kiloton (selectable) nuclear depth charge.

2010: 2). When Ehrhard submitted his PhD thesis in 2000, he wrote that DASH was still ‘the only weapons-delivery UAV ever fielded—a truly revolutionary step’ (Ehrhard 2000: 304).

During the course of the Vietnam War the DASH underwent substantial modifications, with input from ARPA (subsequently renamed DARPA) in which new attributes were acquired that bore little relation to the mission-set within which the drone was originally conceived and developed. These modifications directly and clearly anticipate the subsequent breakthrough of drones technology in relation to the exigencies of the ‘new wars’ of the 1990s and the rise of terrorist/insurgent networks rather than the dominant geo-strategic scenarios that inspired the bulk of investment in the high technology drone ventures of the Cold War. Despite being highly innovative and providing a number of capabilities that had not existed before, DASH was unceremoniously cancelled in January 1971 after the Navy had spent $250 million. Higher than expected cost and lower than expected performance were the official reasons but those who worked on the program felt that by the time ‘ARPA found ways to make it work better, the Navy had already quit caring about the program - they wanted expensive manned aircraft and the power that more spending gave them’.[51]

In January 1965, the Navy had begun a program called *Snoopy*, fitting some of the DASH drones with a real-time TV camera, so that they could be used for spotting and correcting naval fire directed from the Tonkin Gulf onto the Vietnamese coast. Following *Snoopy*, various classified outgrowth programmes emerged, run by a DARPA team deployed to Vietnam, including *Blow Low*, *Nite Panther* and *Nite Gazelle*. *Nite Panther* was a response to the precarious position of Marines stationed at the Khe Sanh Combat Base and surrounding outposts which came under heavy and continuous attack, and became isolated, between January and June 1968 (when the base was abandoned). *Nite Panther* or *Seek Launcher* (which involved base perimeter surveillance), envisaged using the drones to provide reconnaissance for the embattled marines. Reportedly, this system was not ready in time to be used there, but nevertheless these modified drones were flown from the Dong Ha firebase (where the ARPA Research and Development Field Unit was based), located on the South Vietnam frontier of the Demilitarized Zone, until they were lost. The control stations used on the Navy destroyers and video and telemetry equipment were added to

[51] Correspondence with retired DASH operator, May 2016.

two modified 4x4 trucks and they were sent to Vietnam along with three *Nite Panther* drones in April 1968. All three aircraft were lost the same month (Hirschberg 2010). *Nite Panther* subsequently added a low light camera and a 3-hour loiter capability, 'a laser rangefinder and target designator, and an early moving-target indicator (MTI) radar to give it a night/all-weather ability to find targets and direct fire onto them' (Newcome 2004: 88). Additional fuel tanks enabled the drone to roam up to 50 miles from the control ship (the maximum range of the radar system still used to track the drones).

Nite Gazelle took these experiments further, modifying the drones to carry weapons, so that they could not only locate targets and direct fire, but directly attack them. Hirschberg states that these programmes were intended 'to eliminate high value targets in North Vietnam' (Hirschberg 2010: 2) and to 'to interdict North Vietnamese truck supply routes acting as hovering killer drones'. One configuration was an 'anti-personnel weapons platform' that carried 'two XM-18 Bomblet dispensers and two M5 Turrets - one turret carried an XM129 Grenade Launcher and the other a high resolution TV camera. Both turrets were slaved together so the drone controller could track what he was shooting at. Each Bomblet dispenser consisted of six tubes; each tube held 19 bomblets' (Hirschberg 2010: 2). Another concept involved two other versions, 'Attack Drone' and 'Gunship', working as hunter-killer teams, the mini-gun-toting Gunship clearing a low level flight path and Attack Drone following down this path and then releasing two 250lb MK-81 bombs on the designated target area.[52] Newcome states that '[t]hese capabilities were reportedly used effectively against North Vietnamese troops and convoys moving at night', although how effectively is not known (Newcome 2004: 88).

Other aspects of the situation in Vietnam stimulated other modification experiments. *Blow Low*, was a US Air Force effort (monitored by ARPA) initiated in September 1967 to address 'the DMZ gun problem' - in which North Vietnamese forces used the demilitarized zone to fire artillery at southern positions. *Blow Low* equipped the DASH UAV with a classified sensor payload, low light level TV to provide night time stand-off reconnaissance of the DMZ, and then added weapons in order to attack gun positions discovered in DMZ. The *Nite Gazelle* platform was also used to test ARPA's new Laser Aided

[52] See Gyrodyne Helicopter Historical Foundation http://www.gyrodynehelicopters.com/qh-50d1.htm [last accessed 26 May 2018].

Rocket System (LARS), an early generation guidance technology for directing rockets using laser reflections and a forerunner of the Advanced Precision Kill Weapons System (APKWS) developed in the early 2000s to furnish rockets with precision guidance.[53] It appears that armed DASH drones were used to fire rockets at the NVA. Finally, *Grandview* and *Egyptian Goose* demonstrated that it was possible to extend the range of the Dash drones by means of a relay datalink (Reed et al 1990). This too, anticipates what would become a vitally important capability for future drone operations.

Although it is clear that these experiments were developed under pressing wartime conditions, and although there is no doubt these armed drones were used to attack North Vietnamese forces, it is not clear how successful these experiments may have been. Ehrhard reports DARPA found the results 'disappointing' but this assessment seems to refer less to technical performance than to the failure of the program to be transitioned to the services (Ehrhard 2000: 163). As the US sought to withdraw from Vietnam, and with the DASH cancelled, the experiments were defunded and do not appear to have been pursued further. Nevertheless, these DASH experiments followed a chain of steps that closely mirror the Predator modifications in the late 1990s and early 2000s. Leaving aside the ASW role that gave DASH its place in the Navy, the Vietnam modification experiments saw the addition of video reconnaissance, spotting for artillery, early laser designation to enable found targets to be attacked, a data relay for extended range operations, and efforts to couple sensor and shooter to create unmanned hunter/killer platforms. This process saw a drone devised to hunt and kill submarines beyond range of ship-borne weapons evolving, via a spotting role, into a system for the hunting and killing of mobile targets in a ground war, including lorries, artillery positions, and personnel. Also worth noting, in the case of the DMZ artillery problem the issue was not only the technical task of locating and attacking fleeting targets but also related to the political difficulty presented by enemies positioning themselves in territory that the US felt unable to attack directly. This issue would subsequently recur and UAVs would again appear a good potential workaround for 'reaching in' without being forced to try to 'occupy' territory and while still claiming to be upholding (or trying to avoid violating) legal obligations.

[53] The rocket used in Nite Gazelle was part of research that eventually led to the US Army's Copperhead laser guided munition. See Reed et al (1990).

While the experience of actual military operations in Vietnam opened incipient pathways that saw drones begin to become integrated into military organisation and practice, the post-Vietnam period revealed the precariousness of their status. Despite ARPA's experiments, and having bought several hundred vehicles, the Navy cancelled them in 1970 to make way for the manned Light Airborne Multi-Purpose System (LAMPS) helicopter programme that later yielded the Kaman Seasprite and Sikorsky Seahawk (Newcome 2004: 88). The ARPA experiments had taken the DASH platform and changed its capabilities by loading it with a variety of experimental payloads and working on extended range data-link concepts. Following Vietnam, research on these topics continued apace but, as noted, thinking about platforms to carry them turned to smaller, cheaper and rugged mini-RPV designs – more like scaled up model aeroplanes (Van Atta et al 2003b: VI-7). The Lightning Bugs, by contrast, were far more than a few experimental systems. Over a thousand 147s had been bought and they had racked up 3435 combat sorties. In 1972 during the Linebacker II raids, the 147s provided 93% of the bomb damage reconnaissance photography. They looked to have become integrated, to have crossed a threshold from invention and innovation to user adoption. But following Vietnam, a programme that appeared to have made itself permanent soon withered.

The reasons for the post-Vietnam Air Force withdrawal from drones are complex but instructive. Funding cuts, intraservice competition between Strategic Air Command and Tactical Air Command, and the NRO's decision to shut down its Program D and transfer National drones to the Air Force all played important roles. The transition from the 'wartime' of Vietnam back to 'peacetime', however, proved critical. Projections by US planners about the character of a potential future war against the Soviet Union in Europe came back to the fore. In Vietnam, Soviet-supplied air defence technologies had wrought havoc upon US airpower. As noted by Kagan '[t]wo thousand five hundred and sixty-one aircraft and 3,857 helicopters fell to enemy fire, and roughly another 1,200 planes and 1,300 choppers crashed… Three hundred and eighty-three Air Force F-105 fighters were lost out of a total of 833… Half of the aircrews of these lost planes were never recovered' (Kagan 2006: 25). As noted, the allure of drones lay in their ability to perform missions that manned aircraft simply would not have been sent to undertake. Yet, as planners set their sights on the technological sophistication of the projected war environment, they also set a high technology bar against which the drones that had come so far in Vietnam once again seemed inadequate.

Organisational Process and Bureaucratic Politics

Organisational process and bureaucratic politics, dominant considerations in the military innovation studies literature, repeatedly surface as another set of factors that shaped every historical drone development effort and, in some cases, constitute an important explanatory set of factors that prevented specific systems from progressing further than they did. Indeed the main explanation for the dominance of the future war scenario may lie in the way that individual careers and organisational interests were structured by that scenario. The 'peacetime' innovation environment, we have seen, is driven by projections about future conflict rather than the immediate exigencies of battle. The scenarios guiding future war plans, in turn, cannot be understood as directly imposed by external conditions but must be understood as outputs of organisational processes and the result of bureaucratic political bargaining.

The organisational and bureaucratic factors that help to explain the marginality of the drone programmes up to the end of the Cold War, included 'requirements creep' as drone programmes added ever more complex requirements in order to satisfy the demands of different branches of the armed services, 'buy-in' as companies estimated wildly unrealistic prices in order to win initial contracts, and the reassertion of bureaucratic interests and prevailing mental models in war-peace transitions. In this section I also discuss unconventional or 'black' acquisition processes which did enable some programmes to overcome bureaucratic obstacles.

Intraservice relations and 'Requirements Creep'

The Army's *Aquila* perhaps best exemplifies the influence such factors can exert over the progress a development programme manages to make. Aquila was initiated in the course of the post-Vietnam reorientation towards a potential war in Europe (Knox 1994: 1), at a time when various technological advances (not least in electronics and electro-optics) seemed to hold out the possibility of exciting new battlefield UAV capabilities (Alexander (1979: 3), for example, expresses this optimism). After a promising start, however, the program became mired in competing priorities, shifting objectives, delays, cost overruns, and poor performance. After some thirteen years and investment over $1 billion, in 1987 Aquila was cancelled. Aquila confronted a number of difficult technology challenges but its demise is not reducible to technological insufficiency. It was badly mismanaged. As General Don Starry, who commanded of the Army's Training and Doctrine Command (TRADOC) centre during Aquila's early days, told Ehrhard, '"It wasn't just a disaster, we screwed it up beyond all comprehension"' (quoted in Ehrhard 2000: 284).

Compounding the overspeccing described above in relation to future war scenarios, another especially important difficulty in this case was '*requirements creep*', a phenomenon in which technical requirements are added to a programme after it has commenced, thereby increasing overall complexity. Just as a number of branches had identified the need for a battlefield reconnaissance capability during the mission area analysis process, so those branches now saw potential value in the program and sought influence over the Aquila as it moved beyond the System Technology Demonstrator phase. As noted by Knox, the system 'cut across the mission areas of military intelligence, artillery, infantry/cavalry scout missions and, to some extent, aviation' (Knox 1994: 3). On the development side, aviation (AVSCOM), missiles (MICOM) and target acquisition (ERADCOM CSTA) all wanted the budget whilst on the user side, none of the interested parties wanted to bear the cost. In the end the management involved a 'combined arms office with representation from Military Intelligence, Field Artillery, and Aviation' (Knox 1994: 3). By the end of the demonstrator phase, Artillery had already shifted the emphasis from reconnaissance and annotated imagery (i.e., imagery supplied with location data) to target detection and designation, thinking of its new *Copperhead* laser-designated artillery and Multiple Launch Rocket System (MLRS), and the lack of the means to designate targets short of sending troops into potentially very dangerous positions. The full-scale development arrangements reflect a compromise struck between the most powerful of the interested parties. Formally, proponency for the program went to artillery, but AVSCOM (in Missouri) was responsible for building the flight hardware while ERADCOM (in New Jersey) built the data-link (Rosenwasser 2004: 131).

These arrangements seriously hampered the programme but reflected the Army's deeper structural inability to adjudicate intramural priorities. Yet the problem of who should manage the programme was also a reflection of the fact that there was no easy way to fit the drone into the prevailing organisational architecture. Indeed, when it was transferred one participant in the program recalled, Aquila went from being a 'stepchild' at AVSCOM where it wasn't a manned plane to being a stepchild at MICOM, where it wasn't a missile (Knox 1994: 12). This underscores the nature of the difficulties confronting incipient technologies that portend the creative destruction inherent in true military innovation. Their lack of fit is not only a difficulty to be overcome at the point where they seek to transition to user organisations, but also afflicts them during the early invention and innovation stages. Inherited organisational stovepipes can become barriers for incipient technologies that do not fit.

Sponsor-contractor relations: 'Buy-in'

In addition to tensions arising from the differing priorities of intramural supporters, the *Aquila* case also exhibits the problems that can arise from dysfunctional sponsor-contractor relations. General William E. DePuy, then head of Army Training and Doctrine Command (TRADOC), was aware that high and escalating costs caused by long lead times and too much complexity had sunk prior programmes and therefore insisted on relatively bounded parameters for the initial System Technology Demonstrator (STD) (DePuy 13 May 1974, quoted in Knox 1994: 6). Although cost then escalated from $7 million to $17 million, Knox estimates that a '90% solution' had been achieved. The specification for the Full Scale Development (FSD) programme, however, introduced all the daunting technical difficulty of building a vehicle capable of 'full nuclear survivability', a jam-proof data-link and low observability so as to stand a chance against Soviet interlocking air defences. Lockheed, the contractor, produced an 18 volume document explaining that little of what had been learned in the STD would be applicable to the FSD. The Army, however, insisted that the contract could not exceed $100 million, the threshold above which it would be declared a major programme, incurring additional DoD oversight. Lockheed felt the Army was in denial about the size of the technological hurdles imposed by the design specification standards. To win the contract, both Lockheed and Harris Corporation 'agreed to unrealistic prices for their services', seeking to '"buy into" the contract' and hoping 'that downstream the government would bail them out' (Knox 1994: 36). Cost escalation then caused a political scandal that resulted in the programme being axed just as it yielded a system that was not only viable but extremely capable.

Intra-service politics and war-peace transition

Considering the bureaucratic politics of acquisition in general, Sorenson observes that military organisations ‘tend to give some missions higher priority’ than others, possibly those that historically ‘gained [them] fame and resources’ (Sorenson 2009: 93). During periods when funding becomes relatively scarce, such as in the aftermath of a war, ‘bureaucratic competition for weapons and their associated roles and missions intensifies’. Where bureaucratic politics theory usually proceeds to discuss intensification of rivalries over important missions and budgets, another corollary is that technologies that are lower down the pecking order tend to lose out in such processes. These difficulties came to the fore in the post-Vietnam period which saw upheavals in the structure of organisational support for existing UAV programmes and, ultimately, their demise. In 1974, following Nixon’s political pledge not to overfly China - but also motivated by the capability (and cost) of its new satellite programmes - the NRO closed down Program D and transferred the drones to the Air Force. Meanwhile, during the Vietnam War the Air Force Tactical Air Command (TAC) had become frustrated that Strategic Air Command (SAC) ran the Lightning Bugs (a result of their strategic reconnaissance origins and the continuing secrecy of the capability). TAC, whose aviators and aircraft were being shot down in numbers, had no control over the capability and were only provided what SAC felt it could spare. Although in 1967 TAC stood up a drone unit, a statement of bureaucratic intent, the unit languished and its drones were only used as leaflet dispensers late in 1972. Following the United States’ withdrawal from Vietnam, TAC sought to assume control of the drones and in 1976 SAC, now under budgetary pressure and finding its drone capabilities no longer financially supported by the NRO, readily handed them over. Yet, as the Vietnam War receded and TAC’s attention turned first to the scenarios of war in Central Europe and then to the technical complexity imposed on drones by those scenarios, its efforts to create a new and more capable generation of drones stalled. The most important of these post-Vietnam efforts, the Multi-Mission RPV, struggled in testing while TAC began to recognise the cost and inefficiency of launch and recovery procedures (still using the expensive MARS retrieval system) of the system it had fought to seize. Shortly thereafter, TAC abandoned them.

Acquisition channels

In contrast to the risky, costly, technology-stretching development approach taken in systems like the Aquila, Condor and AARS, the historical systems that advanced the furthest along the invention-use continuum emerged from unconventional acquisition channels that stressed quick, practical adaptations to put systems in the field rather than 100 percent solutions. In the case of the 147 series the initial success of the *Red Wagon* programme was set back when Ryan's orthodox, multi-million dollar follow-up proposals (the Ryan 136 and a second follow-on proposal for a drone called *Lucy Lee*) were rejected. Red Wagon was then revived 'by the back door' thanks to NRO funds, which were used to bypass mainstream acquisition and its approval chains, instead channelling the 147 *Firefly* development effort through the Air Force's alternative, quick reaction, development facility – known as Big Safari (Grimes 2014: 231-243, Wagner 1982: 15-25). It was not until 1969 that 147 development was shifted from Big Safari. DARPA's DASH modification experiments and subsequent research on mini-RPVs followed a similar approach in modifying existing platforms, but concentrated on advancing the state of payloads and data-link technology. Where the Lightning Bugs already had a customer, however, DARPA acted as a kind of technology surrogate, seeking to transition technologies in developed to services. Much less is in the public domain about the CIA's approach to drone technology. The *Aquiline*, a small drone initiated by the CIA Office of Research and Development's Applied Physics Division developed under a study contract with McDonnell Douglass, was intended for reconnaissance of sites of interest not located deep within enemy territory such as a radar installation at Talinn, Estonia (Pedlow and Welzenbach 2013: 339). According to one of its CIA participants, this programme was reportedly cancelled when the contractor quoted a development price that was ten times the budget that had been stipulated (Hambling 2007).

Beliefs, Norms and Culture

Pilot bias is often advanced as a candidate explanation for the perennial failure of UAVs to become more firmly established during the Cold War. In this view the UAV poses a fundamental threat to pilots, including the value of their skills and the cultural values that they hold dear and that are said to characterise those military entities concerned with aviation. Clarke (1999: 45-46), for example, provides evidence that such a belief was widely thought to have held back UAV development during the 1970s. Hall, then a Lieutenant Colonel in the US Air Force, believed that '[t]he natural tendency for most people with a stake in tactical air power is to resist RPVs… [t]here can be little doubt that the recoverable RPV is a distinct threat to the status quo of tactical systems' (Hall 1978: 42). Despite abundant anecdotal evidence of the existence of such an attitude right up to the present day, echoed in several interviews, there is little available evidence of the causal role it may have played in obstructing adoption of UAVs in the past. Newcome reports that during 1965 Lightning Bug operators dropped the term 'SPA' in favour of 'Remotely Piloted Vehicle' (RPV) and argues this 'helped convince their own aircrews that they still had a pilot's function' (Newcome 2004: 85).[54] This suggests that those involved experienced some concern about the status of what they were doing and how it might be perceived by colleagues. This issue recurred in the post-9/11 years as the Air Force struggled to recruit sufficient drone operators and tried to battle cultural perceptions of drone operators as inferior to 'real' pilots who flew on-board the vehicles they controlled. Naming was here linked to struggles over acceptance within existing military cultures. In the Cold War period, however, culturally-rooted opposition could easily be disguised by pointing to the evident technological limitations that beset so many systems as evidence that the time of the drone had not yet come.

Political pledges and treaty agreements created constraints that made programmes redundant. President Nixon opted to accept reality in China and to engage, in part to balance against the possibility of a China-Soviet Union alliance. His political pledge to end overflights of China shut down two important high altitude, long range reconnaissance drone projects - the D-21 and the 154 Compass Arrow. Nonetheless this 'concession' has to be weighed against the fait accompli of Chinese nuclear capability, the availability of increasingly powerful satellite reconnaissance options and, again, the reality that the D-21 in particular was pushing beyond what the state of the art in navigation could support.

It was one thing to fly combat missions over south east Asia or secretive reconnaissance missions deep within the Soviet Union but quite another to propose routine

[54] Ehrhard, however, states that 'Air Force Lieutenant General F. Michael Rogers coined the term "remotely piloted vehicle" in 1970 when he worked on the Air Force Systems Command staff. He wanted to emphasize the presence of a human pilot in the control loop' (Ehrhard 2000: vii). Ehrhard cites James E. Biltz, et al. (1974) 'The RPV: Yesterday, Today, and Tomorrow' unpublished research paper, Air Command and Staff College, May, p. 12.

drone operations in Europe. 'See and avoid' rules regulating European airspace, which the drones could not fulfil, made stand-off drone reconnaissance concepts unviable. The possibility of mid-air collision contributed to the marginalisation of drone solutions in the place about which the US was most preoccupied. The problem was not confined to Europe. In the United States drone development operations have been conducted at remote facilities partly in order to ensure the safety of manned aircraft.

Very importantly for this study, and explored in greater depth later, the Strategic Arms Limitation talks and agreements were worded in such a way as to make drones fall under the definition of a cruise missile, largely precluding weapons delivery roles. This contributed to the demise of the strike component of Ryan's modular, multi-mission BGM-34C and stifled weapons delivery drones for the rest of the Cold War and throughout the 1990s. The heading off of strike variants, Ehrhard argues, had profound implications for the status of drones within the armed forces. Culturally, he argues 'the greatest cross-service inhibitor to fielding UAVs has been the general unwillingness on the part of warriors to pursue support systems' (Ehrhard 2000: 493). The consignment of drones to such support roles meant that they suffered from the low status and priority assigned to such roles. This inhibitor, however, contributed to the emergence of a tactical reconnaissance shortfall in the 1990s (manned and unmanned) that created an opening for a new generation of drones to develop.

Problems of Operability

It is not enough for new military technology to be invented, or simply to deliver it to users. The organisational user must make the technology militarily practical. With dedicated organisational accommodation established for battlefield reconnaissance under the Army's Pentomic reorganisation, the SD-1 was quickly fielded but on an interim basis, and then kept on owing to delays with the intended successor. Beyond declaring a system operational and even creating the organisational structure to accommodate it, the operational user must believe in the system.

The failure of most UAVs to advance from research and development to service adoption partly reflects the gulf that separates a demonstrator that can fly and perform to a basic specification and a militarised system. Such a system must do more than demonstrate the ability to fly. The operational user must evaluate overall cost, sortie rates and crash rates and consider the time between component and sub-system failures and the maintenance requirements imposed. High crash rates were a major difficulty and reason for the systems not becoming more thoroughly integrated. The DASH helicopter, which demonstrates so much of the promise of UAVs and anticipates many of the possibilities for their employment that would be explored going forward, was widely distrusted by crews on the ships that launched it. This was partly to do with the inherent technological glitches in such an early system and the specific concerns of operating from the deck of ships.

An alternative strategy is to introduce an ‘interim’ system that accustoms the user to the capability while preparing a better developed follow-on. Ehrhard argues convincingly that the SD-1 and the Pioneer, both introduced as interims but both ending up being kept on indefinitely after the intended heirs failed to materialise, created ‘legions of doubters’ rather than a constituency of support (Ehrhard 2000: 297).

Before the introduction of conventional runway take-off and landing, a number of elaborate schemes were introduced for fixed wing drones – nets, parachutes and the mid-air retrieval used to collected jettisoned Corona satellite film packages. The latter reduced damage to drones in Vietnam and assisted in retrieving drones and increasing sortie rates but it made 147 operations deceptively expensive and required additional manpower.

Another feature of the history is that fielded systems ‘worked’ because the personnel assigned learned on the job how to accommodate the limitations of the system- they made it work. Military organisations do appear to have wanted a ‘drone in a box’ that was easy to use, robust and reliable and tended to pursue the technology rather than investing in people that could make the system work. One of the key insights on the part of the inventor of the Predator was that the drone was more plane than missile and needed well-trained crews who understood how to use and maintain the system. This draws attention to the important point that technological reliability can be influenced not just by technology ‘per se’ but also by the skill of users, and the organisational and operational structures established for operations.

Conclusion

This chapter has underscored that far from being new, drone development has a history that goes back to the beginning of flying machines. Ideas about the utility of a proliferating range of applications led to differentiation over time as systems intended to perform a number of missions suggested quite different technical properties that opened up distinctive development pathways. Such ideas, however, proved difficult to translate into products that were judged to work well enough to be militarily useful. A large part of the reason for their failure to advance beyond invention and innovation, and therefore for their perennially marginal historical status, therefore has to do with difficulties stemming from technological limitations. Putting aside the technological limitations that affected payloads, the specific areas in which technological limitations held back drone development include flight stability, remote control and data-links, launch and recovery, location accuracy and navigation, and the challenges of systems integration. In general, tentative solutions to each of these challenges were progressively found over time that relaxed each of these constraints to some extent. 'Working' or not was not a technical absolute but established in relation to sociotechnical judgments about the use environment and adversary capabilities. Generalising across programmes and across decades, key technological constraints tended to lift due to cross-programme learning and under the influence of wider technical change – although such change 'accrued' to drones and rival technologies in complex ways. Nonetheless, partial solutions introduced difficulties of cost (for example, MARS retrieval) and reliability (for example, drones using inertial guidance systems straying from intended routes). While allowing some drones to advance to use, these drawbacks then complicated and inhibited deeper adoption because of problems of operability. Wider technological change had complicated effects on drone development, with rival technologies such as satellites out-competing drones but subsequently morphing into enablers that revealed their distinctive advantages. The microprocessor revolution and increasing computing power (accompanied by plummeting cost and size), increasingly capable data-links and then the advent of GPS in the 1990s, however, converged in a way that overcame each of the core technical challenges and began to translate long-standing ideas into militarily useful systems.

While technology was a serious constraint, a range of other factors could work to fell drone development programmes. Indeed, rather than seeking to explain the inability of any of the historical systems to become permanently integrated in terms of any one of these factors, it is necessary to consider shifting alignments between them. While taking seriously the moving horizons of technological possibility, this chapter has also emphasised the importance of strategic considerations, organisational process and bureaucratic politics, norms and culture, and problems of operability. In strategic terms, the main obstacle was the dominance of the future war scenario, using linear projections of technological advance based on the experience of World War II. Although the Vietnam war did open up new roles and incipient pathways for drone development, particularly the family of Lightning bugs widely used in that war, this opening was closed down as the dominance of the future war scenario was revived in the post-Vietnam period. The need for unmanned intelligence capabilities vis-a-vis the Soviet Union and China, at a time of advance in air defence technology, also offered a similar opportunity but it was a role, given the stage of development of technology at the time, that ended up being undertaken by satellites.

Shifting strategic requirements were also a product of organisational and bureaucratic processes. Inter-service rivalry, commercial interest and bureaucratic competition all provided obstacles to drone development during this period; indeed, unconventional forms of acquisition proved to be very important as I shall emphasise in subsequent chapters. Norms, the resistance to pilotless aircraft, and political agreements such as SALT as well as the requirements of operability also played a part. In other words, marginality was not just about technology. When technology was improved to a practicable state, there was still the need for alignment between strategic priorities and technology. And during the Cold War, those strategic motivators that opened up pathways for drone development, most notably the Vietnam War, proved to be ephemeral.

4. The Emergence of the Predator

Introduction

By the late 1980s, we have seen, drones had persisted at the margins of US military organisations and their operations for more than forty years, neither abandoned nor really adopted. But where in the 1950s and 1960s the causes of the failure of drones to advance had a heavy component of inherent technological limitations, a range of technology developments set in motion in the 1960s and 1970s meant that by the 1980s technological solutions to those core problems were coming into view that had the potential to make drones 'work' in militarily relevant ways. Yet still development efforts failed to deliver systems that the services would adopt. Although technology challenges were by no means eliminated, the weight of explanation for the continued marginality of drones in this period has to be located amongst some of the other components that must align in order for a new technology to progress along the innovation continuum.

What eventually became the Predator originated in research and development efforts initiated during this period that produced a series of systems – the Albatross, the Amber, and the Gnat – whose air vehicles are strikingly similar and which began in the mind of an individual inventor, Abraham Karem, rather than an R&D lab (although Karem quickly gained DARPA support), large defence contractor, or requirements articulated by any military service or agency. The efforts of Karem and his small team unfolded within a wider landscape of contemporary drone programmes, all of which were mired in difficulties and none of which (with the partial exception of Pioneer) succeeded in gaining a permanent foothold in military organisations and their operations. Predator's forerunners seemed no different. To an observer at the end of the 1980s, it appeared as if this lineage too would die out rather than advancing along the innovation spectrum to be adopted and assimilated. Indeed, as late as the summer of 2000, perhaps the foremost scholar of American drone technology believed that the system still had 'so many combat limitations that its long-term viability remains in question' (Ehrhard 2000: 546).

In making sense of the course taken by Predator's forerunners, two vitally important contextual factors that came into play in the late 1980s and dramatically impacted the course of ongoing drone development programmes, must be taken into account. The first was a far-reaching and multifaceted effort at defense reform, one element of which specifically set out to restructure the management of drone development efforts – thus transforming the bureaucratic-organisational context of drone development. The second was the abrupt end of the Cold War, the profound but ambiguous changes it heralded for the strategic environment, and the hotly debated process of reorienting US security posture accordingly. These transformations of the bureaucratic-organisational structure underpinning defense acquisition and to the wider strategic environment reshaped the context for the development of drones.

The concerted attempt to reform defense acquisition during the 1980s reflects that the problems of defence acquisition in general and drone development in particular were recognised across the defence community and that serious efforts were being made to try to identify the problems and make corrections. Those reforms were guided by the belief that 'servicism' – the tendency to view strategic problems through the parochial lens of a given military group – was the root of the problem and that the solution entailed finding the means to generate 'jointness'. Yet the advent of the Predator was not the result of these reform efforts. Rather, Predator's ancestor was actually cancelled in the course of these reforms, its inventor driven out of business only for his company to be snapped up by a powerful new entrant into the defense industrial market. Ongoing adjustments to the drone acquisition system are only partially responsible for the subsequent progression of the Predator programme. That system instead really reflects the efforts of a network of well-placed and like-minded individuals to bypass what they saw as a dysfunctional military acquisition machinery in order to respond to an acutely-felt reconnaissance shortfall and a changed strategic reality.

During the 1980s and 1990s a series of technologies were becoming sufficiently mature that they promised to overcome some of the lingering technical obstacles to the development of militarily relevant drones. Location accuracy had been addressed by progressively more capable inertial guidance systems. The NAVSTAR programme, then bearing fruit with the Global Positioning System, promised the means to correct INS drift and overcome the problem of location accuracy that had long dogged drone development efforts. High bandwidth, long distance communications links were made possible by satellites, and improvements in computing and software. Such links promised to enable extended range remote control by overcoming the need for line of sight connection. Equally important, these links could enable remote control while simultaneously supporting the real time transmission of larger volumes of sensor data, so that drones began to be able to transmit, for example, full motion video across the world in real time. Software advances combined with GPS enabled more reliable flight control and also made runway take-off and landing a less accident-prone operation. At the same time, the US defense community was increasingly seized by the idea that information and communications technologies would change warfare and by a desire to understand and capitalise on these advances to maintain American military technological superiority. Command, control and communications, the networking of platforms, the growing importance of intelligence, surveillance and reconnaissance, the importance of GPS-enabled precision guided weaponry – unmanned aerial vehicles seemed to fit into, incorporate, and contribute to this emerging suite of technologies and capabilities. Perhaps for this reason they were to receive high level support from some of the prophets and proponents of information technology's transformative implications for defence. All this augured well for drones, but was available equally to all the UAV systems then under development. Yet it proved to be the Predator that managed to harness these technologies and managed to advance along the innovation continuum, while its contemporaries followed the pattern established by prior efforts, and failed to overcome the barriers that separate research and development from adoption and assimilation.

This chapter explores how it came to be that Predator managed to cross the threshold to be adopted, albeit tentatively, by the Air Force. It is about the 'emergence' stage of socio-technological evolution. At this stage, the technological limitations have been largely overcome. New strategic rationales have been developed and these are associated with new mechanisms for overriding conventional bureaucratic acquisition processes. But the technology remains tentative – not yet integrated into a new institutional, cultural and normative framework.

'Technocratic Initiative' and its limits: Leading Systems, the Albatross and the Amber

The early origins of the what became the Predator drone stretch back well into the Cold War, and begin in Israel rather than the United States. In the 1970s, against the backdrop of an already diverse landscape of drone development (discussed in the previous chapter), a promising Israeli engineer-inventor began to apply himself to UAVs in Israel (as noted, the DARPA Calere II mini-RPV drone found its way into Israel's Mastiff, Scout and eventually back to the US in the Pioneer). Abraham Karem's vision of what drones could do, his path-breaking contributions towards addressing the design and technical challenges, as well as his sheer determination in the face of formidable bureaucratic challenges, directly resulted in the emergence of a new lineage of UAVs. Amidst the range of Cold War UAV development pathways it turned out to be Karem's designs, and the capabilities that they emphasised and provided, that would find their way along the innovation spectrum in a way that no other system had managed.

In the early 1970s, Abraham Karem was one of the rising stars within Israeli Aircraft Industries (IAI). In late 1973, while working for IAI on fast decoy drones to trigger the mobile air defence systems that caused such heavy Israeli losses during the Yom Kippur war, Karem had had an 'epiphany' (Whittle 2014a: 15). It is striking that the purposes for which Karem first envisaged endurance UAVs, however, bear little resemblance to the purposes for which they would eventually come to prominence. Initially, he imagined them patrolling the borders of Israel and providing 'an air-to-ground defensive missile system' that would destroy Egyptian tanks at funnel points where they tried to cross the Suez canal (Whittle 2014a: 16). Karem was particularly interested in the possible 'persistence' that UAVs could deliver, envisaging a relatively small fleet of long endurance UAVs providing 24/7 coverage – a concept echoed in the US Compass Dwell program concept of electronic intelligence along the European border with the USSR. At that point (1973), UAV development in the US had mainly (though not exclusively) related to battlefield reconnaissance or to high altitude strategic reconnaissance. The scenario for which Karem initially envisaged his design bore virtually no relation to the missions that would eventually drive the assimilation of its distant descendent. However, his central insight that drones could provide unprecedented airborne endurance transcended the specific scenario that initially inspired him. Indeed, Karem is on record stating that he had no idea of the uses to which his ideas would later be put. Finn states that 'Karem said he imagined his drones involved in a "tactical conflict with the Warsaw Pact, be it on the plains of Germany or as part of our Navy and Marines... I did not envision the collapse of the Soviet Union and the rise of warfare with non-state adversaries"' (Finn 2011).

Karem is often described as 'the inventor' of the Predator, a view that resonates with deep-seated assumptions about invention as an act of creation by singularly talented and determined individuals.[55] Constant, for example, is very clear that men and not 'forces' create new technology (Constant 1973: 557). The story of Predator's origins in the mind and work of a single entrepreneur also resonates with Evangelista's technology push perspective, which explains technological innovation in terms of 'the role of scientists in the promotion of new military technologies' – which he called 'technocratic initiative' (Evangelista 1988: 12). Such technological entrepreneurs, it was argued, fight to overcome the various inertial tendencies (such as bureaucratic politics) that tend to inhibit incipient innovations. Such people, as Hughes argued around the same time (following Law), are more than manipulators of the technical world but are better thought of as 'heterogeneous' engineers who must simultaneously manipulate the social world in order to overcome the range of forces of resistance that threaten to prevent the new technology from taking root (Hughes 1987: 52).

Evangelista in particular argued that in the field of military technology, such entrepreneurs attempt to 'sell' their technology, actively trying to instrumentalise unfolding events and emerging threats and arguing for their technology as providing a solution. This tends towards a view of inventions as solutions in search of problems. For those who saw technologists as driving the Cold War arms race, entrepreneurs were thought to invoke 'external threats more as rationalizations for weapons already desired than as genuine stimuli for new systems' (Evangelista 1988: 13). Evangelista cites Brooks as expressing a typically cynical view:

> '"[e]xperience has taught the military-technical community that it is much easier to sell interesting research if it can be pushed as a fully conceptualized weapons system meeting a well-defined military requirement based on a well-established threat from a postulated opponent. In practice, both the threat and the requirement may have been invented to provide a rationale for a development program started for other reasons, such as to perpetuate existing organizations, or to exploit a "sweet" technical concept…"' (Brooks 1975: 91, quoted in Evangelista 1988: 13).

Karem is a vitally important figure in the development of the Predator drone, but the technologists-out-of-control perspective does not fit the facts of this case. Rather, Karem's

[55] In 2013 *Air & Space Magazine* billed him as 'The Man Who Invented the Predator' (Whittle 2013).

role better fits with Spinardi's finding that inventor-entrepreneurs and technical communities in general can and do actively seek to advance their preferred technologies but do not have it all their own way. With the Predator forerunners, Karem demonstrated a 'sweet' technical concept that he believed would be of irresistible utility to users in the military and intelligence communities. Yet those forerunners were rejected and would have gone the way of so many other drone concepts but for a (at least from Karem's point of view) fortuitous concatenation of emerging circumstances suggesting capability shortfalls and new, urgent needs, and a network of determined and well-placed individuals capable of making use of black world channels and bureaucratic guile to bypass established acquisition practice and revive the programme. Thanks to timing, relevance to emerging problems and high-level backing, during the 1990s the Gnat-750 and its outgrowth, the Predator programme, succeeded in transitioning a drone from research and development to tentative fielding in a succession of operations.

Contemplating the challenge of long endurance, Karem's imagination followed a very different track from the combinations of extremely high technologies that were coming to dominate the secret 'national' US drone programmes of that period. Karem instead thought more along the lines followed by DDR&E Director Dr John Foster and the DARPA mini-RPV experiments of the 1970s – that is, of model gliders, perhaps because he was an enthusiastic and skillful free-flight modeler himself and had been building gliders since his teens (Whittle 2014a: 16).

