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MILITARY INNOVATION IN THE THIRD AGE OF U.S. UNMANNED AVIATION, 1991–2015

by

Robert L. Grant Jr.

June 2020

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Military innovation studies have largely relied on monocausal accounts—rationalism, institutionalism, or culture—to explain technologically innovative and adaptive outcomes in defense organizations. None of these perspectives alone provided a compelling explanation for the adoption outcomes of unmanned aerial vehicles (UAVs) in the U.S. military from 1991 to 2015. Two questions motivated this research: Why, despite abundant material resources, mature technology, and operational need, are the most-capable UAVs not in the inventory across the services? What accounts for variations and patterns in UAV innovation adoption? The study selected ten UAV program episodes from the Air Force and Navy, categorized as high-, medium-, and low-end cases, for within-case and cross-case analysis. Primary and secondary sources, plus interviews, enabled process tracing across episodes. The results showed a pattern of adoption or rejection based on a logic-of-utility effectiveness and consistent resource availability: a military problem to solve, and a capability gap in threats or tasks and consistent monetary capacity; furthermore, ideational factors strengthened or weakened adoption. In conclusion, the study undermines single-perspective arguments as sole determinants of innovation, reveals that military culture is not monolithic in determining outcomes, and demonstrates that civil-military relationships no longer operate where civilian leaders hold inordinate sway over military institutions.

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ABSTRACT

Military innovation studies have largely relied on monocausal accounts—rationalism, institutionalism, or culture—to explain technologically innovative and adaptive outcomes in defense organizations. None of these perspectives alone provided a compelling explanation for the adoption outcomes of unmanned aerial vehicles (UAVs) in the U.S. military from 1991 to 2015. Two questions motivated this research: Why, despite abundant material resources, mature technology, and operational need, are the most-capable UAVs not in the inventory across the services? What accounts for variations and patterns in UAV innovation adoption? The study selected ten UAV program episodes from the Air Force and Navy, categorized as high-, medium-, and low-end cases, for within-case and cross-case analysis. Primary and secondary sources, plus interviews, enabled process tracing across episodes. The results showed a pattern of adoption or rejection based on a logic-of-utility effectiveness and consistent resource availability: a military problem to solve, and a capability gap in threats or tasks and consistent monetary capacity; furthermore, ideational factors strengthened or weakened adoption. In conclusion, the study undermines single-perspective arguments as sole determinants of innovation, reveals that military culture is not monolithic in determining outcomes, and demonstrates that civil-military relationships no longer operate where civilian leaders hold inordinate sway over military institutions.

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TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

ACTD	Advanced Concept Technology Demonstrations
BAMS	Broad Area Maritime Surveillance
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
FY	Fiscal Year
GAO	Government Accountability Office
ISR	Intelligence, Surveillance, and Reconnaissance
JROC	Joint Requirements Oversight Council
RDT&E	Research, Development, Test and Evaluation
S&T	Science and Technology
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Aerial Vehicle
UCLASS	Unmanned Carrier-Launched Strike and Surveillance
USAF	United States Air Force
USN	United States Navy

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I. INTRODUCTION

> We've seen in the world in the last fifty years or so what many consider to be an unprecedented rate of technological change, a process that seems to be speeding up. The impact of this process of change may prove to be profound, no more so than in the military sphere. War, after all, is often assumed to be a particularly technological human enterprise.
>
> —Chris Tuck[1]

A. PUZZLE AND RESEARCH QUESTION

This dissertation seeks to understand a military-technological puzzle that is focused, perplexing, and timely. It is *focused* tightly on the technological subject of unmanned aerial vehicles (UAVs) within the United States military. It is *perplexing*, in that not only do the Air Force, Navy, and Army pursue UAVs in competition with one another, they also exhibit a wide variance of adoption outcomes and there is no single explanation for why military organizations adopt or resist certain types of UAVs. It is *timely* because the services are all under pressure to achieve more automation to reduce risk to American servicemembers and to exploit technology.[2] Although this puzzle is almost as old as military aviation itself, it has become most relevant within the past 25 years. Despite decades of investment and progress toward achieving effective pilotless combat air vehicles that can credibly and safely replace manned aircraft in combat, the U.S. military has not adopted the most capable UAVs.

With difficulties budding from the Global War on Terror, exasperated senior civilians fired Air Force leaders in 2008, causing a change in UAV adoption. Spurred to action, the Air Force and the United States military expanded the UAV fleet; however, the services adopted mostly simple UAV platforms. The prevailing theories of military innovation and organizational studies cannot explain this outcome, given that America had

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[1] Chris Tuck, "Technology, Uncertainty, and Future War," Defence-in-Depth, last modified March 11, 2019, https://defenceindepth.co/2019/03/11/technology-uncertainty-and-future-war/.

[2] In her exploration on the formation of nuclear employment planning, Lynn Eden inspired this opening format in her book, *World on Fire*. Lynn Eden, *Whole World on Fire: Organizations, Knowledge, and Nuclear Weapons Devastation* (Ithaca, NY: Cornell University Press, 2004).

strategic interests in furthering its self-described revolution in military affairs with a goal of countering rising and anticipated future near-peer/peer competitors. Nevertheless, a pattern of UAV adoption emerges and invites inquiry. The services adopted a fleet of lower-end and comparatively cheap UAVs that primarily operate in uncontested airspace, such as the MQ-1 Predator, RQ-2 Pioneer, and RQ-7 Shadow. A modicum of other medium-range capabilities on a few platforms also dot the U.S. military landscape, such as the RQ-4 Global Hawk/Triton and MQ-9 Reaper. The services rejected systems such as the X-45, the X-47 and its follow on, and the RQ-3 Dark Star, leaving behind these more capable UAVs. Only a very few, high-end and secretive platforms are known to exist, such as the RQ-170 Sentinel. This turn of events raises obvious questions: *Why, despite abundant material resources, mature technology, and operational need, are the most capable UAVs not in the inventory across the services? Put more succinctly, what accounts for UAV innovation adoption variation and patterns*?

B. THE PROBLEM'S EVOLUTION, FRAME, AND SIGNIFICANCE

The American quest for military pilotless aircraft started shortly after the Wright Brothers achieved manned flight. That quest runs long through the past century with the employment of UAVs playing a minor role in every major war since World War I. Following World War II, U.S. Army Air Forces General Henry H. Arnold envisioned UAVs as a natural progression of the Air Force. On Victory Day over Japan, the General challenged the organization, saying, "The next war may be fought by airplanes with no men in them at all . . . Take everything you've learned about aviation in war, throw it out the window, and let's go to work on tomorrow's aviation."[3] Yet, for seventy years, the United States only experienced small incremental cycles of UAV development, without fully committing to unmanned platforms.

Part of the problem is that technology limited the extent of how far UAV development could go until the Information Revolution emerged in the 1980s. The U.S. Army and Navy both experimented with remotely piloted, radio-controlled aircraft as early

[3] Chief of Staff of the Air Force, *Global Vigilance, Global Reach, Global Power for America* (Washington, DC: Department of the Air Force, 2012), 2.

as the 1920s. Advances in technology enabled more autonomous, pre-planned routes for UAV intelligence and surveillance gathering during the Vietnam conflict, and by the early 1980s, loitering UAVs with sensor packages and integrated offense weapons emerged thanks to Israel's efforts. Since the end of the Cold War, UAV technology has matured, resulting in a slate of sophisticated, stealthy, and capable UAV technology demonstrators for employment in contested airspace. The technology enabling UAV development included computing power for autonomous operations, sensor packaging for sensing the battlefield, ever-shrinking hardware which reduced weight, digital communications for command and control over global dimensions, and airframe design and materials to facilitate cost reductions.

In addition to UAV technological advances following the Cold War, significant challenges to U.S. airpower materialized as a response to America's overwhelming success during Operation Desert Storm. Competitors' initiatives sought to limit U.S. power projection capabilities with Anti–Access/Area Denial systems in order to hinder the United States' ability to bring military airpower effects to bear. Since 1991, U.S. airpower enabled military success with reasonably low casualties and political risk when executing retaliatory strikes, enforcing no fly-zones, or dislodging relatively weak but militarily capable dictators in places such as Afghanistan, Serbia and Libya. At the same time, emerging Great Power competitors did not rest in seeking to offset U.S. airpower advantages. In fact, by the fall of 2014, Russia's Kaliningrad Oblast on the North Atlantic Treaty Organization's northeast flank seemed near impenetrable by any military combination of U.S. air, land, and sea assets; at least not without incurring extreme risk to forces at severe political costs.[4] A trifecta of Russian coastal defense cruise missiles, surface-to-surface missiles, and surface-to-air missiles systems—not to mention the other conventional platforms of troops, ships, submarines, and aircraft—made gaining and maintaining air superiority over northeastern Europe a practical, if not strategic,

[4] Following Russia's hostile annexation of Crimea in 2014, U.S. European Command and its subordinate service commands, to include U.S. Air Forces Europe, conducted large scale command post wargames focused on defense of NATO problem set such as Exercise AUSTERE CHALLENGE 2015 and USAF Blue Flag.

improbability within acceptable risk.[5] The same can be said for the air and sea defense umbrella China has erected on its eastern coast and in the South China Sea. United States officials were aware of these developments and had an opportunity to innovate accordingly, especially considering the enormous defense spending outlays that followed in the wake of the September 11, 2001, terror attacks against the World Trade Center and the Pentagon.

The conditions and variables that shape organizational change and the adoption of technology in military services demands further explanation. Thus, the research is concerned with the institutional and organization barriers to constructive military UAV innovation and integration into the U.S. military. The research is motived by an interest in discovering the hurdles that must be overcome to foster major technological innovations, especially when they involve organizationally threatening technologies. The research also addresses the variance among U.S. military services in adopting UAVs, given the near identical strategic contexts and the technology available across these services. The research question is part of a broader puzzle of interest to the military security community: *Why is adoption of major technology so hard in the military, given so much is on the line for state security*?[6]

Theoretical explanations originating from rational, institutional, cultural, and sociological perspectives do not provide fully convincing answers to the questions posed here. First, rational-based theories of military innovation suggest that nations and militaries react to threats that limit or impede their ability to meet national security objectives; civilian leaders, then, guide doctrinal choices and direct the means to overcome those

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[5] David A. Schlapak and Michael Johnson, *Reinforcing Deterrence on NATO's Eastern Flank: Wargaming the Defense of the Baltics*, RR1253, (Santa Monica, CA: RAND, 2016), https://www.rand.org/pubs/research_reports/RR1253.html; Michael Kofman, "Fixing NATO Deterrence in the East or: How I Learned to Stop Worrying and Love NATO's Crushing Defeat by Russia," *War on the Rocks*, May 12, 2016, https://warontherocks.com/2016/05/fixing-nato-deterrence-in-the-east-or-how-i-learned-to-stop-worrying-and-love-natos-crushing-defeat-by-russia/.

[6] Thanks to Dr. Peter Denning, Naval Postgraduate School, for his insight towards this question.

challenges.[7] As a result of the threat signals and anticipated political-military competition from China, North Korea, Iran, and Russia,[8] America should have adopted weapons that could preserve offensive military options within acceptable risk and cost; advanced UAVs could have done much to that end. Second, institutional-based theories suggest the politics of bureaucratic competition significantly limits the resources needed to innovate.[9] While true, the U.S. military had abundant resources, money, and support since at least 2001, which could have been used to bring the UAV evolution sooner—at least as envisioned by early Air Force leaders and the proponents of the so-called Revolution of Military Affairs. Instead, investments prioritized the incremental advancement of existing technology and weapon systems, which, interestingly resulted in civilian criticism of the Air Force for dallying.[10]

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[7] Barry S. Posen, *The Sources of Military Doctrine: France, Britain, and Germany Between the World Wars* (Ithaca, NY: Cornell University Press, 1984). Posen is the seminal text on this perspective. Related international relations proponents of this view include Kenneth N. Waltz, *Theory of International Politics* (Long Grove, IL: Waveland Press, 1979); John J. Mearsheimer, *The Tragedy of Great Power Politics* (New York, NY: W. W. Norton & Co., 2001).

[8] For early balance-of-threat concepts see Stephen M. Walt, *The Origins of Alliances* (Ithaca, NY: Cornell University Press, 1987); Richard Betts, "Analysis, War, and Decision: Why Intelligence Failures Are Inevitable," *World Politics* 31, no. 1 (October 1978); Keren Yarhi-Milo, "In the Eye of the Beholder: How Leaders and Intelligence Communities Assess the Intentions of Adversaries," *International Security* 38, no. 1 (Summer 2013); Randall L. Schweller, "Bandwagoning for Profit: Bringing the Revisionist State Back In," *International Security* 19, no. 1 (Summer 1994). Schweller applied balance-of-threats from an alliance formation perspective, but the concept is applicable as well to individual states as they assess their security position in the world.

[9] Rosen, Avant, and Zisk are the leading scholar of this view within military innovation literature. Kimberly Zisk, *Engaging the Enemy: Organizational Theory and Soviet Military Innovation, 1955–1991*. (Princeton, NJ: Princeton University Press, 1993); Stephen P. Rosen, *Winning the Next War* (Ithaca, NY: Cornell University Press, 1991); Deborah Avant, *Political Institutions and Military Change* (Ithaca, NY: Cornell University Press, 1994). Additionally, Michael Horowitz argued for an adoption-capacity theory focused on state resources. Michael C. Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, NJ: Princeton University Press, 2010).

[10] While nuclear enterprise failures were the top issues cited in the firing of then Secretary of the Air Force and Chief of Staff of the Air Force, frustration with the direction of weapons procurement related to UAVs and 5th-generation fighters were additional, compounding reasons. Tom Shanker, "2 Leaders Ousted from Air Force in Atomic Errors," *New York Times*, June 6, 2008, https://www.nytimes.com/2008/06/06/washington/06military.html; "Air Force Must Do More for War, Gates Says," NBC News, April 21, 2008, http://www.nbcnews.com/id/24238978/ns/world_news-mideast_n_africa/t/air-force-must-do-more-war-gates-says/#.XGWigS3MzOR; Retired Air Force Lt. General David Deptula wrote an article a decade later chastising the Secretary of Defense's stance on weapons procurement in the late 2000s. Dave Deptula, "Building the Air Force We Need to Meet Chinese and Russian Threats," *Forbes*, February 11, 2019, https://www.forbes.com/sites/davedeptula/2019/02/11/building-the-air-force-we-need/#79e087b2b97c.

Culturally framed theories of organizational innovation suggest that outcomes for successful transformation depends upon particular strategic and organizational attributes of bureaucratic culture.[11] The Air Force has a history of both prompt innovation and evolutionary progress,[12] but the organization's approach with regard to UAVs drew out developmental timelines to the point of practically rejecting change. Subsequently, more culturally conservative and inflexible military organizations such as the U.S. Navy and Army captured a part of the UAV mission space,[13] making their own significant progress in fielding and operating UAVs within the Air Force's traditional warfighting domain. Organizational culture-based explanations cannot fully account for this history. Many scholars of military institutions and the Air Force would likely point to a heavily entrenched pilot culture as the explanation for why the Air Force was slow to adopt UAVs[14]; however, because this argument is overly simplistic, we need to approach the issue with more nuance. Previous doctoral research in the early 2000s on Air Force adoption of UAVs, for instance, indicated that variables such as organizational orientation, inter-service relations, and a lack of centralized oversight by Congress or the U.S.