Karem was also convinced not only that UAVs had potential but that they were one of the few fields in which an inventor working in their garage could produce something better than the big defence contractors. In his view, the main reason that the defense community had not already become more receptive to drones did not stem from limitations imposed by the frontier of technical possibility at that time. Rather, Karem claims to have seen a vicious circle in which the military were 'uninterested in RPVs other than as target drones' and that, consequently, 'RPVs had been developed either by modellers accustomed to making toys that were cheap to build and replace or by aerospace corporations whose best people worked on more lucrative products and whose unmanned aircraft were designed, like target drones, to be expendable, not least because their customers, the military, demanded no better' (Whittle 2014a: 18-24). In Karem's view, military planners did not understand the available technology well enough to know what drones could do - that reliability could be drastically improved and that other problems, notably regarding longer range guidance, control and relay systems, could be tackled. He believed he could 'prove that performance is largely a result of inspired design and highly optimised and integrated subsystems, not the application of the most advanced technology' (Economist 2012). Karem set out to build a UAV with extraordinary endurance capabilities that was also highly reliable. He appears to have been convinced that such capabilities would be so useful to the military that they would be unable to say no.

Frustrated with what he considered a lack of vision, Karem resigned from his prominent position at Israeli Aircraft Industries (IAI), determined to start his own company and prove his idea. He has stated he was privately warned by friends and colleagues that the incumbent Israeli firms would mobilise to drive him out of business, but this did not initially deter him. By 1977, though, he had decided that his business would not be permitted to succeed in Israel and had emigrated to the United States, where he believed his ideas might be supported. After arriving, Karem initially went to work for Developmental Sciences, Inc., an important player in the US drone industry at that time, where he apparently worked on 'a couple of RPVS' (Hirschberg 2010, Whittle 2014a: 24). Given this timing Karem may have been put to work on Aquila (Developmental Sciences being Lockheed's main contractor on Aquila), SkyEye, or potentially other mini-RPVs then underway. However, Karem is known to have worked on a Black DARPA programme known as *Teal Rain*, run between 1980-1982 (Van Atta et al 2003b: VI-15). Ehrhard presents it as a successor to the Air Force Compass Cope program (Ehrhard 2000: 170) and several sources report that the programme investigated technologies to provide high altitude long endurance capabilities (Hirschberg 2010, Newcome 2004, Van Atta et al 2003b).[56] The Boeing Condor reportedly fell under this programme too (Newcome 2004: 104). Ehrhard notes that Teal Rain explored engine performance but it also investigated 'nuclear-, solar-, and microwave-powered motors, as well as exotic materials and designs' (Van Atta et al 2003b: VI-15). Hirschberg states that Karem approached DARPA in 1978 (before Teal Rain began) with a design for 'a 90,000 ft altitude 5-day surveillance aircraft using a piston engine that produced 65hp at sea level as well as at its highest altitude, through the use of three-

[56] In a footnote, Peebles suggests that the 'Teal' prefix 'commonly refers to sensor systems' (Peebles 1995: 323).

stage turbo-charging, as well as three-stage after-cooling' (Hirschberg 2010: 11). It may even be that Karem's suggestions stimulated the Teal Rain research – then-DARPA Director Robert Fossum claims to have walked into a 1978 meeting where a high altitude long endurance concept was being pitched and decided to fund it (Van Atta et al 2003b VI-18). DARPA contracted a consultant, Ira Kuhn, to evaluate the work, who apparently concluded of Karem that 'this guy is a national asset' (Whittle 2014a: 64). In early 1981, Kuhn described Karem as 'a brilliant designer and engineer, a throwback to the 1940s when one man designed a whole airplane from scratch' (Pincus 1981).

Albatross

Karem left Developmental Sciences in February 1980 to found Leading Systems, after the owners of Developmental Sciences refused to make him a partner (Whittle 2014a: 24). Leading Systems started working out of Karem's garage, initially using private funds (according to Hirschberg), although Whittle states that Albatross was supported by DARPA by means of a $350,000 contract arranged with Kuhn's consulting company, Directed Energy, as intermediary out of concern that auditors would be worried about sponsoring garage-based research. Using little more than 'plywood, homemade fiberglass, and a two-stroke engine similar to those used on go-karts', Karem built 'two prototypes of a high aspect ratio, low empty weight, long-endurance drone, as well as an advanced piston engine, avionics and a ground station' (Lee 2016: 114; Hirschberg 2010: 11).[57] The AV was driven by a rear 'pusher' propeller and bore tail fins that angled downward in a distinctive inverted 'V-shape' so as to provide skids that protected the propeller in take-off and landing. The vehicle weighed 105 pounds when empty but could carry 95 pounds of fuel (Whittle 2014a: 25). Karem initially had one part-time employee but, after a prototype crashed due to problems with subcontractor-made avionics, in October 1982 Karem hired an electronics engineer, also an avid radio-control hobby plane enthusiast, whom he had met at Developmental Sciences, who contributed avionics, ground control, and skill in flying the demonstrator without crashing. Reflecting its relatively long wings (15 feet, compared to

[57] A wing is described as 'high aspect' when it is very long relative to its width from leading to trailing edge (that width is called the wing's 'chord').

a chord of 11.8 inches) and long endurance purpose, Karem named the drone *Albatross* (Whittle 2014a: 23).

At the beginning of 1981, Ira Kuhn (who had evaluated Karem's high altitude engine work) approached Karem to work on a long endurance aeroplane concept, dubbed *Big Bird*, capable of acting as an air-mobile long endurance platform for MX nuclear weapons (Pincus 1981). Karem's design was presented to the Townes Commission (with which Kuhn had good connections), and caught the attention of James Woolsey (who would become Director of the CIA in 1993).[58] Kuhn also persuaded DARPA to support the Leading Systems Albatross. They funded a series of flight tests between 1980-1982 to demonstrate the technical feasibility of long endurance as well as reliability. The Albatross airframe was intentionally built with the lowest technology materials to prove that its advanced performance was not a result of using advanced composites. In November 1983, Albatross was demonstrated at El Mirage air field, California. By then the Leading Systems trio had refined the prototype and most of the equipment and systems used to operate it. Albatross flew for three hours and thirty five minutes in this test flight, but the fuel gauge suggested it could have remained aloft for forty-eight hours or more. Whittle states that when Robert M. Williams from DARPA told 'Air Force experts that Karem was developing a drone able to carry close to its own weight in fuel and fly for two days and maybe more, they assured him that no one could design such an aircraft, that physics made it impossible' (Whittle 2014a: 27).

Amber

Following the November 1983 Albatross demonstration, DARPA invited Karem to develop a larger, long endurance, 'scaled up advanced technology' successor to the Albatross (Hirschberg 2010: 11). This programme, dubbed *Amber*, began in December 1984 with a $40 million development contract between DARPA and Leading Systems, and would run until 1990. DARPA hoped to develop a 'long endurance, low observable UAV with

[58] Much to the irritation of the Air Force, reportedly, Defense Secretary Weinberger was in direct contact with Ira Kuhn on this question rather than going through the mainstream Air Force engineering structures (Dunn 1997: 139).

sophisticated sensors for photographic reconnaissance and electronic intelligence missions' (Van Atta et al 2003b: VI-18).

Like its predecessor, Amber had the inverted-V tail stabilizers and a pusher propeller. Amber, however, was the size of a light airplane (with a wingspan of 28.4 feet compared to the Albatross' 15 feet). Where the small Albatross demonstrators had fixed legs with wheels for runway take-off and landing, the Amber had retractable landing gear, which may have been 'a first for a UAV of this size', and which allowed the drone to carry payloads under the wings and fuselage (Hirschberg 2010: 12). With its spindly landing gear and model plane appearance, Amber still looked 'more akin to the simple battlefield support UAVs, rather than… complex strategic drones' (Peebles 1995: 207). Nonetheless, the drone embodied a number of technology innovations belied by this appearance.

For the project to advance, Karem knew, it would have to successfully make the leap from DARPA to backing by one or more of the armed services. To make this jump, Amber would need to fit in with capabilities and missions that the armed services wanted badly enough to commit funds and on which they would stake their reputations. Before signing the contract with Leading Systems, DARPA had signed a letter of agreement with Lehman, the Secretary of the Navy, in which the Navy (supported by the Marines) undertook to make Amber (if successful) become the low-speed Naval UAV, the replacement for the Mastiffs with which they were then experimenting. This agreement would place Amber in direct competition with the Pioneer. The terms of the 1984 agreement between DARPA and the Navy was for an RPV capable of 24 hours or more endurance at up to 30,000 feet. DARPA would provide $5 million initial funding and once the basic prototype was proved sound the Navy would put in a further $25 million (Whittle 2014a: 53) and then assume lead for transition and production. The Army joined this agreement in 1985, bringing the contract value to $40 million (Hirschberg 2010: 12).

Different parties to this agreement had distinct, if overlapping, objectives. Different sources give differing interpretations of the Navy's interest. Lehman had been impressed by Israel's use of the Mastiff in 1983 in roles such as tactical reconnaissance and artillery spotting. He also thought of using drones to act as spotters for the guns of the four Second World War Dreadnoughts he had brought out of retirement (Whittle 2014a: 50-52). Ehrhard believes the Navy's interest related to their pursuit of a broader 'over the horizon' (OTH) capability. In response to the arrival of the Soviet *Styx* cruise missile the Navy had acquired the *Harpoon* – a cruise missile with a greater range than the *Styx*. The problem was that the Harpoon's range also exceeded the Navy's sensors for locating the position of enemy ships without coming within range of the Styx. A UAV seemed an obvious candidate. Ehrhard interprets this situation as evidence that 'the US military - regardless of service - tends to buy lethal strike systems even if they outpace target acquisition and damage assessment (tactical reconnaissance) capabilities' (Ehrhard 2000: 339).

The Army meanwhile, struggling with the Aquila program, signalled interest in supporting Amber as an alternative battlefield reconnaissance system, but also with a view to seemingly less technologically onerous missions such as monitoring drug traffickers and guerrillas. It was contemplated for the Army Intelligence Electronic Warfare UAV (IEW-UAV) programme (Morocco 1987) and reportedly had champions in Southern Command, who believed it could provide persistent surveillance of drug traffickers in Latin America (Whittle 2013) - they had also experimented with the SkyEye system when attempting to monitor guerillas in El Salvador. It is also clear that the CIA was involved. Ehrhard does not elaborate, despite providing a lengthy discussion of the role of other intelligence organisations (mainly the NRO) in drone development (Ehrhard 2000: 169-170). Whittle also reports CIA involvement in Amber but says 'in just what way and to what extent still remained a secret that participants in the program were forbidden by law to reveal three decades later' (Whittle 2014a: 53-54). This could possibly refer to the Eagle program that former senior CIA operations officer Duane Clarridge mentioned in a December 2001 interview (Coll 143-144 2004; Fuller 2017: 104-105). The emerging experimentation with UAVs in counterterrorism, providing covert support to or surveillance of insurgents, as well as in counter-narcotics roles during the 1980s all directly anticipate post-9/11 missions some 15 years later in which drones were used to locate and track fleeting targets in real time.

For Karem, meanwhile, Amber was the latest iteration of an idea that had first occurred to him during the Yom Kippur war when thinking about guarding Israel's borders with persistent unmanned platforms carrying air to ground missiles. His continuing belief in his long-endurance drone idea a decade later and now in the United States suggests that he still thought about the importance of the fundamental capabilities in terms that went beyond specific missions. In developing Amber, Karem now set out to demonstrate its versatility, perhaps calculating that this strategy would be most likely to net service support. Leading Systems therefore presented a number of designs. The basic version – the B45 –

was designed to carry a number of possible payloads for a number of roles (including surveillance, communications or video relay, radar, signals intelligence, electronic warfare, electronic support measures, jamming, reconnaissance) (Hirschberg 2010: 12). It was would 'carry television cameras and a high-bandwidth data link for real-time video surveillance missions, referred to as a "CNN in the sky" capability' (Newcome 2000: 106). A45 was offered as a 'strike variant' whose nose would instead carry a warhead - and could dive bomb a target by having the wing separate from the pylon (Peebles 1995: 207, Newcome 2000: 106). Importantly for the Navy mission, the A40 Amber variant was designed to be launched from a torpedo tube; recalling its glider heritage, Amber could also be put into a 'deep stall', a technique used by glider flyers, enabling a 'near-vertical landing so it could be used from small ships, submarines or trucks/trailers' and retrieved using a net or landed on a small unprepared airfield – an ingenious alternative solution to the recovery problem (Whittle 2014a: 25). The H55 was proposed as a high altitude version and the R52 carried a moving target indicator radar. Leading Systems was contracted to develop six prototypes of the Basic Amber, of which three were A45 attack models and three were B45 reconnaissance models.

An H55 High Altitude version and the canister launched A40 were both contemplated but never built. An R52 model that 'integrated an MTI radar for ground surveillance' was also developed; 'two were captive flown by MIT Lincoln Labs on a De Havilland Twin-Otter' (Hirschberg 2010: 12). Virtually everything on Amber was custom-built in-house 'because existing components were just not considered to be adequate in terms of performance, affordability and reliability: digital ground control system, engine, propeller and gearbox, computers, digital flight control system, control actuators, wheels, brakes and even tires!' (Hirschberg 2010: 12). During development of the Amber, Karem hired software engineer Frank Pace to build a bespoke flight control system (Whittle 2014a: 55). This, notes Hirschberg, 'was about four times as powerful as the control system for the F-16 at the time, and is essentially the same as is [was] still flying in some of the Predators today, a quarter century later' (Hirschberg 2010: 12).

Having signed the letter of agreement in late 1985, '[i]n a meeting with the assistant secretary of the Navy in late 1985, it was decided that Leading Systems would take their design to production, with as many as 200 aircraft per year.' Karem responded by acquiring 'a 200,000 square foot facility with the required shops for composites, electronics, integration, ground testing, machine shops, etc.,' leasing, and later buying El-Mirage airport to provide a fully-dedicated site for flight testing, training and operations (Hirschberg 2010). Amber underwent flight tests in November 1986, completing initial testing in June 1987 (logging a flight in excess of 20 hours). In September and October 1987 the Basic Ambers were tested again (one of the A45s being lost).

Like Albatross, Amber appeared to be delivering excellent endurance. However, according to a DARPA employee who worked on the project,

> "[it] was not a high-aspect-ratio wing, good aerodynamics, or a lightweight structure, although good designers could do those things, and Abe could do them better than most. The issue really was reliability. Manned aircraft fly for tens of thousands of hours without crashing. So how do you even get in that ballgame? The crowning success of Amber was that by the end of the program, we were able to fly 650 hours without a loss. That was a huge order of magnitude increase in reliability [over other UAVs at the time]" (quoted in Whittle 2013).

Reliability was, at that time, considered to be one of the most important impediments to the progression of drones along the innovation continuum. They crashed, and they were perceived to crash, and although no systematic data had then been gathered concerning reliability rates, it was believed that recovery operations accounted for the lion's share of the trouble. Karem decided that runway take-off and landing would provide the best answer to this problem. He added a camera to the nose to runway launch/recovery versions of the Amber to assist the pilot coming in for landing, and developed a 'cockpit-like ground control station' (Lee 2016: 115).

It is important to note, though, that reliability was not solely addressed by inspired design, integrated sub-systems or other 'technical' means (however impressive). Alongside Amber, Leading Systems also built the very low-cost, low-maintenance Gnat 400. Leading Systems built two versions of the Gnat 400. The Basic Trainer was company funded, used to train LSI pilots, and accrued over 400 flights, 350 hours and 1172 landings by July 1989. The Gnat 400 Advanced Trainer was developed under the DARPA-sponsored Amber program with six built 'for avionics qualification and pilot training.' It was roughly three times the gross weight of the Gnat 400BT and had a 24 hour endurance at 5,000 ft. Controlled using the Amber ground station, Leading Systems pilots had to gain hundreds of hours of experience on the Gnat 400BT before being given control of an Amber. This step significantly contributed to the impressive reliability rates that Amber acquired and strongly suggests that this unprecedented performance was achieved by identifying and addressing human as well as 'technical' constraints on performance (Hirschberg 2010: 13). This echoes the Lightning Bug experience that reliability rates are not simply a function of technology but also of building a body of practice and experience. Things seemed to be progressing well and in September 1987 DARPA transferred Amber to the Navy.

An Amber I 'maturation' version was also developed, and first flew in August 1988. That year Amber demonstrated 30 hours at 17,000 feet, 35 hours at 5,000 feet, and a maximum altitude of 27,500 feet. On 7 June 1988 during a San Diego trade fair, Amber then demonstrated 'flight duration approaching 40 hours at altitudes exceeding 25,000 feet' (Ehrhard 2000: 171). Hirschberg notes that 'Amber I was integrated with the Pioneer TV and FLIR payloads, or could carry three payloads simultaneously: FLIR, ESM and Radio Relay or FLIR, ESM and IR Linescan. It was also integrated with L-Band, L/S-Band and C- Band data links'. Meanwhile, Leading Systems worked on two low-fuel consumption engines, the compact, low vibration KH-800 – capable of medium and high altitude work – and KH-1200D lightweight 'advanced diesel powerplants' that were proposed for the Navy's Heavy Fueled Engine program – something that eventually resurfaced on the MQ1-C Warrior UAV (a Predator descendent) (Hirschberg 2010: 13). Leading Systems drew up plans for two further versions. A production version (Amber III) was larger (37 ft wingspan), with a more extensive payload and more fuel, while Amber IV was a high altitude, long endurance design. Double the size and payload of Amber III, with a 65 ft wingspan, Amber IV used Karem's KH-800T engine, which boasted turbocharger and aftercooler. Leading Systems built all the tooling for Amber III and most of that needed for Amber IV (Hirschberg 2010: 13-14).

Bureaucratic Reform: Defense Acquisition Shakeup and the Joint Program Office (JPO)

At this point, Karem's efforts to build reliable, long endurance drones collided with a series of far-reaching defense reforms that fundamentally reorganised the Pentagon's overall governance structure as well as making inroads into the long-standing question of defense acquisition. Ronald Reagan, sworn in as US President in January 1980, had argued on the campaign trail that the federal government 'overspent, overestimated and overregulated' and sought ways to reduce spending while delivering more efficiently. In office, these intentions were translated into a series of reviews and initiatives intended to identify and execute efficiency savings across government. Rather than seeking to realise savings by making cuts in defence, however, Reagan simultaneously wanted to 'rebuild American military strength' and to that end oversaw a substantial build up of defense spending, which he set out to finance by efficiency savings in the bureaucracy (but for which he would eventually have to rely on deficit spending) (quoted in Butrica 2005).[59] At the same time as these attempts at acquisition reform unfolded during President Reagan's first term, in Congress the Military Reform Caucus (established in 1981) gained in membership and influence, and began to mount attacks on large programmes that it viewed as wasteful. The intense media attention given to the spare parts scandal (which began in summer 1982), initiated by stories sent to the Project on Military Procurement (now the Project on Government Oversight), was seized upon by the Military Reform Caucus in Congress.[60]

Although Reagan's overarching approach to defence was intended to address the perception of the growing threat presented by the Soviet Union, during the 1980s a series of crises (the Desert One rescue operation, the Beirut barracks bombing, the invasion of Grenada) – entirely tangential to this main preoccupation – seemed to lay bare deficiencies in the Pentagon's organizational structure that were preventing sound implementation of

[59] Between 1981 and 1987, defence spending increased by about one third from $133,995 million (1980) to $303,555 million (1989) (Office of Management and Budget 2016: Table 3.2 'Outlays by Function and Subfunction 1962-2020'). Efforts to realize efficiencies in defence acquisition during the early 1980s included the Defense Acquisition Improvement Program (DAIP) (known as the 'Carlucci Initiatives' after Deputy Defense Secretary Frank Carlucci), which made a number of reform proposals aimed at cutting costs, shortening the acquisition process and improving force readiness. The proposals were integrated into Directive 5000.1 in March 1982, but a year later a review found that implementation was mixed. Reform 88, a government-wide reform programme, included measures that addressed defence acquisition. The President's Private Sector Survey on Cost Control in the Federal Government, known as the Grace Commission, also included a Task Force on the Office of the Secretary of Defense, which included examination of the defence acquisition system. The Grace Commission recommendations foreshadow much of the work on defence reform undertaken in Reagan's second term (Butrica 2005**:** 199-223).

[60] The scandal included stories of $640 toilet seats (for the P-3 *Orion*) and $7,000 coffee pots (for the C-5A cargo plane) (Rosenwasser 2004: 67). More recently, accounts of these scandals have taken a revisionist turn, with Butrica calling the claims 'facile' while Sapolsky et al argue that 'we usually do not know the story behind the story, the bureaucratic explanations that should temper greatly the comedic urges of late-night TV talk show hosts' (Sapolsky et al 2009: 80). Secretary of Defense Weinberger responded with his 'Ten Commandments'.

military operations (Kagan 2006: 75, Besson 1998: 15-20, McInnes 2016).[61] The lesson was drawn from these crises was that service parochialism was making unity of command in the field impossible and that the solution lay in 'jointness'. This string of crises combined with the effects of the defense acquisition scandals provided the impetus for two crucial reform efforts of 1986, one directed at the Pentagon governance structure and the other specifically at defence acquisition. The 'most important piece of defense legislation since the National Security Act of 1947', the 1986 Department of Defense Reorganization Act, better known as Goldwater-Nichols (after the principal sponsors of the act, Republican Senator Barry Goldwater and Democrat William Nichols), had been years in the making and had a number of far-reaching objectives (Sapolsky et al 2009: 53-54). Primarily, however, it sought 'to shift power away from the individual military services towards less parochial joint institutions within the DoD' – mainly the Chairman of the Joint Chiefs of Staff, the Joint Staff, and the Commanders in Chief of the Unified and Specified Commands (Besson 1998). To this end, the Act 'augmented command relationships, strengthened the role of the Chairman of the Joint Chiefs of Staff, enhanced joint procurement, and redesigned personnel incentives in order to prioritize "jointness" among the services' (McInnis 2016).[62]

While Goldwater-Nichols focused on far-reaching defense governance reform, the President's Blue Ribbon Commission on Defense Management, known as the Packard Commission, was established in May 1985. It was directed to 'study defense management policies and procedures, including the budget process, the procurement system, legislative

[61] The failure of Operation Eagle Claw (Desert One), the April 1980 attempt to rescue 53 American hostages held hostage in Iran, is widely seen as one such failure. While Kagan acknowledges many of the problems, however, he also points out that '[t]he mission was so challenging… and the obstacles so formidable that it is difficult to imagine its success under even the best possible circumstances. The troops had to fly from carriers nearly a thousand miles across hostile countryside and desert, establish two intermediate base camps and defend them without being detected, infiltrate a hostile and suspicious – and very large – city by vehicle, penetrate a heavily defended compound, rescue hostages spread out in at least two different locations, rendezvous with vehicles, and escape from the heart of an alerted enemy country for a 1,200-mile flight to safety in Egypt' (Kagan 2006: 97-98). The October 1983 bombing that killed 241 US troops in Lebanon, and the US invasion of Grenada (Operation Urgent Fury) the same month were also seen as revealing operational shortcomings derived from structural fragmentation of joint operations (Rosenwasser 2004: 62-63).

[62] For a detailed account of Goldwater-Nichols, including discussion of the relationship to the Goldwater-Nichols Act, see Locher (2002). Sapolsky et al enumerate the Goldwater-Nichols objectives as 'to strengthen civilian authority within the Pentagon; to improve the quality and speed of military advice provided to national command authorities; to improve the services' abilities to conduct joint operations; and, to improve the efficiency of the defense establishment as a whole. These reforms significantly changed the procedures for interaction between civilian leaders and their top military advisers – and the balance of power in American civil–military relations' (Sapolsky et al 2009: 54).

oversight, and the organizational and operational arrangements, both formal and informal, among the Office of the Secretary of Defense, the Organization of the Joint Chiefs of Staff, the Unified and Specified Command system, the Military Departments, and the Congress' (Packard Commission 1986: Appendix B). Chaired by David Packard, chairman of Hewlett-Packard (and who had been Deputy Secretary of Defense from 1969 and had earlier overseen important acquisition reforms (Long and Reppy 1980: 167-172)), the commission was a 'a who's who of defense experts, former policymakers and industrialists' (Rosenwasser 2004: 74), several of whom (including Brent Scowcroft, William J. Perry, and R. James Woolsey) would occupy prominent positions in the national security establishment under subsequent Presidents. Packard himself held broadly similar views to the legislators working on what became Goldwater-Nichols about the need for fundamental reorganisation in such a way as to generate a joint perspective that transcended individual service views. Where Goldwater-Nichols embodies an emerging consensus across the legislature about the content of necessary defense reform, the Packard Commission represents a shift of President Reagan's thinking – partly motivated by a desire to 'seize the initiative from Congress' and part by continuing bad publicity about acquisition – away from the anti-reform views of Secretary of Defense Weinberger that had earlier prevailed (Locher 2002: 281).[63] Thus, in 1985 and 1986, Congress and the White House aligned around a reform-minded intellectual consensus and a sweeping but viable program of reform.

Although it overlapped considerably with the ground covered by Goldwater-Nichols, the Packard Commission focused particularly on the defense acquisition piece of broader defense reform programme. Its many recommendations were grouped under four headings: National Security Planning and Budgeting, Military Organization and Command, Acquisition Organization and Procedures and Government-Industry Accountability. Among its most significant proposals were to centralize and strengthen civilian oversight authority with an Under Secretary of Defense for Acquisition (USD/A); create a three tier management and reporting chain for major programmes; make more flexible acquisition procedures available

[63] Locher writes that at first 'the president and defense secretary envisioned the commission validating ongoing management improvements. Packard believed the two "wanted the commission to come in, look things over, and tell everybody that everything was fine and not to worry." Packard, however, had different plans' (Locher 2002: 294). 'Reagan was focused on the politics of defense reform', Locher argues, and wanted the commission 'to fix the political damage to his administration.' By contrast, Packard 'understood that the magnitude of the issues overwhelmed the defense politics of one administration and that meaningful solutions would benefit the nation for generations' (Locher 2002: 296).

(including a prototyping, or 'fly-before-you-buy' programme, and encouraging commercial off-the-shelf components and/or purchase of 'non-developmental items'); establish benchmarks for programme evaluation; involve the joint community in weapons system selection decisions through a new Joint Requirements Oversight Council (JROC); and, to take steps to improve the calibre of the acquisition corps (Rosenwasser 2004: 75-79).[64] All recommendations were accepted by the President and were variously implemented by National Security Decision Directive 219 in April 1986 and in DoD Directive 5000.1 that September, or incorporated into Goldwater-Nichols and the Acquisition Improvement Act of the same year.

In the mid-1980s, motivated in part by acquisition horror stories but more deeply by an emerging intellectual and political consensus around the necessity of far-reaching defense reform, Congress thus became highly active on defense issues. At this point in time, the US drone development landscape appeared so deeply troubled that it additionally provoked dedicated Congressional intervention. At this point in time the US had (at least) two drone programmes under national reconnaissance auspices – the highly classified AARS and the Boeing Condor. In the unclassified space, under the personal direction of Navy Secretary Lehman the Navy and Marine Corps Pioneer was being introduced. The Army's Aquila, meanwhile was coming to be seen as a disaster – and would be cancelled the following year. The other system under development was the Navy-Air Force Medium Range-UAV, heir to the Lightning Bugs and the BGM-34 Multi-mission drone of the 1970s. The MR-UAV had begun brightly enough in 1985, but would soon become mired in technical problems, delays and cost overruns, running into 'major difficulties with the [ATARS] payload' (GAO 1991, GAO 1997b) and the difficulties of reconciling the requirements of Navy and Air Force. In this context, in November 1987 Congress complained of 'lack of focused management within the Department of Defense for Remotely Piloted Vehicles' and wrote of the need to merge programmes to avoid duplication (US Congress 1987, cited in Rosenwasser 2004: 138). It directed the creation of a Joint Program Office (JPO) in the Office

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[64] The JROC was initially more 'an information clearinghouse among the Services' but further reforms by Secretary of Defense Cheney under President George H.W. Bush broadened its reach into weapons acquisition management. Subsequently headed by Admiral William A. Owens, JROC's purview was further extended to include not just future requirements but also current capabilities. One of the key voices in debates about the implications for warfighting of new information and communications technology, Owens was particularly preoccupied with C3ISR systems (Rosenwasser 2004: 208-209).

of the Secretary of Defense for the management of all service efforts to develop what were now termed Unmanned Aerial Vehicles (as well as cruise missiles), and halved the 1988 budget for service drone programmes pending the JPO's preparation and submission of a UAV 'master plan'. Congress originally wanted the JPO to handle manned and unmanned reconnaissance and to have jurisdiction over classified as well as unclassified drone programmes. In the event the services retained substantive control over manned reconnaissance programmes and the classified drone programmes were grouped under a parallel office, the Airborne Reconnaissance Support Programme (ARSP) (which reportedly sat under the NRO's Defense Support Program Office) (Ehrhard 2000: 503-504). Congress directed both JPO and ARSP to cut at least one programme. The upshot of this was that Condor was cancelled in favour of AARS (which was itself later cancelled) while Pioneer, Aquila and Amber were cancelled in favour of the MR-UAV and the Marines' Exdrone.[65]

Amber thus became a victim of Congressional intervention aimed to rationalize the overall UAV endeavor. Having been worked up under DARPA auspices, Amber was always going to need to win service support in order to stand a chance of progressing beyond research and development. In September 1987 Amber had been transferred from DARPA to Navy lead despite knowledge that available funding and the ongoing UAV shakeup would make it difficult for the Navy to conduct field evaluation while also developing Pioneer (Whittle 2014a: 61). The drafts of the first JPO master plan divided UAV requirements into a family made up of close range, short range, medium range and long range categories.[66] With DARPA support, Leading Systems pitched versions of their Amber III for the Short Range role and Amber IV for the high altitude role as outlined by the JPO. Van Atta et al (2003b: VI-19) report that the Army and Navy felt that Amber did not fit their vision of a 'physically robust forward deployable system'. Hirschberg's view is that 'Amber's capabilities… were so far beyond those of the existing UAV, the Pioneer, which was proposed for artillery spotting for naval ships, that the military had no concept of operation for its use, and it was not selected for operational development.' From the service

[65] Pioneer was kept on due to delays with its envisaged successor, Hunter.

[66] Amber's 'order of magnitude' increase in endurance directly led the Joint Chiefs to create an 'endurance' category in the draft RPV master plan and in February 1989 DARPA publicly referred to an 'unquestioned need on the battlefield' (Whittle 2014a: 61).

perspective, however, the drone's payload capacity, and long endurance-high altitude capabilities imposed operational requirements – prepared airfields and proficient operators – that they simply did not want. From their perspective, the contractor was not listening to their needs and viewed Amber as 'a continuing science project' rather than a product tailored to user concerns (Van Atta et al 2003b: VI-19).[67] This impasse suggests a perennial difficulty that would-be innovations encounter because of their creatively destructive aspect. Some military innovation theorists point out that, to realize the potential of potentially game-changing technology, it is often necessary for established organizational arrangements, doctrine and operational concepts to be changed (e.g. Tomes 2007). But until the benefits of the new technology are demonstrated, users will be reluctant to undertake such an uncertain, risky and arduous undertaking.

The JPO apparently 'issued a requirement for a short range UAV, but didn't provide funds for research' – and prevented DARPA and others from doing so – so that Leading Systems' funding dried up and 'only giant defense contractors such as TRW and McDonnell Douglass could afford to stay in the competition' (Sweetman 1994). LSI partnered with Hughes, partly to overcome the funding difficulty and partly to overcome the objection that they were a small new contractor with no track record or experience of full-scale production. Despite this move the Navy may have felt that it was less risky to deal with the more established companies behind Pioneer. In September 1989, the LSI/Hughes proposal for Amber lost out to the McDonnell Douglas/Developmental Sciences SkyOwl and the Israel Aircraft Industries/TRW Hunter for the Short Range UAV competition. Hunter won, and consequently Amber did not transition to the U.S. military' (Hirschberg 2010: 14). Despite its comparative low cost and proven reliability (it had flown 650 hours without a loss when it was cancelled) the Amber was shelved, and in 1990 the drones were boxed up and put into storage.

[67] Ehrhard reports that 'DARPA had so many problems with him that they insisted his daughter act as chief financial officer and spokesperson for Frontier Systems, the company building his current UAV project for DARPA, the A160 Hummingbird helicopter' (Ehrhard 2000: 171). Whittle reports the tension between the Amber programme manager and Karem as that between the manager's focus 'on process and the inventor's focus on performance, the bureaucrat's imperative to manage the Amber and freeze its design for production and the inventor's impulse to improve his creation as much as possible before production began' (Whittle 2014a: 58). Elsewhere, Whittle reports Karem once telling a roomful of engineers at a major defense company '"Gentlemen, everything I see in this room is nonsensical"' before simply walking out, and another incident when Karem 'called a group of defense acquisition officials "clerks"' (Whittle 2013).

Karem believes the collapse of Leading Systems was engineered to ensure his drones were ‘locked up to protect the incumbents’ (Economist 2012). Ehrhard interprets Amber as evidence of the pitfalls of designs backed by a ‘weak, divided constituency’ (Ehrhard 2010: 21). He suggests that the Navy’s failure to ‘find their voice for it’ may have been due to ‘a combination of the “not invented here” syndrome or difficulty dealing with Abe Karem’s abrasive personality’ (Ehrhard 2000: 172-173). While there is evidence that Karem was difficult to work with there is little to suggest that the Navy dropped Amber because they had not invented it themselves. Rather, it seems partly to have been a case of, as Whittle puts it, push coming to shove – steep reductions in funds forcing the Navy to choose one over the other (Whittle 2014a: 58). This is not to say, however, that the balance of that choice was not influenced by lobbying and advocacy. On balance however, the underlying reason for the abandonment of the Amber is not a conspiracy. Karem’s vision of the vital attributes that the technology could afford imposed organizational and operational requirements that the services were unwilling to accommodate by adapting their structure and concepts for employing the technology. It illustrates the extreme difficulty faced by promising technologies seeking to advance along the innovation continuum beyond research and development when their adoption demands organizational and doctrinal adaptation. Without incentives powerful enough to make users willing to accept the risk, pain and uncertainty of such an undertaking, promising new technology may simply be abandoned.

Regardless, this decision directly caused the collapse of Leading Systems. Prior to the UAV shakeup, the Navy had signalled its intention to purchase Amber systems. In order to fulfil this demand, Leading Systems had to evolve from a small, high-end research and development outfit to a contractor capable of fulfilling scale orders and then providing parts and other support capabilities. This difficulty was perhaps compounded by Leading Systems’ philosophy of designing and building all components themselves. Some years later, the Air Force experience with General Atomics and the Predator system would again underscore the growing pains involved in becoming a contractor capable of fulfilling large-scale orders. Hughes guaranteed $5 million in loans to Leading Systems to help them achieve this scaling up. When the Navy abandoned Amber in November 1990, Leading Systems was effectively driven out of business.

Sensing what might happen, in 1988 Karem began sinking his profits and energy into developing a 'bigger, heavier and less capable' runway launched version that could be marketed abroad (Whittle 2013). This was exactly the strategy pursued by LMSC when it developed the Altair as the Aquila was abandoned. The new LSI model was called the Gnat-750, made its first flight in 1989, and was based on the Gnat 400 trainer vehicles that Leading Systems had built to train pilots before giving them control of an Amber. Like its predecessors (and successors), Gnat-750 also had the now familiar inverted V-tail and pusher propeller and used the Basic Amber engine that was allowed for export. However, in late 1990, due to the financial difficulties created by the cancellation of Amber, and whilst the Gnat-750 was under development, Hughes foreclosed on Leading Systems, taking ownership of everything not belonging to the government.

General Atomics: A New Entrant in the Drone Business

General Atomics Technologies had been bought by Lindon and Neal Blue in 1986. Although the company had begun working on defense technology earlier in the 1980s, prior to its purchase by the Blues, General Atomics had no background in unmanned systems. However, for reasons that remain unclear, when they purchased General Atomics, the Blues were already thinking about building a UAV. In an interview with Neal Blue, Gimbel suggests that the Blues had begun thinking about UAVs as a way to continue supporting the Nicaraguan Contras (Gimbel 2008, Whittle 2014a: 41). In September 1983, following the downing of a South Korean passenger plane that inadvertently strayed into Soviet airspace, Reagan announced that the Global Positioning System would be made internationally available to provide continuous location information (Laskow 2014, Rip and Hasik 2002). At that time the Blues thought that by using GPS it would be possible to launch an attack drone from beyond line of sight, thus preserving deniability (Whittle 2014a: 41).

Between their purchase of General Atomics in 1986 and General Atomics' purchase of Leading Systems in 1991, General Atomics had been working on a UAV design based on the Sadler Vampire, which they had dubbed 'Predator'. The Blues also contemplated using such drones to defend the Fulda Gap from the swarms of Soviet tanks that it was believed would be funneled there in the event of a Soviet invasion of Europe – conceptually not very different from that which Karem had had in mind when thinking about defending the Suez canal. The General Atomics Predator (Sadler model) was displayed at the San Diego Air Show of 1988 (Leading Systems were also displaying the Amber and Gnat), advertised as ‘an unmanned, low cost weapon system to strike enemy targets with guided munitions, cluster weapons, or a high explosive warhead’ (Ropelewski and Smith 1988: 30). While the Sadler Vampire drone had not proven very successful, it is striking that General Atomics were envisioning a weapons platform rather than a reconnaissance asset and despite the failure of this Predator, they remained convinced that this technology concept would eventually and inevitably breakthrough. Ira Kuhn, seeking to keep Karem’s work alive and aware that Hughes were looking to sell Leading Systems, discovered that the Blues were seeking a way into the UAV industry and called Linden. General Atomics then approached Hughes and a deal was struck. Hughes sold the remains of Leading Systems to General Atomics for $1.85 million, ‘one-tenth the value of the physical property alone’ (Whittle 2014a: 66). General Atomics then hired Karem and his team and their UAV work was revived.

Until the acquisition of Leading Systems by General Atomics and the Blues, Karem’s story closely echoes common readings of technological change emphasising the importance of ‘maverick inventor’ types - brilliant, irrepressible figures whose ideas and personalities are often at odds with the established order of things. Like Karem, the Blues believed that UAVs would inevitably come to occupy prominent places across the US military. Where they had lacked Karem’s combination of creativity and technical expertise, they had the money and the will to provide for Karem’s ideas a stay of execution. They also appear to have possessed the political connections and business acumen to carry the technology across the threshold from invention and innovation to adoption and assimilation by users. Their entry into the story lends weight to Hughes’ distinction between different kinds of system-builders. Inventor-entrepreneurs may not have the resources or capabilities to single-handedly carry their invention along the continuum to the point that it becomes assimilated. Frequently, Hughes argues, other kinds of entrepreneurs enter the story, taking inventions and engineering the social world so as to enable to the invention to become established and to advance.

If Karem and his team had made some important design breakthroughs, and possessed the UAV expertise and flying know-how that General Atomics had lacked with the Sadler Vampire program, the Blues possessed a range of assets that made them capable heterogeneous engineerings and system builders – capabilities that were lacking at Leading

Systems.[68] In this context, the Blues may have sensed the risk that institutional resistance could keep the product locked out. According to Coffey (2013: 279-280) '[t]he Blues were looking to the long term: they believed that once the Air Force saw that it was in danger of losing control of a growing segment of military aviation, it would bend to the inevitable, just as it had in the 1950s when it took up missiles despite seeing them as a threat to its prized bomber fleet.' Coffey argues that 'rather than just wait for the Air Force to come to its senses, the Blues pushed. General Atomics spent more on political contributions as a percentage of sales than did any other defense contractor' (Coffey claims that 'its specialty was offering junkets to key congressional staffers (a practice that is now illegal)).' At the least, where Karem's apparently sometimes prickly personality had not always helped him to win over potential customers, the Blues appear to have understood how (and where) to turn on the charm. A later profile in the Financial Times would observe of General Atomics that '[b]ehind its success in winning government contracts has been a formidable and at times controversial lobbying effort' (Lemer 2009). In a rare public interview, Neal Blue observed, 'for our size, we possess more significant political capital than you might think' (cited in Cockburn 2015: 59).

CIA Involvement in drone development

While DARPA had sought to transition Amber to the Navy, the CIA had also reportedly been involved in the programme and remained in touch even as the JPO abandoned it. The Gnat-750, developed in the midst of Leading Systems' bankruptcy, was sold to Turkey and to the CIA. Owing to the veil of secrecy shrouding CIA activities in general, the full extent of CIA involvement in US drone development in general has yet to be revealed. Nonetheless, from publicly available sources, it is possible to glimpse CIA interest in and support of drone development activities. The six-foot long Aquiline mini-RPV, begun in 1965, which was disguised as a bird of prey and designed for reconnaissance of sites of interest on the borders of the Iron Curtain, helped convince General DePuy of the viability of a mini-RPV – leading to the initiation of the Army Aquila programme (Pedlow and

[68] The term describes 'the engineering of the social as well as the physical world' (MacKenzie 1990: 28). MacKenzie argued that the invention of inertial guidance was not just 'a matter of engineering just metal, wires and equations. People had to be engineered too – persuaded to suspend their doubts, induced to provide resources, trained and motivated to play their parts in a production process unprecedented in its demands.'

Welzenbach 2013).[69] Jacobsen mentions a few other CIA drone experiments of the 1970s, including Project *Ornithopter* and Project *Insectothopter*, which both employed flapping wings and were disguised respectively as a bird and an insect. Detail on these projects remains very limited and it is not clear whether they were actually employed (Jacobsen 2012: 346).

There is further evidence of CIA involvement in drone experiments during the 1980s, although again details remain somewhat scarce. One such programme may have been driven by the abduction of CIA station chief William Buckley, as well as a number of others, in Lebanon in 1984. Desperate to find Buckley and the other hostages, Counterterrorism Center head Duane Clarridge had no real-time intelligence on West Beirut and no idea of where they were being held. According to Coll, who interviewed Clarridge, this experience led him to explore technological solutions with CIA Directorate of Science and Technology staff assigned to the Counterterrorism Center (Coll 2004: 143). In his memoir, Clarridge then discusses a conversation he had following the April 1986 F-111B retaliatory bombing raid on Libya, mounted after 'smoking gun' evidence of Libyan involvement in the bombing of a West Berlin nightclub popular with US military personnel earlier that month. In the air raid, two of Gadaffi's children were injured and a third adopted child killed. The French Embassy was also inadvertently struck. This prompted a discussion about the need for 'a better way to send a message to outlaw nations' and a means of getting 'American eyes on the target' in terrorist safe havens. Clarridge revealed that at that point (mid-1986) CTC had five 'operational' devices 'that would send a clear message, with poignant effect, but with minimal loss of life for the recipients, and none for our delivery personnel' (Clarridge 1995: 338). In a subsequent interview with Coll, Clarridge makes clear that this 'system' was 'a highly classified pilotless drone' developed under the auspices of the 'Eagle program' (Coll

[69] Aquiline was possibly intended to gather information on the 'Caspian Sea Monster' detected by satellite reconnaissance in the early 1970s (and which was the Ekranopian hydrofoil) and to 'to follow along communication lines in foreign countries and intercept messages' (Jacobsen 2012: 345-347). See also Fung (2013) and Hambling (2007). Meierdierck, a participant, records his views about the project on the Roadrunners Internationale website, at http://roadrunnersinternationale.com/meierdierck/flying.html#43. General DePuy stated that CIA experiments had convinced them of drone viability in a letter (dated 13 May 1974) to General Harry A. Miley, Jr, then-commander of Army Materiel Command and Lieutenant General John R. Deane, Jr., then-head of Research & Development at the Department of the Army (cited in Knox 1994: 6 and in Ehrhard 2000: 263). This drone-disguised-as-bird concept appears to have persisted. In 2011, reports surfaced of similar devices being used in Pakistan (Baloch 2011).

2004: 143-144). In his footnotes Coll states that he found ‘no previously published account of the Eagle’ but that Clarridge’s claims were corroborated by ‘[o]ther CIA officials’ (Coll 2004: 658).[70] From available information, it appears that the Eagle program was a direct response to the hostage situation in Lebanon during the mid-1980s and probably dates to spring 1985 since Clarridge says that program took a year to produce operational systems, and that these were available by the time of the F-111B bombing. As well as helping to date the program, Clarridge’s remarks also suggest, as noted by Fuller, that ‘rather than drone technology determining policy, it is this pursuit of low-tech solutions to the CTC’s problems which arguably led to the CIA’s development and deployment of drones in the first place’ (Fuller 2015:781).

In rightly highlighting the significance of this system in the history of drone development and the evolution of wider US counterterrorism thinking, Fuller relates a portion of Clarridge’s memoirs as follows: ‘According to Clarridge, the Army sought to develop a ‘gold plated’ version of the device, spending US$900 million, but eventually cancelled the project some years later.’ Clarridge in fact wrote that ‘[a]bout two years later, the Army gave up on developing a *similar* but “gold plated” device, but only after they had spent $900 million on it’ (Clarridge 339) [my italics]. Fuller (2015) concludes that the Eagle program probably employed the Amber UAV system (discussed below), seemingly reasoning that because the ‘similar’ program was Army funded, the UAV system used in the Eagle Program was likely an Army system. Coll also appears to suspect that Eagle used the Amber system (2004: 528). Clarridge claims he had five operational systems in place by the time of a conversation with Casey about the system ‘[a] day or two after the Libyan raid’ of April 14 1986. Clarridge reportedly later told Coll (2004: 143-144) that this system was developed as a way ‘to locate the American hostages’ in Beirut, which, taken with Clarridge’s claim that the system was developed in ‘just over a year’, might date the project to late 1984 or early 1985. Leading Systems formally began work on Amber in December 1984 and the system was flight tested from November 1986 to June 1987. Development was kept secret, however, until information began to emerge about the program in the autumn of 1987

[70] Fuller made Freedom of Information Act requests for more information about the Eagle Program but his requests were turned down by the CIA (Fuller 2017: 105).

(Peebles 1995: 208). It is not inconceivable that the CIA may have had operational Amber prototypes in the spring of 1986 – ahead of the tests later that year.

The main significance of the Eagle program as related by Coll, however, is less the specific system contemplated than it is in demonstrating that, at least dating to April 1986, the CIA Counterterrorism Center not only contemplated using UAVs in counterterrorism operations but had developed an operational system. Clarridge's remarks about this are all the more interesting because they strongly suggest that even at that stage senior Counterterrorism Center staff were actively contemplating using UAVs not only for loitering surveillance over denied areas but also for attack missions. Clarridge told Coll about two attack methods explored in his 'highly classified pilotless drone' program. One scheme entailed loading the drone with two hundred pounds of C-4 plastic explosive and one hundred pounds of ball bearings. In their 1986 post-mortem of the F-111B raid on Libya, Clarridge suggested to Casey that a drone armed in this way could be used to 'send a message' to state sponsors of terrorism. He further suggested that using such a drone to destroy unoccupied commercial airliners in a night time attack on Tripoli airport might have been a more effective way to 'send a message' without incurring collateral and civilian casualties (Coll 2004: 144). As noted, the Amber program did develop an 'attack' version (the A45), which could have performed this first kind of attack mission contemplated by Clarridge. The work on this Amber version (at least three were built) adds weight to the view that Amber was used by the Eagle program. On the other hand, alternative optionally one-way-trip 'dive-bomber' configuration UAVs (akin to a cruise missile), such as the contemporary Air Force YCQM-121 Pave Tiger drone program, might have been used for this first kind of attack mission.

In technological terms, this dive-bomb attack scheme would have been much simpler (especially at a budget of $7 million) than the second scheme described to Coll in which the CIA 'tried to load small rockets onto the drones that could be used to fire at pre-designated targets'. If such a UAV was built it would represent a very important system in the history of drones development. Yenne notes 'there was some discussion' about using SkyEye 'to launch unguided rockets' (Yenne 2004: 39), and later mentions 'some field experiments, such as arming a SkyEye in Central America during the 1980s' (Yenne 2004: 107). Blom reports that the SkyEye R4E-30 'could carry and fire 2.75 inch rockets, Viper rockets, and potentially even "smart" munitions' (Blom 2010: 67), and Dornheim reported at the time that '[f]our 2.75 inch rockets for use against soft ground targets have been carried and fired' (Dornheim 1985: 87). Blom states, somewhat intriguingly that the armed SkyEye 'was evaluated but never ordered by the Army' – a statement that seems deliberately phrased so as not to rule out other entities (Blom 2010: 67).

These sources seem to confirm that UAVs were not only contemplated but actually tested as weapons platforms (as opposed to dive bombers) for use against *soft targets* as early as the mid-1980s. Of course, earlier attack platform uses had been considered and pursued. Attack versions of the DASH were developed during the Vietnam war, while the Have Lemon project (begun in early 1971) experimented with arming Firebee drones with a range of weapons, including Hughes AGM-65 Maverick ground attack missiles and Rockwell GBU-8 Stubby Hobo glide bombs (Yenne 2004: 28-29). However, apart from DASH no UAV is known to have been employed as a weapons platform until the hasty fielding of the armed Predator system in 2001.

CIA involvement in the Gnat-750

The Gnat-750 was officially developed as a less capable exportable model in an attempt to keep Leading Systems in business, but no sales were made before Leading Systems collapsed and was bought by General Atomics. The Gnat-750 was acquired by the CIA in 1993, but Grimes, former director of Big Safari, writes that GA-ASI actually 'developed [it] for another government organization' (Grimes 2014: 329). The Gnat clearly had merit as a spyplane, but it is also possible that the CIA were interested in it as part of their in-house efforts to overcome the constraints of line-of-sight control and relay, experiments that may date to the Eagle program, as well as a platform for classified payloads. Seen in this light the Gnat may have been a successor to Eagle. In 1992 Turkey ordered six, and a ground control station, from General Atomics for $14 million. McDaid and Oliver report that the Turkish Gnat-750s were employed in northern Iraq 'but this may or may not be simply a cover for CIA operations' (McDaid and Oliver 1997: 103). General Atomics continued work on the Gnat-750 and in 1992 it managed 40 hours endurance, reaching altitudes in excess of 25,000 feet. Whittle states that besides the $14 million deal with Turkey, the only other work had been 'a couple of smaller deals for demonstrations and studies' (Whittle 2014a: 68).

Strategic Context Transformed: the end of the Cold War

Amber tried and failed to progress from research and development to make its way into user organisations because it did not simply plug into their existing ideas for operations and because users were unwilling to change their operational schemes to accommodate the system. Yet Amber, and Leading Systems, also became victims of a round of consolidation and prioritisation imposed on the services by a Congress that was infuriated by stories of waste and that was involving itself in the most far-reaching defense reform programme in a generation. Without this Congressional intervention, Amber might have lived a little longer under research and development contracts. Had more money remained available, the services may even have found ways to begin more practical experiments with the drones, although given the hardship involved in incorporating them for uncertain gain, it seems at least as plausible that they would have remained trapped in a marginal space between invention and assimilation, undergoing endless research and development, and desultory field experiments but not advancing further (at least on the military side). In 1985 and 1986 drone development became dominated by political intervention intended to reform and 'fix' the bureaucratic politics and organisational processes of defense acquisition in general and – through the JPO – of drones in particular.

In this period, the United States defense establishment operated in a strategic environment dominated by its concern with the threats posed by the Soviet Union. The armed services overwhelmingly saw their main role as deterring, or if necessary winning, in a war against the Soviets, with the focus on European battlefields. While Congress sought to put the American defence acquisition house in order and to rein in President Reagan's defence spending, the main tasks of the military services and the roles and missions into which drones would need to fit if they were to advance towards adoption and assimilation, flowed from a strategic outlook that was above all dominated by the Soviet threat. The previous chapter argued that that environment made drones attractive in principle in a number of capacities but simultaneously created a constantly receding technological bar against which drones fell short (whereas others, such as Israel, began to exploit the available technology in relation to different strategic circumstances). While drone developers and prospective users were still preoccupied with adapting to the new organisational landscape imposed by Congressional intervention, the sudden and almost entirely unforeseen collapse of the Soviet Union, starting in 1989, transformed the strategic environment in obviously vast, yet strangely ambiguous ways.

The end of the Cold War removed the sole military rival, and the main contingency - war in Europe - for which the US military had prepared over the past half century. Before long, new conflicts were breaking out around the world. George H.W. Bush announced a $64 billion reduction in military spending. At the same time, the nature of the security environment now appeared ambiguous and uncertain, memorably captured in R. James Woolsey's evocation of a slain dragon now replaced by a jungle of poisonous snakes (Jehl 1993). Despite a clear note of triumphalism at having prevailed in the Cold War, the demise of the Soviet Union also threw open a fresh debate about the proper roles and missions that US security institutions should be able to carry out in the post-Cold War world, and how resources should be allocated between competing (and shifting) priorities. These debates had profound implications for defense acquisition because they opened up the possibility that existing missions and capabilities might be demoted or even made redundant whilst affording opportunities for capabilities that were de-prioritised in the Cold War context.

In the aftermath of the Cold War, civilian leaders increasingly called on the US military to develop and perform a number of missions besides the more traditional role of being ready to fight and defeat the military forces of other states. Missions such as 'peace enforcement, drug interdiction, antiterrorism, and the like, cut against decades of responding to the Soviet threat' and sat 'uneasily with the predominant biases within the U.S. military for large-scale, capital-intensive, high technology operations' (Avant & Lebovic 2002: 139). Some argued that a converging range of trends meant that the world had changed in ways that consigned such wars to the dustbin of history and that military force now had to be repurposed for a world in which what would increasingly become known as 'military operations other than war' (MOOTW or OOTW) were becoming the norm. Others saw this as but a brief inter-regnum – a strategic pause – and argued that although the US might need to employ military force in new ways this should not be at the expense of retaining decisive superiority in full-scale war against conventionally capable adversaries.

Various commentators have found the US military reluctant to engage in non-traditional missions, whether because of 'biases' or whether because military professionals saw such operations as misconceiving how military force can be effectively used to achieve strategic and political objectives. However, the US military would have hardly been unique in this, since European militaries exhibited similar resistance and 'the bulk of European armed forces are still organized in ways that suit territorial defence against a Soviet armoured attack, even though this is of little relevance in the post-Cold War world' (Rasmusson 2006: 155). Nevertheless, however reluctant, and with whatever reservations on the part of the military, since the demise of the Soviet Union the US has increasingly employed limited military force in 'the belief that it potentially can resolve [a range of persistent policy problems] expediently', leading to a range of military activities that have been described as 'Discrete Military Operations' (DMOs) (Zenko 2010: 1).[71] The increasing tendency to 'treat the military as an all-purpose tool for fixing anything that happens to be broken,' moreover, may be creating a vicious circle in which the military justifiably claims the need for extra resources to undertake these tasks, meaning less money for civilian agencies, in turn placing greater pressure on the military to 'pick up the slack' (Brooks 2017: 20).

Yet even before these debates gathered momentum, perhaps the most immediate effect on the military derived from calls for a peace dividend and accompanying pressure to consolidate. The end of the Cold War suggested that the United States had returned to a condition of peacetime, leading to calls to turn Cold War swords into ploughshares and dramatically reduce the immense US armaments industry. The overall defense budget was cut under this pressure, with research and development and procurement particularly hit. Yet very quickly, the US found itself drawn into a series of complex regional crises and operations for which, it became apparent, its existing military and intelligence capabilities were not entirely appropriate. The US grappled with the balance between investment in traditional military missions and the capabilities needed for a much broader range. This momentous yet ambiguous transformation of the strategic environment once again generated new and urgent demands, crystallised around a succession of contingency

[71] Sapolsky et al usefully suggest four broad positions in relation to the question of how to use American military power. Primacists are most concerned about the rise of a near-peer competitor (typically China) and tend to see OOTW as distractions. Liberal internationalists tend to believe that US military power can be used effectively in a range of non-traditional roles to advance liberal values (such as no-fly zones, airlift, establishing safe havens, building infrastructure). Selective engagers are more sceptical about the use of force, wary of its limits, the danger of being seen by others as a threat and generally wanting the US to act as an offshore balancer rather than assertive hegemon or world policeman. Finally, those advocating restraint, including Sapolsky, argue that '[b]eyond concern about access to Middle Eastern oil and the danger of nuclear terrorism, the United States need pay little attention to distant turmoil, be it civil war or regional conflict' (Sapolsky et al 2009: 18-21).

operations, that once again opened pathways for the drones under development to attempt to make the difficult transition across the threshold from perennial research and development to adoption and assimilation.

One consequence of the funding squeeze following the Cold War was the services conducting 'what amounted to a multilateral abdication of tactical reconnaissance' (Ehrhard 2000: 508 fn.1296). Amber's demise has to be set in this wider context in which airborne reconnaissance was being reduced to 'a second-class mission'. In September 1993, a Pentagon official told *Aviation Week and Space Technology* that the Air Force was '"getting out of the manned tactical reconnaissance business"' (Fulghum 1993: 44). The Marine Corps and the Air Force cancelled their RF-4 fleets, and the latter also dropped plans for several squadrons of RF-I6s. The Medium Range-UAV which, reflecting the new focus on jointness, was designed so as to incorporate the needs of the Navy, Marines and Air Force and which was explicitly intended for this kind of reconnaissance, followed the pattern of earlier UAV efforts and never saw the light of day. The services appear to have hoped that classified manned and unmanned aircraft and national assets would somehow absorb the shortfall (Ehrhard 2000: 508-509 fn. 1296). Given that the SR-71 (heir of the U-2 and basis of the D-21 reconnaissance drone in the 1960s) was cancelled in 1990 (only to be briefly reinstated from 1995-1998) the 'national' assets being called upon were mainly satellites (AARS might have been, had it worked and had it not been so expensive). Following the Gulf War, however, the emerging reconnaissance problem was clear and coming out of that conflict drones were now widely seen as a solution.[72]

Yet, in a similar way to the problems posed in the late Cold War by the increasing mobility of radar defences and Soviet strategic weapons platforms, events in the wake of Cold War again exposed limitations of satellite imagery. While the Gulf War was widely interpreted as demonstrating the potential of the emerging information and communication technologies, two issues in the Gulf War revealed technical limitations for which some influential figures saw drones as a solution (Rosenwasser 2004: 169). First, there was serious friction between the Air Force and Defense Intelligence Agency (DIA) over discrepancies in battle damage estimates of Air Force attacks leading up to the invasion (Peebles 1995: 209).

[72] Reportedly the reconnaissance shortfall became so acute that 'had the war lasted a few more weeks, Teledyne Ryan model 324 Scarab UAVs would have been pressed into service by Central Command Air Forces' (Fulghum and Scott 1991: 39).

The arguments over bomb damage assessments were indicative of the wider emerging airborne reconnaissance shortfall but also began to expose a qualitative shift in the kind of data to be collected. In successive post-Cold War trouble spots, the US military found that it needed continuing and real-time *surveillance* capabilities as opposed to the more sporadic and snapshot reconnaissance provided by satellite imagery. Air Force intelligence were basing their bomb damage assessments on video recordings of strikes whereas the CIA and DIA used the familiar satellite imagery. The latter consistently underestimated the extent of damage. During the Gulf War, US forces used a combination of manned planes, supplemented to a certain extent by the three available (short range) battlefield reconnaissance drone systems (Pioneer, Pointer, and Exdrone), which could provide functions such as real-time reconnaissance for bomb damage assessment, artillery adjustment, and reconnaissance of planned Apache helicopter routes, mine fields, and enemy positions, albeit limited by navigational difficulties (Peebles 1995: 210-211, Rip and Hasik 2002: 264, Nordwall 1991). Second, and as it turned out an issue that would recur in subsequent conflicts, was the difficulty in tracking mobile Scud missile launchers. These experiences helped reveal that continuous video provided information that overhead imagery could not and suggested that UAVs could perform a number of very useful functions. Peebles (1995: 211) believes that '[f]ollowing the Gulf War, interest within the air force grew in the development of long-range UAV systems that could keep watch on a specific area day and night.'

The disintegration of Yugoslavia served to further reinforce the message that loitering surveillance capabilities would be an increasingly valuable military and intelligence capability. In his study of the evolution of the Predator from the Gnat-750, Strickland makes clear how the nature of the conflict in former Yugoslavia made such a capability seem vitally relevant:

> 'When cities, towns, and villages experience war fought not only by uniformed soldiers but also by former neighbors dressed mostly in civilian garb, the result is a complex human terrain that adds to the inherent fog of war. During the war in Bosnia, the US government was challenged to sort out what actually was happening amidst the often conflicting claims of Serbian, Croatian, and Bosnian Muslim authorities. US government leaders, starting with the president, demanded accurate information on the situation… The most precious intelligence capability needed in Bosnia, however, was the ability to hold specific areas under

surveillance for extended periods of time. Continuing coverage was needed of such areas as the safe enclaves created to separate combatants and potential sources of hostile artillery fire' (Strickland 2013: 2).

Whittle states that President Clinton was 'shocked and chagrined to find out how little his military and intelligence agencies could tell him about what was actually happening on the ground around Sarajevo' (Whittle 2014a: 70-71). A retired Navy official remembered White House staff 'bitterly' wondering how it could be that after spending billions of dollars on intelligence gathering assets it was still not possible to find the main threats in contemporary operations – scuds, SAMs and mortar emplacements (Rosenwasser 2004: 225). Cloud cover interfered with available surveillance but the deeper problem lay in the commitment to satellites for strategic reconnaissance and the intermittent coverage they provided (Lee 2016: 109-110). Without persistent surveillance, 'the answers to key intelligence questions about Serbian atrocities and military operations would contain a high degree of uncertainty and conflicting information, especially early in the war' (Strickland 2013: 2). Moreover, the Serbian military (among many others) had paid close attention to the demonstration of US capabilities during the Gulf War. They 'knew when the satellites were going to pass overhead… hid their weapons in barns and wooded valleys before the satellites arrived, brought them out and fired them when no satellite was scheduled, and moved their big guns at night' (Whittle 2014a: 71). As with the Gulf War the collapse of Yugoslavia exposed the problems with airborne reconnaissance capabilities and encouraged a desire for persistent surveillance as opposed to the photographic snapshots provided by fast reconnaissance and satellite imagery. What they needed was a 'low-cost, low-risk way to monitor the Bosnian conflict and support U.N. peacekeeping operations there' (Newcome 2004: 107).

During the summer of 1993, Deputy Secretary of Defense, William Perry, John Deutch, the Undersecretary of Defense for Acquisition (the post created in the Goldwater Nichols reforms to better manage defense acquisition) and Larry Lynn, the Deputy Undersecretary of Defense for Advanced Programs, organised a Defense Science Board summer study on global surveillance, which explored these issues in depth (Rosenwasser 2004: 192).[73] The attributes of a solution would be tactical flexibility, long endurance, and

[73] This study also established the 'tiers' conceptual framework, around which drone development efforts would subsequently come to be organised.

an ability to transmit continuous information both on fixed locations and on targets moving around in mountainous terrain, often veiled by clouds (Lee 2016: 110).

Given the urgency of the situation in Bosnia, it was clear that a system would have to be fielded in a matter of months. With President Clinton now in the White House, R. James Woolsey became his CIA Director. In the mid-1980s, Woolsey had visited Israel with a delegation of the Jewish Delegation for National Security Affairs where he had been shown small Israeli UAVs flying in the Galilee. Investigating further, he recalled '[t]hey showed me some tapes of previous things they'd done, for example, the UAV would have a laser designator on it. There would be a Hezbollah car. They had some intelligence on a senior Hezbollah official. They'd laze the car with the laser designator, fire a Hellfire from a helicopter over the horizon, and *boom*. I remember thinking, *Wow, that's pretty interesting*' (Woolsey et al 2010). More than a decade earlier, Woolsey had been impressed by Karem's MX carrier idea (Big Bird), and had later served on the Packard Commission. He had also served on a reconnaissance panel for then-CIA Director Robert Gates. Karem had discussed with Woolsey the collapse of his Amber project – as Woolsey describes it, 'all four air forces in the four military services were not interested—all of them were very pilot-heavy—and so his little company had gone bankrupt. I kind of stored it in my mind' (Woolsey et al 2010). Woolsey had unsuccessfully attempted to intercede to save the Amber.

The long endurance, loitering drones that had repeatedly been tabled and shelved through the Cold War once again seemed a potentially ideal solution, this time to the 'problem that there is cloud cover perpetually in Bosnia and we can't find the places where people are getting killed en masse' (Woolsey et al 2010). Contemplating the need for reconnaissance in Yugoslavia, the recently sworn-in DCI immediately thought of reconnaissance drones. He contacted the Pentagon and commissioned a study, and, shocked at being told that a prototype would take six years and cost $500 million, his first call was to Karem (Woolsey et al 2010). Karem told him about the Gnat, explaining his bankruptcy, the General Atomics purchase, and the fact that although three had gone to Turkey, there were some others sitting in a General Atomics hangar.[74] Woolsey discussed

[74] By this point it was clear that the MR-UAV was in deep trouble and it was cancelled in late 1993. The Pioneer and Exdrone, both used extensively in the Gulf War, both lacked the range for the mission (Fulghum 1993: 44-45). There are slightly differing versions of this part of the story. Lee reports that Woolsey was made aware of the Gnat-750 by General George Joulwan, who was then running US Southern Command (SOUTHCOM) – and that Joulwan had learned of the Gnat from Bob Williams, who was working on his staff but

the project with Linden Blue and they apparently agreed to a $5 million price-tag, a fraction of the Pentagon's quote.

Despite efforts to reform and rationalize the UAV acquisition bureaucracy, it still did not seem capable of responding quickly, affordably or usefully to emerging requirements. Indeed, that bureaucracy had almost succeeded in crushing the very system that CIA now saw as the solution. For this reason, it was decided to channel the work through the CIA so as to avoid the constraints of military acquisition.[75] In March 1993, senior CIA figures including Woolsey and the CIA Director of Espionage Operations, Thomas Twetten, were shown the Gnat-750 at el Mirage. This resulted in a decision to purchase 5 Gnats immediately. According to Sweetman '[t]he CIA acquired its Gnat fleet secretly, thereby avoiding the congressional ban on any UAV programs outside the joint office' (Sweetman 1995: 34). Peebles considers that the CIA was given lead because the cumbersome 'funding and acquisition procedures of a military program' would be unable to deliver in time (Peebles 1995: 212). Mazetti, however, suggests that Congressional support was involved in CIA drone missions in Bosnia, reporting 'Woolsey had managed to get a small stash of money to fund the project from Representative Charlie Wilson' the Texas congressman who had organised funding for the CIA's covert operations in Afghanistan in the 1980s (Mazetti 2013: ch. 5).

CIA lead may also have made sense in relation to the CIA's expertise in relay systems. In the process of seeking to rapidly field a loitering surveillance drone in Bosnia the CIA not only selected the Karem UAV design but proceeded to combine it with some of the CIA's ongoing in-house experiments in remote control and relay systems. At this juncture, technologies and operations concepts that had been nurtured within the classified technical community introduced novel capabilities that again changed what the UAV could do. In addition to reliability and the capacity for endurance, a long loitering UAV also 'had to be

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who had previously worked on the Amber at DARPA (Lee 2016: 118). When the Gnat was presented to Woolsey, in this account, he recognized the airframe as Karem's (Strickland 2013, Whittle 2014a: 204). Woolsey attempted to persuade the Pentagon to buy the Gnat and visited the JPO to make enquiries, only to be told that it would take $20 million a year for five years to procure the drone. He therefore approached Perry, Deutch and Lynn directly (Lee 2016: 118, Strickland 2013: 4).

[75] An unnamed defense official explained to Aviation Week and Space Technology that CIA '"funds are unfettered and [Director of Central Intelligence R. James] Woolsey can buy what he wants'" (Fulghum 1993: 44). In November it was reported that the Gnat modifications had a $5 million budget and in January 1994, that along with the three month delay the programme had required an extra $1 million (Morocco 1993: 28, Fulghum and Morocco 1994: 20-22).

able to receive instructions and deliver its data from places far from its ground control site, hundreds if not thousands of kilometers away.' It therefore also 'needed some type of relay to extend its range beyond the line of sight of its ground station' (Strickland 2013: 3). The CIA had been working on this issue through the 1980s, unrelated to Karem's work on the Amber (Strickland 2013). Their work had involved using a second aeroplane to act as a relay between the UAV and the ground station, extending the range. The concept of operations developed for the Gnat-750 entailed relaying its electro-optical visual and infrared video through a manned Schweizer TG-8 relay aircraft to the ground station, which would then send live video via satellite to Washington D.C.. This technology had also been pursued in the Compass Dwell program; relay planes for reconnaissance and electronic intelligence missions at extended ranges can be traced to the Igloo White efforts to sever the Ho Chi Min trail during the Vietnam War, and to DARPA's lofty view experiment with the DASH helicopter in the same period. In the absence of truly autonomous flight of the kind being attempted in AARS or a feasible means of control via satellite, relay plane was the only way to push range beyond line of sight.

Strickland believes the idea made progress within the CIA because the team working on the program, led by 'Jane' – an engineer and pilot who combined 'the technical and operational know-how' of the CIA relay experiments – convinced Woolsey that they could deliver inside a tight timeframe. Woolsey backed his team and was willing to assume the responsibility, and the risk, where the JPO was not. He pushed the program over the objections of skeptical middle managers and inertial bureaucratic forces that would otherwise have slowed or shelved the project (Strickland 2013). That CIA design team then worked directly with the General Atomics team – with Karem brought in to advise – which enabled unusually rapid progress. This team modified the nose of the Gnat-750 so that it could accommodate the relay link in its nose (Peebles 1995: 213). Strickland (2013: 5) concludes that the technical refinements achieved in this short space of time were due to the rare combination of 'a pressing mission need for information; committed leadership at the top and within the ranks; technical and operational expertise; and a lean government-industry partnership with the desire and resources to get the job done quickly'. It was developed and deployed within six months, despite a great deal of criticism from

Congressional Staffers and anonymous defence officials critical of the CIA's 'hobby shop' approach (Peebles 1995: 213-214).[76]

The demise of the Amber reflects themes familiar in the history of drone development, including cyclical funding cuts leading to consolidation of programmes, and difficulty adopting systems that challenge existing organisational arrangements and operational concepts. Amber was not dropped because the technology could not be made to work well enough but because users did not prize what it offered more highly than rivals – including unmanned rivals that were markedly less capable in technology terms. The unforeseen resurrection of Karem's ideas in the form of the Gnat-750, meanwhile, has to be explained in terms of the confluence of several factors. First, the growing tactical reconnaissance capability shortfall across the military, exposed in the Gulf War and again over the disintegrating Yugoslavia made, opened a space unoccupied by manned incumbents and effectively vacated by the collapse of the MR-UAV. The Gulf War and the unfolding catastrophe in the Balkans revealed that the question of fixed to fleeting was a deeper trend that transcended the Soviet mobile nuclear missile problem that so exercised planners in the late Cold War. In this context the national assets upon which military planners had hoped to rely for their view of battlefield no longer appeared sufficient. As noted by Brun (2010), the Gulf War had been closely examined by all – and particularly US adversaries. Mobility, dispersion and disguise were essential to avoid immediate destruction by US air power. Thus the need was not just for more reconnaissance but for a different kind of reconnaissance – persistent, mobile surveillance coverage. To provide this kind of capability a loitering, long endurance tactical surveillance platform was needed.

A further vital characteristic of these crises, however, was that they were not confrontations with technologically sophisticated 'near peer' adversaries. In these crises, the US proved itself largely capable of seizing and maintaining air supremacy. This is not to say that aircraft – whether manned or unmanned – could fly with complete impunity: Captain Scott O'Grady was shot down over Bosnia in 1995, demonstrating that anti-aircraft suppression was not absolute, and both Gnats and later Predators were downed by enemy

[76] It was not plain sailing, however. The Gnats were supposed to be ready by October 1 1993, but a software upgrade on the eve of the final systems integration test flight resulted in a crash that Aviation Week and Space Technology reported under the byline 'Gnat goes Splat' (AW&ST 1993b: 23). It flew again in December, this time more successfully (Peebles 1995: 214).

fire. In this context, drones that may have been considered not survivable enough for a major war were considered viable. Manned aircraft could not provide the same dwell time while – reprising one of the oldest arguments in favour of unmanned reconnaissance – a downed drone did not produce the problems of crew lost over hostile territory. Karem's enduring belief in the significance of endurance suddenly appeared not just useful but the essential platform to provide persistent, loitering, real-time surveillance. As 'peripheral' wars became central in the post-Cold War period, the strategic goalposts shifted in ways that opened up new pathways for drones to advance – underscoring their utility while appearing permissive enough for their employment.

This new need for a tactical dwell collector was recognised with sufficient clarity, strength and urgency because it was exposed by regional crises that acted as a lightening rod for high level civilian and uniformed attention. The desire to see what was happening in Bosnia and frustration at the limits of US reconnaissance created political impetus sufficient to allocate resources, and overcome the hiatus created by the creation of the JPO and the halving of service UAV funds. As had happened in the past, the desire to place something in the field quickly once again encouraged an acquisition strategy emphasising quick modification and combination of existing technologies. This urgency justified the bypassing of 'normal' acquisition channels and the rigorous development and testing processes they implied, even at the expense of operational reliability. Thus, the Gnat-750 was energized by a transition from the general 'peacetime' heralded by the end of the Cold War to a regional crisis situation that, although falling far short of the kind of cataclysmic war for which US war-planners had long prepared, nevertheless succeeded in opening up a more 'wartime-like' acquisition approach to the Gnat. That environment was marked by quick reaction, experimentation, pragmatism, acceptance of risk, and willingness to field a system despite its limitations that mainstream military acquisition would deem immature and unready. The hope was that through real-world deployments the developer and the user could determine the potential of the system while identifying and then ironing out kinks.

Gnat deploys to Albania and Croatia

After Italy withdrew permission to fly the drones from its territory, the CIA Gnat-750s were initially flown from a military airbase in Gjader, Albania. The results were mixed.

Twelve out of thirty missions were completed, the others abandoned due to bad weather and data-link problems (AW&ST 1994: 23). Nonetheless, the drone deployment showed the potential. Tests at Edwards Air Force base had shown that the drones did not show up on radar, and in Bosnia they were 'found to be invisible to Joint-STARS radar' (Fulghum 1994b: 21). The Gnats 'demonstrated real time electro-optical and infrared video' (although they suffered from electronic interference) and they also demonstrated that the footage could be transmitted in near real time back to Washington that was clear enough to distinguish real from decoy missile and artillery sites (albeit by a somewhat cumbersome procedure) (Hirschberg 2010: 15). As Jeffrey Harris, then-Associate Executive Director of Intelligence Community Affairs at the CIA, recalled '[a] guy came out of his townhouse and he had a cup of coffee and what looked like a bagel. He walks into a small courtyard and he puts the bagel in his mouth, he pulls back a tarp, he drops off three rounds from a mortar, pulls the tarp back over the mortar, then eats the bagel and walks in. So here's the form of the new enemy combatant, and here's a technology that is allowing us to make a much better assessment' (Woolsey et al 2010).

Woolsey recalls watching live video footage of events while early forms of email allowed staff in Langley to instruct forward controllers stationed in unmarked vans on runways in Albania to zoom in and out at will (Coll 2004: 529, Strickland 2013: 6). Against the backdrop of increasing frustration with the limitations of fast-moving, high-altitude reconnaissance during the Cold War, the Gnat experiment was an indication that the US was on the cusp of a big improvement on the 'days-old images typically provided by satellites and U-2 spyplanes' (Coll 2004, Newman 2002). The Gnat offered a way to keep track of combatants in real time. It was also making real time intelligence available in Langley that was not available to the military on the spot in Bosnia. This would soon provoke great interest in the military about the Gnat capability.

Although well within range of Bosnia, however, the C-band line of sight data-link and the mountainous terrain of the region dictated the use of the relay plane technique. Video gathered by the drone was sent to a relay aircraft which then sent it to the ground station – which in turn sent it by satellite back to Washington. In practice this created a bottleneck on the longer dwell time of the drones it served since the manned craft spent most of its time in the air flying to and from its designated orbit in the Adriatic. This made it impossible to take full advantage of the Gnat's potential endurance.