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[11] For strategic culture arguments related to innovation, see Dima Adamsky, The *Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the U.S., and Israel* (Stanford, CA: Stanford UP, 2010). Organizational culture advocates include Elizabeth Kier, "Culture and Military Doctrine: France between the Wars," *International Security*, 19:4 (Spring 1995), 65–93; Theo Farrell and Terry Terriff, *The Sources of Military Change: Culture, Politics, Technology* (Boulder, CO: Lynne Rienner, 2002); Terry Terriff, "'Innovate or Die': Organizational Culture and the Origins of Maneuver Warfare in the United States Marine Corps," *Journal of Strategic Studies* 29, no. 3, 475–503, https://www.doi.org/10.1080/0142390600765892.

[12] Success is seen in traditional missions of air superiority, which includes suppression of enemy air defenses, and strategic bombing; success is also seen in evolving cutting-edge technology such as engine design, stealth, and precision strike. Chief of Staff of the Air Force, *Global Vigilance*. A 2016 RAND study suggests the Air Force was highly successful in operational mission innovation for peacetime strategic reconnaissance, strategic deterrent survival, and precision weapons. Adam R. Grissom, Caitlin Lee, and Karl P. Mueller, *Innovation in the United States Air Force: Evidence from Six Cases* (Santa Monica, CA: RAND Corporation, 2016), 87.

[13] S. Rebecca Zimmerman et al., *Movement and Maneuver: Culture and the Competition for Influence Among the U.S. Military Services* (Santa Monica, CA: RAND Corporation, 2019); Carl H. Builder, *The Masks of War: American Military Styles in Strategy and Analysis* (Baltimore, MD: The Johns Hopkins University Press, 1989).

[14] This is the view of Carl Builder's seminal study of U.S. cultures in the 3 main military departments. He suggests pilot culture was the cause of an initial lack of interest in the development of intercontinental ballistic missiles in the 1950s despite the mounting and obvious threat from the USSR. Bottom line, pilots are only interested in flying, and will protect the institution to ensure pilots will fly. Builder, *The Masks of War*, 39–43.

Department of Defense (DOD) were as causally strong as institutional preferences in determining UAV outcomes within the Air Force.[15] Additionally, pilots themselves were the original catalyst behind developing unmanned aircraft development, raising questions about whether the type of pilot matters, if the person's position within the organization is significant, or if there is something about the type of technology and its relation to the organization that determines innovation and adoption outcomes.[16]

Finally, sociological explanations of human behavior as a function of long-term sociocultural development would suggest that the human-social foundations of war are built from an identity engendered over the course of human history, leading to a natural proclivity to prevent the dehumanization of war and keep humans at the center of conflict.[17] The argument suggests that efforts to separate humans, and particularly men, from the tools of war would be unnatural, and so would meet resistance; war, after all, is a human affair. A problem with the sociological view is that while war itself is human, so is the development of weapons.[18] It is correct to see weapons as symbolic and imbued with cultural significance, something cultural commentators have observed about man for eons: The Devil, speaking in George Bernard Shaw's 1902 dramatic play *Man and Superman*, reflects "There is nothing in Man's industrial machinery but his greed and sloth: his heart is in his weapons."[19] It is equally reasonable to view weapons as holding a modestly functional capability bent on the destruction of others with the least amount of harm to one's self and resources. If the function of a weapon is more important to the human

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15 Jon Jason Rosenwasser, "Governance Structure and Weapons Innovation: The Case of Unmanned Aerial Vehicles" (PhD diss., Tufts University, 2004), https://search.proquest.com/openview/53cafb86ced6dc09a781f66ad7bab828/1/advanced.

16 Paul Scharre, *Army of None* (New York: W. W. Norton & Co., 2018), 60–61. Scharre observes that there is "intense cultural resistance within the U.S. military to handing over combat jobs to uninhabited systems," which cuts across services, not just the Air Force.

17 For more on the sociological/sociocultural view and history of war: Robert L. O'Connell, *Ride of the Second Horseman: The Birth and Death of War* (New York, NY: Oxford University Press, 1995); Robert L. O'Connell, *Of Arms and Men: A History of War, Weapons, and Aggression* (New York, NY: Oxford University Press, 1989); Daniel Pick, *War Machine: The Rationalization of Slaughter in the Modern Age* (New Haven, CT: Yale University Press, 1993).

18 O'Connell, *Of Arms and Men*, 21–22.

19 George Bernard Shaw, Act III, *Man and Superman*, http://www.gutenberg.org/files/3328/3328-h/3328-h.htm.

phenomenon of war than the *identity* derived from war's conduct,[20] there is not much need to assume weapons are rooted in male human identity bent toward conflict. Weapons are after all "designed to achieve a purpose,"[21] not just convey an identity. At the same time, the nature of man compels the design towards the effectiveness of weapons.

In sum, the standard explanations behind the U.S. military's difficulty in adopting UAVs, along with the broader outcome of UAV development in the Defense Department, defy standard and conventional expectations, especially given the favorable circumstances in the post-Cold War period. Equally puzzling is why the non-Air Force branches of the U.S. military reenergized their efforts in the race to develop UAVs—with varying degrees of success—resulting in a decentralization of UAV development among all the services, a phenomenon largely unseen in the development of other weapons systems.

Besides the link to state survival and the theoretical complications exposed by the case,[22] the research question is also valuable from historical and policy-making perspectives. The history of UAV development and its adoption into the U.S. military is still unfolding. Most UAV innovations have occurred within only the past years, and innovations have not yet received much attention from military historians. Policy wise, UAVs have an important national security role to play on the international stage. At a minimum, UAVs alter the airpower equation by decreasing the barriers to entry when it comes to fielding an air force. The strategic landscape might in fact be changing from a situation in which only a few can produce fifth-generation aircraft and associated systems, to an environment where there are many states (and non-state actors for that matter) that can use drones to field similar capabilities. Ultimately, the asymmetric air superiority the United States enjoyed might be a diminishing asset requiring a policy shift in aircraft

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[20] O'Connell, *Of Arms and Men*, 14–15.

[21] O'Connell, 5.

[22] Military innovation studies scholar Deborah Avant summarized this relationship, asserting that "even powerful states can face disaster if their military organizations do not respond appropriately to the challenges required by the country's security strategy." Avant, *Political Institutions and Military Change*, 4.

production away from quality to quantity, a renewed focus on countering air defenses, and a significant rethinking of U.S. global strategy.[23]

The United States needs to do better as it transforms and transitions from industrial- to information-age warfare capabilities and practices. With the rise once again of great power competition, and as technology proliferates and empowers smaller actors, UAVs and the greater robotics/artificial intelligence revolution will shape the future of warfare. This research also addresses military organizational learning, national and institutional policy making, as well as an opportunity to challenge a few deeply held assumptions in the broader military innovation studies field surrounding the role of doctrine and the use of ground-centric services as a typology to draw generalizations about the phenomena of military innovation.

C. DEFINING INNOVATION AND UNMANNED AIRCRAFT

Military innovation is not defined by every new idea, incremental technology, or minor change in tactics. Succinctly defined, military innovation is "a change in operational praxis that produces a significant increase in military effectiveness."[24] Innovation indicates changes that: 1) affect how "military formations functioned in the field;" 2) affect military organizations in an unambiguous and significant way; and, 3) result in "greater military effectiveness."[25] Closely related to innovation is the concept of adaptation. Often used in conjunction with the term innovation, a formal definition of adaptation did not arise in the literature, though adaptation often came to describe reactive modifications and learning

[23] The discussion and ideas about policy in this paragraph comes from Horowitz, *The Diffusion of Military Power*, 221–222.

[24] Grissom, Lee, and Mueller, *Innovation in the United States Air Force*, 1.

[25] Adam R. Grissom, "The Future of Military Innovation Studies," *The Journal of Strategic Studies* 29, no. 5 (October 2005): 907, https://doi.org/10.1080/01402390600901067.

behaviors—an "iterative process"—within an "adapt-react" cycle of conflict and field operations.[26]

Military change matters most to the state and organization when such change is significant and meaningful, and thus, Rosen introduced the concept of "major" military innovation. Rosen's definition focused on a "change in one of the primary combat arms of a service in the way it fights or alternatively, the creation of a new combat arm."[27] He differentiates this from incremental tactical weapon evolution; instead, a major innovation involves new interactions and processes to other combat arms and downgrading or rejecting former concepts of operations.[28] Horowitz defined major military innovation as "major changes in the conduct of warfare" that are designed to more efficiently turn capabilities into military power.[29] Horowitz looks beyond only technological change and broadens his focus to all forms of change, indicating that innovation might now always be defined by a preceding change in technology. Taking a slightly different angle on innovation, Pierce categorizes innovations as either sustaining or disruptive, and he defines disruptive innovation as "an improved performance along a war fighting trajectory that traditionally has not been valued."[30] Whether categorized as sustaining, disruptive, organizationally threatening, or major, UAVs and the greater robotics development, are changing the conduct of warfare among states, and UAVs have the potential to alter how military organizations gain efficiencies in the pursuit of military effectiveness and relevancy on today's battlefield—if only services embrace that change.

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[26] James A. Russell, *Innovation, Transformation, and War: Counterinsurgency Operations in Anbar and Ninewa Provinces, Iraq, 2005–2007* (Stanford, CA: Stanford University Press, 2011), 95. Russell describes these "adapt-react" cycles in lecture at the Naval Postgraduate School. A classic example such adaptation occurred during Operation Cobra in World War II, when a U.S. Army sergeant invented a way to enable tanks to cut through hedgerows in Normandy by welding metal prongs, or teeth, onto the front of the tank chassis. This enabled the tanks to move through the hedgerows without exposing vulnerable areas to Germany fires.

[27] Rosen, *Winning the Next War*, 7.

[28] Rosen, 7–8.

[29] Horowitz, *The Diffusion of Military Power*, 22–23.

[30] Terry Pierce, *Warfighting and Disruptive Technologies: Disguising Innovation* (London: Frank Cass, 2004), 1.

Therefore, definitions drawn from theories of military innovation and organizational behavior inspire the concept of innovation used in this paper. Innovation is defined here as the adoption of new "organizational capacities" that results in transformed operational practices and effectiveness.[31] Prior to the point of adoption, emerging technologies or ideas are simply inventions; it is only when a community deeply adopts the invention that innovation occurs.[32] Additionally, by adding the modifier of major technology developments, this qualitative categorization allows us to sift technological developments into those of significant, even disruptive, change and those that are merely evolutionary improvements that do not result in major modifications in practice and organization. Overall, the increasing use of robotic aerial vehicles by military organizations has slowly moved these organizations closer to undertaking a major innovation by adopting high-capacity autonomous drones.

This study is concerned with unmanned aircraft adoption as part of the great robotics revolution, but what constitutes an unmanned aircraft has not always been clear. How does one distinguish an unmanned aircraft from other uninhabited flying machines? That task that has evolved as conceptual lines shifted among uninhabited aircraft, munitions, balloons, and missiles—all entities which the Defense Department now or in the recent past used to describe unmanned vehicles. The terms referring to uninhabited vehicles also changed over time and by service, to include unmanned aerial vehicles, unmanned aircraft systems, small unmanned aircraft systems, and remotely piloted aircraft, with the latest rendition simply being unmanned aircraft. As of June 2019, the DOD defined unmanned aircraft as "an aircraft that does not carry a human operator and is capable of flight with or without human control."[33] Some might argue that a cruise missile,

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[31] Adam Grissom and Peter Denning both emphasize that innovation is contingent upon "adoption" and a change in practice. James Russell further stresses that it is new "organizational capacities" which characterize innovation. Grissom requires a change in not just practice (as Denning emphasizes), but also "military effectiveness." Peter J. Denning and Robert Dunham, *The Innovator's Way: Essential Practices for Successful Innovation* (Cambridge, MA: The MIT Press, 2010), 5–8; Grissom, Lee, and Mueller, *Innovation in the United States Air Force*, 3; Russell, *Innovation, Transformation, and War*, 29.

[32] Denning and Dunham, *The Innovator's Way*, 8.

[33] Office of the Chairman of the Joint Chiefs of Staff, *DOD Dictionary of Military and Associated Terms* (Washington, DC: Joint Staff, June 2019), 230.

hypersonic missile, nuclear warhead, or even a modern artillery round fits this description. The official dictionary of the Defense Department fails to provide clarity on this point as it simply defines a guided missile as "as unmanned vehicle moving above the surface of the Earth whose trajectory and flight path is capable of being altered by an external or internal mechanism."[34] For simplicity and clarity with on-going definitions in this study, I defer to the listing of what the Defense Department and the services classified as unmanned aircraft in its own historically published works, and I avoid lumping in munitions and missiles to the unmanned aircraft category.[35] If there are any discrepancies in what is an unmanned aircraft, I defer to the higher authority organization at the time.

D. ARGUMENT AND HYPOTHESES

Two key variables relate to one another and form the basis of the research. The independent variable of the study is a major military invention, defined as those inventions that have moved from discovery and design to an advanced concept technology demonstrator—a critical precursor to an innovation.[36] The dependent variable is the adoption of technology-based inventions that overcomes the "major" threshold by either: a) radically replacing existing weapon systems that form the basis of combat arms branches, or b) inspires the creation of a new branch of combat arms. There are inventions that do not go on to become innovation as well as those that do. Nevertheless, the dependent

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[34] Office of the Chairman of the Joint Chiefs of Staff, 98.

[35] U.S. Department of Defense and the services started releasing unmanned system roadmaps in 2001. Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap, 2000–2025* (Washington, DC: Department of Defense, April 2001); Office of the Secretary of Defense, *Unmanned Aircraft Systems, 2005–2030* (Washington, DC: Department of Defense, August 2005); Office of the Secretary of Defense, *FY2009–2034 Unmanned Systems Integrated Roadmap* (Washington, DC: Department of Defense, Spring 2009); Office of the Secretary of Defense, *Unmanned Systems Integration Roadmap, 2011–2036* (Washington, DC: Department of Defense, 2011); Office of the Secretary of Defense, *Unmanned Systems Integration Roadmap, 2017–2042* (Washington, DC: The Department of Defense, 2017); U.S. Army UAS Center of Excellence, *"Eyes of the Army," U.S. Army Unmanned Aircraft Systems Roadmap 2010–2035* (Ft Rucker, AL: U.S. Army Training and Doctrine Command, 2010); Office of the Secretary of the Air Force, *United States Air Force Unmanned Aircraft Systems Flight Plan, 2009–2047* (Washington, DC: Department of the U.S. Air Force, 18 May 2009); Office of the Secretary of the Air Force, *United States Air Force RPA Vector, Vision and Enabling Concepts 2013–2038* (Washington, DC: Department of the U.S. Air Force, February 17, 2014).