Weather was also a problem. Newcome notes that '[wh]ile the Gnat's video proved effective when it could get into position, the harsh Balkan weather severely limited these opportunities' (Newcome 2004: 107). After two months the drones were withdrawn but they were redeployed later in the year – this time to an island off the coast of Croatia – with improved sensors and a SIGINT payload (Whittle 2014a: 82, Lee 2016: 120). Subsequently it was reported that the CIA was considering buying three of the Turkish Gnats and fitting them out to perform the relay function, taking advantage of the endurance to increase the time on station of its forward-deployed counterpart. Overall, the Gnat-750 deployments to Bosnia seem to have been modestly successful experiments.

In response to the cumbersome data relay, and funded by the SOUTHCOM Joint Precision Strike Demonstration (JPSD) program office, Karem's team modified a Gnat-750 by attaching a wideband satellite antenna pod to the top of the fuselage and demonstrated data transmission beyond-line of sight without the relay intermediary (Hirschberg 2010: 19). With such a datalink, the possibility now opened up of flying the drone itself beyond line-of-sight by means of the satellite link.

Deutch, who was in close touch with Woolsey at the CIA, delegated a trusted Pentagon representative to observe the CIA Gnat deployment over Bosnia – possibly General Joulwan, now incoming EUCOM chief, who reportedly visited Albania during the deployment (Jahn 1994). Findings from this 'operational demonstration' would be fed into the process of working up the precise requirements for 'a similar but better drone' for the military, resulting in a JPO memo for a new follow-on Endurance UAV program.

Bureaucratic Reform of Tactical Reconnaissance under President Clinton: the Defense Airborne Reconnaissance Office, the UAV Tiers structure

As noted, the senior civilians appointed to the Pentagon and CIA under President Clinton shared a desire to review and rationalise the highly contentious field of airborne reconnaissance. Drones were a central issue in a larger agenda that envisaged 'modernizing the manned reconnaissance fleet… promoting commonality among the Services and establishing (and enforcing) interoperability standards' (Rosenwasser 2004: 192). To further this agenda, in November 1993 a new office was established in OSD, the Defense Airborne

Reconnaissance Office (DARO). Its task was to act as a management structure for tactical reconnaissance as a whole. It was reportedly opposed by the services (particularly the Air Force) but they were unable to oppose it because it was strongly supported by Congress (given its consonance with the ideal of jointness and given mounting frustration with the JPO's dysfunctionality).[77] DARO was positively received by the joint community, which possibly saw it as inevitable and sought to engage and shape the office rather than leave the senior civilians to go it alone (Rosenwasser 2004: 193-194). USD/A Deutch envisaged it as an equivalent of the NRO, and the services perhaps feared that it might achieve that goal. In the event, and despite real budgetary clout (DARO had a single account that collected the reconnaissance development resources scattered across service and classified accounts), its substantive power was limited: 'DARO handled only R&D, but not the manning, training, operation and support of any fielded systems' and as such 'had no operational control, which remained instead with the CINCs and the Services, and had no jurisdiction over requirements' which belonged to the JROC (Rosenwasser 2004: 196).

In the scheme of things, tactical UAVs were a third order concern for DARO. Nonetheless, as the Clinton administration came into office the Hunter – the joint TRW, Israeli Aircraft Industries successor to the Pioneer – dominated the field of tactical drones under development (accounting for two thirds of the JPO drone budget in 1994 - $1.2 billion). Unfortunately, this programme collapsed spectacularly in 1994 and 1995 under the weight of a combination of difficulties including poor performance, lack of reliability, logistics concerns, acquisition management misjudgements and arrangements, requirements creep, the differing maintenance and logistics requirements of the US and Israel and a number of high profile accidents (Rosenwasser 2004: 213-222).

The JPO master plan documents had organised drone development according to a 'family' concept divided into 'close range', 'short range', 'medium range' and 'endurance' categories (with classified efforts beyond its remit) and in 1991 Congress had directed that endurance give priority to close range, short range and medium range. This scheme was

[77] The House Armed Services Committee at this time (July 1993) recommended a CIA-DoD integrated airborne reconnaissance strategy encompassing the full weapons acquisition cycle from R&D through O&M for manned and unmanned vehicles plus sensors, data-links and ground stations (Rosenwasser 2004: 194). Having supported its creation, however, Congressional members and staff later became frustrated with DARO since they lost the direct access to programme managers they had previously enjoyed and since they felt the office 'did not duly consult with or defer to their judgment in appearance or fact, especially on programmes with deep parochial interest' (Rosenwasser 2004: 198).

reorganised along the lines of the Summer 1993 Defense Science Board Study, into three 'tiers'. The JPO's close (50km) and short (200km) range categories were merged, creating a joint tactical UAV (JT-UAV) requirement with variants to satisfy Naval and Army wishes (putting extra weight on Hunter, which now had to do both). The previously deprioritised endurance category was then expanded, initially into three (but eventually four) streams. Tier I was low altitude and long endurance, Tier II medium altitude and long endurance and Tier III reflected a classified high altitude, stealthy days-long loiterer (AARS and its successors). The tiers, although looking like an abstract framework, in fact mapped onto existing research spanning the CIA Gnat-750 work, the military endurance requirement being worked up through the Joint Chiefs channel, and the secretive high-technology work that had been embodied in the AARS. Having been shut out of the programmes framed under the successive JPO master plans, and against the backdrop of Hunter's implosion, the Amber technology at work in the CIA channel now became Tier I, with Tier I in turn becoming the basis for Tier II.[78] It was here that the Predator programme began (Sommer et al. 1997: 10-13).

The Predator

Just as Leading Systems had developed Gnat concurrently with Amber, by the time the Gnat-750 was being modified and deployed in Bosnia, General Atomics already had a more capable successor underway, with reports of a successor in the works going back to at least 1988, and active marketing at aerospace events (Thirtle et al 1997: 9). It had a larger engine (still driving a pusher propeller) to enable it to carry a satellite dish and data-link and a new inertial navigation system that incorporated GPS correction and eventually a new synthetic aperture radar (Lee 2016: 113). The design was visually similar to the Gnat and its

[78] The AARS, for which Tier III made room, proved so packed with secret technology that, as one insider told Aviation Week and Space Technology '"if one had crashed we would have had to bomb it to ensure it would have been destroyed"' (Fulghum and Morocco 1994: 21). The high altitude role was subsequently sub-divided into 'Tier II+', a long endurance wide area, stand-off reconnaissance platform (reminiscent of the Compass and Condor programmes) that became the Global Hawk, and 'Tier III-', a stealthy, penetrating, high altitude loiterer that would be smaller, cheaper and more realistic than AARS (this effort became DarkStar). The battle for AARS is recounted by Ehrhard (2000: 154-159).

forerunners, but again with a longer wingspan, inverted V-tail. Its heritage in the Albatross and Amber was evident. General Atomics, perhaps in homage to their earlier Sadler-inspired model, called the drone *Predator*.

In the Spring of 1993, USD/A Deutch had convened a group of three star officers from across the services and called in CIA Operations Director Twetten, asking him to talk about the Gnat. Even before the CIA deployed the Gnat to Albania, Deutch's medium-term goal was to get the military to start adopting drones (Whittle 2014a: 76). While the CIA took $5 million to demonstrate the Gnat operationally, Deutch worked through a dedicated cell established within the JPO to get a successor underway on the military side and indeed conceived of the CIA demo as one part of a broader strategy to drive reconnaissance drones across the threshold to military service adoption. Two Navy Captains who made up the JPO team were left to figure out the requirements for a 'medium altitude endurance' system on the basis of their own experience, the details of which they then presented (anticipating some resistance) to USD/A Deutch and the Vice Chairman of the JCS (simultaneously the JROC head), Admiral Jeremiah, who signed off immediately (Rosenwasser 2004: 226-227).[79] The formal requirements were then set out in what came to be known as the 'Deutch memo', a single page rather than a detailed requirements document. That memo stipulated ability to fly 500 nautical miles, stay on station for at least 24 hours, carry a 400-500lb payload providing electro-optical and synthetic aperture radar imagery, and fly at altitudes of 15,000-25,000 feet.[80]

On the basis of their investigation of the available options, the JPO duo believed that the Gnat (and the work already underway on its successor at GA-ASI) was so clearly the best option to take forward (not least because of its highly reliable Amber-derived software) that a sole source contract should be issued. In the event a competition was held, based on the Deutch memo requirements, which General Atomics promptly won, with a $31.7 million contract awarded in January 1994. In the meantime, the J2 (intelligence) head in the JCS, Admiral Cramer, who had been directed to explore the endurance UAV concept in response

[79] Jeremiah never convened JROC about the project, in order to head off potential requirements creep (Rosenwasser 2004: 225).

[80] Under Secretary of Defense John M. Deutch *Endurance Unmanned Aerial Vehicle (UAV) Program* memo to the Assistant Secretary of the Navy for Research, Development, and Acquisition, July 12 1993, quoted in Thirtle et al 1997: xvi. The imagery had to meet National Imagery Interpretability Rating Scale (NIIRS) of 6 or better at 15,000 feet and the SAR had to demonstrate 1 foot resolution at the same altitude (Thirtle et al 1997: 11).

to White House exasperation at the state of reconnaissance in Bosnia, had also been looking into stream-lined acquisition arrangements for the programme. He wanted the kind of quick reaction capability employed in some black programmes to expedite fielding of a system to demonstrate to field commanders and seek their input on its utility. He wanted the acquisition managers to set requirements but not specifications, and set the price and then ask the contractor to deliver as much as they could within that limit (Rosenwaser 2004: 206).

It is striking that the tactical endurance drone programme was set in motion without any service having expressed much interest in it. The whole Tier I and Tier II effort was driven by White House disbelief at the state of reconnaissance capabilities in Bosnia, by a network of civilian Pentagon officials (working through the JPO) determined to find a way to push drones into military service, and by the CIA. The Tier II requirement was justified with reference to the urgent needs of the theatre CINC, Joint Forces Commanders and the National Command Authority, seeking to head off the plain fact that both the service-level requirements process and the JROC process had been circumvented. Although the initial plan to fund the programme by reallocating funds from other accounts proved unworkable, General Atomics' careful cultivation of Congressional support (personified by GA-ASI's forceful CEO, retired USN Rear Admiral Thomas Cassidy and supported by 'aggressive lobbying') and the advocacy of Admiral Cramer and his Navy counterparts in the JPO, succeeded in winning over key Congressional figures (Woods 2015a: 33). Air Force Major General Kenneth Israel later told Woods that General Atomics 'had tremendous support on the Hill. There was not one year that I did not get more money than I requested. I was thinking, "who the hell is talking to these people?" (cited in Woods 2015a: 33). Congressman Jerry Lewis, in whose District GA-ASI was based, sat on the Defense Appropriations Subcommittee and the Intelligence Committee and Norm Dicks, also on the Defense Appropriations Subcommittee, was convinced to support the move. In the Senate, Carl Levin and John Warner sponsored an amendment to the FY 1995 Senate defense authorization bill allocating $40 million for tactical endurance drone that GA-ASI was building. Thus, not only did the programme circumvent the services and the joint requirements process (i.e., JROC), but funding for Predator came not from the services but direct from Congress. Finally, although the programme was handed to the JPO (despite its track record), the management cell was insulated by being made to report directly to OSD acquisition leadership (DUSD/AT Larry Lynn) directly (Rosenwasser 2004: 228-229).

In the meantime, and in many ways in keeping with the Packard commission's exhortation to reduce development times and create more flexible acquisition options, OSD had been looking at alternatives to what they viewed as formal acquisition processes that were much too rigid and much too slow to deliver. One of the concepts that was under development was that of the 'Advanced Concept Technology Demonstrator', first launched in 1994 (Thirtle et al 1997). The ACTD was meant to provide an accelerated acquisition pathway (2 to 4 years, contrary to the typical DoD Acquisition Regulation 5000 process) to demonstrate the potential utility of maturing technologies by quickly putting them in the hands of CINCs in actual military deployments, by seeking the ongoing input of users in the development process, and by letting them be the judge of the technology's military utility. If a concept showed promise it could be transitioned to the formal acquisition process. Predator was formally added as an ACTD in April 1994, sponsored by Atlantic Command. It made its first flight (of 20 seconds) on 3 July 1994, five days before the deadline set in the contract (Newcome 2004: 109).

Conscious that the programme was advancing in the absence of a service 'customer', the Predator team were looking at ways to 'sell' the drone. Suspecting that a range of forces were working against their system's quest to become an established military technology, they sought ways to create influential converts to their cause. Part of their strategy was to demonstrate its capabilities to military leaders. They began by employing a private company to take raw video feed and package it on video tapes that could act as a publicity tool. In 1993 or 1994, however, an imagery scientist had been seconded to the team from the CIA Directorate of Science and Technology to improve the video feed with which they were experimenting (Whittle 2014a: 93).[81] Although the Predator could record video, up to that point it could only be viewed on a screen in the GCS, or video-taped and then the tape physically transported for later viewing on another player. The scientist realised that the existing global communications infrastructure made it possible to distribute Predator footage directly to any correctly enabled screen around the world, and had the technical

[81] Lee (2016) reports that he was a 'Big Safari scientist'; Michel (2015) refers to him as 'the man with two brains'; and, Whittle (2014a) refers to him as 'Werner'. He was central in further innovations involving the Predator satellite communications system.

skills to demonstrate the idea. He suggested that in order for decision makers to truly grasp the potential in the technology, standard presentations or even the the video tapes were not enough. Instead, he argued, they should demonstrate the ability to transmit video directly onto the screens of those decision-makers in real time over thousands of miles. In a meeting in January 1995, live video from Ft Huachuca (in Arizona) was piped into a meeting room in the Pentagon – more than two thousand miles away – before a cross-service group of officers. '"That was the breakthrough,"' the scientist believes (quoted in Lee 2016: 122).

The services remained uncommitted. The system had high level backing in Admiral Cramer who did what he could from his JCS position to encourage the Navy. A marinised version was successfully trialled by the carrier battle group Carl Vinson, leading Admiral McGinn to declare '"the era of time-late tenth-of-a-second photo imagery is fading"' (cited in Rosenwasser 2004: 235). The Army's Military Intelligence at Ft. Huachuca, running *Hunter*, provided personnel and in January 1995 the drone demonstrated 40 hour 17 minute endurance there. The Army's Communications and Electronics Command at Ft. Monmouth also pitched in, providing technical and procurement support, including with the Westinghouse SAR common to both systems. Army leaders, however, were understandably suspicious that the satellite link made it vulnerable to being grabbed from ground commanders. Through 1994 and the first half of 1995, the Air Force simply waited and watched.

A turning point came with Predator's performance at the large-scale Roving Sands military exercise of April and May 1995, where it provided 85% of total imagery collected and flew 25 out of the 26 days. Afterwards Joint Special Operations Command asked the Army team operating the drones to participate in their own exercise in the Florida Everglades, while it was also demonstrated in a US Customs exercise. Its reputation growing, EUCOM requested that it be sent to provide coverage of Bosnia that summer. Under Operation Nomad Vigil, Predators (flown by Army aviators) were sent to Gjadar where their tour was extended from 60 to 120 days and where they logged 750 flight hours and 80 missions and provided imagery that informed the decision to launch the Deliberate Force air campaign that August. Two of the ten Predators, however, were lost in this time, one possibly due to enemy fire. Although Ku band satellite link had been demonstrated at Roving Sands – providing the bandwidth to support FMV footage, it was not initially available for operations in Bosnia, forcing operators back onto UHF and time-delayed still imagery. A quirk of geography – a gap in the mountains between Gjadar and Sarajevo - unexpectedly made it possible to return video footage via the C-band radio transmitter and on from the GCS back to NATO regional HQ and the air operations center, both located in Italy. The resulting live footage resulted in a flood of calls requesting the Predators be directed over particular sites of interest (Whittle 2014a: 104). Predator was withdrawn for the winter but returned in March 1996, this time with Ku Band satellite installed (although not yet capable of very high resolution video), under Operation Nomad Endeavour to oversee adherence to the Dayton Peace Accords (this time flown from Taszar air base in Hungary) (Newcome 2004: 109, Lee 2016: 124). It was considered a highly successful, albeit not yet mature system (it was badly affected by adverse weather conditions and maintenance difficulties which grounded 60% of the scheduled flights between March 1996 and April 1997), disproving false claims, assisting in search and rescue, monitoring elections and ceasefire agreements, and keeping vigil over mass graves to prevent interference (Rosenwasser 2004: 239, Lee 2016: 152).

The Air Force had been stand-offish and had largely been uninvolved in the ACTD, choosing to sit 'on the sidelines' (Rosenwasser 2004: 236). In the wake of Roving Sands and the buzz created by the Bosnia deployment and a formal declaration from Atlantic Command that Predator fulfilled the critical real-time intelligence requirement articulated in the Deutch memo, however, both the Army and the Navy began drafting requirements documents, signalling a desire to claim ownership of the Predator when the ACTD came to an end (Lee 2016: 148, Rosenwasser 2004: 241). The new Air Force Chief of Staff, General Fogelman was concerned by 'a worrisome gap looming in the nation's airborne reconnaissance capabilities' as a result of the retirement of the RF-4 fleet, and appears to have been a sincere believer in the emerging drone technology (Whittle 2011: 10).[82] Yet he also realised that the operational success of the system meant that it would now be fielded and 'the ramifications if it did *not* claim Predator' (Rosenwasser 2004: 237-238, Lee 2016: 181). '"Predator took on a life of its own,"' Fogelman afterwards told Ehrhard, '"and I thought it best that airmen operated the system"' (quoted in Ehrhard 2000: 540). Fogelman thus decided the Air Force should 'wrest control' from the Army and mobilised to do so

[82] In an interview, Fogelman told Whittle '"[w]e were slowly denuding ourselves of air-breathing reconnaissance capability,"' when '"all of a sudden, as a result of this ACTD, there appears to be something on the horizon that might be helpful."' (Whittle 2011: 10).

(Ehrhard 2010:50-51). Despite the millions invested by the Army in a drone training facility at Fort Huachuca, Arizona, Fogelman stood up a dedicated unit, the 11th Reconnaissance Squadron (actually reactivating the squadron that had flown the Lightning Bugs in Vietnam and then experimented with arming them) to accommodate the system. The 11th was established before any decision had been taken about handing Predator to the Air Force. Soon after, however, Fogelman convinced the JROC that the Air Force should own the Predator. In 1996, complex joint management arrangements were put in place by OSD and JROC to preserve jointness, with the Air Force made the 'lead service,' but the Navy being left control over system development and procurement (Whittle 2011: 10). These arrangements proved chaotic and over the next few years (under the new USD/A Chief Jacques Gansler, who had very different views from Deutch regarding the services' proper role in acquisition) the Air Force progressively took over the programme. Congressman Jerry Lewis again assisted when, as vice chairman of the House Intelligence Committee, he inserted a provision in the 1998 intelligence authorisation bill 'mandating that all authority over Predator and all its funding be transferred to the air force' (Cockburn 2015: 60).

Something remarkable had happened. The Predator had been cooked up by OSD civilians without any service input or interest, based on a forerunner that the services and JPO had actually cancelled. It had been field demonstrated through an entirely new acquisition channel and had so successfully begun to demonstrate the utility of its real time video surveillance capabilities that it succeeded in changing the Air Force calculus. At some point in 1995 the Air Force decided that it could no longer be ignored for fear that a rival service would acquire a system that impinged on what they viewed as Air Force mission territory. The ACTD had made the drone seem inevitable, awakening inter-service competitive instincts strongly enough that the Air Force became willing to contemplate the discomfort involved in making the organisational, doctrinal and militarisation adjustments necessary to incorporate the system. Civilian manipulation and circumvention of the acquisition system, the services, and even jointness had managed to cast a drone across the threshold separating research and development from adoption. Nonetheless, as the Air Force would discover in the following years, this marked not the end but the beginning of Predator's integration into the service.

Adoption and 'normalisation'

When it was transferred to the Air Force, Predator was very much a promising, but still experimental, system that continued to be affected by poor weather. The quick reaction-esque acquisition channel provided by the ACTD meant that it was fielded quickly, and developed in small numbers through a series of quick iterations. This had real advantages – capabilities were being adjusted to suit feedback from operational commanders learning on the fly in active operations. The strategy of placing the experimental system in the hands of real-world users and letting them trial it had the effect hoped for by the civilian leaders whose bureaucratic guile had breathed new life into the Karem design. It created momentum behind the system sufficient to change the services' calculus about the system. No longer able to ignore it, the Air Force resolved that they therefore had control it.

While the Air Force worked to seize total control over the programme from the vestiges of jointness, internally it had to work out what a normalised Predator programme would look like. It decided to organise into squadrons, the basic organisational unit of the Air Force, and it decided that Predator should be flown by rated pilots. This fitted with Karem's and GA-ASI's thinking about reliability (and the Air Force were worried that non-rated personnel would cause embarrassing crashes) but it also made sense given that the Predators would operate in airspace shared by piloted aircraft. Unfortunately, nobody joined the Air Force to become a pilot in the hopes of sitting in a ground control station (Rosenwasser 2004: 281). The Air Force therefore assigned pilots to the squadron through forced selection or volunteering rather than the selection boards used for more prestigious positions, and soon found that other parts of the Air Force were using it to clear out what they saw as 'dead wood' (Lee 2016: 156-157, 162). Predator pilots were denied flight pay available to pilots of manned aircraft, undermining the notion that what they were doing was 'really' piloting. The Air Force career structure was not adjusted in such as way as to make Predator an attractive proposition until 1999-2000. Being assigned there initially became a career killer. A sign was reportedly put up above the entrance to the 11th Reconnaissance Squadron reading 'Leper Colony' (Rosenwasser 2004: 282).

Air Force contemplation of how to manage the programme going forward revealed a tension between the impulse to normalise and the desire to continue to deploy the system, and to preserve the agility of modification and development that was the hallmark of the

ACTD period. The impulse to normalize was supported by strong arguments. Answers were needed for basic questions about issues such as reliability, spare parts, maintenance, logistical and support infrastructure, development funding, and the numbers of aircraft to be purchased. ACC wanted to move to a situation in which the use of contractors was phased out, to 'bring Predator into the "regular" Air Force, integrate the system with the Service's logistical infrastructure, raise levels of reliability and supportability, and make the system as culturally embraced as the F-16' (Rosenwasser 2004: 289). The embattled first commander of the 11th Reconnaissance told Ehrhard that the whole Predator operation had to be built from the ground up, saying they built '"everything from parts bins in our maintenance hanger to Functional Check Flight profiles to use every third flight when an engine overhaul was required,"' while the then-ACC UAV office head, Colonel Barton, pointed to the effort and expense involved in turning GA-ASI, a new entrant in the business, into a mature contractor capable of providing the necessary supporting products and data (Ehrhard 2000: 543). Grimes admits that the transition was not easy, recalling '[i]t took GA-ASI a while to grasp the fact that they could not go to the field and make unilateral changes without telling anyone (and without prior approval), no matter how much improvement resulted' (Grimes 2014: 330).

The other side of the debate argued the merits of keeping it 'special', emphasising continuing experimentation and modification at the cost of reliability (Rosenwasser 2004: 286). This too had strong arguments. The quick reaction approach meant that in 1996 GA-ASI was working on a de-icing system to help cope with the difficulties of flying in poor weather. A number of other innovations were also introduced, including a more powerful turbocharged Rotax 914 engine that became a new Predator iteration, designated RQ-1B (Cantwell 2007: 24). OSD guidance suggested that the goal need not be complete normalisation while the Congressional supporters of the Air Force bid for control now recommended (first through the House Intelligence Committee) that Big Safari and not ACC assume control over acquisition (Whittle 2011: 11, Grimes 2014: 329). The House intelligence committee staffer who made this suggestion was a retired Air Force chief master sergeant who had worked on the Air Staff as chief of airborne reconnaissance operations, and knew Bill Grimes and Big Safari well (Whittle 2011: 11). The language was subsequently dropped in House-Senate deliberations about the Defense Authorization Bill, which led to DARO being abolished and OSD being instructed to hand the UAV programmes back to the armed services (Whittle 2011: 11). Jumper mediated the intra-Air Force debate about Predator innovation, wanting the reliability and support base built but wanting it done as soon as possible, convening a task force to expedite the provision of technical data. It would be years before the Air Force weaned itself off of contractor support for maintenance, planning and supply (Rosenwasser 2004: 293). In the end, ACC assumed management of the Predator programme and set about writing an Operational Requirements Document (from which requirement the ACTD was exempt), but acquisition authority was handed to Big Safari, which soon opened a new detachment at the General Atomics facility at Rancho Bernardo (Whittle 2011: 11).[83]

Innovation in Operation Allied Force: WILD Predator

Predators returned to south-east Europe once again in 1999 as part of NATO's air campaign in the Federal Republic of Yugoslavia, which attempted to use airpower to compel President Milosevic to withdraw forces from Kosovo and end the displacement and expulsion of ethnic Albanians from the province (Byman and Waxman 2000, Lambeth 2001). At that time the Air Force was grappling with the challenges of normalising the Predator, and notwithstanding the deployments to Bosnia in the ACTD phase, and despite incremental technical improvements (it had just installed de-icing equipment on some of its drones), ACC proved reluctant to send the drones (Lambeth 2001: 95). At this point the Air Force reportedly possessed just six Predator systems (of four vehicles each) (Cullen 2011: 219). While Predator undoubtedly needed the detailed work that was being undertaken to bring it up to scratch, from the Big Safari perspective some of what was being insisted on went too far. ACC's reluctance is an indication of precisely the kind of trouble with traditional acquisition processes that had driven civilians such as Perry and Deutch to try to bypass it.

The Predators deployed to Kosovo had a number of capabilities, augmenting J-STARS in tracking moving targets, and 'collecting signals intelligence (SIGINT) through its ability to

[83] Big Safari, mentioned in relation to the development of the Ryan Firebee drones in the previous chapter, went on to play an extremely important role in Predator innovation. Unlike the mainstream channels, notes Whittle, Big Safari 'was largely exempt from the usual steps in the normal acquisition process—lengthy operational requirements analyses, technology trade and risk assessment studies, preliminary design, full scale development, and developmental and operational testing, all punctuated by formal "milestone" reviews. Big Safari existed to get new technology into the hands of operational users fast. It did that by aiming for "the 80 percent solution"—rather than perfection—and by ignoring what Big Safari insiders disdained as "administrivia" (Whittle 2011: 11).

approach threat emitters more closely than manned aircraft and to monitor low-power transmissions, such as those from cell phones and portable radios operated by enemy ground troops' (Lambeth 2001: 94-95). Significantly, they started to be used in unforeseen ways, employed to validate pilot reports of possible SAM or ground-force targets on the move, since the rules of engagement often required two sets of eyes on potential targets. From reconnaissance, the drones became introduced into 'the collateral-damage management loop and sent out to put real-time eyes on candidate targets that had already been located but not identified, so as to verify that they were valid military target' (Lambeth 2001: 95-96). In the course of operations, the Air Force realised the need for better sensors and began to wrestle with the problem of how to incorporate Predator missions into the overall management of wartime airspace to avoid accidents. Lambeth considers the use of UAVs in Kosovo one of the three most important innovations of the war.

Predators were deployed to an air base near Tuzla (Bosnia). They came into their own in part because of a NATO ban on flying below 15,000 feet. This was imposed out of NATO wariness of the threat of anti-aircraft missiles (particularly after the downing of a F-117 Nighthawk) as well as MANPADS, and political refusal to accept loss of air crews. The idea was conceived to use Predator to drop below cloud cover, and locate targets (often mobile targets) that armed, manned aircraft could then attack. This idea immediately threw up the problem of how the Predator crews were to provide accurate location information to their colleagues. With no technical means to pass on objective location data, drone pilots resorted to the inefficient and frustrating strategy of attempting to describe the location with reference to geographical features and terrain. To air force professionals the solution to this problem was blindingly obvious: the Predators needed to be equipped with laser designators that could be used to 'paint' targets and cue armed counterparts by transmitting target data across the larger command network via satellite (Coll 2004: 530). Nine days into their deployment, this possibility was being discussed in the United States, receiving high level backing from Air Force Chief of Staff General Ryan (who had succeeded Fogelman, and was instrumental in persuading the Navy to surrender their sensor turrets) and General Jumper (who had forcefully worked to normalise the Predator after the Air Force mobilised to snatch it, and who was now Commanding US Air Forces in Europe) (Whittle 2013: 12, Frisbee 2004: 65-66, Boyne 2009: 43). An instruction was rapidly transmitted and the Big Safari Predator team was given just three weeks to deliver a laser designator-equipped Predator (Boyne 2009).

In an effort called effort Wartime Integrated Laser Designator (WILD), they swapped out the Wescam turret that had been introduced by the Army and with contractor support added a Raytheon AN/AAS 44(V) forward looking infrared turret that could lase targets (but lacked a daylight video camera). In a test on 4 May a Predator accurately lased a target for an F-15E Strike Eagle and an A-10, and a live weapons test followed 8 days later (Frisbee 2004: 62, Grimes 2014: 330-331). Two or three such drones arrived in Bosnia on 23 May and demonstrated the capability even though the bombing ended before they could be employed in combat. ACC, however, had refused to let its personnel operate the modified craft (they were flown by Materiel Command) and stipulated that the adjustment would not be made permanent, considering it a 'violation of doctrine' (Frisbee 2004: 62-63, Grimes 2014: 331, Rosenwasser 2004: 354). Upon their return to the US, the WILD Predators were stripped of their Raytheon turrets, which were put into storage, and replaced with the old Wescam turrets (Boyne 2009). Very soon, however, this decision would be overruled, yet again in response to the course of events. In the course of those events, not only would Predator undergo further technical innovations that further transformed its capabilities, but real assimilation would take place. Rather than simply being 'normalised' into the Air Force structure, however, Predator's assimilation occurred at the heart of a novel and largely covert security infrastructure evolved to prosecute the post-9/11 war on terror.

Conclusion

There seems little doubt that while multiple arguments could be (and were) made for the military and intelligence utility of unmanned systems, as far back as the early 1970s Abraham Karem came to believe that the most important attribute they could afford was endurance. Importantly, Karem's insistence on endurance as the key vehicle property does not appear to have been rooted in the requirements of a particular strategic environment or the exigencies of a particular crisis. It is striking, then, that the property of endurance appeared critically relevant in relation to a succession of pressing concerns, from the guarding of Israel's borders, the monitoring of the Fulda Gap, and the 'basing' of MX missiles, to the OTH cueing of long range missiles, the detection of ballistic missiles, the locating of mobile scud missile launchers, and, in the post-Cold War world, the tracking and targeting of dispersed enemy forces, the locating of mass graves, and the monitoring of ceasefires.

Perhaps Karem's second vital insight was that even if the mini-RPV proponents were right to stress lighter and more capable payloads, the approach to platform design had to emphasise reliability if it was to stand a chance of yielding a system that would be adopted and integrated by military organisations. Karem and his small team possessed the technical capabilities to translate these core attributes into a series of progressively more capable air vehicles. Yet Karem was also deeply suspicious of the acquisition system, and the perils of requirements creep. He sought to create small, cohesive teams sticking to clear and bounded objectives.

Karem's team, with DARPA support, pursued and demonstrated longer and longer endurance and unprecedented degrees of reliability, through technical expertise (for example, in efficient engines and state-of-the-art flight control software), custom-built and tailor-made components, and investments in training up operators. Yet the design still could not transition from research and development into a military programme of record, which is to say owned, sustained and incorporated into the plans, routines, structures and operations of a military service. The reasons for this failure to advance are not reducible to technological limitations, even though it is true that the system was not without technical issues. Woolsey points out that Karem had established the basis of what would become the Gnat and Predator 'for DARPA at the end of the 1970s' but 'nobody would buy it, for bureaucratic reasons, and it was slumbering' (Woolsey et al 2010). The proximate reason for the abandonment of Amber was the Congressionally mandated funding squeeze that accompanied the formation of the JPO, and the Navy's (Amber's formal sponsor) decision to focus on Pioneer. The deeper reason, however, seems to have been that to benefit from Amber's potential it could not simply be 'bolted on' to existing structures and concepts of operation. The services expected to state what they wanted and for the contractor to build to those desires. When something different was offered (even though 'different' was also 'more capable' in this case), but at the price of organisational and doctrinal pain for uncertain gain, the user preferred to decline. Thus Karem does fit the description of an inventor-entrepreneur but, as Spinardi (1997) observed of British nuclear researchers, Karem was far from 'out-of-control' and certainly did not have it all his own way. In Karem's particular case, his extraordinary skill at manipulating the technical and material world appears to have exceeded his ability to engineer the social world of bureaucracies and personalities.

The survival of the technology following the bankruptcy of Leading Systems is due to the intervention of General Atomics. While clearly the Blue brothers had been looking at drone technology for some years, their decision – brokered by Karem's ally Ira Kuhn – and their true role remains to some extent obscure.[84] Nonetheless, GA not only had the financial resources to provide Karem's work with a stay of execution, but also appears to have amassed the heterogeneous engineering skills that are vital to nurturing sympathetic coalitions across the web of 'demand side' institutions – in Congress, OSD, and operational users including the military services and the intelligence community.

The arrival of a network of like-minded and well-placed civilians at OSD, including Perry, Deutch and Lynn, and Woolsey at CIA under President Clinton revived endurance drones. Woolsey argues, however, that 'what we really did, with [Karem's] help, was resuscitate something that had been developed but nobody was doing anything about because the bureaucracy was really kind of impossible' (Woolsey et al 2010). Moreover, he believes '[w]e did it for something well under $10 million, and over two development periods, one of about six months and one of about three or four months… It is a very good illustration of how an agency, particularly when they have people like [the team assembled to develop the Gnat] can do stuff fast if you just get out of the way' (ibid.). Although bureaucratic innovations (including the JPO and subsequently the DARO) affected the drone acquisition landscape in this period, the endurance drone was deprioritised under this system and would have remained so but for the 1993 Summer Study and subsequent civilian insistence. Real world experience, meanwhile, did provide ample evidence of a need for persistent battlefield reconnaissance. This network of individuals, however, is responsible for generating the impetus for the CIA Gnat-750 (branded Tier I) and the Tier II tactical endurance UAV (fulfilled by Predator) of 1993-1995. The ACTD was the vehicle to advance the Predator in the total absence of service buy-in while also effectively

[84] One financial analyst observer told the *Financial Times* '"[t]he thing is General Atomics doesn't seem to see itself as a company… Management sees it as a national research lab like Los Alamos, incubating new technology of national significance" (Lemer 2009).

circumventing the joint community. This strategy was justified with reference to emerging urgent requirements in the context of the post-Cold War tactical reconnaissance shortfall. It was backed by Congress, in part through careful persuasion both by the OSD and by General Atomics through their forceful and respected CEO. Yet the Tier I and Tier II drone programmes reflect a deliberate strategy to circumvent the mainstream acquisition channels – both the service-led model and the turn to central management in pursuit of jointness – that had failed to see a single UAV advance and that had contributed to sustaining worrying airborne reconnaissance shortfalls more generally. In this it was a bold experiment that pitted wilful civilians against the established bureaucratic processes of the very organisations that they led.

In hindsight, Predator is an embodiment of two converging trends that constituted the dominant defense establishment debates of the post-Cold War period. The first was the tension between what the military services tended to consider the main business of preparing for the major wars of the future, and the proliferating range of contingencies and OOTW to which those services were repeatedly being deployed. Trends that had begun much earlier – notably the transition from fixed to dispersed and mobile targets (a direct effort to compensate for US reconnaissance and precision capabilities) – were correctly interpreted by some observers as necessitating not just more but *different* kinds of reconnaissance capabilities, and those capabilities strongly suggested endurance drones as the appropriate sensor platform. At the same time, the post-Cold War contingencies involved environments in which the air defence threat was sufficient to concern casualty-averse decision-makers but permissive enough that drones could be sent in (the likely attrition rate was acceptable for the reconnaissance returns). Thus alongside the foreboding antiaircraft environment that oriented Cold War planners to set a high technology barrier for drones, a new set of contingencies opened up for which drones seemed well placed. Drones further seemed appropriate because of the other set of preoccupying trends – the technological advances whose implications an influential group of defense intellectuals took to describing under the rubric of a 'revolution in military affairs'. Those technologies included smaller, cheaper, more capable sensors, real-time high bandwidth satellite communications, and precision guidance enabled by software advances and the GPS system. These technical advances held out the prospect of overcoming obstacles to the military viability of unmanned systems: far greater capability and reliability.

Even Ehrhard admits '[i]t is inescapable that Predator would never have been built under the service-centric approach' (Ehrhard 2000: 547). While indeed it 'reached the flightline through the side door, as it were, rather than through the conventional requirements process', it was not 'fortuitous timing, interservice rivalry, and the personal intervention of a visionary chief of staff' that got it there (Ehrhard 2000: 536). Instead, it was above all the civilian gamble of circumventing established acquisition practice and attempting to demonstrate a capability in the absence of any service desire for it. That gamble paid off. The technology demonstration approach, although having the drawback of yielding systems that still had a long way to go to become 'normalised', also paid off. It succeeded in generating momentum behind the system that was strong enough to make the system seem inevitable. While Fogelman appears to have recognised the merit and potential of Predator in its own right, the success of the demonstrator approach changed the bureaucratic calculation of the Air Force. Having been content to wait out the tenure of the civilian OSD insurgents under Fogelman they mobilised to grab the system rather than let it be claimed by a rival. The civilian gamble had the effect of stimulating interservice rivalry in a way that facilitated Predator adoption.

Ehrhard also makes the important balancing point that 'while flying prototypes have a certain seductive charm, there are no shortcuts to a properly militarized UAV able to be fully integrated into service combat plans. That process takes time, money, and unwavering service commitment' (Ehrhard 2000: 536). This is certainly true. But without this approach it is not clear that the services, or a construction such as the JPO, would have been capable of yielding a UAV worth integrating. Nonetheless, having seized the Predator the Air Force then relived the debate about formal versus flexible acquisition processes and headway required the forceful and close attention of General Jumper, who sought to normalise Predator as far as possible while maintaining flexible, responsive acquisition under Big Safari auspices.

What was the status of Predator following the Kosovo campaign? Formally, it had found a home in a dedicated service which was investing a great deal into normalising it within its own structures and routines. It enjoyed high level backing, but ACC largely believed that Predator had a very long way to go, remained sceptical, and restricted UAV funding when DARO was dissolved in 1998 and it regained budget control. The civilians had achieved their goal of foisting an endurance drone onto the service, but despite its powerful backers within the Air Force Predator was far from secure. By early 2001 the Air Force had just 16 Predators. The position of the Lightning Bug family at the end of the Vietnam War was arguably much better cemented, yet within a few short years the drones had been boxed up and the squadrons disbanded. Predator had emerged in the sense that it had passed well beyond R&D projects such as Compass Cope and it had been repeatedly and usefully deployed – and in strict formal terms it had been adopted by the Air Force. Yet it could still have died on the vine. It still had plenty of sceptics – not least those who doubted the relevance of its mission, those who doubted its military reliability and utility, and perhaps those who felt it threatened their roles, careers and professional values. Its future, as Ehrhard noted at the time, was still far from assured.

5. The 'bin Laden problem' as a stimulus to Predator innovation

Introduction

This chapter explains why and how Predator development converged with, and was redirected by, attempts to find new ways to address the growing unconventional threat posed by Osama bin Laden and the al Qaeda network in the late 1990s, and specifically by the difficulty presented by bin Laden's sanctuary inside Afghanistan. During the 1990s, recognition of the growing threat posed by al Qaeda created a thorny policy problem for the Clinton administration, as international terrorism had for previous administrations. In his Afghan sanctuary, bin Laden appeared beyond the reach of law enforcement repertoires. Existing intelligence repertoires, meanwhile, had had limited success in obtaining 'actionable' intelligence on bin Laden's whereabouts and movements inside Afghanistan. This frustration led to the initiation of a search process to develop alternative and supplementary options, and Predator was 'turned up' in the course of this search. Making this connection, in turn, acted as a stimulus to further technical innovation as the existing Predator capability was transformed by innovation in the system of remote control in order to provide persistent surveillance of bin Laden's compound in Kandahar Province, known as Tarnak Farms.

Secret, CIA-run surveillance missions using a detachment of Predators produced real-time footage of people at the compound amongst whom analysts believed they had found bin Laden himself. Having discovered him, this mission then served to turn up the further problem that though Predator could provide seemingly 'actionable' intelligence, the time taken to act on that intelligence was such that by the time a missile arrived the situation could have changed substantially. Once again the endurance drone concept long advocated by Karem appeared uniquely suited to addressing an emerging and entirely unforeseen contingency. The palpable frustration of this realisation acted as a stimulus to the fast-tracking of incipient Air Force experiments in arming the Predator. A weaponised Predator, it was understood, put a qualitatively new capability in the hands of national security decision-makers and in that sense put a qualitatively new option on the table for addressing the problem posed by bin Laden in Afghanistan. Whether or not this capability would have been employed in the pre-9/11 context, however, remains far from certain.

Nonetheless, the decision to arm the Predator led to realisation of the potential legal and diplomatic difficulty that could arise if a missile was fired from Germany, in turn provoking further technical innovation in the system of remote control operations to enable firing from inside the United States. The process through which the Predator was developed to become capable of 'split operations', armed, and then further developed for 'remote split operations' seems to fit Posen's argument that in times of rising threat civilians intervene to override the inertial tendencies of military bureaucracies to impose military innovation. In this case the rising threat posed by bin Laden provoked the US government to grapple with a problem for which existing capabilities seemed inadequate, and began a search process for alternative capabilities.

Arming the Predator

Despite General Jumper himself driving the addition of a laser designator to some of the Predator fleet during the Kosovo campaign, the Air Combat Command (ACC) struggled to accommodate the move and, rather than making the addition permanent across the fleet, at the end of the Kosovo campaign the three modified Predators had the Raytheon laser designator turrets swapped out for the earlier Wescams. Although justified on the grounds that it did not fit established doctrine and of budgetary constraints, the addition of the laser designator had profound implications for the role and status of the Predator and this may have been an underlying factor behind the removal of the Raytheon turrets. With this capability, the drone was no longer confined to reconnaissance – which tended to be regarded as a second-tier and low-status task inside the Air Force – but also became capable of acting as a forward air controller, which involved the responsibility for directing munitions onto targets (Lambeth 2001: 95-96). Although from a technological perspective the swapping of one sensor for another looks like an incremental change, in this case it had major implications for the status of the system within the Air Force. General Jumper very clearly articulated this, stating that 'we had to stop considering this a thing that could be flown sort of by anybody' because the designator made it 'a system that is going to carry all the burden and weight of being able to put bombs on targets… in the Air Force, the people who hold that responsibility are credentialed warriors, who have to go through a training' (Jumper, quoted in Rosenwasser 2004: 356). While the formal reason for the decision to remove the designator turrets was the un-programmed cost of the modification (Lee 2016: 189), the organisational significance of this modification would not have been lost on the ACC bureaucracy, which may have been resistant to make such a move permanent at least without more detailed discussion. Bill Grimes, the Big Safari Director whose team installed the designators, told Lee '"[w]hen Kosovo ended, ACC took the laser designator off the vehicle as if it were a deadly parasite"' (2016: 208). It was another example of the difference between the standard acquisition mentality, with its emphasis on thorough processes and establishing solid foundations for new systems, and the quick reaction mind-set that wanted to continue exploring the potential of the technology rather than 'freeze' it where it stood at the point of transfer from the ACTD.

The addition of the designator had been driven by the acute frustration experienced in the course of operations. This recognition of needs in operations is analogous (on the user side) to the 'anomalies' that Constant identified (on the developer side) as creating sites of congregation for technical communities. General Jumper (then heading USAFE rather than ACC), however, appears to have interpreted the addition of the laser designator not as a temporary experiment but as a stepping stone to what he called the 'next logical step' – arming the Predator (Whittle 2014b: 169). This, again, implied a change in the status of the Predator within the Air Force that was likely to encounter resistance.

It was around this time that the idea of arming the Predator began to surface inside the Air Force. There is evidence that the idea of arming drones (an idea that had precedents dating at least to the DASH modifications of the Vietnam War, post-Vietnam experiments in which Mavericks and other TV-guided weapons were fired from modified Firebees, and some of the mini-RPV experiments of the 1970s) was circulating more widely during the mid-1990s. In 1996 it was tabled for inclusion in the defense authorisation bill by Senator Curt Weldon, who sponsored a provision adding $10 million to the draft text, expressly for the purpose of experimentally arming either Predator, Pioneer or Hunter (and adding a laser designator). The idea was reportedly "aggressively opposed" by DoD and excised from the bill (Bone and Bolkcom 2003; Whittle 2011: 13; Whittle 2014a: 171, citing private 2004 correspondence between Sen. Weldon and Sean Frisbee).[85] Another tributary towards

[85] Bone and Bolkcom refer to Hearing of the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee (2003) 'Fiscal Year 2004 Budget Request for Unmanned Combat Aerial Vehicles and Unmanned Aerial Vehicle Programs.' March 26.

armament traces to 1998, when the Air Armament Center (AAC) Commander, Major General Kostelnik, preoccupied with trying to build momentum behind an experimental weapon called the Small Smart Bomb (SSB), hit on the idea of firing it from the Predator. When he approached General Atomics to discuss the idea in 1999, he was told that the company had already been working on the idea – they had already begun work on the Predator B (which later became known as the Reaper) (Cullen 2011: 41, Lee 2016: 190, Whittle 2011: 15-16). The first General Atomics 'Predator', based on the Sadler Vampire (rather than the Karem lineage), had also been contemplated as a weapons platform (Ropelewski and Smith 1988). One of the Amber variants (the A45) had been designed as a dive bomber – blurring the line between drone and missile, it was a sort of optionally returnable loitering missile – but it appears not to have progressed beyond DARPA-sponsored research and development (Hirschberg 2010).

Yet in the mid-1990s, the notion of arming drones led to a completely different track of drone research involving the design of an altogether new kind of aerial vehicle – the unmanned combat aerial vehicle (UCAV). Pushed by Congress (in turn part motivated by concern about the perceived growing casualty aversion of the American public), the Air Force began to pursue a strand of research that was entirely different from the relatively slow, propeller driven, long-winged Predator. Stealthy, fast and manoeuvrable, this development spur suggests an underlying line of reasoning that held the fundamental tasks of warfighting relatively constant and contemplated gradually swapping out manned incumbents for unmanned. Predator, even armed, did not fit into this picture of the future combat environment owing to its perceived inability to survive in an anti-aircraft environment. Some in the Air Force, however, were thinking about the Predator not in terms of established warfighting tasks but as a possible solution to problems thrown up in Iraq, in Bosnia and in Kosovo. This list included the desire to gather reconnaissance data without risking the downing of aircrews, the need to get beneath cloud cover (necessitating lower altitude flight), the need to find and track mobile, often hidden or disguised, targets, to distinguish decoys, and to inform pre-strike collateral damage assessments and post-strike BDA (and therefore to shift from fleeting reconnaissance to persistent surveillance). In Kosovo the laser designator addition resulted from a search for more efficient ways to pass target information from drones to manned, armed counterparts to attack targets before they could slip away. With hindsight these trends can make the arming of the drone itself appear self-evident, a natural progression. Yet the proximate cause appears to have been Kostelnik's instrumental desire to advance the Small Smartbomb development. He arranged for the idea to be pitched to General Jumper, now heading ACC, at the Air Armaments Summit in March 2000. Jumper reportedly agreed to support Predator weaponization, provided that it did not require additional funding (Lee 2016: 191, Whittle 2011: 18).

Jumper claims that while heading USAFE during the Kosovo campaign he had understood the need to reduce what is known as the 'kill-chain' – the decision-making chain between locating and prosecuting a target – from tens of minutes to seconds (Rosenwasser 2004: 362). While the Air Force was undertaking work to make the process of passing target information from Predator to armed counterparts more efficient, Jumper afterwards claimed that at the time he thought that directly arming the drones was the best solution, combining a 'slow-moving "sensor" with a modestly-armed "shooter" to form a "hunter-killer"' (Rosenwasser 2004: 362). In Jumper's view, however, this option was largely screened out of Air Force thinking, since it necessitated a '"complete switch of mentality"' (Rosenwasser 2004: 362). Nonetheless, in a letter from ACC to Air Force Headquarters dated 1 May, 2000, Jumper's thinking on the subject clearly indicated that he now envisaged Predator growing from reconnaissance only to a 'FAC-like resource, with look-out, target identification, and target acquisition roles using the inherent and proposed EO/IR/laser targeting/laser designation capabilities and upgrades.' The letter, however, went further and supports Jumper's recollection: 'ACC, AFMC, and the Air Armament Center (Eglin) are moving out on the next logical step for USAF UAVs using Predator – weaponizing UAVs' (quoted in Whittle 2011: 17). With this letter, ACC expressed the intention to make the Predator its first operational, weaponized drone (the UCAV work remained experimental). Just as adding a laser designator had had social implications that made it much more than a mere technical modification, the step of adding weapons was, for 'technical, legal, and cultural reasons… a giant one' (Whittle 2015).

The CIA and the 'bin Laden Problem'

During the same period that the Air Force internal innovation processes around the laser designator and the question of UCAVs and weaponized Predators were unfolding, the White House and the CIA were becoming increasingly preoccupied with formulating an effective policy to address the growing threat posed by international terrorism. During the 1990s the reigning paradigm within which terrorism was framed and handled was law enforcement. Terrorists were treated primarily as criminals and the basic policy response was to seek to arrest and prosecute them for their crimes. Yet within the United States national security community, a persistent but sub-dominant perspective argued that the law enforcement approach might not be sufficient, and that the US should also have alternative approaches at its disposal. In particular, it was sometimes argued that the CIA should be authorised to undertaken covert action against terrorists, and that elements of the military's special operations forces might also be used for counter-terrorism purposes. During the 1990s, however, there was profound ambivalence regarding the use of such options. CIA paramilitary activities and special operations had both led to political firestorms in the 1970s and 1980s, generating reluctance on the part of political leaders as well as concern within CIA and DoD about recommending such activities.

Although concern about the Soviet Union had absorbed the bulk of US intelligence efforts throughout the 1980s, during that decade terrorism became an increasing problem. The April 1983 bombing of the US Embassy in Beirut (killing 63 people, including 17 Americans of which 7 belonged to the CIA station), the bombing of a US barracks in Lebanon that October (killing 241 US servicemen and injuring 60 more, with a second blast killing a further 58 French paratroopers), the kidnappings in Lebanon the following year, the 1985 hijacking of TWA flight 847 (in the course of which a US serviceman on board was murdered), the 1986 bombing of a West Berlin discothèque (the *La Belle*) popular with American service personnel (leading to retaliatory air strikes against Gaddafi in Libya), and the 1988 PanAm-103/Lockerbie bombing all contributed to a sense that terrorism was becoming an increasingly serious problem – reflected by a January 1986 Presidential Finding on terrorism and the creation of the Counter Terrorist Center at the CIA the next month (Fuller 2016: 89-95, Naftali 2005: 135-136). As recounted by Benjamin and Simon (2002) – who worked as aides to Richard Clarke during the Clinton administration – in the early and mid-1990s the problem persisted. With the February 1993 World Trade Center truck bombing, the Bojinka airline plot uncovered in the Philippines, both orchestrated by Ramzi Yousef (apprehended in 1995), the 1998 bombings of the US embassies in Nairobi and Dar-es-Salaam, killing 224 and injuring 5,000 people, bin Laden and al Qaeda announced the threat that they now posed. The foiled plots against the Radisson Hotel in Amman and Los Angeles international airport and botched attempt to attack the U.S.S. *The Sullivans* with an explosives-laden skiff in Aden harbour, intended as an orchestrated group of attacks and intended for the eve of the new millennium, further signalled the continuing threat to US intelligence. In October 2000, however, the plan of attack for the *The Sullivans* was to be successfully executed against the U.S.S. *Cole* in Aden harbour, killing 17 sailors and ripping a hole forty feet high and forty feet wide through the inch-thick hull of the $1 billion vessel.

By the time of the Cole attack the United States had been struggling, albeit somewhat fitfully, with the question of formulating the correct policy approach to the evolving problem of terrorism for decades. For all the trillions invested in military forces and technology and in the intelligence agencies, the United States lacked suitable tools. More deeply, those concerned with terrorism in the White House, CIA and elsewhere across the United States government 'struggled to reframe their understanding of terrorism, discard old, deeply held beliefs, and formulate a new notion of what the United States needed to do to confront a fast-changing threat' (Benjamin and Simon 2002: ch. 6). Indeed, as Clinton arrived at the White House, the CTC confronted a variety of actors but was mostly (and understandably) focused on Hezbollah (backed by Iran) which bombed Jewish targets in London and Buenos Aires in 1994 and the Khobar Towers complex in Saudi Arabia in 1996. The Aum Shinrikyo cult with its sarin gas attack on the Tokyo subway, and white supremacists, such as Oklahoma City bomber Timothy McVeigh and Atlanta City Olympic Complex bomber Eric Rudolf, helped garner generic attention for terrorism but, as it turned out, further muddied the waters.

Driven by this mosaic of threats, however, this period was marked by efforts to develop new counter terrorism tools. These included the tracking of terrorist financing, offering bounties for wanted persons, and reviving the controversial practice of rendition (a policy pursued in the 1980s), which was pursued during operations in Bosnia (Woods 2015a: 37), and used to capture Ramzi Yousuf and leading members of al Gama'a al-Islamiyya, which attempted to assassinate the Egyptian President and in 1997 murdered 60 tourists in

Luxor, Egypt.[86] The 1995 Omnibus Counter-Terrorism Bill sought to strengthen domestic surveillance powers but provoked stiff public and Congressional resistance. The same year Clinton signed Presidential Decision Directive 39, the first counter-terrorism PDD since 1986 (which among other things made Richard Clarke, until then handling a 'Global Issues' portfolio under National Security Advisor Tony Lake, Clinton's counterterrorism director). PDD 39 sought to establish the principle that every department or agency that could contribute to counter terrorism should do so and to establish the principle of information sharing between FBI and the White House and NSC over domestic terrorism (Clarke 2004: 90-92). It emphasised the danger of a nexus between terrorism and Weapons of Mass Destruction (WMD), the need to protect critical national infrastructure from debilitating attacks, and affirmed the practice of rendition and the military's role therein (Naftali 2005: 237-246). In September 1996 Clinton requested, and received, $1.097 billion for counter-terrorism from Congress (Clarke 2004: 130).

Amidst the confusing 'rogue's gallery' of terrorist groups and threats, bin Laden did not initially stand out to counter terrorism officials (Naftali 2005: 260). By the time of his February 1998 fatwa/declaration of war against the United States, however, the research into terrorist financing, intelligence from the CIA Khartoum station (then headed by future CTC director Cofer Black), and especially the walk-in of Jamal Ahmed al-Fadl and resulting treasure trove of information, had identified bin Laden as more than just a 'terrorist financier'.[87] In 1995, when the assassination attempt on Egyptian President Mubarak was traced to Sudan, the interagency Counterterrorism Security Group (CSG) had considered direct action in Khartoum. When the Joint Staff briefed on plans for a special forces attack, however, they counselled against it. In a passage that illuminates the limited range of

[86] The term 'rendition' as commonly used refers to apprehension of a suspect either without the knowledge of the host government or its acknowledgement of such knowledge, meaning without the detainee passing through a court process in the country where they are detained. It is thus distinguished from extradition, which refers to a formal process, normally regulated by treaty, involving the transfer of a person from one sovereign jurisdiction to another and typically involving the legal system of the country of detention. The term 'rendition' is sometimes used as a blanket term for all instances of the transfer of persons from one sovereign territory to another – thus encompassing extraordinary rendition and extradition. The rendition programme led Ayman al-Zawahiri to declare that Islamic Jihad would respond 'in a language [the American's] will understand' (Woods 2015a: 37-38). Regarding attempts to go after terrorist financing, Clarke (2004: 98) describes how efforts to raid the Holy Land Foundation, which was providing financial support to terrorism, were opposed on grounds of bank secrecy and concerns about alienating Arab Americans.

[87] Al-Fadl walked into the US Embassy in Eritrea having embezzled money from bin Laden, and entered FBI witness protection in the US. See Mayer (2009) ch. 6.

options available to the United States at the time, Clarke quotes National Security Advisor Tony Lake saying of the military proposal '"[t]his isn't stealth… It's going to war with Sudan,"' and the military briefer replying, '"[t]hat's what we do, Sir. If you want covert, there's the CIA."' The CIA, however, had no such capability in Sudan (Clarke 2004: 141).[88] Under pressure from the US and the UN, Khartoum asked bin Laden to leave and assisted him in doing so (leasing an Afghan jet for the purpose). By spring 1996 he had returned to Afghanistan, where he had earlier played a prominent role in the anti-Soviet jihad, and in which he had continued to run training camps that taught recruits from around the world. He stayed first in Jalalabad, then controlled by a regional *shura* dominated by Haji Qadir (and not under Taliban control), but it seems that he soon built stronger relations with the Taliban and moved on to Kandahar, heartland of their increasingly powerful and ambitious movement (Coll 2004: 325-328). That year, CTC had opened a dedicated bin Laden issue station, codenamed Alec. Rather than a physical station opened in Khartoum, Alec was a prototype 'virtual' unit that attempted to take advantage of new technologies and act as a focal point bringing together multiple sources, including NSA intercepts (Coll 2005: 310). The unit, and Richard Clarke at CSG, started working up plans to act against bin Laden and his associates in Sudan, but before their efforts could be developed or cleared, bin Laden relocated.

Bin Laden and the Afghan Sanctuary: "a dearth of bright ideas"

Bin Laden's move to Afghanistan made the task of capturing him even more difficult than it had been in Sudan. In 1996 the country was embroiled in civil war, the nominal government was in tatters and the Taliban movement was on the rise. Having had deep links with the mujahedeen resistance during the Soviet occupation, the US had since closed its embassy, withdrawn most of its CIA connections, and even pulled out USAID humanitarian assistance. The White House, CSG, and CIA looked at a number of options. The threat posed by bin Laden was considered serious enough by CTC that plans to somehow

[88] In 1996 Clarke reports that CIA Director George Tenet vetoed an extraordinary rendition operation against an al Qaeda operative in Khartoum while DoD again supplied options that amounted to going to war with Sudan. Clarke's view is that '[w]hether it was catching war criminals in Yugoslavia or terrorists in Africa and the Middle East, it was the same story. The White House wanted action. The senior military did not and made it almost impossible for the President to overcome their objections', while letting 'the word spread down the ranks that the politicians in the White House were the ones reluctant to act' (Clarke 2004: 145).

snatch him from Afghanistan were being considered, although as 1997 drew to a close recently-confirmed CIA Director Tenet (who had been the departing John Deutch's deputy) perhaps reflected the broader CIA opinion that bin Laden remained a fairly low priority next to issues such nuclear, chemical and biological weapons proliferation (Coll 2004: 366).[89] During the Soviet occupation between 1979 and 1989 the CIA had maintained close working relations with the Pakistani government and particularly the Inter Services Intelligence (ISI) service in order to support the anti-Soviet mujahedeen resistance. Following the Soviet withdrawal, the 1989 closure of the US embassy in Kabul and the collapse of the Soviet-backed Najibullah government in 1992, however, CIA contact had dwindled to the point of virtual non-existence. This was part of a post-Cold War trend in which the CIA divested from much of the developing world.

The one remaining active connection between the CIA and a network with links into Afghanistan was related to an attempt to locate and, if possible, capture Mir Amal Kasi. In 1993, while in the United States, Kasi had fired upon CIA workers queuing to enter Langley. Having killed two people and wounded three more, incredibly, he managed to escape to Pakistan and was hidden by inhabitants of the border areas of Afghanistan and Pakistan. To pursue him the CIA contacted families who had fought the Soviets and who could travel across the Durand line separating Pakistan and Afghanistan. This old network was reactivated under the code name FD/TRODPINT and provisioned with hundreds of thousands of dollars, weapons and geolocation equipment (Coll 2004: 372). The team and their CIA handlers worked up plans to mount an operation to capture Kazi inside Taliban-controlled parts of Afghanistan in case he could not be lured to Pakistan (which he ultimately was). Kasi was eventually betrayed by those sheltering him. In summer 1997 the TRODPINT group was passed to Alec Station.

The idea was to use this 'tribal' team to capture bin Laden, hold him in a pre-prepared cave somewhere near Kandahar for up to 30 days, and then summon an American special forces team to collect him.[90] For the operation to proceed, however, the CIA envisaged either a Federal indictment against him or either Sudan or Saudi Arabia accepting

[89] This is surprising given that al Fadl reportedly told his interrogators that bin Laden had attempted to buy uranium (Coll 2004: 367).

[90] The legal basis for the operation was President Reagan's Executive Order 12333, which allowed such pursuit but forbade assassination.

him for trial. The thirty-day holding period was offered since although the 'concept' of the capture plan was approved, an actual indictment remained pending and the US was reluctant to contact other governments until bin Laden had been captured. Bin Laden was traced to a fortified compound, known as Tarnak Farms, located roughly three miles from Kandahar airport and surrounded by 10-foot walls. The first cut of the plan therefore involved waiting for him to leave the compound and attempting to ambush the (well-armed) convoy he would travel in. The CIA was informed of an unsuccessful ambush on the road outside the compound in 1997. After this point they focused on a night raid on the well-defended Tarnak Farms compound to try to snatch him from there (Coll 2004: 375-379). The operation was rehearsed in the United States on at least three occasions in late 1997 and 1998 and the proposal sent to the White House for approval.

The plan was very deliberately formulated as an attempt to render bin Laden to justice and it was made very clear to the team that this was not to be an assassination attempt. As George Stephanopoulos, a White House adviser to Clinton during his first term, wrote, 'of all the words you just can't say in the modern White House,… none is more taboo than "assassination"' (Stephanopoulos 1997: 34). Indeed, a well-established tradition of Presidential Executive Orders affirmed this as official policy. In the wake of the Church Committee's investigation of US involvement in plots to assassinate foreign leaders, in February 1976 President Ford had issued Presidential Executive Order 11905 banning 'political assassinations.' Ford's ban was superseded by Carter's E.O. 12036 of January 1978, which extended the ban to encompass proxies and contractors. Reagan's E.O. 12333 reaffirmed the ban. His administration was divided, however, as to whether the ban applied to terrorists. Secretary of Defense Weinberger advocated recourse to the UN and treating terrorism as criminal activity rather than a threat to national security. Others, including Secretary of State Schultz and CIA Director Casey, advocated a more aggressive strategy that was eventually embodied in National Security Decision Directive 138. Though signed by the President, this directive was never fully embraced (Fuller 2015: 773-779). The Iran-Contra scandal, which engulfed some of the key figures advocating the more aggressive approach to terrorism (including Col. Oliver North), may have contributed to NSDD 138's lack of traction.

During the Clinton years, there were calls in Congress, and in the media, to reconsider the assassination ban – notably in relation to terrorism and Iraqi President

Saddam Hussein (Thomas 2000: 105 fn.3). Amongst those favouring lethal action against terrorists, one strategy – which was developed by CIA Director William Casey and CIA Chief Counsel Stanley Sporkin in the 1980s – was to argue that the term 'assassination' applied narrowly only to state leaders, and therefore that the Presidential ban on assassination did not apply to terrorists (Fuller 2015: 779). Yet, as Tenet notes in his memoirs, the 'policy of the U.S. government [in the 1990s] was to treat terrorism as a law-enforcement problem' (Tenet 2007: 108). For this reason the Presidential authority granted to the CIA and the TRODPINT team in a Memorandum of Notification of May 1998 was carefully worded to provide latitude for the team to use self-defence in a capture attempt, but not for assassination (Rizzo 2014). During preparations it was continually emphasised that this was to be a capture attempt and *not* an assassination. It was recognised that bin Laden and his bodyguards would be likely to resist and accepted that he may be killed during the attempt. This would be legally acceptable provided it happened in the course of a sincere effort to apprehend him. Despite wanting bin Laden captured, as thoughts turned to a raid on the compound Clarke was reportedly concerned that it would likely result in some combination of women and children being killed, bin Laden escaping, and the operation further enflaming anti-American sentiment. He also apparently thought that the team were likely to be 'mowed down' as they approached the perimeter wall, which was defended by machine gun nests and tanks (Coll 2004: 395, Clarke 2004: 149).

Beyond concerns about the viability of the operation, the 9/11 Commission later recorded that that assistant head of the CIA Directorate of Operations, James Pavitt, seemingly 'thought the operation had at least a slight flavour of a plan for an assassination' (9/11 Commission 2004: 113). The CIA senior chain of command was reportedly unanimous in advising against the operation. Sandy Berger was worried that the evidence against bin Laden was too thin and that he might be captured only to be acquitted. Even Schroen, who called it '"the best plan we are going to come up with to capture [bin Laden] while he is in Afghanistan"' gave it about a 40% chance of success (9/11 Commission 2004: 112, 114). By May 29 the 'tribals' plan had been called off with a request that they look at the possibility of another ambush attempt on the road between Tarnak Farms and Kandahar City. Tenet states that he took the decision not to proceed with the Tarnak Farm attempt, so it was never presented to the White House for final approval (9/11 Commission 2004: 114). In his memoirs, he wrote '[a]lthough there were a number of opportunities, we could never get over the critical hurdle of being able to corroborate Bin Ladin's whereabouts, beyond the single thread of data provided by Afghan tribal sources. Policy makers wanted more' (Tenet 2007: 109). Around the same time, Clinton instructed Tenet to travel to Riyadh to explore the possibility of Saudi intelligence making contact with the Taliban. The Saudi intelligence chief eventually secured a pledge from Mullah Omar to expel bin Laden – but no action followed. Following the dropping of the tribals plan, the notetaker at a CSG meeting recorded a '"dearth of bright ideas around the table"' (9/11 Commission 2004: 115).

Once again, the question presented itself: what to do about bin Laden and his network more broadly? When the military was asked to present options, they looked like going to war. The covert channel was blunted by bin Laden's retreat to a place where the CIA had very limited contacts, and the concrete option that had been formulated to capture him had been subject to a range of objections, not least feasibility and political risk. Expressly forbidden from planning assassination attempts, capture attempts were the covert channel option.

The East African Embassy Bombings: military retaliation and political fall-out

The East African Embassy bombings of 7 August, 1998 rocked the Clinton administration. Intelligence evidence quickly made clear that al Qaeda were behind the attack (Naftali 2005: 264-265). Treating it as an 'act of war', the administration contemplated retaliatory military strikes against bin Laden and al Qaeda. In the wake of the embassy bombings, Clinton wrote in his memoirs, he 'became intently focused on capturing or killing [bin Laden] and with destroying al Qaeda' (Clinton 2004: 441). The White House considered a range of military options, including unconventional or low-grade warfare led by special forces, and gunship attack raids on Tarnak Farms, but quickly settled on Tomahawk cruise missile strikes. They had in mind the precedents of Reagan's strikes against Libya and the strike against the Iraqi intelligence services in response to their 1993 plan to assassinate former President George H.W. Bush in Kuwait. The JCS had already directed CENTCOM to make plans for such strikes before the embassy bombings and they identified 8 training camps in Afghanistan, including Tarnak Farms (9/11 Commission 2004: 116). The CIA then received intelligence about a leadership meeting at Zawar Kili, in Khost Province. Opinion varied about the quality of the intelligence, the likelihood of bin Laden attending and the likely efficacy of a missile strike. Clarke remembered that when Tenet gave information about the meeting and a missile strike was tabled, '[t]he Principals were resolute: if al Qaeda could issue fatwas declaring war on us, we could do the same and more to them' (Clarke 2004: 84). Sandy Berger told the 9/11 Commission '"I assure you they were not delivering an arrest warrant… The intent was to kill bin Laden"' (cited in Naftali 2005: 265). In addition, the al Shifa factory in Khartoum, financially linked to bin Laden, was added to the list of targets after EMPTA, a chemical precursor for VX nerve gas, was detected there in late 1997.

The decision to use missiles strikes in this way was framed as a military action, justified in terms of right of self defence, and was to be conducted by the military. This approach avoided the need for the secret Presidential findings that would be required for the CIA to undertake any kind of raid using ground forces, and thereby seemingly avoided the necessity of debate about the legal basis of the attack and whether it amounted to an assassination. Clarke states that the successive legal authorities developed by Clinton did not apply to missile strikes 'because our interpretation of the military's authority is that they can fire missiles when ordered to do [so] by the commander in chief without regard of whether or not there is a finding or an MON. The finding and the MoN are not designed for overt military action; they are designed for covert CIA activity' (Clarke 2002: 19).

Cruise missile strikes were launched on 20 August against both targets. They were not a success. While the meeting at Zawar Kili appears to have taken place, bin Laden and the senior leaders had left by the time the missiles hit the complex (9/11 Commission 2004: 117). The strike made clear that even on rare occasions when the US received intelligence not about where bin Laden had been but about where he would be, missile strikes still might not succeed. '[I]n hindsight', wrote Tenet 'I'm not certain at the time we fully comprehended the missiles' limitations. The slow-flying missiles are a good choice for taking out fixed targets such as pharmaceutical factories but are far less ideally suited to targeting individuals who wander around during the several hours between the time the missile is launched and when it lands at its preprogrammed spot' (Tenet 2007: 116). The flight time from the Arabian sea to Khost was some two hours, flying through Pakistan's air space.

The destruction of the al Shifa plant caused a media storm and Clinton was accused of trying to distract attention from the domestic scandal about his relationship with a White House intern. Beneath the media criticism, however, the cruise missile strike in Afghanistan had proven ineffective (Gormley and Speier 2003). Charged with planning further strikes (Operation Infinite Resolve), the Pentagon now began to push back, arguing that the rationale for strikes was not sufficiently defined and pointed to the lack of targets in Afghanistan. Navy ships and two submarines were nevertheless stationed off Pakistan with the idea that the CIA's Afghan team might locate bin Laden and, if he was not at a location already pre-programmed into the submarine cruise missiles, they could use their geolocation equipment to direct a strike. The missiles would again have to overfly Pakistan, and this approach still did not overcome the difficulty of the transit time of the missiles from submarine to target and the possibility that the situation on the ground would change while the missile was en route. Other military options – including the possibility of special forces AC-130 'Spooky' gunship attacks and the use of 'boots on the ground' special forces attacks – were tabled but did not develop, possibly screened out by reluctant military commanders (Schultz 2004). The 9/11 Commission reported conflicting versions of events but did not definitively establish why these plans did not develop.

In late 1998 the CIA received a single source of intelligence about bin Laden's whereabouts, but, unable to verify with a second source, missiles were not fired. During February 1999 intelligence was received indicating that bin Laden was on a hunting trip in Helmand province. Again the team was dispatched, satellite imagery gathered and analysed, and the matter debated over five days. Out of fear that members of the UAE royal family were present, doubts about the intelligence and concern about political embarrassment, the missiles were not fired. That May, the CIA learned bin Laden was in Kandahar and monitored him for five days and nights. Again no action was taken, and the 9/11 Commission Report did not establish why, pointing only to the differing perspectives of differing participants, although it speculates that a further missile strike may have been blocked on political grounds in view of the bombing of the Chinese embassy in Belgrade during the NATO campaign that month. No further cruise missile attacks were contemplated after this point.

The missile strikes had not been the sum of the US response to the Embassy bombings. They had drawn up a more comprehensive plan, in which Clinton imposed sanctions on bin Laden and the counterrorism policy sought to combine diplomatic pressure, financial disruption and covert action inside Afghanistan. A sustained campaign of missile strikes against al Qaeda and Taliban targets was also contemplated, but this last was unanimously rejected by Clinton's national security team as too '"bomb happy"' (Coll 2004: 421).

In mid-1999 Cofer Black, former CIA station chief in Khartoum, became CTC head and sought to push a more aggressive agenda. At his behest contact was made with the Uzbek regime of Islam Karimov, whose country shared a border with Afghanistan and against whom bin Laden was supporting the Islamic Movement of Uzbekistan. Meanwhile, the possibility of working more closely with the remaining Afghan resistance to the Taliban was more carefully explored. Contact with this resistance had begun to be re-established in September 1996 when Islamabad station chief Gary Schroen flew to Kabul to meet veteran guerrilla commander Ahmed Shah Massoud, then-defense minister in the collapsing Afghan government. During the Soviet occupation Schroen had personally delivered cash stipends to Massoud's group, but those connections had ended in 1991 (Coll 2004: 3). The main purpose of Schroen's visit was a CIA project to buy back missing stinger missiles passed to the rebels during the Soviet occupation.[91] The pair also discussed the possibility of Massoud using his networks to try to locate bin Laden. Nothing was firmly agreed and Schroen returned to Islamabad the next day. Less than a week later the Taliban drove Massoud from Kabul. By 1999, CIA teams from Islamabad and from Washington had made repeated visits to Massoud at Taloquan in northern Afghanistan. At the behest of Cofer Black and his team, the CIA began to use this relationship to seek information on bin Laden's whereabouts, though Schroen and others stationed in Islamabad doubted Massoud's ability to penetrate Taliban territory.

It appears that in 1999 the net result of shared dissatisfaction with the status quo and a great deal of time invested in searching for solutions to the bin Laden problem yielded little more than paralysis in Washington. In early 2000 the Derunta camp near Jalalabad became subject of interest. The northern alliance forces had much better networks in this part of Afghanistan than they did around Kandahar; a satellite was re-positioned and pictures examined. Massoud's men were provided with 'an optical device, derived from technology used by offshore spyplanes' capable of producing imagery from ten miles away (Coll 2004: 492). Massoud had his men make a Katyusha rocket attack against the facility,

[91] Massoud, in any case, had received just 8 of the more than 2,000 stingers passed to the rebels but made positive noises about selling them back and also agreed to make contact with other commanders across the north to explore further missile recovery.

provoking further dismay among CIA lawyers – proxy forces could only be supported in capture attempts. That spring, frustrated by the still-sketchy intelligence, Clarke brainstormed yet again. The CSG considered a range of options, including placing tracking devices on bin Laden's plane, a phony television tower to act as long-range spy camera, and the possibility of using the special forces extraction teams used to pursue suspected war criminals from the Yugoslav wars to monitor Tarnak Farms and other locations of interest. Nonetheless, even after two of its embassies had been bombed, the United States seemed unable to formulate good response options whether diplomatic, military or covert. In Afghanistan, bin Laden appeared beyond their reach.

Afghan Eyes

The CIA was unable to provide the kind of intelligence on bin Laden's whereabouts and movements to enable the US to take action with the means then at its disposal. Before authorising action, the White House wanted corroboration of scanty human intelligence accounts; the information they were receiving often came from a single source. As Tenet recalled, 'we could never get over the critical hurdle of being able to corroborate Bin Laden's whereabouts, beyond the single thread of data provided by Afghan tribal sources. Policy makers wanted more' (Tenet 2007: 109). Some form of technical collection seemed the only way to provide this kind of corroboration (Crumpton 2012: 148). The existing technical means were of limited use. The time delay between satellites taking pictures and the images being interpreted meant they were not 'actionable' – a problem mirrored in the way Serbian forces were employing dispersion, mobility and disguise in 1999. Paralleling the Bosnia experience, U2 and satellite reconnaissance 'could not single out mobile targets or individual faces' (Coll 2004: 527). As the 9/11 Commission observed, '[s]ome of the advanced technologies that gave [the US] insight into the closed-off territories of the Soviet Union during the Cold War are of limited use in identifying and tracking terrorist individuals' (9/11 Commission 2004: 88).

Related to this was the difficulty not of knowing where bin Laden had been, but where he *would* be. Particularly when contemplating missile strikes, the missile flight time, plus the time needed for decision-makers to discuss the possible strike and make the decision to fire, might mean a lead time of six hours (Mazetti 2013: ch.5). By then, even assuming bin Laden was identified, he would likely have moved on. Meanwhile, there was the risk that the situation on the ground might change whilst the missiles were on their way, creating a risk of civilian casualties. Finally, despite the vaunted precision of cruise missile strikes, their accuracy was not perfect. A celebrated artist, Layla al-Attar, had been among those killed in the 1993 missile attack on the Iraqi intelligence services (Reuters 1993). During the August 20 1998 missile strikes, one wayward missile landed not in Afghanistan but in a village in Pakistan, killing several people (9/11 Commission 2004: 134).