[36] Cesaer Marchetti, "Society as a Learning System: Discovery, Invention, and Innovation Cycles Revisited," *Technological Forecasting and Social Change* 18, no. 4 (1980): 272, https://doi.org/10.1016/0040–1625(80)90090-6.

variable is not an either-or outcome when one looks closely at UAV episodes. Instead, the dependent variable has outcomes including the options of not adopt, adopt weakly, and adopt strongly. An episode that ends with "not adopt" represents those programs that were abandoned. The "adopt weakly" outcomes represent those episodes in which the service employed the new technology—with or without some organizational change—but did not replace the core mission set and identity associated with the service. One non-UAV example of this is the Air Force's adoption of intercontinental ballistic missiles. An "adopt strongly" outcome categorizes those episodes where a service fully embraces a major innovation by adopting the new technology into a core warfighter branch, drastically altering manpower or organizational constructs, and often includes shedding older technologies or identities at the same time. This definition supports James Q. Wilson's assertion that "real innovations are those that alter core tasks," usually requiring major costs to the institution to adopt the innovation.[37] Prominent examples of this include the Navy's adoption of the aircraft carrier and Army's adoption of the tank.

The mechanisms that cause the independent variable to develop into UAV adoption (an innovation) are the focus of the inquiry. The initial application of the four main perspectives—rational, institutional, cultural, and sociological—all appeared insufficient to explain the service's UAV adoption outcomes. A more methodical approach is needed. By applying a rigorous testing of the hypotheses against key cases, I expect to reveal each theory's value against real-world cases of innovation and discover whether the theorized factors are necessary or sufficient to lead to particular outcomes. Several main theoretical causal factors emerged from the military innovation literature review, covered in Chapter II. This section introduces the main causal factors drawn from military innovation perspectives and proposes four overarching hypotheses to represent those perspectives. Reference Table 1 for the causal factors by perspective. Recognizing the danger and potential error in summarizing a certain perspective into a single hypothesis, I privilege the latest arguments while remaining critical that the latest arguments are not always satisfying empirically or logically. Absent more quantitative data measuring, the degree of how much

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[37] James Q. Wilson, *Bureaucracy: What Government Agencies Do and Why They Do It* (New York: Basic Books, 1989), 225.

an element is present and how much it affects the case is imperfect. Furthermore, this approach maintains a wide range of alternative causal factors (hypotheses from other studies), in order not overly bias major views over minor ones and to maximize validity in this complex case.[38]

Table 1. Factors of Innovation Perspectives

Perspective	Factors Impacting the Perspective
Rationalism *(Includes Civil-Mil Relations)*	1) Assessed adversary threat by state 2) Assessed adversary threat vs friendly capabilities 3) Level of state civilian input/direction on innovation adoption to service 4) Degree of civilian control/intervention on service promotion mechanisms 5) Degree and speed of underlying science & technology maturation
Institutionalism	6) Congressional mandates, laws, inquiries 7) Human resource redirection (including promotion policies) 8) Evidence of learning traps such as methodism and groupthink 9) Degree of service doctrine match to national strategies and policy 10) Degree of discussion/debate across service about specific innovation 11) Degree of principal-agent consensus; civilian incentive for new ideas 12) Perception of domestic (inter-service) vs international threats
Cultural *(Org Behavior)*	13) Presence/strength of organizational learning ethos 14) Focus of service-level learning efforts 15) Impact of policy preference as function of service culture
Sociological	16) Assessed degree of social identity derived from victory in conflict 17) Strength of the view of gender in relation to war and social norms/values 18) Degree of sociocultural association of the preferred weapon(s)

The first three proposed hypotheses draw from the military innovation literature while the fourth hypothesis springs from sociological perspectives. The first hypothesis, derived from the rational perspective, is that to accept high-end innovations that alter a service's historical solutions to critical mission area problems, an external threat must exist and be beyond current organizational capacities to solve. The hypothesis keeps the focus on utility that comes from bounded rationality based on information feedback loops. Applying the hypothesis to the UAV problem set, the hypothesis could be restated: none of the services from 1991–2015 held such a perception; therefore, they all resisted, rejected,

38 Alexander George and Andrew Bennett, *Case Studies and Theory Development in the Social Sciences* (Cambridge, MA: MIT Press, 2004), 80.

or abandoned high-end UAVs. The next hypothesis stems from the institutional perspective, which states that without synergistic support from a service, Congress, the Secretary of Defense, and the primary defense industry companies, a service will not procure a high-end innovative weapon system. The institutional hypothesis, when overlaid with the research question, becomes very specific: none of the military institutions from 1991–2015 experienced sustained and simultaneous support from congress, the defense secretary's office, and corporate industry for high-end UAVs as a core requirement in force planning, resulting in no favorable adoption outcomes. The third hypothesis proposes that a service's prevailing organizational preferences, which stem from the dominant culture, determines adoption outcomes. Reworded specifically for the UAV research question, the hypothesis states that none of the service's preferences supported adoption of high-end UAVs. The fourth hypothesis comes from the sociological perspective. From this lens, I propose that each of the service's dominant warrior cultures derived its identity and meaning from a uniquely desired level of direct human combat through a weapons system of choice; therefore, the services resisted innovations to the degree that the innovations altered the corresponding social perception of conflict.

Finally, the innovation phenomenon does not occur in a vacuum; there are several factors that are important to note which help clarify the scope conditions surrounding innovation. Contextual factors affect the initial conditions of the independent variable and must be considered when drawing comparisons and conclusions. Those factors include national and military service budgets, existing international treaties, broad national government policies, grand strategies such as the national security strategy, and the context of war and peace. Figure 1 shows the relationship of the variables, the context, and the hypothetical pathways leading to or impacting the dependent variable.

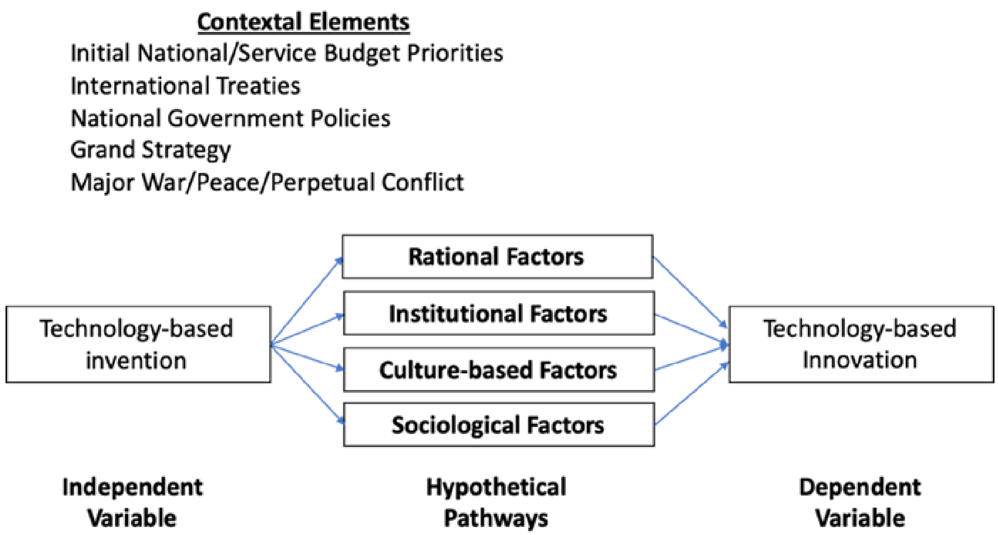

Figure 1. Relationship of Variables and Hypotheses

E. APPROACH OF THE STUDY

1. Case Types: High-, Medium-, and Low-End UAVs

Returning to the research question's focus on innovation outcomes associated with UAV types, there are three main sets of UAVs in which to test the hypotheses: high-end, medium-range, and low-end UAVs. The attributes that distinguish one category from another include the vehicle's level of autonomy, aircraft performance characteristics, intended mission, technological sophistication, and payload. This list synthesizes and distills attributes as described over time by the major military documents and roadmaps associated with UAV development.[39] Automation refers to the degree of automation based on the Sheridan scale of autonomy and the autonomous control level scale—both used as common standards across industry and the DOD—as well as overall computing power.[40]

[39] See footnote 33.

[40] The autonomous control level moves from level 1 as "remotely guided" to level 5 as "group coordinated" and a level 6 of "group tactical replan." Level 10 is fully autonomous swarms. Of note, almost all the UAVs fell at or below the autonomous control level of 3 and only the UCAV (X-45/X-47) had a goal of level 6. See Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap, 2000–2025*. The Sheridan Autonomy Scale is bounded by level 1 where the computer offers no assistance, a level 5 is the computer executes if the human approves, and level 10 the computer decides everything, ignoring the human. Andrew Renault, "A Model for Assessing UAV System Architectures," *Procedia Computer Science* 61 (2015), https://www.doi.org/10.1016/jprocs.2015.09.180.

The aircraft performance characteristics considered includes altitude, speed, and weight of the system—which the Defense Department uses to group all UAVs—and also factors in turn radius/G-force and range, as well as survivability in a non-permissive environment. The mission attribute considers the UAV's intended purpose and the degree of risk those mission sets typically operate under. Technological sophistication factors in the degree that off-the-shelf technology was used in the airframe, materials, and design of the aircraft, to include stealth and communications. Finally, the payload attribute considers such elements as the sophistication of sensor packages, weapons, and electronic attack, or the combination of all three.

This study anchors the UAV sets within U.S. military organizations—Air Force, Navy, and Army—in order to systematically explore the variety of outcomes based on bounded organizational dynamics of each service. The Air Force and Navy are the focus of the study; however, it is difficult to stovepipe each service, as if it is separate from interservice considerations and influences—especially when some of the UAV episodes become joint ventures. Therefore, the Army will have highlights throughout but does not have a chapter dedicated its UAV episodes. This approach enables a more orderly narrative and a straight-forward exploration of how each UAV type fared within each service, giving us nine cases to explore. From the greater instance of automation and robotics invention, UAVs are one of only a few major subcategories that all three services share a common interest and employment in the same domain.[41] By selecting three military organizations within the same country, the research holds constant the degree of technological knowledge and national strategic culture across the cases. This improves cross-case analysis and prevents having to account for these variables, which would be the case if Israeli, Russian, or Japanese cases were considered.[42] Since one of the major objectives of this research is heuristic exploration, it is both permissible and important to consider a wide variety of

[41] For instance, the Navy uses underwater unmanned vehicles, but the Air Force is not competing with the Navy to develop similar systems for use in the water. While the Air Force might have a tangential interest in micro UAVs, it is the land forces such as the Army that have near exclusive use within the immediate operating areas of small units such as companies and platoons.

[42] Outside the United States, Israel and Japan have the most robust civil and military UAV industry, though there are dozens of countries, like Iran, that have active unmanned aerials system industries.

variables; furthermore, such research can remain strong without having to examine numerous cases or restrict the number of variables.[43] That said, the case selections have recognized limitations, as none of these cases and services necessarily represents a tough test or most-likely case.

Narrowing down from the greater population of unmanned aircraft of every conceivable size and design, I limit the UAV systems considered to those which show strong competition across the services. The first limitation is by group, focusing on UAVs that fall in Groups 3, 4, and 5 as defined by the DOD; vehicle weight, flight altitude, and speed are used to delineate the groups as shown in Figure 2.[44] This is important to ensure comparisons across similar technologies available and to consider systems that challenge or replace existing manned system that enjoy their own combat arms branch today. Within the Navy, the focus is on the X-47, R/MQ-4, and UCLASS. For the Air Force, important systems in this group include the RQ-3, X-45, MQ-1, MQ-9, and RQ-4. Other high-tech systems that would be of interest are the RQ-170 and RQ-180, but due to the classification of those systems, I anticipate challenges in accessing data for those systems. The cases are primarily focused on the warfighting services only, as the dependent variable hinges on adoption, not just experimentation or invention. I have excluded the U.S. Marine Corps, as most of its UAV program fall in the small- and micro-UAV Groups 1 and 2. The one Marine Corps program, an unmanned helicopter that falls within the larger Group 3, is replicated by both the Navy and the Army. As for technology demonstrators built by the Defense Advanced Research Project Agency, I only include those UAVs when the Agency was in a deliberate partnership with a service and became a critical part of program on the way to adoption. Again, any purely experimental and advanced concept demonstration programs, such as ultra-high altitude, solar powered UAVs are not considered. Clandestine and Homeland Security agencies are also excluded since they typically have small, niche programs, often rising from or reflecting major military innovation efforts.

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[43] George and Bennett, *Case Studies and Theory Development*, 45.

[44] The groupings are defined by weight, max operating altitude, and speed. Group 3: <1,320 lbs. / <18,000 ft mean sea level / <250 knots; Group 4: >1,320 lbs. / <18,000 ft mean sea level / any airspeed; Group 5: >1,320 lbs. / >18,000 ft mean sea level / any airspeed. U.S. Army UAS Center of Excellence, *"Eyes of the Army,"* 12.

UAS Category	Maximum Gross Takeoff Weight (lbs)	Normal Operating Altitude (ft)	Speed (KIAS)
Group 1	0-20	<1,200 AGL	100 kts
Group 2	21-55	<3,500 AGL	<250
Group 3	<1320	<18,000 MSL	
Group 4	>1320		Any Airspeed
Group 5		>18,000 MSL	

This study focuses Groups 3, 4, and 5. Representative UAVs for these groups are: Group 3: RQ-2; Group 4: MQ-8, MQ-1; Group 5: RQ-4, MQ-9, and X-45/X-47/UCLASS.

Figure 2. Joint UAV Group Classifications[45]

Table 2 shows the coding of each UAV attribute using an ordinal score of either high, medium, or low; a subjective average of the categories for each unmanned aircraft is provided at the right. Finally, the last column indicates the adoption outcomes of the UAVs, when applied, showing variation among the outcomes and military services.

45 Source: Office of the Secretary of the Air Force, *United States Air Force Unmanned Aircraft Systems Flight Plan, 2009–2047*, 25.

Table 2. UAVs Coded by Overall Case Type and Adoption Outcome

UAV System	Service	Automation	Performance	Mission	Technology	Payload	UAV Case Type*	Adoption Outcome
UCLASS	Navy	H	H	H	H	H	**H**	**NA**
RQ-3 Dark Star	AF	M	M	H	H	H	**H**	**NA**
J-UCAS-N (X-47)	DARPA/Navy	H	H	H	H	H	**H**	**NA**
J-UCAS (X-45)	DARPA/AF	M	H	H	H	H	**H**	**NA**
RQ-4 Global Hawk	AF	M	M	M	M	M	**M**	**AW**
MQ-4 Triton	Navy	M	M	M	M	M	**M**	**AW**
RQ-2 Pioneer	Navy/USMC	L	L	L	L	L	**L**	**AW**
MQ-8 Fire Scout	Navy	M	M	M	M	M	**M**	**AW**
MQ-8 Fire Scout	Army	M	M	M	M	M	**M**	**AW**
MQ-5 Hunter	Army	L	L	L	L	L	**L**	**AW**
MQ-25 Stinger	Navy	H	M	L	H	L	**M**	**AW**
MQ-1C Gray Eagle	Army	M	L	M	L	L	**M**	**AW**
MQ-1 Predator	AF	M	L	M	L	L	**L**	**AW**
MQ-9 Reaper	AF	M	M	M	L	M	**M**	**AS**
RQ-7 Shadow	Army	L	L	L	L	L	**L**	**AS**

LEGEND:	L=LOW	NA=NOT ADOPTED
	M=MEDIUM	AW=ADOPTED WEAKLY
	H=HIGH	AS=ADOPTED STRONGLY

* Summary Average of the 5 attributes

J-UCAS-N: Joint Unmanned Combat Air System-Navy

J-UCAS: Joint Unmanned Combat Air System

UCLASS: Unmanned Carrier-Launched Strike and Surveillance

The bounded time period, 1991 to 2015, frames the cases in a way that provides several advantages. First, it affords a variety of strategic, contextual environments such as periods of relative peace (1991–1999), minor war (1999), major war (2001–2008) and perpetual conflict (2001–present). Second, the period is characterized by a significant growth in different types of UAV inventions and operational employment that outpaces previous eras; it is the height of significant invention for UAVs. Third, the period provides the opportunity to build upon previous dissertations and books, which mostly ended their studies in the early 2000s.[46] A slight overlap with these previous works can help create a more coherent story and understanding across the genre. I end with 2015 to provide a recent point of data and analysis in order to avoid speculating about evolving data sets and

[46] Thomas Ehrhard, "Unmanned Aerial Vehicles In the United States Armed Services: A Comparative Study of Weapon System Innovation," (PhD diss., John Hopkins University, 2000); Rosenwasser, "Governance Structure and Weapons Innovation; Stephen Wheatly, "Unmanned Aircraft Systems (UAS) and Innovation," (PhD diss., University of Calgary, 2006), which examines historical developments for trends on the on-going revolution in military affairs.

uncertain trends that are obscured due to classification issues and the major changes in national policy that are still unfolding under the Trump administration.