Clarke later recalled that the difficulties of getting actionable intelligence 'caused us to look for another way of finding bin Laden, and we asked the community management staff and the JCS-3 to look at finding a second source of information about where bin Laden was, so that when we had intelligence information from HUMINT sources that he was at a particular location, we could confirm it' (Clarke 2002: 10).[92] Mazetti reports that in fact due to his 'frosty relationship' with both Tenet and Pavitt (Head of the Directorate of Operation), Clarke 'decided to go around them' by asking Charles Allen, the CIA Assistant Director for Collection, to conduct 'an independent review of various options for spying in Afghanistan' (Mazetti 2013: ch.5). Mazetti argues that Allen worked with personnel from the Pentagon Joint Staff to consider a range of options. According to the 9/11 Commission, in 'late 1999 or early 2000' Vice Admiral Fry, the Director of Operations on the Joint Chiefs (i.e. the JCS-3) assigned his chief information operations officer, Air Force Brigadier General Gration to 'develop innovative ways to get better intelligence on Bin Ladin's whereabouts' and get 'reliable eyes on Bin Laden in a way that would reduce the lag time between sighting and striking' (9/11 Commission 2004: 189).

It was in the course of this brainstorming that the Predator first entered the discussion about the problem of bin Laden and his Afghan sanctuary. One suggestion was to use long-range cameras to hold a location that bin Laden was known to frequent under surveillance. It was further suggested that a Predator reconnaissance drone could be used to keep him under observation while the decision was made about whether to attempt to

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[92] 'Community Management' refers to the CIA Office of the Director of Community Management, and 'JC3' refers to the Joint Chiefs of Staff Directorate for Operations. See US Senate Select Committee on Intelligence and US House of Representatives Permanent Select Committee on Intelligence (2002).

snatch him or to launch a missile strike. Someone, somewhere, had made the connection between the loitering surveillance capability of the Predator and the problem of locating bin Laden and holding him under surveillance long enough to act. Crumpton credits 'Alec', whom he describes as a Pentagon intelligence specialist seconded to the CTC (Crumpton 2012: 150).[93]

At the CIA, reaction to the idea was divided. Mazetti reports that there was a great deal of internal disagreement within the CIA about using the Predator to try to spy on bin Laden, with DDO Pavitt and DCI Tenet sceptical but Charles Allen (Director for Collection), Cofer Black (CTC chief) and Richard Blee (head of Alec Station) all in favour. He reports that the issue came to a head in a meeting 'that quickly degenerated into a shouting match' (Mazetti 2013: ch.5). The main objections centred on drawing funding from other areas of the CT effort, the risk of them crashing or being shot down in Afghanistan, and the question of where they would be based: at the time, writes Mazetti 'the idea of the CIA establishing military-style bases anywhere in the world seemed crazy' (Mazetti 2013: ch.5). Crumpton (2012: 151) reports that CIA Special Activities Division pushed their own UAV, which lacked the satellite data-link against Predator – an interesting aside that belies the CIA's central importance in the Predator's emergence in the first place. When Black was overruled by DDO Pavitt, however, he simply went to Clarke at CSG who, as Black predicted, wanted to try something new (Whittle 2014a: 146).

On April 25, 2000 Clarke circulated a memo entitled 'Afghan Eyes'. Momentum swung behind the project thanks to a network of high level advocates across the involved government entities that was capable of over-riding internal resistence within the CIA. After months spent debating how the operation would be funded resources were eventually allocated (DoD would split the cost with the CIA) for a 60 day trial run (9/11 Commission 2004: 189, 506 fn. 113). Frustration at the White House level as well as within the CT community had now reached such a fever that the weight of internal objections on the part of senior CIA leaders could be overcome with a little bureaucratic guile.

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[93] In fact, Whittle states, ADCI for Intelligence Collection, Charles Allen, had 'already worked a bit with General Atomics when the company sold the CIA the Gnat 750s the Agency flew over Bosnia from Albania in 1994' but prior to this brainstorming 'hadn't thought of using a UAV to solve the problem that had vexed him for almost two years' (Whittle 2014a: 146).

Flying Predators over Afghanistan immediately suggested a significant political obstacle. Those neighbouring countries that might be willing to allow the operation would only do so if the presence of the American teams flying the drones into Afghanistan could be kept secret. During Bosnia, Iraq and Kosovo the Predators had been flown from friendly countries and forward deploying the relevant crews and equipment had not been a problem. For Afghan Eyes such a visible presence was not going to be possible. As it turned out a technical solution proved to be forthcoming.

The scientist who had earlier demonstrated live Predator FMV of events in Arizona to an assembled audience in Washington came up with the idea. In Bosnia the first Gnat deployments had used C-band line-of-sight control for take-off and landing, to control the drone during its flight, and to recover sensor data. The satellite on the ground control station was then used to send that data back to the US via a satellite in space. Efforts were then made to extend the effective range by means of a relay aircraft that maintained direct line of sight with both the GCS and the drone. Experiments were then conducted on the Gnat to control it indirectly via a satellite link. Initially the links were low bandwidth, enabling remote control and limited sensor data recovery but not real-time FMV transmission. Subsequently, higher bandwidth connections were achieved using the ku-band frequency. With this arrangement it became possible to control the drone over the horizon using the satellite on the ground control station, provided a satellite was positioned overhead within the 'footprint' of which the ground station was sited and within which the drone remained. Due to the slight delay in sending and receiving information due to the enormous distances and the fractions of time taken by the computers, for take-off and landing forward-deployed pilots switched back to C-band line of sight control to begin and end the flights.

Identifying a suitable satellite in orbit covering Europe and Central Asia was no mean feat. The CIA would have to lease commercial bandwidth, which was scarce at the time owing to international media preparations to cover the Sydney Olympic Games (Mazetti 2013: ch.5). The scientist was able to borrow a large satellite dish from ACC and have it flown to the US base at Ramstein in Germany, home of USAFE (Whittle 2014a: 152-153). The majority of the equipment and personnel needed for the Afghan Eyes operation could be based there. Crews could work rotating shifts during the Predator's long flights, resting in relative comfort at shift's end. Meanwhile, a minimal CIA-led team of two contractor pilots and two mechanics (called a 'launch and recovery element' (LRE)) would be discretely sent to an airfield in one of Afghanistan's neighbours. They would take with them 'a suitcase-sized line-of-sight control and UHF datalink system' to launch the drone using the line of sight link, whereupon the team in Germany could take over using the satellite connection and fly the mission from there (Grimes 2014: 332-333). Sensor data and communications from Ramstein to the CIA in Langley, Virginia would then use existing undersea fibre-optic cable connections. An operations centre was set up at the CIA, where Air Force and CIA personnel worked 'from midnight to dawn, watching black-and-white aerials of Afghanistan unfurl eerily before them' (Coll 2004: 532). Clarke recalls it was a capability that until then they 'had only seen in Hollywood movies' (Clarke 2004: 220). When necessary, the detachment in Ramstein would then return the drone to its point of origin, where the waiting, forward-deployed detachment would resume control for landing and undertake necessary maintenance and preparation for subsequent flights (Whittle 2014a: 152, Michel 2015).

The scientist called this arrangement 'split operations'. To contemporary participants the technical accomplishment seemed like something from Hollywood movies or science-fiction. Yet the technical achievement had important implications for debates about the political viability of a sensitive espionage mission. The launch and recovery element was very small and very discreet, useful for keeping the mission secret. Yet the satellite relay meant that information from the mission could be shared and studied in all-but-real time, drastically reducing lags between gathering data, analysing data, and making decisions. Rather than the fleeting reconnaissance available from existing collection platforms, moreover, the Predator could loiter above Tarnak Farms for hours on end. The Predator afforded a capability that had been lacking: persistent surveillance.

While work on the Predator and the system of technical control was underway, the CTC sought to draw together as much information (including IMINT, SIGINT and increasingly HUMINT) as they could from multiple sources to help decide where to fly the drones, including NSA liaison, NRO satellite imagery and intelligence from foreign intelligence organisations. Crumpton recalls that '[f]iguring out how to build and manage an interagency team' to fly the drones was 'a monumental technical, operational, and leadership challenge' (Crumpton 2012: 152). More than a dozen agencies were essential (including Defense Intelligence Agency (DIA) and National Imagery and Mapping Agency (NIMA)), he states. His aside is an indication that, from an early stage, exploiting the capabilities afforded by Predator necessitated not only organisational accommodation on the part of the CIA, but wider change in interagency working relations.

Flights began from Uzbekistan's Khanabad airfield, close to the border with Afghanistan, in September 2000 (Woods 2015a: 39). The group flying the missions was designated the 32nd Expeditionary Air Intelligence Squadron. It was a mixed group including GA-ASI staff, pilots and sensor operators 'borrowed' from ACC's 11th Reconnaissance Squadron, Big Safari Predator project staff, and CIA personnel (Grissom et al 2016: 78). The small launch and recovery element forward-deployed at the Uzbek airfield would launch the drone, and then hand off control to their counterparts in Ramstein for the duration of the mission, then retake control to perform the landing manoeuvre. Contrary to the initial scepticism expressed about the mission inside the CIA, the results were seemingly impressive. On two occasions, the crew operating a Predator discretely circling above the Tarnak Farms compound believed they had spotted bin Laden, seeing what seemed to be a tall man in white, flowing robes surrounded by a security detail (9/11 Commission 2004: 190). Clarke remains 'convinced that I was looking at bin Laden' (Clarke 2004: 221).

The crew thought a cruise missile would be dispatched whilst their drone continued to circle above. None was fired. The reason given in Washington was that it would take several hours for a missile launched from the Indian Ocean to arrive in Kandahar and the fear was that by the time it arrived, the situation would have changed. This was analogous to the situation previously faced in Kosovo: having used a Predator to locate a target, there was still no way to act on that information. On one occasion, Taliban MiGs were sent to investigate a strange radar signal. The Predator crew expected to be shot down but the drone proved surprisingly difficult for the pilot to spot, indicating that although it was not 'stealthy', it nonetheless was not easily detectable. Autumn turned to winter and, with these issues still unresolved, the weather-sensitive Predators were withdrawn. Former CIA Director Tenet later told the 9/11 Commission that Afghan Eyes illustrated that 'we did not have a timely response option, even if the policy decision had been made and weapons were positioned and ready' (Tenet 2004). Crumpton remembered '[w]e had bin Laden in our electro-optical sights, but we had no realistic policy, no clear authority, and no meaningful resources to engage the target… [i]t was all sadly absurd' (Crumpton 2012: 155).

Air Force-CIA Convergence on Arming Predator

In Washington, the dawning realisation of this problem during Afghan Eyes explains an abrupt uptick in the schedules and sense of urgency in the Air Force Predator weaponization project that was underway at the same time. In the same way that frustration in Kosovo generated the impetus for the WILD Predator, to the CIA, Air Force and contractor personnel involved in Afghan Eyes it was obvious that if the Predator had been armed they could have fired on a person that they believed was bin Laden. As the CIA observers in Langley received the drone footage coming in from Afghanistan, several people began to argue that rather than linking the drone's sensors to cruise missiles launched from Arabian Gulf, which would take time to reach a target in Afghanistan, it would make more sense to arm the Predator itself. A senior Pentagon official involved in this process recalled that when the footage obtained of bin Laden (or the person believed to be bin Laden) was shown to the Secretary of the Air Force, Air Force Chief of Staff and the Assistant Vice-Chief, directions were given to step up the arming schedule already under consideration (Woods 2015b).

The original Air Force schedule of a weaponized product by 2004 was hastily brought forward. The SSB munition proposal advanced by Kostelnik, which had initiated Air Force armament discussions around Predator, was dropped. Only a few other small enough munitions had been shortlisted as possibilities, and of those the Air Force soon settled on the Army's anti-tank AGM-114 Hellfire missile. Among its advantages were that it was already operational and that it was designed for use with the Raytheon AN/AAS-44(V) lasing sensor turret introduced onto Predators in Kosovo and would also work with the AN/AAS-52 Multi-Spectral Targeting System (MTS) underway to replace it. Lee reports that when General Ryan and General Jumper approached ACC and the Air and Space Directorate for support with arming, they encountered resistance and thereafter turned to Col. Boyle, the Director of Intelligence at USAFE, who had carried responsibility for the Ramstein portion of the Afghan Eyes operation (Lee 2016: 193). In July 2000 Jumper received an accelerated 3 month timetable for the experiment from the Air Force but GA-ASI (the Predator contractor) claimed it could be done in two months for $2 million. A deal was struck. The interest from outside the Air Force is suggested by the fact that Clarke's deputy, Cressey, on the NSC staff was dispatched to watch the firing experiments.

The technical problems involved in this modification proved to be more easily surmounted than the institutional and legal obstacles. The modification required Congressional consent via a New Start Notification since it had not already been approved in the appropriations process (Frisbee 2004: 68). While this was granted it delayed work since Air Force lawyers forbade 'touch labour' until formal approval was received. The most serious legal question, however, hinged on whether the armed Predators were deemed to constitute a ground-launched cruise missile under the terms of the 1987 Intermediate-Range Nuclear Forces Treaty (INF). The INF banned ground launched cruise missiles with ranges between 500-5,500km, and defined cruise missiles and 'weapon-delivery vehicles' in such a way as to include both dive-bomber type drones and those acting as weapons delivery platforms. Drones performing non-lethal tasks were permitted as category D 'cruise missiles' as defined under the Senate weapons acquisition guidelines on this issue (Rosenwasser 2004: 139-140). Yet following the ratification of this treaty, Rosenwasser argues, 'the entire national security establishment thought that armed UAVs were outlawed, and DoD had precluded such efforts for the past 13 years' (Rosenwasser 2004: 367). This appears to have been reinforced by institutional resistance – in an interview Major General George Harrison states his belief that the Pentagon and CIA '"reconnaissance mafia was dead set against armed, because if you armed it would divert you from your primary job of target development. So there was strong resistance, I mean strong resistance, I can't overstate it"' (quoted in Woods 2015a: 31).

The NSC set up a Compliance Review Group to address the issue of armed Predators and of the X-45 UCAV programme. Very interestingly, the Karem/General Atomics approach of treating their drone like an aeroplane carried the day. Since the drone took off and landed on a runway, the group determined, and because it would release weapons but itself return intact, it was ruled not to be a cruise missile. The same reasoning was applied to the X-45. This view was expressed in a secret December 2000 'discussion paper' which while not formal, established the government's position on the issue. When the view was set out to Russia, they 'raised questions but did not object' effectively acquiescing to the US government's desired view on the topic (Rosenwasser 2004: 368). With this, armed drones were no longer prohibited by international treaty.

New Start authorization was granted on 21 September and work began. The treaty issue, however, was still under review in October 2000 when al Qaeda struck again, nearly sinking the USS *Cole* in Aden harbor. The Clinton administration strongly suspected al Qaeda but Clinton told the 9/11 Commission that the necessary evidence to state this in public was not in place when he left office (9/11 Commission 2004: 194). Military plans were worked up for sustained attacks on both al Qaeda and the Taliban in Afghanistan, but not implemented. By then the Air Force had set Big Safari and General Atomics to work on the technical modifications whilst awaiting a legal opinion, but they were forbidden from physically attaching a missile to the Predator. A range of technical questions had to be addressed. They had to be sure that the wings would not be torn off by the launching of the weapon and the weapon had to be integrated into the Predator computer software. They had done all they could by mid-October and the new MTS sensor was not going to arrive from Raytheon until mid-December.

Legal clearance was granted around the time the sensor arrived, and the modifications commenced on Jan 2, 2001 (Whittle 2011: 22). President George W. Bush was sworn in later that month. Cofer Black and Richard Clarke immediately began urging the new administration to take bin Laden seriously, and keenly followed the progress of the armed Predator experiments. Firing tests began three days after Bush's inauguration. In February, armed missiles began to be fired from a Predator (Whittle 2014a: 189). In March a new phase of development began, involving the integration of software and the new MTS sensor ball, which was first demonstrated in early April (Whittle 2011: 23. Whittle 2014a: 194).[94] At this point, the CIA development track re-entered the picture with civilian engineers working on the Army Hellfire programme brought to the CIA to discuss how effective a Hellfire missile – intended to destroy tanks – would be against buildings and individual people (Whittle 2014a: 191-192). According to Whittle the team were shocked by the experience – indicating that the normative taboo against assassination extended well beyond the CIA. Yet the Big Safari team working on the project were under no illusions. The CIA had a contractor build a 'replica' of bin Laden's house at Tarnak Farms on the China Lake test range in Nevada, although far from a 'stone for stone replica' what was actually built

[94] The MTS sensor combined infrared, a longer-range laser designator compared with the AN/AAS-44(V) sensor, which could illuminate targets at ranges above five miles, as well as a daylight, colour video camera. It also became 'one of the first-ever "staring" infrared sensors… able to detect heat within its field of view the way a camera senses light, rather than producing an image by the less advanced scanning method used in the Forty-Four ball' (Whittle 2014a: 195). The new features were immature, and the Big Safari team experimenting with the new sensor were highly critical in the spring of 2001.

bore little resemblance to the compound (Gellman 2002, Whittle 2014a: 201). Watermelons were placed inside the compound, on the recommendation of a munitions expert from the Army Redstone Arsenal in Huntsville, Alabama, to approximate what the effects of the missile would be on a human being. The development work undertaken during April and May 2001 revealed numerous technical challenges that had to be ironed out. Whittle summarises these challenges well: '[t]he hybrid system – a featherweight drone originally designed to carry sensors but not weapons; a missile originally designed to attack tanks from low altitudes, not people from several miles up and away; a prototype sensor ball drafted into service before its creators deemed it ready – was very much a work in progress' (Whittle 2014a: 311).

To summarise, there is clear evidence that the idea of arming the Predator developed indigenously within the Air Force and was actually being pursued by the time that Afghan Eyes was conceived. From the Air Force perspective, weaponising Predator was not initiated with the aim of hunting bin Laden. Far from having a united position, however, different groups and individuals within the Air Force appear to have had different views both about the Predator's transition from surveillance to a forward air control role (embodied by the laser designator), and the further transition to weaponization that was announced by General Jumper. At least, there was a tension between the fast-track, experimental approach embodied by Big Safari, which quickly fielded new capabilities and 'standard' acquisition paths that required much more time and money, but could produce higher levels of reliability and sustainability.

At the same time, there is evidence of intramural opposition to arming and the ACC instinct for a thorough and steady approach to the work led them to envisage a longer time line and a more thorough development process. Forces of 'resistance' such as these were overwhelmed by the impetus of the NSC and CIA and high level champions within the Air Force who were very clearly thinking about al Qaeda and developing an option for killing bin Laden that might be effective and that might over-ride a number of the objections that became 'showstoppers' of other options tabled (Shultz 2004). This in turn derived from the perception of the persistent and growing threat posed by al Qaeda and the frustration of those responsible for national security at their own apparent impotence, a perception gleaned from intelligence reporting, bin Laden's public statements and from a trend line of increasingly serious terrorist attacks. The Big Safari acquisition channel and mentality of the contractor provided the quick reaction attitude and technical capability to telescope the arming process from four years to two months.

The intent behind the fast-track arming experiments in the summer of 2000 is made very clear by the fact that a scale model replica of bin Laden's house at the Tarnak Farms complex was established on the Naval test firing range at China Lake in Nevada. This is a rather strong indication that the network of individuals pushing the programme clearly believed that given that he could not feasibly be captured and given the threat he and his organization posed, bin Laden should be killed. It is, however, a moot point whether the political leadership would actually have agreed to the pulling of the trigger, had Predator been armed on the two occasions during Afghan Eyes that its crews and CIA analysts believed bin Laden had been positively identified. Clearly those running the operation and figures such as Clarke would have argued in favour. It is not surprising that in statements made post-9/11 those who were involved tend to claim that they would have done so. Tenet, for example, wrote in his memoirs '[i]f we had been able to provide timely and reliable information about where UBL was at a given moment, and precisely where he was going to be a number of hours hence, while simultaneously assuring policy makers that an attack could be conducted without endangering many innocent women and children, the administration would have ordered the use of military force' (Tenet 2007: 109). Grissom et al (2016) suggest that 'operational' problems - risk of civilian casualties, the potential for U.S. combatant losses, and a lack of capabilities for time-sensitive targeting explain why bin Laden was not attacked prior to 9/11.

These operational factors were substantial, yet it is still tempting to wonder whether an attack would have been undertaken had those operational problems been overcome. Within the CIA, the armed drone provoked tremendous anxiety and debate since it raised in a very stark way the question of assassination. For a generation, the CIA had eschewed risky paramilitary operations in general. Throughout the process of trying to develop CIA-run options to address bin Laden and al Qaeda the Agency and the White House had been extremely careful to skirt the ban on assassination, going to great lengths to emphasise that the objective of operations would be to capture, even if it was accepted that bin Laden or his associates may be killed while resisting capture. The armed drone could loiter, and could strike with precision, but it could not capture. White House officials such as Berger became exasperated with a situation in which a cruise missile strike could be sanctioned but a missile strike could not.[95] Yet it would be the CIA, not the military, operating the drone. “This was new ground,” Tenet told the 9/11 Commission, asking: ‘What is the chain of command? Who takes the shot? Are America’s leaders comfortable with the CIA doing this, going outside of normal military command and control?’ (9/11 Commission 2004: 211). He was ‘appalled’ when Charlie Allen and CIA Executive Director Krongard said they would happily pull the trigger ‘telling them that they had no authority to do it, nor did he’ (ibid.). John McLaughlin, then CIA Deputy Director, argues “‘You can’t underestimate the cultural change that comes with gaining lethal authority… When people say… “it’s not a big deal,” I say to them, “Have you ever killed anyone?” It is a big deal.” (quoted in Mazetti 2013: ch.5).

The 1986 global counterterrorism finding was modified three times under President Clinton. Presidential Decision Directives 39 (1995) and 62 (May 1998) both ‘reiterated that terrorism was a national security problem, not just a law enforcement issue’ (9/11 Commission 2004: 108). Although some of the detail of these findings remains classified, in testimony, Clarke portrayed a situation in which the President sought to maintain the general ban while providing limited authorities to take action against al Qaeda. He claimed that the ‘CIA would ask for an authority. They would rapidly get it. We would wait. Nothing would happen. We would ask them for more plans and more options. They would come forward and say they needed more authority, specific, narrow authority, and they would be given that authority – all the while a growing sense of frustration, I think, on behalf of the principals that none of these authorities were being utilized effectively to kill him or his lieutenants or to capture, in the remote possibility that capture could have occurred’. Clarke spoke of concern in the White House to avoid creating ‘an American hit list’ (Clarke 2002: 18).

The convoluted and lawyerly wording of policy directives on this subject in the late 1990s (Clarke describes the Memoranda of Notification signed by Clinton as ‘Talmudic’) reflect the conceptual and normative gulf that separates that time and now. Terrorism before 9/11 was seen through the lens of criminality and not war. While Clinton was willing to countenance covert operations by proxies, those operations had to be sincere efforts at

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[95] Clarke recalled an especially heated session in the White House Situation Room in which Berger asked, “So, you guys are perfectly OK if Bill Clinton kills bin Laden with a Tomahawk missile, but if Bill Clinton kills him with a 7.62-millimeter round in the middle of the eyes, that’s bad? Could you tell me the difference between killing him with a Tomahawk and an M16?” (Clarke cited in Mazetti 2014: ch.5).

capture and not assassinations, which since the 1975 Church Committee investigations and President Ford's Executive Order banning them, were considered illegal and unacceptable even in covert operations. The 1998 embassy bombings provoked Clinton to consider military as opposed to CIA options, including special operations forces. Yet, as Shultz persuasively shows, there is substantial evidence that the military hierarchy opposed the use of such force and did what it could to discourage and screen out such options from NSC and White House consideration, even when civilians such as Clarke were pushing for them.

The counter-terrorism community in the CIA was forbidden from lethal action, the military considered terrorism not to be in their lane, and the civilian leadership inched towards but was unable to overturn the legal ban and – perhaps more deeply - the normative taboo against what was seen as assassination, even for bin Laden. Benjamin and Simon report that in 2001 Directorate of Operations chief Pavitt argued that the armed Predator would endanger the lives of operatives around the world. Now that it was actually available Tenet reportedly stated his view that it would be a 'terrible mistake' for the CIA to use the weaponized Predator and suggested that the task should go to the Air Force (Benjamin and Simon 2004: ch.8). Tenet told the 9/11 Commission that the CIA did not have the authority to conduct such an attack. Some of the underlying concern seemed to be the ambiguity about whether an attack of this kind would be a military attack or a covert assassination attempt. Yet in his initial confirmation hearings, Tenet had told the Senate Committee on Intelligence that he intended to reduce covert action and paramilitary activities (Fuller 2017: 142). In August 2001 a meeting of the deputies decided that the CIA could in fact mount such a strike since it could be justified as an act of self defence rather than assassination. Their opinion, however, would have to be referred upwards to the principals.

When the Bush administration arrived in early 2001 it retained Tenet as CIA Director and kept on Richard Clarke as an NSC senior director. Clarke lost his role on the Principals Committee regarding terrorism but was asked to chair an interagency review on al Qaeda. Clarke once again pushed the more vigorous strategy for bin Laden that he desired. This time he proposed a comprehensive plan to Stephen Hadley, deputy to incoming National Security Adviser Condoleeza Rice, which encompassed al Qaeda in Afghanistan and the Taliban. As Hadley afterwards explained, '[t]he premise was, you either had to get the Taliban to give up al Qaeda, or you were going to have to go after both the Taliban and al

Qaeda, together… [a]s long as al Qaeda is in Afghanistan under the protection of the Taliban . . . you're going to have to treat it as a system and either break them apart, or go after them together' (Gellman 2002). In these discussions, Clarke recommended deploying the armed Predator and using the Northern Alliance and joint special forces Uzbek commando teams to infiltrate Afghanistan (Benjamin and Simon 2004: ch.8). Clarke had advocated resuming Afghan Eyes in spring 2001 but others, including Black, rightly pointed out that even if bin Laden was spotted no action could be taken pending the arrival of the armed version. While the CIA could borrow USAF drones for the operation the question also arose of who would pay if vehicles were damaged or lost. Hadley directed that the armed Predator should be deployed by early September. They were not.[96] The Principals met on September 4 for the first dedicated meeting about al Qaeda. Clarke aggressively underlined the dangers and sought to break bureaucratic paralysis – 'are we serious?', he asked. 'Is al Qaida a big deal?' (9/11 Commission 2004: 212). The Predator programme was discussed but it was decided that it was not yet ready and that another attempt to field it should be made in spring 2002. The 9/11 Commission Report (2004: 214) suggests that the meeting concluded that the armed Predator would be made available as an option for the military but the CIA would continue to operate it as a reconnaissance system. Yet at the same time as this was happening the Predator ground control station was being specially modified to separate the firing control from the rest of the system. The reason for this was that the military remained uncertain about whether *its* people would have legal authority to pull the trigger and they thought that the job could be delegated to a CIA officer in the GCS who was covered by Presidential Finding (Whittle 2014a: 224).

Conclusion

Having adopted the Predator, the Air Force was torn between the bureaucratic impulse to normalise it – an approach that promised to put the programme on a more

[96] Lee points out that had this deadline been achieved 'armed Predators would have been operational in Afghanistan before the September 11 attacks' (Lee 2016: 198). This is technically possible but in view of the bureaucratic wrangling that dominated so much of the discussion about Predator deployments over the previous months and years it seems far from certain. Moreover, to the additional question of whether armed Predators could have averted 9/11 – implied in the title of Michel's (2015) article about the arming of the Predator – the hijackers began entering the United States in January 2000 and killing bin Laden in September 2001 therefore may not have disrupted the attack.

‘business-like’ footing and integrate it more thoroughly into Air Force doctrine, structure and training processes – and the impulse to pursue further modifications. With high level support, something of the quick reaction approach was retained since the system was handed to Big Safari for development. For the instrumental reason of marketing the SSB, the Air Force became drawn into discussions about arming the drone. The earlier addition of a laser designator had significant implications for the status of the system within the air force since it meant operators ‘graduated’ from being reconnaissance providers to being forward air controllers and thus ‘warriors’. By arming a drone this transformation would be further extended. Yet the Air Force, perhaps understandably, was in no rush and envisaged a four-year process of testing and careful evaluation before releasing such a capability into the real world of operations.

While the Air Force wrestled with the internal challenges of ‘normalising’ Predator, the CIA forged ahead in its thinking. Closely in touch with the Big Safari development conduit in the Air Force, the CIA pushed further path-breaking innovation in the remote control arrangements for the system, setting in motion a new concept of operations that virtually cast off range constraints. The impetus came from an unlikely and unforeseen source – bin Laden’s move from Sudan to Afghanistan, where he became much more difficult to monitor. As the CIA, CSG and White House sought to formulate response options to this growing problem, they hit upon the idea of using a reconnaissance drone. This chapter has argued that the connection established between the bin Laden problem and the Predator drone redirected the Predator innovation pathway.

Predator was initially seen as a means to obtain a technical source to corroborate human intelligence sources. This realization drove further innovation in the system of remote control, enabling split operations for the first time. Having successfully put ‘eyes on’ however it was immediately realized that there was no means to act on the information. The idea floated had been to launch a cruise missile against bin Laden, but the distance from the submarine to Kandahar meant that the situation on the ground could change during transit, meaning he might leave the scene or civilians might arrive, posing a risk of unacceptable collateral damage. The decision-makers wanted to guarantee that he would be there when the missile arrived, not when it left the submarine. Amidst the visceral frustration of the team involved it was realized that the Air Force had initiated armament experiments, and via the White House the project gained new impetus and was fast tracked.

Although this fast-tracking suggests that decision-makers actively contemplated killing bin Laden if they could, the authorities under which such an operation would be conducted remained to some extent uncertain. The CIA and military seriously debated who would pull the trigger for this reason, and in the pre-9/11 political climate there was a great deal of reticence about pulling the trigger, even against the terrorist leader behind the East African Embassy bombings and the attack on the USS Cole.

6. The Assimilation of the Predator lineage in the Global War on Terror

Introduction

This chapter argues that the psychic shock of the terrorist attacks on the United States of September 11th 2001, and the political decision to respond to those attacks by declaring what came to be articulated as the global war on terror, generated a set of military and paramilitary contingencies in which the unique combination of attributes afforded by the MQ-1 Predator lineage came to seem indispensable. In the course of US entanglement in the ‘matrix of ongoing, overlaid, interlinked and overlapping conflicts’ that Burke usefully calls the ‘9/11 Wars’, in the ensuing years this class of drones came to be assimilated into the Air Force and CIA, the Joint Special Operations Command and the Army and a set of practices scarcely conceivable in the pre-9/11 environment (Burke 2012: xviii). The traumatic surprise of 9/11, exactly the kind of attack that had preoccupied US counterterrorism officials for years, and the fundamental shift both in US al Qaeda policy and its basic foreign policy, led to a dramatic redirection of the pathway of Predator development.

While post-9/11 innovation in the Predator did involve substantial improvement to the technology, those improvements occurred within the basic architecture already established in an embryonic way by pre-9/11 attempts to develop new options regarding bin Laden in Afghanistan. Post-9/11 Predator innovation therefore relates less to the further technical development of the Predator platform per se (even though there has been very substantial development) than to the objectives and practices to which its persistent surveillance and strike capabilities were directed and the wider organisational change entailed in the construction of these new security repertoires. Some of the most important – and notorious – of these practices involve using armed drones to hunt and kill people believed to be involved in terrorism or insurgency. Although these practices have been employed in the ‘big wars’ of Afghanistan and Iraq, they have also come to be applied in a series of other territories with which the US is not ‘at war’. Such practices, unthinkable before 9/11, are made technically feasible by the development of the armed Predator technology, but became normatively and politically ‘do-able’ because of the profound shock of 9/11 and the political imperative to make war on terror articulated as the necessary response. The capabilities afforded by the technology in pursuit of these new objectives and practices, moreover, could not be fully exploited through 'grafting' of the technology onto existing organisational arrangements and operational concepts. Rather, the assimilation of the Predator lineage in the co-evolving mosaic of counter-terrorism and counter-insurgency practices of the war on terror entailed major innovation encompassing the technological, organisational and doctrinal. The practices of Predator use developed in the post-9/11 period did not come pre-packaged with the Predator configuration established in course of pre-9/11 attempts to develop options regarding the bin Laden problem. Rather, those practices had to be worked out and institutionalised.

In this chapter I argue that post-9/11 Predator innovation is less about change at the platform level and much more about the ways in which the platform became enmeshed in wider socio-technical systems. In this sense, vary far from being 'grafted' onto existing organisational arrangements and doctrine, as Sapolsky et al (2010) have argued of military innovation from the fall of the Berlin Wall to the 9/11 attacks, Predator's assimilation involved incorporation into post-9/11 organisational networks orchestrated by JSOC and the CIA that involved new working relations and radically new practices. This profound organisational and doctrinal innovation enabled the exploitation of the capabilities afforded by the Predator in new ways. The catalyst for this assimilation, then, was the external shock of 9/11, but the open-endedness, and even quasi-permanence of the ensuing contingencies has sustained this pathway and prevented its foreclosure in the face of reassertions of future war scenarios. Perhaps the outstanding feature of the post-9/11 period, and the key driver of its assimilation, has been near insatiable demand for scarce Predator coverage, across conventional forces operating in Iraq and Afghanistan, Special Operations Forces operating in these countries and several others besides, as well as CIA Predator operations.

The chapter proceeds by examining how the 9/11 moment opened new possibilities for using drones. It then describes the challenges of learning to use the system during the invasion of Afghanistan, underscoring the point that having developed a technology, users must learn to exploit it. It then explains the use of drones in the invasion of Iraq and, most importantly, the innovations introduced by General McCrystal in the large scale effort to eliminate what General Petreaus called the 'irreconcilables' during the subsequent US counter-insurgency efforts (Petreaus 2013). The penultimate section describes the two pathways of counter-insurgency and counter-terror that faced President Obama during the 'surge' in Afghanistan and how the former was closed off while the latter evolved into a new military-paradigm.

September 11, 2001

It is certainly possible to imagine counter-factual histories in which the United States articulated a very different understanding of the meaning of 9/11 and subsequently embarked on a different path than the one actually taken. At the time there were 'loud voices in the administration who favoured a much narrower 'law enforcement' approach' (Burke 2012: 46). Peace scholars and activists, meanwhile, argued that the response should be to frame 9/11 as a criminal act or crime against humanity (Kaldor 2001). Within minutes of United Airlines 175 striking the South Tower of the World Trade Center, however, President Bush reportedly called Vice President Cheney, telling him '"We're at war"' (Woodward 2002: 15). That evening, in his Oval Office address to the nation, Bush referred not only to intelligence and law enforcement agencies, but to US military forces and for the first time to 'the war against terrorism.' In the following days, Bush and his team began to articulate the contours of a 'Global War on Terror' as the necessary response to 9/11. Burke argues that widespread assessments of this declaration as reflective of a 'simple and instinctive view of the world', neglect the extent to which the Global War on Terror did have 'intellectual coherence and internal logic' and miss that the primary task was not to find and 'punish those responsible for 9/11 but to prevent such attacks from happening again' (Burke 2012: 45). Donald Rumsfeld, then Secretary of Defense, portrays those days as 'a time of discovery—of seeking elusive, imperfect solutions for new problems that would not be solved quickly. There was no guidebook or road map for us to follow' (Rumsfeld 2011: 352). While the language of war had been quickly chosen, the following months and years would be characterized by a painful process of groping for ways to clearly articulate the kind of confrontation that the US was engaged in and to reorient existing security capabilities to the new tasks seen as crucial to 'winning'.

Yet, to the dismay of both President Bush and Rumsfeld, as they searched for options the administration discovered that the US military had no plans in place to mount an offensive against al Qaeda in its main sanctuary. As the US Army official history notes, '[i]n hindsight, it is perhaps difficult to understand why the US Government did not have a plan in 2001 to mount an offensive against terrorist targets in Afghanistan' (Wright et al 2010: 28). Tenet recalls that '[t]he president had been disappointed to learn that the Pentagon had no contingency plan in place for going after al-Qa'ida and the Taliban' (Tenet 2007: 176). Rumsfeld had come to the Pentagon determined to impose a defense transformation agenda on what he viewed as a legacy military that was ill-equipped for the post-Cold War security environment and non-traditional threats. In a speech at the Pentagon on September 10, 2001 he had declared his intention to 'liberate' the Pentagon from its own bureaucracy. 'Innovation is stifled not by ill intent but by institutional inertia,' he argued.[97] Rumsfeld had also been very critical of what he viewed as the Clinton administration's ineffectual response to terrorism (Woodward 2002: 17), but was now appalled by the dearth of options that he was offered by his Generals. The military 'seemed to have contingency plans for the most inconceivable scenarios, had no plans for Afghanistan, the sanctuary of bin Laden and his network. There was nothing on the shelf that could be pulled down to provide at least an outline' (Woodward 2002: 22). The experience must have only strengthened Rumsfeld in his transformation convictions. In an acerbic memo to the Chairman of the Joint Chiefs he asked, '"Given the nature of our world, isn't it conceivable that the Department ought not to be in a position of near total dependence on CIA in situations such as this?"' (cited in Mazetti 2013: ch.4). He said later that he 'wanted creative ideas, something between launching cruise missiles and an all-out military operation' but found that such options were not forthcoming (Woodward 2002: 38). He was especially perplexed by the reluctance of his department to propose options rooted in the 'array of Special Operations Forces' that the US had been developing for years (Schultz 2004).

Within the CIA, by contrast, counterterrorism officials, in concert with Richard Clarke, had spent much of 2000 and 2001 developing comprehensive plans for dismantling al Qaeda and therefore 'already had on [their] shelves the game plan for going after both al-Qa'ida and its protectors, the Taliban, in Afghanistan' (Tenet 2007: 171). Having been cautious about covert operations without clear legal authorities from the President, the CIA

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[97] His speech was viewed at https://www.c-span.org/video/?c4497613/rumsfeld-dept-def. It is quoted verbatim in his memoir *Known and Unknown*.

now actively pitched them to the White House. Tenet and Black presented their plan on 15 September to the President's war cabinet at Camp David. Black made an impression on President Bush (Mazetti 2013: ch.1). The centre of their proposal was an extremely ambitious covert warfare plan that involved inserting small teams of CIA and Special Forces and attempting to stitch together and mobilise an anti-Taliban coalition (recounted by Schroen 2005).[98] Black was explicit that capture operations would not be feasible and that the mission would involve killing al Qaeda members. He also argued that there was no way to fight al Qaeda without fighting the Taliban. Black expressed confidence about the plan, explained that it could be set in motion quickly, and stated is belief that it would take weeks to succeed. The CIA aimed to 'strangle [al Qaeda's] safe haven in Afghanistan, seal the borders, go after the leadership, shut off their money, and pursue al-Qa'ida terrorists in ninety-two countries around the world.' In contrast to DoD, the CIA Director wrote, the CIA 'were ready to carry out all these actions immediately, because we had been preparing for this moment for years' (Tenet 2007: 178). While the Pentagon continued to pitch large scale military invasion as its response, the CIA was offering something different. CTC were offering the President the first compelling response option he had heard. '"I was impressed,"' Bush told Woodward later (Woodward 2002: 46). By late 2001, 'Bush had put the CIA in charge of a global manhunt' and CTC would become the hub of a secret war (Mazzetti 2013: ch.1). The CIA's three armed Predators would be in the vanguard of that hunt. With laser designators and hellfire missiles, the team referred to them as WILDfire Predators.

In addition to the profound shift in the respective roles and relations between DoD and CIA, this shift of initiative had further implications for the internal workings of the CIA. Halperin and Clapp argue that, like the military services, the CIA is also a large bureaucracy characterised by sub-groups. They identify three distinct groups 'according to their notion of

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[98] The CIA plan advanced in the September 13 NSC meeting was not developed in the preceding 48 hours. Rather, it reflected the thought that had gone into the bin Laden question over the preceding eight months of the Bush administration, prompted in part by Clarke's review process, but also by the CTCs's longer engagement with this question, stretching back to the *Cole*, the embassy bombings and before. Tenet complained in his memoirs that the 9/11 commission 'failed to recognize the sustained comprehensive efforts conducted by the intelligence community prior to 9/11 to penetrate the al-Qa'ida organization. How could a community without a strategic plan tell the president of the United States just four days after 9/11 how to attack the Afghan sanctuary and operate against al-Qa'ida in ninety-two countries around the world?' (Tenet 2007: 121-122).

what the essence of the agency ought to be: intelligence gathering, clandestine operations, or intelligence analysis' (Halperin and Clapp 2006: 34). The clandestine operations group, long marginalised after the scandals of the 1970s and 1980s, was radically re-empowered by the way the President relied upon the Counterterrorism Center in the opening of the war on terror. Virtually overnight Cofer Black, Richard Blee and other senior figures within the CTC, supported by Tenet, 'became vital authors of American military and foreign policy' (Coll 2018: 39). As noted in the previous chapter, at its inception the CTC was the brainchild of a group of officials in the Reagan administration who had sought to advance a more aggressive counter-terrorism policy and who believed that the dominant law enforcement paradigm for addressing terrorism was inadequate. In the wake of Iran-Contra, however, 'Clarridge's war-room vision [for the CTC] was replaced with the cautious, analytical, report-writing culture that Casey and Clarridge had sought to break out of in the first place' (Fuller 2015: 784). Seen from this perspective, the significane of 9/11 was that it seemed to demonstrate that the 'hardliners' had been right all along while enabling the sudden rehabilitation, empowerment and restitution of their beliefs about the appropriate apparatus of response. The previously dominant view that terrorism was exclusively a 'law enforcement' issue, as expressed by Weinberger and his successors, was swept aside.

In the aftermath of 9/11, President Bush established fundamental changes in the rules governing the use of force against bin Laden, the al Qaeda network and the Taliban regime that had sheltered him.[99] The first concerned the military and was embodied in the

[99] The Bush administration did pursue the possibility of apprehending bin Laden. Prior to 9/11 the US and Saudi Arabia had repeatedly sought bin Laden's extradition, and 'at least twice, Bush conveyed the message to the Taliban that the United States would hold the regime responsible for an al Qaeda attack' (Gellman 2002). Taliban leader Mullah Omar had refused, citing his duty under the Pashtun code of honour (the Pashtunwali) to provide *melmastia* – hospitality (Barfield 2010: 266). For a period of about ten days the Bush administration sought to work through Pakistan to secure bin Laden's expulsion from Afghanistan to a third country. The Director-General of Pakistan's ISI reportedly told CIA liaison officers that in a meeting on September 17, 2001, Taliban leader Mullah Omar told him that '"only his death or mine"' would end his obligation to protect his guest bin Laden (quoted in Coll 2018: 61). Barfield adds that, '[s]eeking domestic support for his intransigence Mullah Omar called for an assembly of clerics to meet and affirm his claim that because bin Laden was a guest of the country, he could not be given up… the three hundred assembled clerics told Mullah Omar that he must indeed protect his guest, but that because a guest should not cause his host problems bin Laden should be asked to leave Afghanistan voluntarily as soon as possible' (Barfield 2010: 266). According to Coll, when Omar summoned bin Laden, the latter swore he was not responsible for the attacks. Omar then asked the United States to provide proof of bin Laden's guilt before acting. On the 20th, President Bush used his address to a joint session of the Congress to issue an ultimatum to the Taliban: give up al Qaeda and permanently close the camps, or share in their fate. The ISI continued efforts to intercede and buy time for the Taliban, but the US administration had run out of patience.

Authorization for the Use of Military Force agreed by Congress and signed into law on September 18. At around the same time, however, the President also signed secret findings that granted dramatically expanded powers to the CIA. John Rizzo was then the Deputy General Counsel in the CIA's Office of General Counsel (the most senior career CIA lawyer since the GC is a political appointee), and he was deeply involved in drafting the authorities, as he had been with earlier authorities concerned with bin Laden during the Clinton administration. A decade later, Rizzo stated 'pretty much my entire career had been spent one way or the other in drafting presidential findings and reviewing the implementation of those findings. I had never in my experience been part of or ever seen a presidential authorization as far-reaching and as aggressive in scope. It was simply extraordinary' (quoted in Moughty 2011).

The Clinton administration had been increasingly concerned with bin Laden and al Qaeda but had been extremely careful about the way that they drafted authorities for covert actions by the CIA. Paul Pillar, deputy of the CIA's CTC at the time, told Woods '[t]here was a sense that the White House did not want to put clearly on paper anything that would be seen as an authorization to assassinate, but instead preferred more of a wink-and-nod to killing bin Laden' (quoted in Woods 2015a: 48). In the summer and early autumn of 2001, the internal debates in the Bush administration about whether to renew Predator flights revealed continuing discomfort in the CIA and DoD about 'pulling the trigger' on an armed drone, could such a thing be made to work (Woods 2015a: 48). The political and normative context looked quite different in the aftermath of 9/11. The secret memorandum of notification, signed by Bush on September 17 2001, gave the CIA clear authority to conduct a range of operations to disrupt al Qaeda around the world. It authorised the CIA to kill al Qaeda or other terrorist operatives, without requiring case-by-case approval from the President (Bush 2010). It also authorized the CIA 'to operate freely and fully in Afghanistan with its own paramilitary teams, case officers and the newly armed Predator drone' (Woodward 2002: 88).

Wartime learning with Predator in Afghanistan: A Duct Tape War

By September 15, before CIA paramilitary teams had started to enter Afghanistan and link up with the Northern Alliance, three armed Predators were already at a 'scruffy little airfield' in Uzbekistan with a small, 'CIA-led' launch and recovery element (LRE) of the EAIS, the Air Force/CIA construct that had flown Afghan Eyes missions on behalf of the CIA (Whittle 2014a: 243). On this mission, however, their counterparts were no longer located in Germany. Among the many issues that had contributed to the delay in deploying the armed Predator for a renewed Afghan Eyes mission had to do with the Split Operations technique. This technique, devised for the original mission (to make the forward deployed contingent smaller and less visible), meant that the person who pulled the trigger would be physically located at the US base in Ramstein, Germany. An NSC lawyer pointed out that under the US Status of Forces Agreement with Germany, the US would first need to notify the German authorities. This legal obstacle had provoked further technological innovation. As officials mulled the problem, the scientist responsible for Split Operations suggested that it might be possible to arrange for the ground control detachment in Ramstein to be moved back to the United States, connecting to Ramstein via a Pentagon transatlantic fibreoptic cable. If a decision was taken to fire a missile, the trigger could then be pulled from inside the United States, even if the route taken by the data passing from control to drone and back still had to pass through Ramstein.

This Remote Split Operations (RSO) system was still being tested on 9/11. Within hours, the team involved were contacted and told that, experimental as it was, they were to start flying armed missions in Afghanistan immediately. That summer the EAIS had been set up in discrete trailers on the grounds of the CIA's campus at Langley, Virginia (not at USAF ACC at Langley Air Force Base or Creech AFB, Nevada, the centre of USAF Predator operations). The personnel were a mixture of Air Force pilots and sensor operators, contractors from General Atomics and L-3 communications (another contractor on Predator that worked on RSO) and the CIA, indicating the inter-organisational complexion of the undertaking. (Whittle 2014a: 228).

For operations in Afghanistan, the question of who would fire weapons and under what authority, which had caused such anxiety through the summer, seemed to have been overcome both in the military track and for the CIA. The 'Authorization for the Use of Military Force Against Terrorists' that had been approved by Congress, indicated that use of force would be governed by the laws of war. At the same time, however, the secret authorities granted to the CIA meant that they had clear written approval for lethal actions, and, according to Whittle, the text 'specifically empowered the CIA to use the armed

Predator for that purpose' (Whittle 2014a: 244). As the EAIS prepared for the first, experimental, armed Predator flights, it was tasked with hunting and, if possible, killing, not only bin Laden but now also a narrow list of 'high value' individuals – al Qaeda and Taliban senior leadership. The procedure agreed for the mixed CIA-USAF operation appears to have been that it would be Colonel Ed Boyle, Air Force commander of the EAIS, who would give the order to fire, and that the legal basis for this order would be the laws of war and Title 10 of the US code. Yet in order for him to issue this order, CIA Director Tenet or a delegated official such as CTC head Cofer Black would first have to authorise a shot.

On September 18th the first of the new weaponized Predators flew into Afghanistan, controlled from a station 7,000 miles away. On 22nd September, one of the three available wildfire drones was lost near the city of Mazar-i-Sharif when the ku-band datalink was lost. It seems however that the EAIS Predators did not actually begin to carry missiles into Afghanistan until October 7, alongside the wider air campaign, which was managed from Saudi Arabia by the USAF CAOC (Thompson 2018). The Predator flights, however, were run under CENTCOM and the CIA, although it was agreed that the Joint Forces Air Component Commander for the wider air campaign would be briefed about strikes. Unsurprisingly, problems soon surfaced with this arrangement.

With bin Laden in hiding but with the broader wartime authorities now in place, the Air Force-CIA Predator teams pursued additional targets, including Taliban leadership. The Taliban leader Mullah Omar was on a list of names of approved targets that had been developed and signed off by the White House. The armed Predator, fast-tracked with a view to killing bin Laden in the months before 9/11, was already being used to stalk and, if possible, to kill other individuals. On October 7, a Wildfire Predator followed a convoy of vehicles heading out of Mullah Omar's compound. The Predator system now had the ability to distribute live video imagery to multiple locations. Footage of this operation was being viewed by CENTCOM chief General Franks (in Florida), by Air Force Chief of Staff General Jumper in the Pentagon and in the CAOC in Saudi Arabia (a screen was also installed at the White House). To keep the capability secret, however, the CAOC chief could not view the Predator footage in the main headquarters and had no way to communicate directly with the Predator crew. A debacle ensued. A Predator strike was authorized only to be countermanded by the CAOC. The subjects being monitored by the drone then moved to another location, and went inside a building leaving guards with the vehicle outside. Hours were spent debating whether a building in view was a mosque, with CENTCOM preventing a strike whilst CAOC moved F-14s and then F/A-18s into position to bomb the building. No order came to fire and confusion reigned as to why not. Eventually, Franks at CENTCOM appears to have ordered the Predator to fire a missile at the car outside, apparently hoping to provoke people to leave the building. People poured out, and in the confusion, Mullah Omar appears to have escaped. Recriminations flew between the CIA, CENTCOM and the CAOC (Whittle 2014b). The episode demonstrated that there was much still to be done working out how to manage command authorities between the compartmented CIA-led EAIS and the wider air campaign. The new capabilities afforded by the technology raised new dilemmas.

Other episodes indicate the difficulties of learning to use this fledgling system not only on the fly in the context of active operations, but also in the context of the highly unusual character of the wider campaign, with its emphasis on CIA and Special Forces partnering with local allies, backed by airpower. On one occasion a CIA Predator flight identified an airstrip under construction and contacted counterparts on the ground to seek clearance to strike two individuals whose clothing suggested them to be foreigners. The foreigners in question turned out to be CIA personnel. Technical difficulties also continued to affect the still experimental system. One participant recounted how, on another occasion, the Predator's communications system rebooted just as the operator launched a missile at a radar site. At least one more Predator was lost in the first three months of the campaign. As one Pentagon official who was closely involved in the development of Predator observed of the Wildfire deployment, for those involved '"it was a duct tape war"' (quoted in Michel 2015).

Measures were taken to clarify the command authorities governing CIA Predator operations. The Wildfires were integrated into the CAOC Air Tasking Order, coordinating operations with the rest of the Air Force (Whittle 2014a: 265). On November 16, US intelligence tracked Mohammed Atef, described as al Qaeda's military commander (and perhaps the third name on Bush's list of al Qaeda most wanted after deputy leader Ayman al-Zawahiri) to a meeting outside Kabul and a EAIS Predator was sent in to provide video. This time, there was less compunction about collateral. Three 2,000lb bunker buster bombs were dropped on the hotel, with the Predator firing its Hellfires as well. In macabre contrast to the pre-9/11 debates about using force against bin Laden, close to a hundred people were reported killed in this attack (Woods 2015a: 43-44, Zenko 2012).

Mullah Omar's (possible) escape took place just as Operation Enduring Freedom began. Hours earlier a barrage of 50 cruise missiles had been launched against an array of fixed targets, including the Taliban air defences and al Qaeda camps that had been mapped by interagency counterparts (such as DIA and NIMA) being coordinated from CTC. The Wildfire Predators thereafter found themselves sharing Afghan airspace with coalition airpower run from Saudi Arabia and bound up with the wider campaign (which was based, as noted, on the 'light footprint' blueprint outlined to Bush at the NSC meeting of September 13 (Schroen 2005)). The apparent success of this strategy subsequently won plaudits and generated debate about whether this 'Afghan model' was more widely generalizable.[100] This narrative, however, downplayed how the failure of the preferred 'southern' strategy led to an overreliance on northern alliance commanders, which had profound consequences for the post-war order (Burke 2012: 47-49). In addition to trying to locate particular individuals, the Predator teams also began to work alongside other parts of the campaign. Via a secure system, the Predators were able to communicate directly with B-2 crews flying into Afghanistan from Missouri, providing information on the location of Taliban air defences (Whittle 2014a: 264). CIA paramilitary teams, special forces, local allies, and a network of local informants that had been assiduously built up by the CIA over the preceding months fed information into the CTC intelligence system intended to tell the Predator where to look for particular individuals.[101] With the laser designation capabilities, the CIA Predators could also use their designator to sparkle targets for manned counterparts to attack. The capacity to designate moving, 'fleeting,' targets as opportunity arose became increasingly important since Afghanistan, one of the poorest countries on earth, did not possess a large and sophisticated military infrastructure for the USAF and

[100] Important contributions to the debate about an Afghan model include Biddle (2003), Andres et al (2005/6), Biddle (2005).

[101] Tenet remembers '[w]e were working with eight separate Afghan tribal networks, and by September 11 we had more than one hundred recruited sources inside Afghanistan. Satellites were repositioned. The imagery community had systematically mapped al-Qa'ida camps. We engaged the Special Operations Command and used conventional and innovative collection methods to penetrate al-Qa'ida in Afghanistan and the rest of the world. We expanded our open source coverage (spy-speak for reviewing open media, such as newspapers and radio) of al-Qa'ida' (Tenet 2007: 120-121).

coalition partners to attack. At CAOC request the Predator would loiter for hours over an area and, if the target appeared, would call in a F/A-18, F-14, F-15, F-16, B-1B, B2 or B-52 and could also call on special forces AC-130U or AC-130H planes. New tactics began to emerge, with Predator being used to track and attack people fleeing from an initial strike, to validate intelligence reports about meetings and as a source of evidence that people being targeted could be classified as combatants (Whittle 2014a: 266). The special forces AC-130s made such a noise on approach, however, that their targets scattered before they could bring their weapons to bear. Big Safari therefore modified existing equipment that allowed the drone to transmit its video footage via C-band antennae to a module installed in the gunships. Soon thereafter a means was created to enable special forces on the ground below the Predator to receive its footage in real time. This became the Remotely Operated Video Enhanced Receiver (it was called ROVER II). At least 147 of these devices were ultimately ordered and L-3 Communications afterwards began building a series of smaller, lighter and more capable derivatives (Whittle 2011: 28, Grimes 2014: 336-337). Pauls reports that demand for this capability 'became so overwhelming that advanced targeting pods used by manned aircraft… were [also] equipped with the system… demand… greatly exceeded the capacity that existed' (Pauls 2012: 17-18). More than 10,000 of such devices are now available to US forces (Lee 2016: 241). Predator was increasingly being used to share real-time information across the battlespace: one analyst likened it to 'a reconnaissance version of Twitter' (Daniel Gouré, quoted in Hastings 2012).

The interagency CIA-Air Force Predator deployment involved vehicles with laser designation capability, carrying weapons and operated from the United States. It had pushed ahead down the experimental modifications track, seeking to incrementally acquire new capabilities from the basic platform. Predator was certainly rough and ready – deemed not 'operationally suitable' in summer 2001 by the Director of the Office of Operational Test and Evaluation (Cockburn 2015: 67-69). Yet when the Air Force decided it wanted the Predators of the 11th and 15th Reconnaissance Squadrons to operate in Afghanistan, none were armed and many still lacked the laser designator. Also lacking remote split operability, the Air Force instead took advantage of the fact that Pakistan made Shamsi and Jacobabad airbases available to the United States. It used the split operations control system, with some GCS sited in Kuwait, until the Air Force could introduce remote split operations, which it did in March 2003 for Operation Iraqi Freedom (Lee 2016: 224-228).

Just as the WILD project changed the status of the system within the wider organisational setting, through the CIA armed Predator deployment, the status of the system changed once again. As observed by Cullen,

'Predator pilots became decision-makers, and Predator's weapons transformed Predator pilots and sensor operators into war fighters – Predator crews could create effects on the battlefield they could observe, evaluate, and adjust. Although Predator pilots and sensor operators employed the system safely from the ground from what looked like a desk, weapons distinguished the tasks Predator crewmembers accomplished from the tasks of an office worker or a staff member. Predator crews could kill people and break things, and although they were not physically at risk in the ground control station, they were hardly less vulnerable than F-16 pilots flying well over Iraq and Afghanistan's negligible air threats' (Cullen 2011: 245).

Having been flung into Afghanistan untested, Whittle suggests that they began to earn respect across the military when active operations revealed the capabilities they provided. He cites the case of the battle of Takur Ghar (also known as 'Robert's Ridge'), which occurred during Operation Anaconda in early 2002. Operation Anaconda was an attempt to encircle and defeat al Qaeda and Taliban fighters who had dug into a well-designed interlocking series of fortifications in the Shah-i-Kot Valley. After the initial assault, efforts were made to capture elevated positions on the mountainsides, from which to direct fire. One of the positions, the summit of Takur Ghar, was selected and a helicopter dispatched with reconnaissance troops whose job was to take and hold the position. Upon coming into land the helicopter immediately came under fire from well-concealed enemy emplacements and a Navy SEAL, Petty Officer Neal Roberts, fell from the helicopter (Milani 2003). This precipitated frantic efforts to retrieve him, resulting in a group of Green Berets being pinned down on the mountainside. Whittle recounts that that night an armed drone was assigned to provide surveillance and it was able to destroy an enemy machine gun nest that was too close to the trapped American soldiers to be safely attacked by fighter jets. It was then able to maintain contact with the beleaguered soldiers throughout the night and then direct a rescue craft to a safe landing site the next day. After that, according to one of the operators, no one doubted the Predator's usefulness (Whittle 2014a: 298).

Yet years later 'fierce disagreement' would remain about what happened on Takur Ghar (Naylor 2018). Colonel Andrew Milani, who conducted a detailed academic investigation into this incident (interviewing participants, examining forensic evidence and climbing the mountain himself) has a very different interpretation of the Predator's impact on events to that related by Whittle. To begin with, he finds, on the strength of the situational awareness provided by the Predator, C2 was transferred from the Task Force (RECCE) commander in the valley to a battlestaff in Oman – more than a thousand miles away (Milani 2003: 19). Milani judges the footage received 'as nearing only 20/200 visual acuity' and proceeds to provide a forensic account of the evidence of what transpired on the mountaintop. He notes that 'General Hagenback has suggested that he saw, on live Predator feed, Roberts immediately taken captive by three enemy personnel and executed' while others 'viewing the same feed, reported seeing Roberts maneuvering against the enemy, getting shot several times, and finally attacking an enemy bunker with his pistol - until fatally wounded' (Milani 2003: 25). Clearly, the footage was ambiguous enough to allow strikingly different interpretations of the same event. He concludes that Roberts was either killed by enemy fire, or died in the fall from the helicopter. Noting that the body of another of the US soldiers killed in the rescue attempt was found in one of the al Qaeda bunkers, Milani further notes that even after exhaustive analysis of all available evidence, including the Predator footage trained on the mountaintop, what happened to him is also not clear. Thus, Milani takes away a strikingly different message about the Predator from the Takur Ghar episode than Whittle, pointing to the danger of it giving remote decision-makers the impression of a situational awareness that they do not possess.[102]

[102] The ambiguities of Predator footage, and the potentially disastrous consequences of those ambiguities persisted, and are vividly illustrated by the released transcript of a February 2010 strike on a convoy of vehicles in western Uruzgan, initiated on the basis of Predator observation but executed by two special forces OH-58 Kiowa helicopters. Cockburn argues, scathingly, that the episode was 'a tribute to the notion that if it is possible to see everything, it is possible to know everything' but concludes that 'however miraculous the technology, the information it delivered was inevitably ambiguous.' Personnel then interpreted this ambiguity through the lens of their training and assumptions – seeing rifles where there were none, interpreting prayer as suspicious activity and identifying military aged males where there were women and children (see Cockburn 2015: 1-16).

Expansion of demand: USAF Predator in Operation Enduring Freedom

The air campaign in Afghanistan opened on October 7, but by the following day the list of 'low-collateral military targets' had already been exhausted. Seeking to manage expectations, albeit with some hyberbole, a senior Air Force official had told the press '"[t]he number of militarily significant targets you can count on your fingers and toes"' and explained that the skill that would be honed would be 'long-term surveillance and then quick reaction once a "fleeting target" like a car or group of people starts moving' (Fulghum 2001b: 28). With Taliban air defences destroyed in the opening bombing, the US took full control of the skies (Lambeth 2006: 84). From the tenth day of the campaign, attention turned increasingly to 'emerging targets.' Harking back to the 'tank-plinking' effort of Operation Desert Storm, the emerging strategy came to be called 'Taliban-plinking' by some, with the intended goal of picking off Taliban and al Qaeda leaders and other targets of value one at a time' (Lambeth 2006: 93-96). Aircraft were cleared to fly lower, while much of the target identification was performed by special forces teams now inserted on the ground. In this context, the Predator stood out, much as it had in Bosnia and Kosovo, as a way to search for and monitor potential targets. '"Why can't we fly more than one Predator at a time?' the President reportedly asked his war cabinet. "We're going to try to get two simultaneously," replied Tenet. "We ought to have 50 of these things," Bush said' (Woodward 2003: 192-193). The Air Force and CIA were already at work on scaling up the operations that the EAIS could perform. The Air Force established a new Reconnaissance Squadron, the 17th, in March 2002 for this purpose. It 'initially… pulled assets from the 11th and 15th RSs' and was scheduled to become fully mission capable by 2005 (Aceto and Kennedy 2002). The 17th reportedly began serving its CIA 'customer' in 2004 (Woods 2014).

After initial hesitation about deploying its Predator fleet (reported at the time to be owing to communications upgrades), the Air Force shipped its own Predators for operations in Afghanistan, where as noted they were reportedly flown from Shamsi and Jacobabad in Pakistan (Fulghum 2001b: 29). At that point, the USAF had established two reconnaissance squadrons operating the Predator, both belonging to the 57th Operations Group, 57th Wing, and both located at Indian Springs Air Force Auxiliary Field, Nevada (Indian Springs was renamed Creech Air Force Base in 2005). The first of these was the 11th Reconnaissance Squadron, which General Fogelman had set up in 1995 as the bedrock of his bureaucratic gambit to wrest control from the Army. The second squadron, the 15th Reconnaissance

Squadron, had been set up in summer 1997 (Huerta and Mullen 2000: 5). By 2000 the Predator had logged over 6,600 combat hours. By February 2003 the USAF would have an inventory of 48 Predators (Bone and Bolkcom 2003: 5). As noted, this fleet was not yet equipped for remote split operations and was not armed. As they had in Bosnia and Kosovo, these drones sometimes struggled in the strong winds, whilst the wings iced up crossing the mountains, which reportedly accounted for at least two of three Predator losses by early November (Fulghum 2001a: 39). This difficulty led to the hasty installation of a de-icing system.

Nonetheless, the Air Force use of Predator as a reconnaissance drone during OEF was itself a component part of 'an overarching intelligence, surveillance, and reconnaissance umbrella' made up of multiple reconnaissance platforms that gathered multiple kinds of data (Lambeth 2005: 253). He argues that the gathering and 'fusion' of data from 'mutually supporting sensors' across multiple platforms during OEF was unprecedented in its extent. In this it not only deepened and accelerated connections between 'sensors and shooters' (eventually to the extent of combining them on the armed Predator) but also 'between those with execution authority at the point of contact with the enemy and more senior decisionmakers at all echelons up the chain of command' (Lambeth 2005: 254). The USAF reconnaissance Predator was distinctive as a platform in the persistence it afforded combined with its ability to descend to lower altitudes, but was also an embodiment of this real-time information distribution – capable of sharing information with AC-130s, special forces on the ground with ROVER pads, the CAOC in Saudi Arabia, CENTCOM in Florida, the Pentagon, the CIA and even to the White House (Lambeth 2005: 253). During OEF, the Air Force began to use its E-8 JSTARS to identify particular areas of interest from a wider field and then send in a Predator to investigate the relatively smaller area with its narrower field of view sensors, freeing up the E-8 to resume its search. If Predator operators detected targets, they could then call in attacks from other aircraft. In this way Predator began to fit into the wider suite of USAF operations orchestrated from the CAOC. Alternatively, signals intelligence might be used to cue the Predator to investigate an area and assist in the process of generating targeting data.

All this data distribution imposed heavy demands on bandwidth, and bandwidth became a key constraint even on the extremely modest six Predators taken to OEF by USAF. Of these, only two could be kept in the air at any one time (Lambeth 2005: 279). At the same time, the distribution of real time surveillance video to senior leaders created temptations for senior decision-makers both at the CAOC and CENTCOM to become absorbed in the footage and in tactical level decisions rather than focusing on the broader strategic picture.

Iraq, Special Operations Forces and the Predator

Some of the most influential national security figures of the Bush administration brought to office a preoccupation with Iraq and Saddam Hussein that bordered on obsession. After 9/11, they worked hard to link the attacks and the al Qaeda network to Hussein's regime and eventually succeeded in launching the United States on the path of regime change in Baghdad, a decision that was cynically and tenuously justified as another part of the war on terror. Once again, the invasion seemed to demonstrate the prowess of the United States military, sweeping through Iraq with impressive speed.[103] By spring 2003, the US was embroiled in two military occupations. Yet invading Afghanistan and Iraq was clearly not the same as destroying al Qaeda. In the former case, at least, the sanctuary in Afghanistan was eliminated, although having driven the Taliban from power the US simultaneously found that al Qaeda leaders and fighters slipped away and, as in previous interventions, that they now found they could not avoid 'confronting the problem of local order' (Latham 2001: 77). Distracted by the Iraq adventure, Afghanistan became America's 'forgotten war', and from 2004 the Taliban, who were seemingly utterly beaten in early 2002, began a startling comeback. In Iraq, meanwhile, early and rapid battlefield success was not matched by clearly articulated political objectives or a clearly defined understanding of how to establish the foundations of a post-Saddam political authority that would enable withdrawal of US forces (Schadlow 2017: 221). As the situation in the country deteriorated, a new organisation, which became known as al Qaeda in Iraq (AQI), began a campaign of sectarian terror aimed at provoking civil war between the Sunni and Shia communities.

Although he received a great deal of public credit for the war in Afghanistan, Rumsfeld had been extremely frustrated by the way his department had found itself playing

[103] Various scholars argue that the 2003 invasion of Iraq was less a 'dazzling' demonstration of US military strength, as Boot (2003) among others argued, and more a demonstration of the unwillingness of Iraqis to fight for the regime (Kaldor 2018: 126-127).

second fiddle to the CIA in the opening bouts of the war on terror in Afghanistan. He was especially interested in using Special Operations Forces (SOF) in the war on terror and, within the SOF community, those 'black' units focused on direct action 'whose existence is not acknowledged and whose operations are not only always classified/clandestine, but often covert, meaning that the operation is not readily observable and can be plausibly denied by the US government' (Jackson and Long 2009: 139).[104] Indeed, SOF had worked closely on the ground with the CIA in the initial campaign. Rumsfeld wanted these forces to play a vital role in the war on terror, but realised that in order for them to operate independently they would have to reduce their dependence on the CIA by developing their own intelligence capabilities. He was particularly drawn to the Joint Special Operations Command (JSOC), a counter-terrorist special operations group founded in the wake of the failure of an attempted hostage rescue in Iran in 1980 to better coordinate the special mission units within each of the services, and Gray Fox, a separate and secretive special forces intelligence group that Bush transferred to SOCOM by executive order (Mazetti 2013: ch.4, Scahill 2013: ch.8).[105] In addition, a human intelligence organisation known as the Strategic Support Branch, was also established within the Defense Intelligence Agency (DIA) to support special operations, 'reinterpreting U.S. law to give Defense Secretary Donald H. Rumsfeld broad authority over clandestine operations abroad' (Gellman 2005). These figured prominently in Rumsfeld's bureaucratic struggle to regain DoD initiative and leadership in the campaign against al Qaeda.

As conditions grew worse in Iraq, Special Operations Forces, and JSOC in particular, became a critical part of US efforts to quell the insurgency.[106] JSOC had initially been focused on 'the deck of cards' – a list of high-value Ba'athist leaders topped by Saddam Hussein (Schultz 2018). The approach they developed was pioneered in Afghanistan but more fully developed in Iraq. At heart it entailed the creation of 'inter-agency teams', which

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[104] The term 'Direct Action' can be used to include a number of missions (direct action, special reconnaissance, counterterrorism, and counter-proliferation) in contrast to 'Unconventional Warfare', a term that can encompass unconventional warfare, foreign internal defense, civil affairs, psychological operations, and information operations) (Jackson and Long 2009: 136).

[105] According to Jackson and Long, Gray Fox is one codename for the Army's Intelligence Support Activity (ISA), 'the most covert of the three known major [Special Mission Units] SMUs' (Jackson and Long 2009: 141).

[106] There is a vital debate about why violence in Iraq peaked and then dropped in Iraq in 2007-2008. My focus on SOF innovation here is to show how Predator was incorporated into an emerging SOF counter-terrorism approach, rather than to make any claims about the causal relationship between that approach and violence levels in Iraq. See Biddle et al (2012).

combined personnel and expertise from across a range of government organisations, to undertake network-based targeting. These teams sought to 'fuse' all-source intelligence with 'operational capability' – meaning the ability to act, whether through an arrest, a special forces raid or an air strike. As counter-insurgency strategies were adopted in Iraq and Afghanistan, these aggressive efforts to expose and destroy terrorist and insurgent networks had to be calibrated with population protection, leading some to speak of integrated counter-terrorism and counterinsurgency (Lamb and Munsing 2011). Lamb and Munsing argue that '[u]nlike the unmanned drones that kill terrorist suspects from afar, the new capability was not a high-profile technological breakthrough, but rather an underappreciated organizational innovation' (Lamb and Munsing 2011: 5). Niva, similarly, emphasises the organisational dimension, arguing that 'the central transformation enabling [what he terms]… shadow warfare has less to do with new technologies and more to do with new forms of social organization'. Rather than contrasting the organisational and the technological too sharply, however, he points to the way that 'the increasing emergence of network forms of organization within and across the US military', driven by the 9/11 wars, has 'made possible the integration of UAVs' in new ways of fighting (Niva 2013: 187).

Harnessing these deepening inter-organisational working relations to their core commando skills, JSOC developed a targeting cycle that they came to summarise as 'find, fix, finish, exploit and analyse' (a sixth step, 'disseminate', was later added), with the acronym F3EA(D) typically used as shorthand. As General McCrystal explained, '[a] target was first identified and located (Find), then kept under continuous surveillance to ensure it hadn't moved (Fix), while a raid force moved to capture or kill the targets (Finish). Material of intelligence value was deliberately secured and mined, while detainees were interrogated to find follow-on targets (Exploit); the information this exploitation yielded was then studied to better know our enemy and identify opportunities to further attack its network (Analyze)' (McChrystal 2013: ch.10). ISR was used mainly in the find and fix parts of the cycle. JSOC much preferred to conduct raids in order to capture suspects for interrogation as well as other evidence, such as cellphones, laptops, and 'pocket litter', for intelligence analysts to exploit (Warrick and Wright 2008). An air strike would destroy such evidence.

Senior leaders of these JSOC operations have emphasised the importance of intelligence, surveillance and reconnaissance (ISR), and drones as a crucial platform for gathering such data, in their efforts. Their emphasis is not on the technology per se, but on the way they learned, in the course of practicing ‘counternetwork operations in Afghanistan and Iraq’, to incorporate and utilise the kinds of ISR available through drones as part of a wider sociotechnical system. In particular, they stress the integration of UAVs into a wider ‘all-source intelligence network’ and ‘unified operations and airborne collections with all other intelligence disciplines under a single command’ (Flynn et al 2008: 56). Waging a global war on terrorism required developing the means to detect ‘a low-contrast foe… camouflaged against civilian clutter’ (ibid.). To try to expose these networks JSOC orchestrated the drawing together and ‘fusing’ of multiple strands of intelligence. Doing this entailed forging collaborative relations across organisational stovepipes. At JSOC’s headquarters at Balad air base north of Baghdad, ‘long-haired computer experts’, ‘wizened intelligence agents’ and ‘crisply clad military officers’ worked side by side (Warrick and Wright 2008). Already highly skilled in commando raids, the innovation in JSOC in the crucible of Iraq was to forge working relations with multiple government partners, including CIA, FBI, NSA, NGA and DIA, in order to combine skills and information from across organisational stovepipes and thus build the richest possible intelligence picture to cue their operations (McCrystal 2013: ch.11).

Airborne ISR was provided via a number of platforms, including manned helicopters and planes, but Predator proved particularly valuable to the JSOC operations in Iraq. The wider intelligence operation was used to send the ISR platforms to focus in on particular places. JSOC began to request ‘massed ISR’ to try to find particular people and locations amongst the wider population. Massed ISR involved calling upon multiple ISR assets to concentrate attention on specific places for extended periods of time. Flynn et al describe some of the techniques developed for the employment of ISR in the following years. The ‘unblinking eye’ was a kind of multi-sensor, 24/7 ‘long dwell airborne stakeout’ of locations or individuals. ‘Nodal analysis’ entailed following a subject of interest as they moved around and recording the locations and people they met, and then investigating those in turn, seeking to reveal the physical infrastructure being used by the opponent. The ‘vehicle follow’, self-explanatory, proved ‘surprisingly central to understanding how a network functions’ (Flynn et al. 2008: 58). Yet insurgents, aware they might be under surveillance, began adopting elaborate counter-measures, such as switching vehicles whilst under bridges, and ducking out of the back windows of houses they entered. Massed ISR meant that mission controllers could pursue a mobile subject of interest whilst still maintaining surveillance of a location, or pursue more than one subject if a group split up. McCrystal found it ‘a fascinating situation in which new, emerging technologies made dispersed operations possible, but [in which] our processes had not yet figured out how to effectively leverage them. We quickly recognized the need to fully integrate every available intelligence source, both operationally and psychologically, into our force and spent the next few years perfecting approaches that would do that. Ultimately, we used a combination of liaisons, constant communication, and eventually the formation of SOF Predator units, to create the close partnership needed’ (McCrystal 2013: ch.9).

Massed ISR created tensions with conventional forces, who also wanted the ISR platforms on hand for their own operations and for whom more widely dispersed and ‘fairer’ sharing of available resources seemed to make more sense. Where JSOC found it indispensable to exposing clandestine networks, conventional forces increasingly came to value Predator’s capabilities in watching over patrols and convoys and in providing close air support. ISR was in heavy demand across the military in Iraq, but there was limited supply. ‘When I took command in 2003,’ JSOC Commander McCrystal wrote later, ‘for all of Iraq we normally had access to just one Predator, which we augmented with a helicopter we had outfitted with a camera on its fuselage’ (McCrystal 2013: ch.9). In early 2005 Special Operations Command and the Air Force agreed that an additional Predator Squadron would be created within Air Force Special Operations, which eventually became the 3rd Special Operations Squadron. As this squadron became available, it would become increasingly tailored to the methods being developed by JSOC while freeing up the USAF 15th Reconnaissance Squadron. The AFSOC colonel responsible for establishing the special operations drone squadron has described how they began keeping a log recording what was being observed, creating a historical record out of which patterns of behaviour began to emerge, which in turn was fed into the wider intelligence mosaic involving airborne and space-based ISR, signals intelligence, human intelligence (Woods 2015a: 78). McCrystal recalls that having special forces professionals sit with analysts to examine Predator video feed had important effects in building mutual respect and making operators active participants in targeting rather than waiting to be handed assignments (McCrystal 2013: ch.9). This was one facet of a wider attempt to merge the intelligence and operations functions in order to achieve much higher operational tempo.