2. Research Objectives and Methods

The dissertation is anchored by two "theory-building" research objectives.[47] The first objective is *theory-testing*, which deductively seeks to identify and describe the causal factors from the extant theoretical lenses that hold true within and across cases.[48] The second research objective focuses on *heuristic building*, through an inductive approach, to identify potential new mechanisms, relationships among mechanisms, and the contextual conditions that shape or activate combinations of mechanisms leading to innovation outcomes.[49]

I use a multi-method research design combining within-case inference and cross-case inference generalization.[50] For the within-case inference portion, process tracing provides the means to "build and analyze data on causal mechanisms."[51] Process tracing further provides the means to test individual cases and UAV episodes regarding the claims made about causal factors from the rational, institutional, and cultural lenses.[52] I independently test for the causal factors, reflected in Table 1, and looked for overall patterns of mechanisms, when mechanisms clustered, and under what circumstances the mechanisms emerged. After completing the within-case data gathering and analysis, I proceed with a "structured, focused comparison" across cases and UAV episodes to

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[47] George and Bennett, *Case Studies and Theory Development*, 73–74. There are six types of theory building research objectives: atheoretical/configurative idiographic; disciplined configurative; heuristic; theory testing; plausibility probes; and building block.

[48] Stephen Van Evera, *Guide to Methods for Students of Political Science* (Ithaca, NY: Cornell University Press, 1997), 90. "A theory testing dissertation uses empirical evidence to evaluate existing theories"; George and Bennett, *Case Studies and Theory Development*, 75.

[49] George and Bennett, *Case Studies and Theory Development*, 75; See also, John Gerring, *Social Science Methodology, A Criterial Framework* (Cambridge, UK: Cambridge University Press, 2001), 118–124. In a limited way, the dissertation will also be a theory-proposing dissertation, as described by Van Evera, based on constraining causal mechanisms. Van Evera, *Guide to Methods*, 90.

[50] Gary Goertz, *Multimethod Research, Causal Mechanisms, and Case Studies: An Integrated Approach*. Princeton: Princeton University Press, 2017, 1–6.

[51] George and Bennett, *Case Studies and Theory Development*, 223.

[52] George and Bennett, 46, chapter 10.

analyze contexts, mechanisms, and the hypotheses.[53] To facilitate both the within-case inference assessments and create the means to conduct the cross-case comparison in a structured, focused way, I started with the same set of prepared questions to standardize my research of each case/episode, as well as to ensure a common framework through which to compare across the various cases/episodes (Appendix A).

The actor level of analysis for each perspective is different, resulting in unique methodological challenges when testing and comparing cases or outcomes. The rational perspective sits astride the national and service-levels of analysis. The institutional perspective resides primarily at the service level, while the organizational culture perspective moves across both the service level and down to sub-groups within the organization (e.g., pilots and non-pilots). Finally, the sociological perspective spans everything from the nation to the individual. To deal with these methodological concerns, I explore and test hypotheses from the rational, institutional, and cultural perspectives with a focus on the service level—the level all three perspectives have in common—while remaining sensitive to the dynamics and nuance occurring above and below the service level. The sociological hypothesis is treated as an exercise in logic within which to consider the larger societal culture within America and the services. In this way, empirical and logical tools of comparison are engaged in the analysis of UAV adoption outcomes within and across services.

As for the data required to conduct the study, readily available government and secondary sources comprised most data and figures used for this dissertation. Some primary sources contributed as well. Each of the services' historical agencies, UAV centers of excellence, laboratories, and archives, in addition to the major offices and directorates associated with UAV development specifically and acquisitions in general provided rich insight to the events and factors affecting UAV outcomes. During review and gathering of source material, I remained conscious of who spoke (or coordinated) with whom, for what

[53] George and Bennett, 63.

purposes and under what circumstances as a systematic way to assess players, processes, and mechanisms.[54]

Since the dissertation is an unclassified work, any classified data and proprietary technology and processes are not addressed. This limited the robustness and richness of research analysis and testing; however, that limitation only really impacted the most cutting-edge and recent programs such as the RQ-170, which approached the fringes of the time period considered. While technology is important as an antecedent to invention, it is the mechanisms and factors that shape adoption of that technology that remained the focus of this dissertation; therefore, those mechanisms were not likely to be constrained by classified data or processes.

I conducted interviews with civilian and military leaders to provide historical depth and accuracy to the research.[55] The interviews balanced Air Force and Navy personnel, a list of which is found in Appendix B along with their general background. Throughout the research process, I attempted to incorporate first-hand accounts regarding the view of threats and mission challenges, institutional challenges, and to gauge the cultural forces at work in the UAV episodes. In all, an assessment of innovation mechanisms and variables were explored, while remaining sensitive to the discovery of new independent variables and mechanisms. The interviews used the same set of prepared questions to start (Appendix A) but also explored data through extemporaneous questions as a means of follow up and clarification.

F. DISSERTATION STRUCTURE AND OVERVIEW

To start, Chapter II provides an in-depth literature review of military innovation studies and related perspectives on how and why innovation occurs within military organizations. From this literature review, it is shown how the hypotheses arose and are anchored in existing theory. Additionally, as part of the background for the specific military

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[54] George and Bennett, 18n32, 100.

[55] Jeffrey M. Berry, "Validity and Reliability Issues in Elite Interviewing," *PSOnline* (December 2002): 679–682; Joel D. Aberback and Bert A. Rockman, "Conducting and Coding Elite Interviews," *PSOnline* (December 2002): 673–676.

innovation problem surrounding UAV adoption outcomes, a brief historical overview of UAV development and employment by the United States shows the depth of the puzzle and problem as not only a recent phenomenon but one of historical weight with continuities of its own since the World War I era. Chapter III establishes a historical view of UAV adoption across the Army, Navy, and Air Force, periodizing the past in a novel manner. The chapter explores the security environment, general state of technology, and each service's strategy, culture, scientific approach, and UAV plans between 1991–2015. These considerations conform with the rational, institutional, and cultural perspectives and their factors found in Table 1. The chapter concludes with a short introduction to the DOD's major processes that shape the research, development, and acquisition cycles. For those with a solid understanding of these issues, the reader can use this chapter primarily as a reference.

The dissertation is structured to facilitate analysis from within a single service while providing the building blocks necessary to conduct cross-case comparisons as well as comparisons among adoption outcomes by UAV types (high-end, medium, and low-end). Therefore, Chapters IV and V are dedicated to the U.S. Air Force and U.S. Navy respectively. Each chapter has a subsection dedicated by UAV type: one each for high-end, medium-end, and low-end UAVs. The hypotheses are explored and tested within the UAV types, and each chapter ends with a summary and conclusion based on within-service observations.

Chapter IV investigates five U.S. Air Force episodes of UAV development between 1991 and 2015, finding strong rational and institutional influences on outcomes, along with counter-intuitive and nuanced cultural factors within the organization. High-end UAVs selected for the study include the RQ-3 DarkStar and X-45 that spanned developmental years from 1995 to 2006 and were intended to operate in highly contested environments. The RQ-3 was a high-altitude endurance surveillance platform with low observable qualities designed into a cutting-edge airframe. Likewise, the X-45 was intended to conduct strike missions against adversary targets in anti-access/area denial environments; both the RQ-3 and X-45 were intended to be lower cost acquisition projects. The medium-end UAVs included in the study include the MQ-9 Reaper and RQ-4 Global Hawk, which have varying developmental and acquisition periods that cover the majority of the studies time-based boundaries. The MQ-9 became the USAF's most strongly adopted UAV, while the RQ-4 remained mired in prohibitive costs and the competition from other surveillance platforms in the inventory. The only low-end UAV examined is the MQ-1 Predator, a DARPA and industry led effort that would eventually become the Air Force's own success story; however, the fraught path to procurement not only led to weaker adoption outcomes but exposed many competing causal mechanisms of innovation that would impact future episodes such as the MQ-9.

Chapter V also analyzes five UAV episodes under U.S. Navy management from the same time period, many different requirements from the Air Force and a more nuanced cultural landscape. For the most past, several of the Navy episodes had joint interaction with USAF programs, or built on initial Air Force programs to become the Navy's own efforts such as the Unmanned Carrier-Launched Strike and Surveillance (UCLASS) and MQ-4 Triton. The high-end UAV episodes under the Navy rubric include the X-47 Pegasus and its follow on program, the UCLASS. The X-47 achieved several technological breakthroughs for carrier operations from 2006 to 2014. The Navy eventually rejected the short-lived UCLASS, which was intended to operate in high-threat environments like its X-45 predecessor but suffered from indecisive purposes along with several non-rational factors. Medium-end UAVs include the MQ-8 Fire Scout, a helicopter-like system, and the late-adopted MQ-4 Triton, which has a 75 percent design similarity to the Air Force's earlier Global Hawk program. Finally, the low-end UAV program explored in the chapter, the RQ-2 Pioneer, began as a small lot purchase by the Navy and Marine Corps in the mid 1980s; the Pioneer's value to the study is as much in what factors brought about its temporary life-cycle extension, how it contributed to wartime operations and re-opened the eyes of the Navy and broader DOD to reconsider UAVs.

Chapter VI concludes the dissertation by returning to the research objectives of theory testing and heuristic building. First, the chapter analyzes the Air Force and Navy UAV case types (high-, medium-, and low-end) through a within-case analysis of the four main hypotheses and then evaluates cross-case comparisons. Following the theory assessments, the chapter explores the explanatory power and the relationship among mechanisms of military innovation. The research found a core materialist relationship between rational and institution factors that forms core mechanisms acting upon adoption outcomes; furthermore, the analysis suggests that cultural and sociocultural perspectives held influence, but these ideational lenses are positioned as peripheral mechanisms that have greater influence within certain contexts. Additionally, the chapter deliberates on practical implications for military organizational and national efforts to modernize forces. Finally, this chapter offers an assessment regarding limitations of the study as well as recommendations for future research.

The dissertation describes and explains the determinants of organizational behavior and outcomes within military organizations related to military technological innovation. It is a study of an institutional case of reluctance to innovate in comparison to sister service development of similar technologies; furthermore, I seek to explain Air Force and Navy behavior following the 1991 Gulf War, and the question of what theories of military innovation and organizational learning can explain the U.S. military's challenge to meet operational problems early in the 21st century. For the services, what senior leader decision and stances reaped success or failure in a variety of internal and external relationships, resource sharing, and institutional effectiveness? Ultimately, the research will provide insights to the broader question posed earlier: *Why is it hard for military organizations to relatively quickly adopt important innovations?* By looking at the time period between 1991–2015 and the episodes associated across this particularly important invention—high-end UAVs—theoretical, intellectual, and practical knowledge emerged from the research. These rational, institutional, and political lessons hold important implications that are actionable. Moreover, lessons included cultural insights as well, though these prove more difficult to implement and take a long time to change.

Overall, the results of this research are of interest to the Air Force and Navy in general, with special emphasis on senior leaders, acquisition professionals, American security strategy and policy makers, defense industry partners, and scholars of military innovation and security studies. It is of interest tangentially to scholars of international relations and senior leaders of other U.S. military services. The research helps answer other broad questions of security studies interest such as: How has the U.S. military adapted, or failed to adapt, to emerging technology? When do U.S. military services become interested in technological innovation? Is this an instance of bureaucratic inertia or a case of organizational culture?

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II. LITERATURE REVIEW

Technology is only one of strategy's dimensions, but it always plays.[56]

The study of military innovation, a subset of Security Studies, uses social sciences to understand the mechanisms and variables that determine innovation outcomes within military organizations. As part of the human condition,[57] military conflict and the changing character of warfare prominently features accounts of technological change such as the introduction of the cross-bow and gunpowder.[58] As a distinct field of endeavor emerging in the latter half of the 20th century, military innovation studies grew through a series of debates between organizational studies and political science, using historical case studies as a prime methodology. Scholars in both organizational and political traditions used a variety of sub-field perspectives to develop both descriptive and prescriptive accounts of innovative phenomena within military organizations; over time, the two fields converged. This literature review analyzes the debates between and within these two major fields, considers the evolving definition of innovation, evaluates areas for further research related to military and institutional change in the face of emerging technologies, and reviews historical UAV development and adoption cases.

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[56] Colin S. Gray, *Weapons for Strategic Effect. How Important is Technology?* (occasional paper No. 21, Center for Strategy and Technology, U.S. Air War College, January 2001), 36, https://pdfs.semanticscholar.org/00f9/6d37a7ea62c8952e7e1d7054089fb4dfd65b.pdf.

[57] It is largely accepted across the strategic studies community that the nature of war is immutable and fixed while the character of warfare is ever changing and highly dynamic. For an overview discussion on this subject, see Michael Sheehan, "The Evolution of Modern Warfare," in *Strategy in the Contemporary World*, ed. John Baylis, James J. Wirtz, and Colin S. Gray, 5th ed. (New York, NY: Oxford University Press, 2016), 33–51.

[58] These accounts, rooted in the historical methodology, are plentiful. Generally, military historians preferred to discuss war-time success as an outgrowth of technological advancements or a matter of military genius. Adam Grissom identified several salient examples of this trend to include J.F.C. Fuller, *Armament and History: A Study of the Influence of Armament on History from the Dawn of Classical Warfare to the Second World War* (New York: Scribner's, 1945); S.L.A. Marshall, *Night Drop: Normandy* (New York: Jove, 1984); and D. Douglas Dalgleish and Larry Schweikart, *Trident* (Carbondale: Southern Illinois University Press, 1984). See Grissom, "The Future of Military Innovation Studies." Another key example includes Donald MacKenzie, *Inventing Accuracy: a Historical Sociology of Nuclear Missile Guidance* (Cambridge, MA: MIT Press, 1990).

Early innovation scholars utilized organizational theory as a basis for research, starting in the late 1960s through 1970s. From this perspective, the behaviors of government organizations can best be "understood less as deliberate choices and more as outputs of large organizations functioning according to standard patterns of behavior."[59] From this view, military organizations are concerned with resources and prestige,[60] and the organizations become stuck in standard operating procedures. Graham Allison summarizes this behavior as one of routines, or "tendencies,"[61] that make organizational change difficult, which then turns meaningful learning into a long-term prospect. Put another way, tangible innovative change only occurs as a response to disasters.[62] Stephen Rosen would later argue that once an organization becomes a bureaucracy, it is actually "designed not to change."[63] The idea that military organization are highly inflexible remained a hallmark of innovation studies until the middle of the 1990s.[64] In sum, these works represented researchers' efforts to "explain instances of irrational consistency" when organizations should have changed due to compelling environmental changes but did not.[65]

Dissatisfied with the lack of rich, theory-based explanations, political science scholars in the mid-1980s started exploring causal explanations to better describe how and why militaries innovated. Arguing against the early organizational theories that militaries

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59 Graham Allison and Philip Zelikow, *Essence of Decision: Explaining the Cuban Missile Crisis*, 2nd ed. (New York: Addison, Wesley, and Longman, Inc., 1999), 143. Allison's Model II framework focuses on organizational behavior.

60 Resources as a major driver of organizational behavior evolved from Max Weber (1922), *Economy and Society* (Berkley, University of California Press, 1978).; Max Weber, *The Theory of Social and Economic Organization* (New York: Oxford University Press, 1947).; James Q. Wilson, "Innovation in Organization: Notes Toward a Theory," in *Approaches to Organizational Design*, ed. James D. Thompson (Pittsburgh, University of Pittsburgh Press, 1966), 195.

61 Allison and Zelikow, *Essence of Decision*, 144–147. These tendencies are guided by what March and Simon termed a logic of "appropriateness" where individual and organizations holistically base calculations of actions/decisions on the ability to retrieve experiences and institutional knowledge that inform what is "appropriate" to do.

62 Avant, *Political Institutions and Military Change*, 4. Because of these organizational tendencies, Avant argues that military organizations are often unresponsive to the nation's needs.

63 Rosen, *Winning the Next War*, 2.

64 Rosen.

65 James Wirtz, personal communication, May 8, 2020.

find it hard to change, Barry Posen, in his seminal book *Sources of Military Doctrine*, countered that militaries do change, but only as a response to civilian intervention. Posen applied a rigorous, social-science based approach to military innovation studies.[66] Foregoing "historical narratives, operational histories, and bureaucratic-political case studies," Posen demonstrated a compelling empirical argument by framing military innovation theory in a positivist-structural epistemology.[67] Posen based his work on Realist assumptions from the international relations perspective. Posen rejected the descriptive organizational behavior theories of military change and innovation in favor of a more generalizable and predictable argument grounded in political science and international relations perspectives, particularly Neorealism.[68] Essentially, Posen tested organizational theories against Neorealism's structuralist framework,[69] concluding that balances of power drove a state's executive leaders to induce change in military doctrine when necessary. The theory and arguments by Posen launched new scholarly interest in military change, transformation, and innovation and opened the aperture beyond managerial, leadership, and organizational behavioral explanations to tie military change more directly to theories of international politics.

The richness of Posen's ground-breaking theory and research sparked a flood of intellectual activity by other scholars seeking to shape the research program and explore the military innovation studies subfield as a part of security studies under the broader

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[66] Posen, *The Sources of Military Doctrine*. Posen showed the linkages among international relations, grand strategy, and the development of military doctrine to drive capability development. Specifically, Posen sought to understand the determinants of a nation's security posture—offensive, defensive, or deterrence—and how that posture relates to or is shaped by the military's doctrinal development. For the first time in security studies, military innovation gained a more rich and robust causal linkage to civil-military relations and a nation's grand strategy; furthermore, Posen showed that changes in military capabilities and organizational structures was not a simple tit-for-tat game among military competitors. Suddenly, historical, tech-based explanations did not hold sufficient explanatory power.

[67] Grissom, "The Future of Military Innovation Studies."

[68] The Realist and Neorealist schools of international relations argue that relative military power is the primary mechanism for achieving security. For example, Mearsheimer argues that great powers are "determined largely on the basis of their relative military capability." Mearsheimer, *The Tragedy of Great Power Politics*, 5. How a nation develops that capability or the role that innovation plays in securing victory once power is amassed, is not addressed by Mearsheimer. See also Waltz, *Theory of International Politics*.

[69] Farrell and Terriff. *The Sources of Military Change*, 27.

discipline of international relations. Since 1984, the evolution of military innovation studies generally followed trends in the broader international relations literature—moving from Realism to Liberalism to Constructivism—and organizational studies. Following Posen's book, military innovation scholars posed questions that went beyond issues narrowly related to technological evolution.[70] Using a variety of historical case studies, the researchers sought to empirically test questions such as:

- "When and why do military organizations make major innovations in the way they fight?"[71]

- What is the relationship of strategy, military doctrine, and innovation?[72]

- "Is it easier for them [military organizations] to innovate in peacetime, when the enemy is not engaging them in combat, or is innovation easier in wartime precisely because they can learn from combat?"[73]

Other general questions emerged in the military innovation studies literature:

- What are the characteristics of successful innovation?

- Why do nations with similar capabilities and resources develop different means and ways that lead one to victory and the other to defeat?

- What are the contexts that most shape whether a military innovates or not?

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70 There is a separate but related literature focused on the Revolution of Military Affairs, most prominently championed by Williamson Murray and Eliot Cohen among others, which focuses on radical military-technological transformation from a historical perspective. This line of thinking developed significantly following the United States' tremendously lop-sided military triumph over Iraq in the 1991 Gulf War. Eliot A. Cohen, "A Revolution in Warfare." *Foreign Affairs* 75, no. 2 (1996): 37–54, https://www.doi.org/10.2307/20047487; Williamson Murray, "Thinking About Revolutions in Military Affairs." *Joint Forces Quarterly* (Summer 1997), http://www.dtic.mil/dtic/tr/fulltext/u2/ a354177.pdf.

71 Rosen, *Winning the Next War*, 1.

72 Posen, *The Sources of Military Doctrine*.

73 Rosen, *Winning the Next War*, 1.

- Who are the actors that influence innovation and adaptation, and how does that work at the various levels of war?
- When and how does innovation occur "top-down" versus "bottom-up"?
- Can innovation and adaptation be isolated to technical developments, or is there a larger social, economic, organization, and cultural aspect to this phenomenon?

To answer and codify the military innovation studies research program, scholars used a variety of social science based, multi-disciplinary methods challenging one another over theory validity and explanatory power. In 2006, Adam Grissom summarized the field into the competing schools of "civil-military relations, inter-service politics, intra-service politics, and organizational culture."[74] From these schools, Grissom, Lee, and Mueller then identified the most prominent independent variables explored by scholars: geopolitical threats, technological advancements, bureaucratic politics among services, the cultural framing of problems, and operational-tactical adaptation in the field.[75] To simplify these schools and variables used by organizational and political scientists, I chose three perspectives to frame the broader debates within the interdisciplinary military innovation studies subfield: rationalism, institutionalism, and culturalism. These perspectives reflect the categories of chronological arguments and the incremental building of theory within the field.

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[74] Grissom, "The Future of Military Innovation Studies," 908.

[75] Grissom, Lee, and Mueller, *Innovation in the United States Air Force,* 2. While organization learning theory remains important and tangentially related to understanding military innovation, it tends to influence both the cultural and intra-service schools of thought within the field of innovation military studies.

A. LOGIC OF RATIONALISM (EMPIRICISM, STATE POWER, AND UTILITY)

The first perspective, rationalism,[76] sees military innovation as a "pragmatic" result of direction handed down to military departments by state executives as a response to external security threats in the international system. According to this materialist, instrumental view, the senior state official formulates a grand strategy in response to the nation's relative power position in the international system.[77] The state official then rationally chooses either a primarily offensive or defensive military approach for the best utility and directs the military services to adjust their doctrine and weapon systems accordingly.[78] This perspective of military innovation, championed by Barry Posen in *The Sources of Military Doctrine*, draws heavily from the Neo-realist traditions of international relations and assumes that political leaders are attuned to a "knowable enemy" in the international strategic context,[79] are motivated by security concerns and threats, and base decisions on cost-benefit strategic calculations of power balancing.[80] Furthermore, it assumes a perspective where the pattern of arms developments and military innovation is based on empirical, positivist feedback loops at the civilian level of leadership;[81]

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76 Rationalism in this case does not refer to a philosophical, epistemological rationalism of the classical sense, where knowledge is gained independent of sensory experience. Rationalism is used as short-hand for an empirical, data-driven process associated with rational-choice models, utility, and such. Peter Markie, "Rationalism vs Empiricism," in Edward N. Zalta, ed., *The Stanford Encyclopedia of Philosophy*, Fall 2017, https://plato.stanford.edu/cgi-bin/encyclopedia/archinfo.cgi?entry=rationalism-empiricism.

77 Jack Snyder, "One World, Rival Theories," *Foreign Policy* 145, (November–December 2004): 55.

78 Posen, *The Sources of Military Doctrine*. See also Williamson Murray and Allan R. Millett, ed. *Military Innovation in the Interwar Period* (Cambridge: Cambridge University Press, 1996), which explores this perspective as one mechanism among many in military innovation efforts. This unitary state actor is covered extensively as well as Model I, the Rational Actor Model, also referred to a "logic of consequences" in Allison and Zelikow, *Essence of Decision*, 13.

79 Alan Millett, "Patterns of Military Innovation in the Interwar Period," in *Military Innovation in the Interwar Period*, Williamson Murray and Alan R. Millett, ed., 335.

80 Key works outlining the Realist and Neo-realist positions include Hans J. Morgenthau, *Politics Among Nations: The Struggle for Power and Peace* (Boston, MA: McGraw-Hill, 1993); Waltz, *Theory of International Politics*.; Mearsheimer, *The Tragedy of Great Power Politics*.

81 The rationalism perspective of military innovation uses empirical, not rational, philosophic foundations for knowledge development. For more on the distinction, see Peter Markie, "Rationalism vs. Empiricism," *The Stanford Encyclopedia of Philosophy* (Fall 2017 Edition), Edward N. Zalta (ed.): https://plato.stanford.edu/entries/rationalism-empiricism/.

furthermore, militaries do not seek strategic adaptations on their own, choosing to focus on tactical-level adjustments and improvements only. Rationalism suggests that innovation within military organizations requires an external catalyst to effect meaningful change and is based on utilitarian reactions evolving from the state's position (economically, militarily, geographically, etc.) within an anarchic global system. Put another way, "military change is a rational response" to changes in the strategic environment at the behest of civilian masters;[82] furthermore, it is a deliberate calculation.[83] Eliot Cohen argues for this model of an active and intervening civil-military model in Supreme Command, challenging Samuel Huntington's earlier theories, which stressed an independent military best left alone from civilians in order to set wartime agendas and the matters of defense.[84]

Several scholars since Posen exposed the shortcomings of rationalism as a paradigm for military change. Theo Ferrell and Terry Terriff note that the Neorealist approach ignores the role and ability for *ideas* to affect military change either positively or negatively; furthermore, this approach fails to give sufficient attention "to the role of domestic politics in shaping strategy."[85] Additionally, Deborah Avant points out that rational choice and a Neorealist model of military change depends too much upon the assumption that civilians pay attention to security interests and have the time and inclination to induce change to military doctrine—and thus the direction of innovation and planning—when necessary.[86] Starting in the early 1990s, these challenges to rationalism produced an institutional-based set of theories and arguments within the military innovation studies genre.

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[82] Farrell and Terriff, *The Sources of Military Change*, 271. As one can see, the assumptions of organizational theory built in the 1960s and 1970s underpin this perspective, namely that organizations are built to be routine and efficient, therefore, organizations will not seek meaningful change on their own.

[83] Stephen P. Rosen, *War and Human Nature* (Princeton, NJ: Princeton University Press, 2005), 1.

[84] Eliot A. Cohen, *Supreme Command: Soldiers, Statesmen, and Leadership in Wartime* (New York: Anchor Books, 2002).

[85] Farrell and Terriff. *The Sources of Military Change*, 271.

[86] Avant, *Political Institutions and Military Change*, 4.

B. LOGIC OF INSTITUTIONALISM (POLITICAL POWER AND GROUPS)

The second view of military innovation, institutionalism, challenges the rationalist-based unitary actor models and intrusive civil-military requirements of the rationalist perspective. Instead, institutionalism considers the impact of both foreign and domestic factors upon innovation outcomes. As early as 1970, Graham Allison summarized this perspective as government politics,[87] and along with Halperin, revealed the importance of domestic bureaucratic politics a couple of years later.[88] Institutionalism is loosely related to advances in Liberalist international relations theory, which broadened the level of analysis beyond state unitary actors and included domestic and non-state level actors; the military services are among those actors. Scholars working within this perspective argue that intragroup and intergroup dynamics drive innovation and that the nature of bureaucracies has many sources of change, best achieved when actors within the bureaucracy are rewarded with a significant gain in resources or prestige.[89] In the early 1990s, Stephen Rosen, Deborah Avant, and Kimberly Zisk championed this perspective of military innovation, claiming that the quality of integration between military doctrine and national security goals depends on much more than civilian direction as described by rationalism. The domestic and institutional variables are equally if not more important mechanisms.[90]

Stephen Rosen framed his research as a problem of getting bureaucracies to innovate in order to prevent fighting the last war while also seeking to understand how and when military organizations make major innovations. Posen found that abundance of resources and influence by major subgroups of an organization "was neither a barrier to

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[87] Government Politics is synonymous with Model III in Allison and Zelikow, *Essence of Decision*. Allison and Zelikow use this model to challenge organizational theory as a set of outcomes, and instead, is the result of bargaining of actors at all levels within hierarchies through the "interaction of competing preferences," Allison and Zelikow, *Essence of Decision*, 255.

[88] Graham T. Allison and Morton H. Halperin, "Bureaucratic Politics: A Paradigm and Some Policy Implications," *World Politics*, Vol 24 (Spring 1972).

[89] Kimberly Zisk, *Engaging the Enemy: Organizational Theory and Soviet Military Innovation*, 1955–1991 (Princeton, NJ: Princeton University Press, 1993).; Rosen, *Winning the Next War*; Avant, *Political Institutions and Military Change*.

[90] Farrell and Terriff, *The Sources of Military Change*, 10–12.

nor a guarantee of innovation."[91] He claimed that focusing on budgets was not as important as once thought, and he went on to say that when an organization did not redirect human resources to shape innovation development, promising inventions and early adoptions of innovation efforts either stalled or were rejected altogether.[92] Additionally, Rosen observed that military innovation does not have to necessarily include behavioral changes in the organization, but can be characterized by producing new military technologies.[93] Also, military innovations were only loosely contingent upon intelligence about adversary behavior and capabilities; analysis and wargame simulations reduce uncertainties related to imperfect information about an adversary's technological development, especially in peacetime.[94] Rosen indicated that neither intelligence analysis about the enemy, nor cost-utility alternative analysis, necessarily drove military technological innovation. He claimed that military organizations typically adopted innovative technologies when faced with increasing informational uncertainty within the strategic environment.[95] The adoption of technology, therefore, was shaped as a result of probabilities gleaned from imperfect intelligence analysis and wargame simulations. Finally, regarding civilian oversight and initiation of innovations, Posen assessed that civilians had a relatively small role in deciding which new capabilities to pursue, though they helped protect or accelerate innovations underway. Like other institutional-based scholars, Posen found that civilian control over promotion mechanisms affected innovation efforts in peacetime, while civilian scientists prompted technological innovation but did not have a major role in outcomes.[96]

Using what she termed "institutional theory," Avant built upon Posen and Snyder's organizational theories studying the mechanisms that determine how well military doctrine

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[91] Rosen, *Winning the Next War*, 252.