The development of Special Forces drone operations had far-reaching implications not merely for ownership of the fleet of vehicles but for the reach-back analytic support of the ISR products generated by these platforms. Air Force processing, exploitation and dissemination (PED) was processed through an emerging ISR analysis network initially known as the Distributed Ground System (DGS) which grew into the Distributed Common Ground System (DGCS), a major Air Force weapon system programme. Dissatisfied with the ability of the USAF DGS to support their needs, in 2006 SOCOM established its own special operations DGS at Hurlbert Field in Florida, standing up the 11th Intelligence Squadron to manage it. By 2008, Woods reports, the 11th was handling half of all video being produced by the total Predator and Reaper fleet (Woods 2015a: 79). In keeping with the JSOC philosophy of co-locating intelligence and operations, small 'reach-forward' PED elements were deployed alongside operations. These elements could control on-board sensors, rewind and review footage of 'key events' and helped enable real-time 'dynamic re-tasking' in response to developing situations.

While much of the academic literature on Predator operations in the war on terror has focused on 'targeted killing' of high value individuals/targets (HVIs/HVTs), JSOC employed Predator mainly in a surveillance capacity to find and fix targets, and only rarely in an airstrike 'finish', preferring (where feasible) to conduct raids whose aim was to capture rather than to kill. The wider special forces strategy within which Predator was employed, moreover, was not based on a simplistic theory of 'cutting off the head of the snake', as several critics of 'drone warfare' have argued. McCrystal, perhaps the central figure in the development of JSOC's operations, states that early on he came to believe that 'a strict decapitation strategy was unlikely to work'. Rather, they sought to deny the insurgents the ability to set the pace of the confrontation, putting them under continuous pressure so that they 'would be consumed with staying alive and thus have no ability to recruit, raise funds, or strategize.' '[I]nstead of trying solely to decapitate the top echelon of leaders', he wrote, their strategy was rather to 'disembowel the organization by targeting its midlevel commanders. They ran AQI day to day and retained the institutional wisdom for operations. By hollowing out its midsection, we believed we could get the organization to collapse in on itself (McCrystal 2013: ch.10). Lieutenant General Sacolick recalled that rather than decapitation the intention was rather 'to disrupt, degrade, and dismantle their networks faster than they could re-establish them' (quoted in Schultz 2016: 108). Moreover, JSOC leaders in these operations understood ‘that an effective COIN and CT program can take you only so far’; McCrystal has stated, ‘[t]here is no VE Day. We put AQI on its back… But until the political causes of the conflict are addressed, it could reemerge’ (Schultz 2016: 109-100).

The Development of Predator operations beyond the ‘battlefields’ of Afghanistan and Iraq

President Bush had made clear that the war on terror would extend beyond the ‘declared’ battlefield of Afghanistan, also launching multiple efforts against suspects all over the world, some military, some law enforcement efforts with local partners (Woods 2015a: 50). In the wake of the bombing of the USS Cole, the State Department and FBI had sought to work with counterparts in Yemen to arrest people responsible. After 9/11 Yemeni President Saleh assured the US of his support, and entered into secret discussions about hunting down al Qaeda members, including those responsible for the Cole bombing inside Yemen. In early 2002 Saleh sent Yemeni troops to arrest Qaed Salim Sinan al-Harethi, who was implicated in the Cole bombing, and dubbed the ‘godfather of terror in Yemen’ by US Embassy officials (Scahill 2013: loc. 1712, Smucker and LaFranchi 2002). A firefight broke out in which 17 Yemeni soldiers were killed, and al-Harethi escaped (Karon 2002). While cautious about allowing US special operations forces to operate on the ground, Saleh was much more comfortable with the use of Predators, provided that such operations were kept secret (Mazetti 2013: ch.6). This suggests a way in which the Predator’s technical attributes ‘worked’ politically to make targeted killing feasible outside of ‘hot’ battlefields in the war on terror compared with other options available to the US. Leaders such as Saleh felt more comfortable with a remote approach that did not entail American soldiers conducting operations on the ground, and the domestic outrage that this would be likely to provoke when word got out.[107]

[107] Rogers finds it ‘curious… that drones are also viewed as less problematic by the states they are in operation *against*’, which misses the basic point that Predator and Reaper are not employed *against* the state but against networks of individuals and infrastructure on that state’s territory. She argues that ‘[d]rones seem to manifest a less obvious trespass than a manned incursion, making a lower imposition on national sovereignty’ (Rogers 2014: 2). Political leaders such as Saleh seem to have found it so, but there seems little doubt that their use has provoked outrage among large sections of the wider public in countries such as Pakistan and Yemen.

In reportedly the first use of a Predator in a targeted killing outside of Afghanistan, on November 3 2002, al-Harethi was killed by a Hellfire missile, along with five or six others (one of them, Kemal Derwish, an American citizen), whilst travelling in an SUV in Ma'rib governorate, Yemen.[108] Widely reported as a 'CIA drone strike' at the time (Johnston and Sanger 2002), this first case of targeted killing beyond the 'declared' battlefield exhibited similar collaboration across multiple parts of the US government as with JSOC operations. Woods quotes a senior official, who said, '"[t]he best way to view this thing is holistically, as the work of the United States government"' and points to involvement of special forces, the US Embassy, the NIMA and the NSA in the hunt (Woods 2015: 56). Hersh further stresses a joint US-Yemeni intelligence team 'working out of a situation room in Yemen' (Hersh 2002). According to then-Centcom Deputy Commander Delong, al-Harethi and his colleagues had been under surveillance for some time after making rare use of one of several phones and SIM cards that had been linked to him by a special forces intelligence team sent to Yemen. Having located him at a compound, a raid was being prepared when, abruptly, a group that included al-Harithi got into an SUV and drove off (DeLong 2004).

Circling above was a Predator, flown from a secretive corner of Camp Lemonnier, a former French outpost in Djibouti across the Bab al-Mandab Strait on the African continent. Although armed, the drone was primarily there to provide surveillance of the compound, but immediately began following the vehicle. A satellite phone found to be associated with al-Harethi was activated inside the vehicle. This was picked up by the NSA, whose analyst then listened into the phone call, reportedly identifying al-Harethi speaking in the background (Bamford 2008: 135). Certain that their target was in the vehicle, the drone was able to locate and destroy it with a Hellfire missile. Rather than a purely 'CIA' mission, however, it appears from this early case that the apparatus of drone operations already entailed new working relations between a host of agencies and organisations across the US government, including special operations forces and the NSA. It also demonstrates that the sensors carried by the drone were only one component of the total intelligence collection

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[108] Woods points out that there may have been a seventh person in the car, Abdul Rauf Nassib, who was later involved in organising a prison break, although it is unclear how he could have survived the explosion. Woods cites (2004) Yemen arrests 'al-Qaeda members' *BBC News* [Retrieved from http://news.bbc.co.uk/1/hi/world/middle_east/3531657.stm]. More importantly, however, in 2004 Nassib was eventually arrested and stood trial in Yemen's Special Penal Court for his role in the Cole bombing, and was *acquitted*. This trial was not covered by the media but information about it was released by wikileaks (Woods 2015a: 58).

process used to find the targets it was sent to attack. It also appears from DeLong's account that the mission was not planned from the outset as a drone strike, but that the strike was hastily improvised after al-Harithi left the compound before it could be raided. Finally, reflecting the veil of secrecy that still lingers regarding the basic authorities underpinning drone strikes beyond 'battlefields', there is some uncertainty from the available sources about whether the strike was authorised by the CIA or the Pentagon. From DeLong's account it seems that, as with operations in Afghanistan, both CIA Director Tenet and Delong at CENTCOM were involved in the decision, with the latter having final authority to 'make the call'.

Although it did not prove particularly controversial at the time, using the drone in this way was a major step. It demonstrated that the United States was asserting the right to engage in warlike activities in any country where al Qaeda or affiliate groups were operating. This suggested a very different conception of the geography of the war on terror compared with 'traditional' war. It stood in contrast to the campaigns in Afghanistan and Iraq, which inexorably resulted in occupation of territory, regime change and the consequent challenge of 'governance operations'. Rather than seeking to occupy territory, this approach envisaged applying warlike means to specific individuals associated with al Qaeda regardless of their location, in the event that they could not otherwise be captured. At the time Hersh reported that al-Harethi 'was on a list of "high-value" targets' drawn up by President Bush, and that at that time there were seven "top guys that they're really after" on that list (Hersh 2002). A senior intelligence official involved in the planning told reporters at the time "[a]s soon as we could do it, we wanted to do it", and by this time the CIA had about a dozen armed Predators, with two coming off the General Atomics production line every month (quoted in Thomas and Hosenball 2002). This early experiment was unstitched, however, by the administration's inability to resist discussing the operation in public, despite the promises made to Saleh. Further Predator operations inside Yemen were cancelled and would not resume for eight years.

Back in Afghanistan, the impressive speed of the victory against the Taliban notwithstanding, Osama bin Laden, as well as significant parts of the al Qaeda network and the Taliban, managed to bribe US proxies into allowing them to escape across the border into the Pakistan frontier region during Operation Anaconda (Williams 2013). Bergen has reported how CIA operatives calling in air strikes at Tora Bora requested that US Special Forces be deployed to try to seal the escape routes through the mountains into Pakistan. These troops were withheld as senior military command preferred to stick with the 'light footprint' approach that seemed to be working so well. Bergen has described the US operation in Tora Bora as 'one of the greatest military blunders in recent U.S. history' (Bergen 2009). Both Talban and al Qaeda members thus found refuge beyond Afghan territory in the territory of Pakistan, where 'they were allowed to carve out a sanctuary by Pakistani officials who arrested al Qaeda terrorists in the cities but largely left the Taliban… unmolested' (Williams 2010: 873). As well as providing a lifeline to what remained of al Qaeda in Afghanistan the havens established across the border in Pakistan subsequently enabled the reorganisation of the Taliban and the planning and prosecution of a Taliban insurgency in Afghanistan from 2004. In the meantime, the Bush administration became preoccupied with invading and occupying Iraq.

The invasion of Iraq diverted resources as well as political attention away from Afghanistan, including the available Predators. A former special operations commander has recounted how, in 2005, 'drones were a rare commodity… because they were being fielded in Iraq as fast as they could be deployed', and that 'it was not until 2009 and 2010 that we had enough assets to use drones for… "pattern of life" operations' (Waltz 2015: 209). Sanger concluded from interviews with 'senior officials' that this was a 'huge mistake' since the Predators were so much more valuable in the mountains of Afghanistan, whereas other platforms would have been suitable to the terrain in Iraq. Rohde and Sanger were told by the official, '"If we were not in Iraq, we would have double or triple the number of Predators across Afghanistan, looking for Taliban and peering into the tribal areas" (in Pakistan), as well as "the 'black' Special Forces you most need to conduct precision operations [and] more CIA… We're simply in a world of limited resources, and those re sources are in Iraq… Anyone who tells you differently is blowing smoke," he told the journalists (Sanger 2009, Rohde and Sanger 2007). Yet, aides believed that the reconstitution of the Taliban and the establishment of an al Qaeda safe haven in FATA, and the failure to kill or capture either bin Laden or his deputy al-Zawahiri increasingly ate at Bush (Sanger 2009: xxiv). Beginning in December 2003 President Musharraf (shaken by an al Qaeda assassination attempt against him in Rawalpindi) authorised the use of CIA armed Predators, and the first confirmed lethal strike had taken place in June 2004, it was only in

2008 that Bush decided to employ the drone more intensively inside Pakistan (Coll 2018: 201, Woods 2015a: 100-101). Woods records that, under pressure from candidate Obama, 'the Bush administration… decided to tear up the 2004 secret agreement on FATA drone strikes', dispatching Director of National Intelligence McConnell and CIA Director Hayden to pressure Musharraf to agree to more intensive strikes there. Yet, because Bush only arrived at this decision in the final year of his presidency, Woods aptly labels him an 'occasional assassin'.[109]

The escalation of drone strikes in FATA was underpinned not only by the new agreement with Musharraf but also by relaxing the rules governing the conditions under which a strike could be mounted – known then as 'the permissions' (Sanger 2009: 236). In the course of this escalation, the CIA began to conduct what have been described as 'signature strikes'. The CIA 'no longer had to identify its target by name; now the "signature" of a typical al Qaeda motorcade, or of a group entering a known al Qaeda safehouse, was enough' (Sanger 2009: 236). Then-CIA Director Hayden has described these strikes as being 'designed to known al-Qaeda locations and activities even when specific identities were unknown'. Hayden reports that signature strikes 'always had multiple threads and deep history' and, alluding to the legal justification for this type of strike, argues '[t]he United States viewed these attacks as legitimate acts of war against an opposing armed enemy force' (Hayden 2016: 337-339. This insider view is not shared by all professional observers of the programme, however, and remains a source of controversy in part because the intelligence picture underpinning the strikes is not (for obvious operational reasons) open to scrutiny. Zenko, for example, argues that it remains unclear how the policy fits 'with the bedrock principle of distinction founded in international humanitarian law' (Zenko 2016). Meanwhile, in the last months of the Bush administration, the list of al Qaeda targets was expanded to around twenty names (Sanger 2009: 236).

[109] This ramping up of drone strikes in 2008 is captured by Bureau of Investigative Journalism data, according to which there were 17 drone strikes in Pakistan between June 2004 and July 2008, and then 32 just in the second half of 2008. See https://docs.google.com/spreadsheets/d/1NAfjFonM-Tn7fziqiv33HlGt09wgLZDSCP-BQaux51w/edit?usp=sharing. For a useful visualisation of the escalation of drone strikes in FATA from 2008, see https://drones.pitchinteractive.com.

Obama and the Predator

Much to the surprise of many of his supporters, while President Obama put an end to aspects of the Bush war on terror apparatus such as so-called 'enhanced interrogation techniques', he soon signalled that his administration would continue other important aspects of what was already in place (Savage 2015). It turned out that he was persuaded by the case for using armed drones in the war on terror and would not only continue but 'double down' on the system established in the twilight of the Bush administration. As President-elect he had received a briefing from the Director of National Intelligence that explained much of the intelligence apparatus that had been built up under Bush and that underpinned drone strikes – in particular NSA communications intercepts and a network of human sources on the ground. For the drones to be effective, he was reportedly told, they required 'spies on the ground telling the CIA where to look, hunt and kill' (Woodward 2010: 6). Three days after taking office, 'Obama authorized two Central Intelligence Agency drone strikes in northwest Pakistan which, combined, killed an estimated one militant and 10 civilians, including between four and five children' (Zenko 2016).[110] The central pillar of Obama's campaign critique of Bush foreign policy was that they had failed to calibrate the response to the threat. By declaring war against both terrorists and those who harboured them, he argued, the war on terror had become an occupation of two countries that provoked insurgency and international hostility and tied the US military down. Shane argues that even before taking office, candidate Obama came to see Predator as a 'third choice between doing nothing, on the one hand, and invading countries, on the other' believing that if used judiciously, they 'offered a way to scale the solution to the problem' (Shane 2015: ch.7). On al Qaeda, his administration's mantra became 'disrupt, dismantle, defeat' (Sanger 2012).

Obama had also argued that the invasion of Iraq had been an enormous error while portraying Afghanistan as the 'good' war and advertising an intention to address the deteriorating situation there. Kaplan has portrayed the Obama White House as shot through from the beginning with differing views on the appropriate policy for Afghanistan and Pakistan. Wikileaks materials support the view that Vice President Biden was particularly sceptical about the slide towards counter-insurgency efforts in support of the Afghan

[110] For a description of this strike see Woods (2015: 152-155).

government (Sanger 2012: 53). Obama himself appears to have become sceptical even as he was sending extra troops. It is noteworthy that he chose General McCrystal, who had led the transformation of JSOC into what a British special forces participant memorably dubbed an ‘industrial-scale counter-terrorist killing machine’, for command in Afghanistan (Hookham 2015). McCrystal turned out to be sympathetic to the counter-insurgency strategy developed and applied in Iraq and sought additional large-scale troop deployments.[111]

Biden, meanwhile, argued that it would be more politically feasible to use combinations of drones and special forces to go after al Qaeda in what were now its main sanctuaries in Pakistan’s tribal areas and Yemen. This view pointed to a leaner, ‘bare-bones’ counterterrorism option that did away with the expansive ambitions for Afghanistan (Sanger 2012: 75). Initially, Obama appears not have made a choice. According to Kaplan ‘[h]is declared *goal* for the war… a sober scaling-back from Bush’s dreams of erecting a Western-style democracy with the full panoply of human rights – was simply “to disrupt, dismantle, and defeat al Qaeda in Pakistan and Afghanistan, and to prevent their return to either country in the future.” How to do this – whether to pursue the COIN approach, which had been endorsed by nearly everyone in his cabinet, or Joe Biden’s more limited counterterrorism approach… the President didn’t exactly say. Or rather, he straddled both’ (Kaplan 2010: 320).

These political dynamics helped drive a dramatic expansion of drone strikes in FATA under President Obama. His briefing as President-elect, he told Woodward had ‘“confirmed that fact that you had the Taliban, the Quetta Shura, the Haqqani network, a whole range of these al Qaeda affiliates, essentially, who were operating very aggressively. And we were not putting a lot of pressure on them” (Obama, quoted by Woodward 2010: 11). It was becoming clear not only that al Qaeda had established a new sanctuary across the border from Afghanistan, but also that the same territory was being

[111] In his short time as commander, before resigning because of a controversial article that appeared in *Rolling Stone* (Hastings 2010), McCrystal would set stringent rules for reducing civilian casualties and was criticised for being insufficiently enemy centric. Following his resignation, McCrystal was replaced by Petreaus. The arch-COINdinista promptly removed the limits set by McCrystal, unleashing night raids and air power with the aim of inflicting as much damage as possible on the Taliban military and shadow government before the surge began to draw down.

used a base and safe haven for various Taliban organisations who were moving across the border to attack US, NATO and Afghan National Security Forces. Drones provided a way to reach into this territory and apply pressure not only to al Qaeda, but also to Taliban organisations that were sustaining the insurgency in Afghanistan and posing a direct threat. Yet Obama also seems to have come to view drones as a centrepiece of an approach to enemy groups after drawdown from Iraq and Afghanistan. Under Obama, according to data compiled by the Bureau for Investigative Journalism, there would ultimately be some 375 confirmed drone strikes in Pakistan, the vast majority in FATA, with between 2095-3415 people killed.

One political effect of Obama's embrace of drone strikes both in and beyond declared battlefields and against not only al Qaeda but a widening array of non-state 'affiliate' actors, was to entrench and begin to normalise these practices as US policy. Despite a great deal of criticism from the left, the fact that it was the Democrat, constitutional lawyer President, who had come to office on a wave of hope, who ramped up the drone operations did much to legitimise their use. Visibly uncomfortable with the mounting criticism of his use of drones, Obama sought to justify and normalise them.

Conclusion

During the 1990s there was an extensive debate about an impending revolution in military affairs driven by sweeping technological change in computing and communications. An important critique developed in this debate, however, which held that fully exploiting the new technologies would entail starkly different practices, and that these new practices could not be implemented simply by 'grafting' the new technology onto existing organisational structures, processes, training incentives and career structures. Exploiting the new technology, it was argued, would necessitate commensurate innovation in domains such as doctrine and organisation. Such change, involving the abandoning of the known and venturing into new territory, would be difficult and uncertain. The organisational and bureaucratic politics theory, so central in military innovation studies, predicts that change of this kind would be inherently difficult and likely to encounter multiple forms of resistance. Much of this literature evaluates different mechanisms seen as powerful enough to over-ride such resistance in 'peacetime' conditions. In the previous chapter it was argued that a connection made between an emerging and specific national security problem acted as a direct stimulus to a set of innovations applied narrowly to just three vehicles. In this chapter, we see that that the shock of 9/11 and the declaration of a war on terror in response generated a set of contingencies within which this Predator configuration became the standard.

In the Predator case, then, the basic technical architecture that would come to such prominence during the war on terror was already conceived, and in the process of being tested and evaluated, when the 9/11 attacks occurred. Before 9/11 the rising threat posed by bin Laden and the inadequacy of existing capabilities to meet the specific difficulty of gathering 'actionable' intelligence on him inside Afghanistan stimulated a series of innovations to the Predator reconnaissance drone that had been fielded in earlier operations such as Bosnia and Kosovo. This innovation, still immature and experimental on 9/11, was putting a new capability 'on the table' for decision-makers: the ability to generate persistent, real-time surveillance of locations of interest and to strike targets identified in those locations from the same platform as that carrying the sensors. After 9/11, the US government did not start from scratch, but drew on an existing capability that was specifically tailored to the bin Laden problem and that was years in the making. Rather than 9/11 triggering the development of the technology, the main effect was to transform the context and thereby the significance of this system. This changed context, and the irresistible utility of the system in that context, drove its assimilation within the Air Force and within the operations of two of the leading protagonists of the war on terror: the CIA and JSOC.

The outstanding question before 9/11 had been whether decision-makers would choose to employ this system, once it was made to work 'well enough'. The normative sway of the ban on assassinations created reticence on the part of senior decision makers about giving explicit authorisation for a targeted killing operation. Senior CIA officers at that time carried painful memories of the way, they felt, their organisation had been hung out to dry by previous political leaders who had asked their predecessors to undertake similar activities, had not provided clear authorisation and then had allowed the agency to take the blame. The effect of the 9/11 attacks was to transform this political context so that President Bush felt not only comfortable but obliged to sweep away the existing normative constraints on using the system to hunt and kill not only bin Laden but a growing list of other individuals. Predator's weaponised loitering surveillance attributes proved ideal for these tasks. In this changed political context a new regulatory basis for drone use was put in place that was politically unthinkable on September 10th 2001. The Authorization for the Use of Military Force (AUMF) agreed by Congress created conditions for open-ended war against al Qaeda and affiliate groups or sponsors, but also of major importance for drone operations were a new raft of secret authorities granted to the CIA.

Although initially designed for monitoring and hunting bin Laden, in the course of the large-scale troop deployments in Iraq and Afghanistan, the Predator proved to be extremely useful in a number of other roles, particularly when invasion gave way to occupation and insurgent violence, much as their forerunners had been during successive engagements in the Balkans. Learning to use the system in new ways in the course of actual contingencies was difficult, not least owing to lingering difficulties with the technology itself. These difficulties reveal that military technological innovation is much more than the successful invention and fielding of a system; users still have to work out how best to employ the system. This knowledge does not come pre-packaged with the technology but has to be built up through practical use and experience. The utility of the system in multiple roles created insatiable demand for the system and competition over scarce Predator resources by different military and intelligence actors. This enormous bottom-up demand was coupled with high level civilian insistence that USAF rapidly upgrade its existing fleet for laser designation, weapons and remote split operations, and increase its Predator fleet as fast as the contractor could produce them.

An important objection to the Predator from within the Air Force concerned its vulnerability to anti-aircraft measures, which was widely taken to mean that it would be useless in a 'real' war. Yet in the actual contingencies of the 9/11 wars, areas of operation have consisted of territories where air supremacy had been rapidly established through a wider campaign (as in Afghanistan after OEF and Iraq after OIF), in places where the anti-aircraft threat was not too severe (as it had been in pre-9/11 Afghanistan but also in Somalia), and in countries whose leaders consented (though often under pressure and usually through deals that were kept secret from their citizens) to permit their use against agreed targets, possibly in particular regions where the state's reach was contested or attenuated, as in Pakistan and Yemen. At a time when US conventional military forces have become capable of defeating any theoretical adversaries in a 'real war', the adversaries actually faced deliberately adopted approaches intended to blunt this overwhelming, technologically enabled conventional military superiority.

Although using the Predator in counter-terrorism operations around the world has helped drive technical consolidation and refinement of the system itself, post-9/11 Predator innovation has entailed the enmeshing of the system at the heart of much larger socio-technical systems. Both the CIA and the Joint Special Operations Command have incorporated Predator operations into intelligence systems whose purpose is to identify and locate members of terrorist and insurgent groups in order to 'take them off the battlefield' either by capturing or, when this is judged not possible, killing them. These wider systems are secretive, but their contours have been made apparent through memoirs and other writings of former participants, as well as national security reporting, and the disclosures of the likes of Edward Snowdon. One crucial dimension of these systems is that they do not correspond to specific national security organisations but entail networked relations across organisations, and efforts to combine relevant intelligence data from multiple sources. This apparatus both employs drones as a crucial platform for the gathering of multiple forms of data (video surveillance and signals intelligence) that are fed into the system, whilst also generating information that is used to direct the drones to particular places or to follow particular people or vehicles. Employed in these ways, drones have not simply been 'grafted' onto pre-existing ways of doing things but form an integral part of new practices, enacted by novel organisational networks forged after 9/11. These practices constitute one of the most important innovations in military and intelligence affairs of the war on terror, judged both by the visceral moral and legal controversy they have provoked but also by the emerging consensus among observers of these programmes that they have had devastating effects upon terrorist and insurgent groups wherever they have been employed.

Assimilation is not merely a case of 'working' in a technical sense. Technology must work politically, too. Many of candidate Obama's supporters (and opponents) were taken aback by his decision to rely more heavily on drone operations in the war on terror and his efforts to justify, legitimate and normalise these operations. His support for drones was ultimately driven by his conviction – which he shared with his closest national security advisors – regarding their efficacy and necessity. While much of the criticism around drone operations relates to airstrikes beyond 'hot' battlefields in countries with which the US is not 'at war', drones have also proven politically expedient for leaders of countries faced with dangerous terrorist and insurgent groups, whose effective control over swathes of their territory is limited and challenged. Where foreign troops prove too controversial, the lower visibility, and apparent efficacy, of drones has proven a compelling mix. Yet on a political level they seemed to hold out an option that would enable the US to continue to suppress terrorist and insurgent organisations around the world while simultaneously allowing President Obama to withdraw US troops from messy and protracted operations in support of state-building operations whose feasibility he doubted. Such a move, moreover, appears to have been motivated in part by concerns regarding China and Russia, which were both becoming increasingly assertive.

In this it is possible to observe a turn in US security policy towards lighter footprint, lower visibility, less expensive forms of intervention, which the Oxford Research Group have labelled ‘remote control warfare’. The availability of drone technology enables the view that such an approach is practicable. Yet it also seems to signal a turning away, as Niva concludes, from ‘ending violence or solving the social and political problems that produce the challenges to ‘the present global order’ in the first place’ (Niva 2012).

Conclusion

This thesis set out to explain why so many historical UAV development efforts did not advance into use, and how and why the Predator managed to advance to adoption, and came to be assimilated in a range of new security practices after 9/11. It has favoured a broad view of what innovation is and entails, encompassing historical efforts to make ideas about unmanned flight into military useful systems, the lineage of drone development efforts that yielded the Predator, the processes by which the Predator overcame multiple pitfalls that undid other systems, further technical iterations and the way Predator was assimilated into a novel set of security objectives and practices after 9/11. It has sought to present the broad ecosystem of historical drone development efforts, and to explain why these systems only advanced so far, but no further. The literature on technological innovation routinely criticises 'technological determinism'. The historical record suggests that pathways for technological development are opened up or closed down according to organisational and bureaucratic forces, especially beliefs about the future threat environment, and thus are indeed 'socially shaped'. Yet practical limitations on the capabilities the existing technology could be made to support play a vital role in explaining why, despite the undisputed theoretical appeal of military drones, decades of investment and dozens of development programmes did not yield systems that became assimilated into US security organisations until the advent of the Predator in the 1990s and 2000s. Technological limitations were not a monolithic absolute, however. Rather, shifts in the state of the art over time in a variety of sub-fields and systems led to important changes in the potential military applications of drone technology. While these technical constraints were not absolutes, they mattered. Over time, however, as many of the fundamental technical constraints began to be lifted by wider technical advances, the burden of explanation for the continued marginality of military UAVs during the 1980s and 1990s shifts to other factors, in particular military organisational process and bureaucratic politics.

The thesis then offered a detailed examination of the specific efforts that yielded the Predator system and its forerunners. This examination stressed the essential technical attributes – endurance and reliability – that the designers of that system chose to emphasise, and the way those attributes 'fit' with emerging trends in ways that transcended specific situations. At root, the inventor's belief in the fundamental utility of these attributes was borne out by evolving operations and contexts of use and this, coupled with his ability to translate his insight into a viable system, formed the vital bedrock for Predator's progress along the innovation continuum. It is Predator's endurance that generates such appeal across a range of contemporary roles in which the system is employed.

The case also seems to bear out the broad consensus in the literature that military organisations may resist new technologies. This thesis has drawn on the notions of paradigms and trajectories from the innovation studies literature to argue that the way scenarios of future war are defined encourages technical development along certain pathways that seem relevant whilst excluding others. Yet actual contingencies, I have suggested, may reveal capability shortfalls that can make incipient but peripheral technologies seem suddenly relevant. Technology advances, in part, not from one or other state but through the tension between these conditions over time and the way contingent events can interrupt and redirect the trajectory of developing technology. The case of Predator exhibits service resistance to a technology whose apparent lack of 'survivability' made it seem irrelevant to future war scenarios but whose other properties did seem attractive to unconventional users.

Though a capable inventor-entrepreneur, Karem lacked the 'heterogeneous engineering' skills needed to navigate his creation through the acquisition process and the gulf that separates experimental and developmental settings from operational uses and user organisations. In achieving the transition to users and operations, the efforts of a network of well-placed civilian leaders in the Pentagon and the CIA, key Congressional support (seemingly achieved with the help of contractor lobbying efforts), and the use of a novel acquisition approach proved vital though, again, because the capabilities afforded by the drone seemed to leaders to be vitally relevant to emerging operational settings and problems. Despite shortcomings that made 'mainstream' acquisition experts sceptical, the capabilities afforded by the Predator created enormous demand amongst operational 'customers' during successive contingencies in the former Yugoslavia, and created a situation in which the Predator came to seem suddenly inevitable, provoking a climate of inter-service rivalry in which the senior Air Force leadership mobilised to take control of the system. In this context, feedback provided through operational use then acted as a stimulus to further technical modifications, with the addition of a laser designator. This technical modification enabled Predator crews to take on the responsibilities of directing weapons onto targets, turning them from airborne surveillance into forward air controllers, a role and responsibility that changed the status of the system and its crews within the Air Force.

In this thesis I have argued that military technological innovation is fundamentally about making and institutionalising connections between shifting technological possibilities and military operational applications and users. Further Predator innovation occurred in relation to the unforeseen connection made to the policy conundrum posed by Osama bin Laden's sanctuary in Afghanistan. This connection provided the impetus for new concepts for remote control operations, drawing upon expertise inside the CIA, enabling control of a drone via satellite uplink and casting off range limitations that had dogged earlier development efforts. In turn, the fast-tracking of armament efforts using the AGM-114 Hellfire missile promised once again to transform the drone's capabilities, with profound implications for its organisational status. Although these modifications would yield a platform both for persistent surveillance over Kandahar and to strike bin Laden from that platform if the opportunity arose, it remains unclear whether this system would have been employed prior to 9/11 had it been ready (or ready enough) sooner.

Finally, it was argued that the 9/11 attacks and the war on terror response to those attacks gave rise to a mosaic of contingencies, operations and consequences within which there came to be enormous demand for the capabilities uniquely provided by the Predator lineage. Though the basic technical outline of the post-9/11 Predator was already established on the eve of the attacks, the post-9/11 contingencies have driven the incorporation of the Predator system in the course of the development of larger socio-technical systems. It is because the Predator, embedded in a wider socio-technical system and new organisational relations, enables novel practices – doing different things – that it represents 'major' military innovation. For all that it seemed a flimsy, ungainly, slow, 'not operationally effective' system, by providing capabilities that were unavailable from other, ostensibly much 'higher-tech' systems the Predator has demonstrated a range of possibilities for which there has been insatiable demand.

In the Air Force, Predator operations have to be seen as part of an evolving suite of ISR platforms and a global support infrastructure for the distribution of that data, its 'fusion' with other forms of intelligence data and analysis. While recent investigative reporting suggests that CIA missions are flown by a dedicated Air Force squadron, CIA missions would appear to be bound into another system, with the CIA orchestrating an intelligence process involving expertise and input from multiple other agencies and organisations in order to cue their drones. JSOC, which also stood up its own drone operations, meanwhile, established its own DCGS tailored to the requirements of its kill/capture operations, within which drones and other platforms were mainly used in vital ISR support functions. Together these systems provide the US with the ability to employ drones in multiple ways, across multiple geographies, and against a range of 'low-visibility' adversaries.

Where Predator's sceptics have continued to criticise its presumed lack of survivability in a 'real' war, in the actual contingencies dating back to Predator's first deployments in the Balkans, rapid degradation or defeat of the anti-aircraft threat has quickly given rise to contexts in which the Predator's capabilities have proven highly desirable in a number of inter-related roles. Predator has gained particular notoriety for its use in the practices of targeted killing and signature strikes both within 'declared' theatres of war such as Afghanistan but also in countries with which the United States is not at war (with the secret consent of the leadership). Although the legal basis for these operations is murky and contested, US officials have become convinced that armed drones are an extremely effective tool for decimating the leadership of designated non-state networks in remote safe havens where they are beyond the effective reach of other alternatives. Despite enormous public protest relating to the vexed question of civilian casualties, US officials also appear to believe that collateral damage is minimal in such strikes and argue that Predator and Reaper, in large part by virtue of their ability to provide extended monitoring of situations, is the most discriminating tool in their arsenal. Beyond these tasks, however, Predator has also proven extremely useful in a number of other capacities, including ISR provision, and close air support of troops on the ground.

From another perspective its utility can be interpreted as a direct consequence of the overwhelming conventional military dominance that the US has established for itself since the end of the Cold War. As adversaries have realised US strengths, they have adapted by seeking to blunt that advantage by opposing US military power in asymmetric ways. It is this adaptation that is responsible for the post-Cold War move from fixed to fleeting, reflecting understanding of the need for disguise, dispersion and movement to evade precision airpower supported by an ever-improving constellation of sensors. Predator's persistent surveillance, in this sense, can be interpreted as a US counter-innovation to this trend among adversaries.

The case of the Predator has interesting policy implications for understanding innovation processes. In a recent article, Rogoway has speculated that the Predator C Avenger, a General Atomics follow-on to the Reaper that is thought not to have been extensively purchased, appears to use a 'stealthy planform' reminiscent of the retired F-117 Nighthawk. Rogoway suggests that the Avenger 'would… be well suited to conducting discreet and flexible missions over less than welcoming airspace in Syria from bases in nearby neighboring countries', since it would be stealthy enough to risk in defended territory but not so stealthy that employing it would pose an unacceptable risk of losing the technology to adversaries (Trevithick and Rogoway 2019). If true, this would suggest that Predator C has begun to address the concerns about survivability that dogged Predator's development. It would further suggest something important about the innovation trajectory charted by this lineage. Many of the historical drone programmes struggled with the paradox, faced by many new technologies, that to achieve their potential they need the feedback and learning that comes with use and iteration, but military organisations have often proven reluctant to purchase *before* such performance levels are attained. The Predator lineage was able to benefit from feedback by gaining a foothold in 'peripheral' mission areas, and as the system has matured it has been possible to produce iterations that are progressively more 'capable', judged by the yardstick of future war.

The forms of counterterrorism drone warfare that have evolved since 9/11 have involved the incorporation of the armed drone as an integral element of much larger socio-technical systems. Those systems now bind a network of stakeholders and perform important political functions. The large technical systems literature suggests that over time such systems take on 'momentum' that makes them resilient. In the innovation literature, this property is associated with 'lock-in' – a phenomenon in which increasing returns to adoption bind us into potentially sub-optimal outcomes (Arthur 1989, Cairns 2014). Some observers of drone warfare express concern that having 'turned on the tap', it is going to be difficult to switch off (Woods 2015a). Kaldor and Nightingale (unpublished, 2014) have suggested that 'technology can reinforce particular ways of seeing the world and pathways of action. As institutions adapt to reinforce those options, they become more likely. This can have positive consequences if the direction of technical change is aligned with strategic aims. But if it isn't, or if those aims change, or if the process of technical change becomes locked in to the point it achieves institutional momentum, then technical change can be counter-productive.' Drone technology in general struggled for many years to advance along the innovation continuum to a point where military users fully adopted and incorporated it into their organisations and operations. In its war on terror applications, the assimilation of the Predator has become a concrete response pathway that may in turn contribute to marginalising other possible response pathways.

Interviews

Washington, D.C. and New York, December, 2013

Dr Lisa Schirch, 11 December, 2013

Peter Singer, Brookings Institution, 11 December, 2013

Phyllis Bennis, Institute for Policy Studies, 12 December, 2013

Sarah Chayes, 12 December, 2013

Andrew Wilder, United States Institute for Peace, 12 December, 2013

Fred Kagan, American Enterprise Institute, 12 Decembe,r 2013

Karin von Hippel, Charles Call, Ted Andrews, Ben Beech, Elizabeth Carol, Josh Erdossy, Bureau of Conflict and Stabilization Operations, Friday 13 December, 2013

Mark Jacobsen, German Marshall Fund, Friday 13 December, 2013

Stephen Heintz, Rockefeller Brothers Fund, New York, Monday 16 December, 2013

Carlos Terrones – Senior Governance Adviser (Afghanistan 2011-2012), State Department

Ellen Laipson and Mona Yacoubian, Stimson Center, 17 December, 2013

London

Alice Ross and Jack Searle, Bureau for Investigative Journalism, 14 May, 2014

Peter Papadakos, last program manager for the DASH weapon system, email correspondence, May 2016

Washington D.C. and New York, November 2017

Andrew Cockburn, journalist, 7 November 2017

Dan Grazier and Mandy Smithberger, Project on Government Oversight, November 2017

John Feffer, Institue for Policy Studies 16 November 2017

Paul Scharre, Center for a New American Security, 17 November, 2017

Pierre Sprey, defense analyst, 17 November 2017

Caitlin Lee, Rand Corporation, 29 November 2017

Peter Bergen, New America Foundation, 30 November 2017

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