[92] Rosen.

[93] Horowitz, *The Diffusion of Military Power,* 38.

[94] Rosen, *Winning the Next War*, 254. Intel analysis narrowed the range of possible futures and simulations identified a range of potential military requirements.

[95] Rosen, 251.

[96] Rosen, 256.

eventually aligns and integrates with national security goals. She focused on the interaction between structure and process. Avant concludes that civilian leaders create incentive structures to influence military service preferences, and that as incentives change, so do perceptions toward ideas. Essentially, she concludes that "civilian intervention is neither a necessary nor a sufficient condition for military responsiveness" when it comes to military doctrinal change; instead, it is the degree of unification between the principle and agent. Ideas are only as convincing as the enticements that back them.[97] In concert with Posen, Avant reasserts that changes in international threats are not enough to compel an organization to innovate or change.[98]

Concurrently, Zisk criticized Posen's conclusions, noting that military organizations do not always resist doctrinal innovation, do not value status and stability over all else, and that international-system level theories do not best explain military change despite theoretical parsimony.[99] Expanding on the foundation of earlier organizational theory, Zisk found that military officers remain sensitive to their perceived adversary's changing doctrine and force capabilities and will pursue changes to their own doctrine and capabilities to meet state security interests. Additionally, Zisk challenged the monolithic view of organizations—often reflective of only senior leadership—arguing that officers have individual political and personal considerations that they bring to debates about policy and doctrinal development. She goes so far as to list "age, length of service, educational experience, and psychological predisposition" as factors influencing the direction and outcomes of innovation efforts.[100] Zisk concludes that senior military and civilians as security policymakers are both state actors seeking solutions to international security problems as well as bureaucratic actors seeking to maintain the "health of their

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[97] Avant, *Political Institutions and Military Change*, 5.

[98] Farrell and Terriff. *The Sources of Military Change*, 274.

[99] Zisk, *Engaging the Enemy*, 3. Zisk explored five hypotheses: the correlation of foreign threats to military innovation; innovations aligned to organizational interests; domestic threats outweigh international threats in importance; discussion and debate on policy innovations will permeate the community; relationship between community building and interest formation.

[100] Zisk, 4.

organizations."[101] Furthermore, Zisk assessed that outcomes are not fully explainable by structural and procedural mechanisms alone. She found that "organizational interests constrain beliefs and behavior, but do not determine beliefs or behavior."[102] Finally, Zisk confirmed Avant's earlier finding that that an organization's innovation ethos played a role in shaping and determining outcomes. Neither scholar explored that avenue further, leaving room for a future cultural turn in the military innovation studies literature, which I examine in the next section.

The study of organizational change as a function of group political and power dynamics peaked in the early 1970s through 1980s,[103] likely shaping the institutionalist movement in military innovation studies by Posen, Avant, and Zisk. Rooted in psychology and behavior disciplines, organizational group studies sought to understand the way groups interact with other groups, clients, and stakeholders. Fundamental to group behavior in organizations is that organizations are "political systems," and "when people get together, power will be exerted."[104] This is the proverbial empire building so often spoken about by members of an organization when chiding power-hungry colleagues. But power is not just individually generated. Political activity is often determined more by organizational culture, which begins to muddy the waters with the cultural perspective of military innovation. For now, it is important to note that beyond the levels of trust engendered within and among groups, organizational factors such clarity of roles, evaluation practices, reward allocation systems, performance demands, and other organizational practices impact political maneuvering and action among groups.[105] All these factors have an effect on the ability of an organization to learn; that is, to adapt and change. These practices effect

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101 Zisk, 3–6.

102 Zisk, 184.

103 Stephen P. Robbins, *Essentials of Organizational Behavior*, 6th ed. (Upper Saddle River, NJ: Prentice Hall, 2000). See References for Chapter 11, "Power and Politics," 284.

104 Robbins, *Essentials of Organizational Behavior*, 153–166.

105 Robbins, 162.

the degree of "fragmentation," "competition," and "reactiveness," experienced across and within groups of the organization.[106]

Leveraging the efforts and lessons of organizational group behavior and its effect on change/innovation, foreign policy experts took seriously how institutional learning behavior affected policy and world politics; this occurred long before military innovation scholars took up institutionalism as a perspective for innovation and change. Objecting to the rational choice school of thought, Halperin and Allison proposed a bureaucratic politics model as a framework that focuses on individuals and their groups as they follow "regularized circuits" of bargaining, with the "bargaining and the results" shaped by organizational processes and values.[107] The processes are highly correlated to organizational behavior studies, while the values component of their work relates more closely to cultural arguments examined in section below. It was not long until other models of governmental institutions emerged as well.

Related to organizational change and group interaction, the Iron Triangle model emerged as a way for political science scholars to describe the dynamics of change (and stagnation) within governmental institutions. This model describes the bonds among stakeholders in policymaking among congressional committees, interest groups, and an administrative agency.[108] For military matters, that triangle would comprise the Pentagon, Congressional armed services committees, and armaments manufacturers. Eisenhower alluded to the strengths of Iron Triangles when he warned in 1961 against the power of the

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[106] Robbins, 270–271. Fragmentation is due to specialization and creates stovepipes and warring factions; competition undermines collaboration—as exacerbated by group politics; reactiveness keeps management's attention on crisis problem solving instead of on creation.

[107] Allison and Halperin, "Bureaucratic Politics: A Paradigm and Some Policy Implications," 43–44. This model implies that actors act rationally based on "various conceptions of national security, organizational, domestic, and personal interests" instead of a single rational choice. In the end, any decision or policy is an unstable, temporary compromise. Halperin expanded on the cultural aspects of bureaucratic politics in the subsequent Morton H. Halperin, Priscilla A. Clapp, and Arnold Kanter, *Bureaucratic Politics and Foreign Policy* (Washington, DC: Brookings Institution Press, 1974). For a definition of learning and a deeper survey of the learning literature, see Jack S. Levy, "Learning and Foreign Policy: Sweeping a Conceptual Minefield," *International Organization* 48, no. 2 (Spring 1994).

[108] Duncan Watts, "Iron Triangle," Dictionary of American Government and Politics, s.v. "Iron Triangle," accessed July 17, 2019, http://libproxy.nps.edu/login?qurl=https%3A%2F%2F search.credoreference.com%2Fcontent%2Fentry%2Feupamgov%2Firon_triangle%2F0%3FinstitutionId%3D901.

military-industrial complex. In our case, a military service could easily be substituted for the Pentagon as one of the triads. Since the early 2000s, the power of triads has waned as "issue networks" now dominate and disrupt the triangles.[109] These networks are wider and looser than the triads, but leverage information, media, and other forms to relax the stranglehold of Iron Triangles.[110] Change and innovation are now viewed as a function of collaborative networks, not just interrelated groups in government institutions and bureaucracy.

Though initially concerned with business, management, and government bureaucracy, the concept of adaptive innovation within government's military organizations was a logical next step. Some outstanding works within this genre include *The Logic of Failure*, *Military Misfortunes*, *Why Air Forces Fail*, *The Echo of Battle*, and *The Agile Organization*.[111] In studies about military organizational learning, the aspect of failure took center stage. For the organizational learning theorist, failure to learn is both a factor of faulty thinking or imaging[112] and faulty organizational structures.[113] There are both the personal shortcomings of individuals along with structural problems that lead to

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[109] Rod Hague and Martin Harrop, *Comparative Government and Politics: An Introductory Guide* (New York: Palgrave, 2004), 172. One example given in the Dictionary of American Government and Politics of triads disrupted by issue networks is the tobacco industry; another is that military expenditures on weaponry drop in times when there is not an over threat to the country.

[110] Duncan Watts, Dictionary of American Government and Politics, s.v. "Issue Networks," accessed July 17, 2019, http://libproxy.nps.edu/login?qurl=https%3A%2F%2Fsearch.credoreference.com%2Fcontent%2Fentry %2Feupamgov%2Fissue_networks%2F0%3FinstitutionId%3D901; See also Alan Grant and Edward Ashbee, *The Politics Today Companion to American Government* (Manchester, UK: Manchester University Press, 2002).

[111] Dietrich Dörner, *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations*. (Cambridge, MA: Perseus Books, 1989); Brian M. Linn, *The Echo of Battle: The Army's Way of War*. (Cambridge, MA: Harvard University Press, 2007); Robin Higham and Stephen J. Harris, ed., *Why Air Forces Fail: The Anatomy of Defeat.* Revised ed. (Lexington, KY: University Press of Kentucky, 2016); Eliot A. Cohen and John Gooch, *Military Misfortunes, The Anatomy of Failure in War* (New York: Free Press, 1990); Simon Reay Atkinson and James Moffat, *The Agile Organization: From Informal Networks to Complex Effects and Agility* (Washington, DC: DOD Command and Control Research Program, 2005).

[112] Dietrich Dörner, *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations*. (Cambridge, MA: Perseus Books, 1989). Dörner concludes that habits of "methodism" lead to "seeing new situations in terms of old, established patterns of action;" another habit is to form "ballistic decisions" as a tendency to ignore consequences due to economizing for time and effort. Finally, our efforts to info-gather, plan, and process solutions is strongly shaped by our human need to self-protect a positive image of our own competence. Page 187–188; See also Linn, *The Echo of Battle*; Higham and Harris, ed. *Why Air Forces Fail*.

[113] Cohen and Gooch, *Military Misfortunes*; Atkinson and Moffat, *The Agile Organization*.

learning failures. The habits built into leaders over decades of serving in the same organizational structure can become ossified and inflexible despite the need to change due to pressing challenges.[114] But to simply blame the organizational leader as an individual reflects a reductionist fallacy; the lesson is to understand the critical tasks as an organization sees them and how that shapes individuals' behavior within the organization. Using Army history, Brian Linn argues that the institutionalized cultural assumptions derived from previous wars, and the desire to fight particular types of wars, leads to repeated failures to learn and innovate appropriately including failures in strategy, technology, doctrine, and leadership.[115] Working from Air Force cases of wartime failures, Higham and Harris conclude that three categories of failure exist: those that never had a chance, those that succeeded at first but failed in the end, and those that failed but soon after found victory.[116] The conclusion from the Air Force cases is that airpower victory in war is highly dependent upon the long-term health and interconnectedness of government, industry, and populace before and throughout wartime.[117]

In the latest turn of argument, Michael Horowitz maintains institutional and organizational factors as drivers related to innovation but proposes the adoption-capacity theory to factor in organizational theory, institutional theory, cultural theory, and international relations theories all at once. This syncretic effort resulted in the first attempted holistic theory of military innovation. Adoption-capacity theory suggests that financial costs and the burden of organizational requirements to affect change define the distribution of innovations around the globe as well as determine the way each actor makes decisions.[118] Horowitz concludes that the degree and speed to which states and organizations adopt major military innovations is based on an inverse relationship to cost

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[114] Cohen and Gooch, *Military Misfortunes*, 232.

[115] Linn, *The Echo of Battle*.

[116] Higham and Harris, ed. *Why Air Forces Fail*, 4–5. These are names colloquially referred to as the "dead ducks," "hares," and "phoenixes" respectively.

[117] Higham and Harris, *Why Air Forces Fail*, 355.

[118] Horowitz, *The Diffusion of Military Power*, 30.

and organizational capacity to absorb change.[119] While parsimonious and attractive, the theory neglects to consider culture as a intervening variable, despite Horowitz's efforts to deflect such criticism. Additionally, the argument rests on a tautology that those who can change will, and those that cannot will not. On top of that, the adoption-capacity theory fails to fully account for Avant's institutional factors, such as officer promotion incentives, and discounts Posen's findings that large program costs did not necessarily deter military organizations or nations from adopting innovative and disruptive change.

Despite many strong arguments within the institutionalist and organizational behavior perspectives, there are challenges and weakness as well. Rosen found that the impact of budgets, money, and resources did not have as great an effect on innovation outcomes, weakening the bureaucratic theory expectation that resource fights would drive outcomes. Instead, "talented personnel, time, and information" had greater impacts on innovation.[120] Another common pitfall of group dynamics within organizations includes groupthink, where group pressures for consensus drives out critical thinking or minority views.[121] Additionally, Avant determined that a high degree of innovation ethos and organizational flexibility with regard to learning and adaptation will result in an ideological struggle within the organization, which is a good thing. In other words, organizational culture seems to matter, but to what degree is the question.

C. LOGIC OF CULTURE (SHARED MEANING, VALUES, AND IDENTITY)

Since the 1990s, the cultural view has ascended within military innovation studies, with mixed results. Stuart Griffin observed that only the organizational culture school of military innovation disputed rational-structural explanations by introducing cultural, anthropological, and social causal factors that challenged predominant epistemological

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[119] Horowitz, 32–39.

[120] Rosen, *Winning the Next War*, 252.

[121] Robbins, *Essentials of Organizational Behavior*, 99–100. See also Irving L. Janis, *Groupthink: Psychological Studies of Policy Decisions and Fiascos*, 2nd ed. (Boston, MA: Houghton Mifflin Company, 1982).

views within the field.[122] Following rationalism and institutionalism, this third view frames military innovation as a phenomenon of culture.[123] The organizational culture perspective takes cues from international relation's constructivist theory.[124] Military innovation literature emphasizes two cultural perspectives: organizational culture and strategic culture. A third, much broader sociological perspective—a sociocultural perspective—opens the aperture of the cultural perspective to consider factors not traditionally examined by military innovation scholars. These three perspectives of organizational culture, strategic culture, and sociocultural aspects are the focus of this section.

A rich literature exists about military organizational culture and how organizational culture contextualizes organizational policy, processes and innovation outcomes. Originating in the 1940s, organizational culture studies boomed in the 1980s as business leaders renewed interest in corporation styles. Organizational culture "is regarded as a more or less cohesive system of meanings and symbols" and is manifested in espoused values, "assumptions about social reality," and the "affective aspects of membership in an organization."[125] Assumptions about how the world works and what solutions produce the best results become ingrained in organizations over time;[126] therefore, "organizations exist

[122] Elizabeth Kier and Dima Adamsky provide the most dominant culturally affiliated arguments in the field of innovation studies. Stuart Griffin, "Military Innovation Studies: Multidisciplinary or Lacking Discipline?" *The Journal of Strategic Studies* 40, no. 1–2 (2016): 205, https://doi.org/ 10.1080/01402390. 2016.1196358. See original works: Elizabeth Kier, "Culture and Military Doctrine: France between the Wars," *International Security*, 19, no. 4 (Spring 1995); Dima Adamsky, *The Culture of Military Innovation* (Stanford, CA: Stanford University Press, 2010).

[123] Elizabeth Kier, *Imagining War: French and British Military Doctrine Between the Wars* (Princeton, NJ: Princeton University Press, 1997); Farrell and Terriff, *The Sources of Military Change* (2002).

[124] Alexander Wendt, "Anarchy is What States Make of It: the Social Construction of Power Politics," *International Organizations* 46, no. 2 (Spring 1992); Alexander Wendt, *Social Theory of International Politics* (Cambridge, NY: Cambridge University Press, 1999); Martha Finnemore, "Constructing Norms of Humanitarian Intervention," in *The Culture of National Security: Norms and Identity in World Politics*, ed. Peter J. Katzenstein (New York: Columbia University Press, 1996).

[125] Mats Alvesson, *Understanding Organizational Culture* (London: SAGE Publications, 2002), 3.

[126] Edgar H. Schein, *Organizational Culture and Leadership*, 4th ed. (San Francisco, CA: John Wiley & Sons, 2010).

to constrain action in line with knowledge and preferences."[127] In other words, "organization is bias."[128] One can assess organizational culture in many different ways, but two methods stands out: Dennis Coyle's grid-group model[129] and Stephen Robbins's seven character-traits list.[130] Coyle's model, favored by political scientists, used "grid," which describes the degree of structure and accompanying constraints such as rules, facts, means, and lack of exit, and "group," which describes the degree of social versus individual cultural tendencies as expressed in ends, values, and such.[131] The second model includes seven characteristics, which "in aggregate, capture the essence of an organization's culture."[132] Robbins's seven characteristics include innovation and risk taking; attention to detail; outcome orientation; people orientation; team orientation; aggressiveness; and stability (status quo in contrast growth). Subsequently, U.S. military organizations took interest in related cultural work as an outgrowth of their reflection on the Vietnam War era.

Carl Builder laid the foundation for contemporary discussions on military culture in his renowned work, *The Masks of War*, which explored U.S. military service's identity and bias. Using a psychological lens of personalities, Builder's study laid a foundation of organizational characteristics, norms, and preferences that has stood the test of time. Builder identified the main altars of worship that drive service identity; for the U.S. Air Force, that alter is technology.[133] While related to the idea of organizational masks and influential to Builder's work, Halperin differs slightly and instead recommends the concept

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[127] Dennis J. Coyle, "A Cultural Theory of Organizations," in *Culture Matters: Essays in Honor of Aaron Wildavsky*, Richard J. Ellis and Michael Thompson, ed. (Boulder, CO: WestviewPress, 1997).

[128] Michael Thompson and Aaron Wildavsky, "A Cultural Theory of Information Bias in Organizations." *Journal of Management Studies*, 23, 273, quoted in Dennis J. Coyle, "A Cultural Theory of Organizations," in Richard J. Ellis and Michael Thompson, eds., *Culture Matters: Essays in Honor of Aaron Wildavsky* (Boulder, CO: WestviewPress, 1997), 62.

[129] Dennis J. Coyle, "A Cultural Theory of Organizations," 62.

[130] Robbins, *Essentials of Organizational Behavior*, 235.

[131] Coyle, "A Cultural Theory of Organizations," 62.

[132] Robbins, *Essentials of Organizational Behavior*, 235.

[133] Builder, *The Masks of War*. The Army's altar, according to Builder is the Nation and its citizens; the Navy's altars are tradition and independence.

of organizational "essence."[134] In other words, the dominant group's cultural identity informs how it sees the organizations mission and what capabilities are best to accomplish the mission. Whether described as bias, masks, or essence, the concepts endure in their descriptive power. In 2019, a U.S. government-sponsored study of organizational culture's impact upon institutional rivalries confirmed that Builder's characterizations stand, with culture still driving "each service's competitive goals and behaviors, which both strengthen and impede services' ability to adapt and react."[135]

As the culture perspective grew in importance within the field of military innovation studies, scholars determined that culture profoundly shapes interests and that the degree of agreement across subcultures within the organization shapes how and what civilian leaders spend their time on toward generating innovative change.[136] Kier attacks the rational and functional determinants of a military's doctrine, instead alleging that organizational culture combined with domestic political concerns drives whether a military chooses an offensive- versus defensive-based doctrine and the consequent weapons/policy choices.[137]

Following Kier's work, retired Marine Colonel Terry Terriff examined the U.S. Marine Corps as a case of innovation culture and argued that the Marine Corp developed a cultural norm of paranoia in response to repeated attempts to disassemble or absorb the organization.[138] Finally, organizational culture can be used to predict a service's reaction and support or rejection of policy changes by civilian leadership. Culture becomes the lens

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[134] Halperin, Clapp, and Kanter, *Bureaucratic Politics and Foreign Policy*, 27. The book argues that the Air Force's essence is to fly combat missions, while the focus of those missions has changed over time. The essence of the Navy is to "maintain combat ships whose primary mission is to control the seas. The Army's essence is ground combat capability and is "less interested in those function that they view as peripheral," such as advisor groups, air defenses, special forces, or counter-insurgency efforts.

[135] Zimmerman et al., *Movement and Maneuver*, 183. The report concludes that while competition has changed in method and modality among the services since the Goldwater-Nichols Act of 1986, institutional competition remains highly entrenched and combative due to cultural determinants of organizational goals.

[136] Kier, "Culture and Military Doctrine."; Kier, *Imagining War.*

[137] She argues against Posen's theory that doctrines arise as a rational response to external threats as well as against Jack Snyder's theory that militaries always choose offensive doctrines as a bureaucratic-institutional means to garner greater shares of government budgets and resources.

[138] Terriff, "'Innovate or Die'."

through which policy preferences emerge and policymakers can use specific tools to gain bargaining leverage to move military policy and innovation by understanding these lenses.[139] Critics rebut Kier often on the basis that she over-reaches in her insistence on the explanatory power of her theory and that it lacks generalizability,[140] though most agree that she successfully challenged Posen and Snyder's rational and functional arguments about offensive doctrines as the default for all military organizations.

Organizational culture is not only applicable to determining general policy positions, Mahnken argues that organizational culture can impact technology development and adoption as well. Mahnken observes that technology itself was shaped by the culture of each of the U.S. military services; in fact, he alleges that culture shaped technology more than the other way around.[141] Accentuating this relationship of technology to culture, Bousquet similarly identified specific scientific approaches to war rooted in the predominant scientific and technological frameworks of particular periods of time: mechanistic, thermodynamic, cybernetic, and "chaoplexic" (a network-centric theory based on non-linear science).[142]

Exploring culture from a national perspective, Dima Adamsky took a slightly different approach regarding military innovation, instead looking at strategic culture. Adamsky argued that a nation's strategic culture affects the way defense experts intellectually frame paradigmatic change. Essentially, a nation's cognitive culture affected the entire security apparatus's learning processes, adoption of technologies, and doctrinal

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[139] Jeffrey W. Donnithorne, "Principled Agents: Service Culture, Bargaining, and Agency in American Civil-Military Relations," (PhD diss., Georgetown University, May 2003), https://repository.library.georgetown.edu/bitstream/handle/10822/559479/Donnithorne_georgetown_0076D_12323.pdf?sequence=1; Zimmerman et al., *Movement and Maneuver*.

[140] Robert J. Young, review of *Imagining War: French and British Military Doctrine Between the Wars*, by Elizabeth Kier, H-Net Reviews (September 1997), https://www.h-net.org/reviews/showrev.php?id= 1301; Russell, *Innovation, Transformation, and War*.

[141] Thomas G. Mahnken, *Technology and the American Way of War Since 1945* (New York: Columbia University Press, 2008), 10. Mahnken argues that technology can dramatically alter the structure of organizations while at the same time a service's culture in turn "determines which options are more or less attractive."

[142] Antoine Bousquet, *The Scientific Way of Warfare: Order and Chaos on the Battlefields of Modernity* (New York: Columbia University Press, 2009).

changes resulting in and explaining the variance across nations with regard to “military innovation based on similar technologies.[143] When considering the same technology, cognitive styles intervene and shape both a theory of victory and how and why a nation generates particular innovative outcomes.[144]

The third perspective I consider under the broad cultural perspective is anchored by a sociological lens outside the normal program of military innovation studies, but this lens delivers a long-standing psychological explanation of warfare and how sociological factors impact weapon choices. The proponents of such a view suggests that human sociological and evolutionary forces. This perspective draws heavily from culture studies,[145] neurosciences,[146] psychoanalysis,[147] philosophy,[148] and biology,[149] focused on the interaction between people and the culture they live within. It manifests in such ways as material and emotional features of the society, and is reflected in attitudes, reward and praise practices, and technology. The sociocultural view assumes people are social beings and that the change in institutions occurs from emotional connections and identity through the socially constituted processes of ideas and stories until they harden into institutions and material expressions of society. Human nature’s “emotion, stress, and hormones such as testosterone are important players” in behaviors and choices related to issues of war, peace, and warfare. Thucydides’ assertion that fear, honor, and interest drive much of humankind’s bellicosity finds its home in this sociocultural perspective—especially if interests are interpreted as the biological and neurological makeup of male and female.

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143 Adamsky, *The Culture of Military Innovation*, 131.

144 Adamsky, 131.

145 Karen Huffman, Karen Dowdell, and Catherine Ashley Sanderson, *Psychology in Action*, 2nd ed. (John Wiley & Sons, Inc., 2017), 7; O’Connell, *Of Arms and Men*.

146 Rosen, *War and Human Nature*.

147 Daniel Pick, *War Machine: The Rationalization of Slaughter in the Modern Age* (New Haven, CT: Yale University Press, 1993).

148 O’Connell, *Ride of the Second Horseman*.

149 All the books in this section used biological forces as explanations at one point or another.

This is not to say the argument about war and weapons is based on biological determinism,[150] but rather socially constructed within the limitations of human experience and biological development.[151] In other words, “war cannot be externalized and alienated from humanity, since human identity itself . . . is founded on war.”[152] To take it one step further, manhood is founded upon war. Logically then, weapons transform man “into a creature to be reckoned with,”[153] and if one understands this sociologically, then it is easier to understand weapons development outcomes as symbols and artifacts of sociocultural significance.[154] If this is the case, then UAV development must be considered an outgrowth of historic and evolving sociological factors. Specifically, if UAVs threaten a military organization’s identity of shared meaning, status, and construct of human nature as practiced through a certain approach to warfare, then the military organization will resist or outright reject the UA. The opposite is equally true.

The cultural lens is not without its shortcomings. Many scholars point to the problem of proving that the phenomenon of culture exists in constructivist approaches. Also, it is very challenging to define terms and concepts associated with culture with any degree of specificity, thus making it more challenging to test culturally based theories. Even more problematic, culture is relative, not absolute, and changes with time. Finally, the methodology of process tracing fails to reveal strong causation for both organizational culture and cognitive culture approaches, as admitted by both Kier and Adamsky. Culture, in the end, represents a set of ideas “rather than a determinant of behavior,” and the ability for culture to explain behavior is limited.[155]

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150 Rosen, *War and Human Nature*.

151 Peter L. Berger and Thomas Luckman, *The Social Construction of Reality: A Treatise in the Sociology of Knowledge* (New York, NY: Anchor Books, 1966).

152 Pick, *War Machine*, 46.

153 O’Connell, *Of Arms and Men*, 21

154 O’Connell, *Of Arms and Men*, 5.

155 Adamsky, *The Culture of Military Innovation*, 140.

D. INNOVATION GENESIS AND CONTEXTS

Military innovation scholars identify four contested origins from which innovation starts: top down, bottom up, internal and external. Top down is leadership driven, often through the use of hierarchical power, charismatic power, or the shaping of rules, doctrine, and processes.[156] A bottom up view of innovation perceives innovation and adaptation as an outcome of organic field and staff work that incrementally accumulates into organizational transformation through reactive adaptation.[157] The internal perspective derives primarily from the cultural school of military innovation depending on the unit of analysis (state or organization), while external drivers spring from primarily realist and institutionalist camps. I assess that none of these origins hold a privileged place among military innovation theorists, and the catalysts are generalizable in most contexts.

In addition to the directional origins of innovation, scholars within military innovation studies and management studies identified that innovation—and particularly technical innovation—moves in cycles and degrees. One way to look at the degree to which an organization incorporates an innovation, is the incremental increase over time through ever-widening levels of acceptance, routinization, and assimilation across the organizational enterprise.[158] Another view is that organizations move in phases from invention, to partial adoption, to full adoption.[159] A third view, one more hotly debated, is that the degree of innovation occurs either as incremental evolution or more drastically as

156 Posen and Rosen are the dominant theorist in the top down category, with Cohen supporting through his view of civil-military intervention.

157 The bottom-up origin of adaptation captured the military innovation studies field's attention over the past ten to twelve years, resulting in efforts to show when and why effective adaptions occur and how those variations become formal institutional doctrine. Theo Farrell, "Improving in War: Military Adaptation and the British in Helmand Province, Afghanistan, 2006–09," *Journal of Strategic Studies* 33, no. 4 (2010); Russell, *Innovation, Transformation and War*; Robert T. Foley, Stuart Griffin and Helen McCartney, "Transformation in Contact: Learning the Lessons of Modern War," *International Affairs* 87, no. 2 (2011): 253–70, cited in Griffin, "Military Innovation Studies," 200.

158 Matthew A. Douglas, Robert E. Overstreet, and Benjamin T. Hazen, "Art of the Possible or Fool's Errand? Diffusion of Large-scale Management Innovation," *Business Horizons* 59 (2016): 379–389.

159 Denning and Dunham, *The Innovator's Way*, 8.

revolution.[160] War speeds things up; the pace of innovation in peacetime is more measured. Reform and revolution are the watchwords of peacetime, while adaptation and evolutionary experimentation occur in wartime. For example, it is in peacetime that radical changes took place within the German military's doctrine and weapons between the World Wars, and the United States vastly reformed following the Vietnam conflict with the Goldwater-Nichols Act, professionalization, and the second offset's adoption of stealth, space-based communications, and precision weapons. During war, incremental adaptions is the norm, such as the tit-for-tat spiral of responding tactics changes in the improvised explosive ordnance fight in Afghanistan between the United States (and its Allies) and the Taliban.

As for cycles of innovation, the innovation literature provides no overarching framework or typology; only one study on the Air Force describes immediate, short. and long cycles, respectively reflecting sortie debriefs, fiscal year (FY) development plans, and multi-year development plans.[161] Within the organizational theory literature, a different explanation is offered, suggesting that innovation takes place through technology adoption models and S-curves. In both models, technology experiences early adoption and growth by a few ambitious actors, but adoption will then reach a bend toward exponential adoption before hitting a second bend leading toward plateaued use and eventual phaseout.[162] These S-curves have no defined timeline, but are holistically impacted by social, cultural, scientific, and economic factors. Finally, the timing of military transformation is likely critical to its adoption.[163] While technology might be suitable, the intellectual strategy and rationale for the use of technology might hinder technological development.

Contextually, military innovation scholars orient innovation cases as taking place in one of two primary environments: peacetime and wartime. This approach helped

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160 "An [revolution] is a combination of new military organizational goals and structures with new operational practices on the battlefield that are sometimes but not always driven by new technologies." Michael Horowitz and Stephen Rosen, "Evolution or Revolution?" *Journal of Strategic Studies* 28, no. 3 (June 2005), 441, https://doi.org/10.1080/01402390500137317.

161 Grissom, Lee, and Mueller, *Innovation in the United States Air Force*, 89–91.

162 Francis Stokes Berry and William D. Berry, "Innovation and Diffusion Models in Policy Research," in *Theories of the Policy Process*, ed. Paul A. Sabatier (Boulder, CO: Westview Press, 2007).

163 Erik J. Dahl, "Net-Centric before its Time—The Jeune École and its Lessons for Today," *Naval War College Review* 58, no. 4 (Autumn 2005), 129.

delineate when and if variables/mechanisms were present and if so, how the variables determined outcomes. Rosen summarized Posen's view that peacetime innovation occurs not because of threats from an adversary, but when "structural changes in the security environment" provided incentive to generate fresh promotion options for young officers embarked on new ways of war.[164] Additionally, Posen determined that in wartime, reforms occur most often when linked to new "measures of strategic effectiveness" within the organization.[165]

E. EVALUATION OF THE LITERATURE

The military problem of innovation outcomes and adoption as related to UAVs is the focus of this dissertation. From the literature on innovation studies, outcomes within military departments to innovate or not are a result of complex mechanisms. In their efforts to create the means and ways to ensure effectiveness in meeting current and anticipated problem sets, military departments do not operate in a vacuum apart from a state's civilian leaders. Nor does a military service operate as an island apart from other services and the broader state security apparatus as it shapes its understanding of likely threats, determine missions, and competes for resources. Finally, military departments function as an institution of the state for the purpose of war and as an organization built on precepts and assumptions that provide a structure to efficiently meet goals.[166] Taken as a whole, these dynamics can result in a wide range of outcomes when it comes to the decision to innovate, partially innovate, or not innovate at all. Prescriptive solutions of predictive value exist but are highly challenged as well. Like its parent field of international relations there is a give and take relationship within military innovation studies between parsimony and the richness of theoretical description as the unit level of analysis drives further down to the individual actor level.

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[164] Rosen, *Winning the Next War*, 251.

[165] Rosen.

[166] This is inferred by Zisk's theory and conclusion of the role of military officers and how they execute that role in relation to efforts to innovate doctrine and forces.

The military innovation studies field remains far from settled. Opportunities exist to challenge and expand the "research agenda" both theoretically and in practice.[167] As recently as 2016, leaders in the field identified current gaps in theoretical knowledge as to the role and effect of Social Shaping of Technology, critical theory, and reflective epistemologies on military innovation.[168] Additionally, military innovation scholars remain concerned that the field is stalling, is in jeopardy of becoming a niche specialty, and has become defined by a highly-conservative approach[169] that instinctively defaults to "structural and functional analyses."[170] Additionally, most of the originating academic disciplines that scholars used to examine military innovation have not readily accepted military innovation empirical research as studies within their own fields.[171]

Beyond these methodological concerns, the literature only recognizes peacetime and wartime as the context for innovation, making it hard to understand how militaries innovate when the distinction does not fit neatly into those categories.[172] Recent doctrinal changes in U.S. joint publications nascently recognized this conundrum.[173] Therefore, I propose a third contextual category of military innovation: perpetual conflict, which lasts decades. This is the condition where nations and their military services navigate long-term and short-term innovation amid encompassing and unending low-intensity conflict. The two studies that loosely consider long-term innovation during wartime include Andrew Krepinevich's study of the Army in Vietnam and Terry Pierce's research on disruptive

[167] Griffin, "Military Innovation Studies: Multidisciplinary or Lacking Discipline?" 214.

[168] Griffin, 214–218.

[169] Griffin, 207.

[170] Kier, "Culture and Military Doctrine," 92.

[171] Griffin, "Military Innovation Studies: Multidisciplinary or Lacking Discipline?" 208–211.

[172] For now, a simple description of wartime is the sustained engagement of military operations against a sizable foe that can do physical harm to the state; peacetime is the opposite. Peacetime is the opposite. Of course, there is difficulty in cleanly delineating peacetime from wartime in the modern world system, as well as the evolving ways that nations and military departments describe national security threats.

[173] Joint Chiefs of Staff, *Strategy*, Joint Doctrine Note 1–18 (Washington, DC: Joint Force Development, April 25, 2018), III-1. State and non-state actors are characterized along a composite spectrum of "cooperation," "conflict below the threshold of armed conflict," and "armed conflict." It is the within the second category that the phenomenon of innovation as not fully been studied.

innovation.[174] This third contextual category begs the question: How do military services ensure appropriate and adequate innovation for future battles in the midst of sustained, decades-long conflict?

One of the major limitations of the military innovation literature is the contested yet universal use of the four directional origins of innovation. It is not necessarily problematic that innovation originates from top, bottom, internal, and external catalysts (though there was a time when this was not given). The debate needs to evolve. The more interesting question is what are the mechanisms that determine the cycle speed and degree of acceptance—that is, the variance of organizational change—regardless (and perhaps because of) where the innovation process stems. Taking a cue from Terry Pierce's engine of innovation, his model of needing a driver and fuel for change is helpful, but not fully useful as framed to disguise innovation and then push it through an organization. There are motivational mechanisms that spur on the process, but they are not limited to leadership and management factors. Additionally, there are mechanisms that will dampen the prospects of innovation that are not a matter of management wizardry. There is ample opportunity to re-frame the origin, cycle, and degree aspects of military innovation based on a more measured and constrained mechanism perspective.[175]

Another problem within the innovation literature is that the cases for testing theories are heavily biased toward ground-force institutions, calling into question the assumptions from which many theories are based. The predominant methodological and empirical frames within the innovation literature imply a few key assumptions. Those assumptions include: 1) military services innovate in a similar way to allow generalization across the service cases; 2) the civil-military relationships and institutional political dynamics with regard to military innovation can be generalized and modeled primarily through Army/ground-force examples; and 3) the strategic culture of the state is

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[174] Andrew Krepinevich, *The Army and Vietnam* (Baltimore: Johns Hopkins University Press, 1986); Pierce, *Warfighting and Disruptive Technologies*.

[175] Mechanisms "produce or generate" or prevent outcomes and are sufficient for outcomes. Complex mechanism "constitute robust competition" and are not causes. Gary Goertz, *Multimethod Research, Causal Mechanisms, and Case Studies: An Integrated Approach* (Princeton: Princeton University Press, 2017), 34–45.

deterministic enough that it leaves internal differences among branches of the military as a weak independent variable.[176]

As recent as 2016, scholars lamented that not only has the innovation literature field focused almost exclusively on ground force innovation since 9/11, but more significantly, Adam Grissom claimed "the Air Force innovates differently than other military organizations."[177] The Army tends to innovate first through doctrinal changes led by senior leaders, while the Air Force tends to innovate without significant changes in its doctrine, and even sometimes without change to its organizational structure.[178] This is important to note, because if that is the case, then the bulk of military innovation studies literature—from the outset of Barry Posen's seminal book *The Sources of Military Doctrine*—is potentially biased, incomplete, inconclusive, or needs reframed altogether. Since much of the military innovation literature rests first upon the development of doctrine and then doctrine's integration with national objectives, the premise that doctrine is an independent or intervening variable to successful innovation in all military organizations bears reexamination. James Russell, in his study of the U.S. Army in Iraq, concludes as much, stating that he and others have more recently determined that doctrine was a "weak," but still important, independent variable with regard to military innovation.[179] Can both scholars be right—doctrine is critical and doctrine is ancillary? Grissom's study of the Air Force contradicted Russell's conclusion that doctrine was not a key determinant of innovation in the Army. Grissom suggested that doctrine plays very different roles within the Army and Air Force; doctrine drives innovation in the Army, but lags innovation in the Air Force. Unfortunately, Grissom did not conduct case comparisons to prove his point.

The Air Force as a department deserves further scrutiny as a case within the innovation literature; this would help determine the relative merit of the above

[176] There is an implicit and growing debate within the literature concerning these assumptions, as well as to the link between doctrine and the outcome of military innovation.

[177] Grissom, Lee, and Mueller, *Innovation in the United States Air Force*, 88.

[178] Grissom, Lee, and Mueller, 88–92. Of note, there was little comparative discussion within this monograph between Army and Air Force organizations. This observation was made based on the literature overview within the field. A more careful analysis is needed to corroborate this claim.

[179] Russell, *Innovation, Transformation, and War*, 29.

assumptions. Equally limiting in the search for explanations is that literature on organizational learning rarely includes Air Force cases; when Air Force innovation is studied, scholars within the military innovation studies field rarely consider organizational learning perspectives. Overall, the cross-pollinating of military studies theory and practice into other academic fields of study has not happened with any regular frequency.[180]

Finally, opportunities exist for specific research cases that are underrepresented in the literature. The first, the USAF, was introduced above. Grissom, Lee, and Mueller lament the dearth of Air Force case studies.[181] Beyond a few prominent examples (e.g., Close Air Support in World War II and the strategic bombing force), additional inquiry to develop specific explanations[182] within the Air Force could provide insight into innovation efforts within emergent warfighting domains such as space, cyber, and information. The second set of cases that have had limited exposure in the literature are those cases dealing with robotics as a broad category of technical innovation.

F. CONCLUSION

Innovation as military science and organizational behavior is crucial to strategy and state security; furthermore, innovation adoption and diffusion—whether technological, conceptual, or organizational change—molds the character of international conflict. Military innovation research uses several perspectives to explain the phenomenon, each emphasizing different causes and mechanisms, to include systemic rational choice, institutional politics, and organizational culture. A utilitarian view would simplify the adoption of innovative technology, saying that if the innovation brings an advantage, the organization will adopt it; if not, the organization will reject it.[183] Social scientists reject this view, and a vigorous debate on what perspective and causes best explain military

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[180] Griffin, "Military Innovation Studies: Multidisciplinary or Lacking Discipline?" 219.

[181] Grissom, Lee, and Mueller, *Innovation in the United States Air Force*, 92.

[182] Van Evera emphasized the value and preference for a "generalized specific explanation" in theory building, which identifies "the theories that govern" a specific event, as an example of a more general phenomenon. Van Evera, *Guide to Methods*, 15–16.

[183] Ina Sophie Kraft, "Military Discourse Patterns and the case of Effects-Based Operations," *Journal of Military and Strategic Studies* 19, no. 3 (2019): 86, https://jmss.org/article/view/58290.

innovative outcomes has ensued for the past thirty years. The sociology of war provides another view of how states and militaries shape their approaches to war, take meaning from conflict, and shape weapon choices. Given that no single perspective trumps the others, the best conclusion is that the "process of military innovation is highly complex and is not reducible to general statements on revolutionary technologies and broad strategic documents."[184] Unmanned aircraft as part of greater robotics trends[185] in the changing character of warfare offer a relatively unexplored but hot topic in strategic force production, organizational behavior, and the future of conflict.

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[184] Laura Schousboe, "The Pitfalls of Writing about Revolutionary Defense Technology," *War on the Rocks*, July 15, 2019, https://warontherocks.com/2019/07/the-pitfalls-of-writing-about-revolutionary-technology/.

[185] Paul Scharre, "Why Drones are Still the Future of War; Troops Will Learn to Trust Them," *Foreign Affairs*, February 15, 2018, https://www.foreignaffairs.com/articles/united-states/2018-02-15/why-drones-are-still-future-war.

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III. COMMON CONTEXTUAL FACTORS TO UAV EPISODES

> . . . high technology weaponry, ridiculed in the past, [is] now coming into their own and saving lives—not only American lives and Coalition lives, but the lives of Iraqi citizens.[186]
>
> —President George H.W. Bush, 1991, Operation Desert Storm

This chapter delivers the common contextual factors across service cases that impact the rational, institutional, and cultural perspectives introduced in Table 1 of Chapter I. Chapter III also describes the historical and budgetary context leading up to, and during, the UAV adoption episodes of 1991 to 2015; furthermore, it explains the predominant security strategy perspectives at the national- and service-levels of the U.S. government, and the chapter situates the period of interest in its technological context while exploring service specific approaches to scientific and technological development. Paraphrasing historian Wilfred M. McClay, military innovation efforts begin in the middle of an on-going security context, and military organizations are laden with prior-held experiences, incentives, assumptions, and constraints, which impact how an innovation-adoption episode unfolds.[187] Prior experiences and results from earlier acquisition efforts inform the thoughts of individual actors and whole organizations. The political-economic realities and government-institutional roles compete for resources, constraining each other's decisions. Furthermore, intra-governmental processes and organizational practices cause each invention to resolve in distinctive ways. What follows prepares the reader with a baseline of relevant contextual knowledge that enables detailed UAV programmatic discussions in chapters four through six, as well as deepens the factor test analysis of UAV adoption episodes with respect to the military innovation hypotheses of rational, institutional, and cultural factors. The chapter concludes with a short introduction to the

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[186] Alan Geyer and Barbara G. Green, *Lines in the Sand: Justice and the Gulf War* (Louisville, KY: Westminster/John Knox Press, 1992), 137, cited in Zimmerman et al., *Movement and Maneuver,* 201. Spoken by Bush at a press conference during the Gulf War, referring to precision guided weapons, which rely upon the Global Positioning System (GPS) for navigation. Navigation with GPS would be a vital development to overcoming the navigational limitations of UAVs since their invention in 1915.

[187] Wilfred M. McClay, *Land of Hope: An Invitation to the Great American Story* (New York, NY: Encounter Books, 2019), 3. McClay's line is: "History always begins in the middle of things."

DOD acquisition process and key-actor roles. Those knowledgeable of UAV historical development, military history of the U.S. services, and the DOD's acquisition system can use this chapter as reference and move to the case studies.

A. UAV PERIODS AND OUTCOMES IN THE UNITED STATES

The U.S. military's pursuit to construct an unmanned aircraft began within a decade following the Wright Brothers' first flight in 1903. The hope of achieving sustained and controlled flight without pilots became the next frontier of aeronautical evolution.[188] Within the United States, UAV development progressed in what can be described as three sequential epochs of time, as show in Figure 3, and named based on the broad outcomes of the period. The first epoch, from 1915 to 1958, resulted in only a few operational systems within a narrow set of capabilities due to the slow progress of technology. The second epoch, from 1959 to 1990, was driven by several influences: increasingly capable but constrained technology, the nation's prevailing Cold War grand strategy, and weak intra-service management. This epoch produced checkered UAV adoption results but had bursts of promising growth that the DOD never fully capitalized on in the latter half of the epoch. Finally, the third epoch, from 1991 to 2015, was driven by four trends: expanding technological capability; shifting and uncertain political-military relations reshaping treaty obligations; a perpetual, global counterinsurgency fight; and an effort to move to a truly joint, interdependent force among the U.S. services. Whether America is still in the third UAV epoch, or on the cusp of a new fourth epoch, remains uncertain and debatable as the United States deepens its return to a grand strategy based on great power competition, attempts to extricate itself from unending global counter-terrorism and nation-building efforts, and expands the underlying technology of UAVs across a wide variety of missions, sizes, and human-machine teaming.

[188] The idea of "promise and problem" is inspired by Rebecca Grant, Preface, in Thomas P. Ehrhard, *Air Force UAVs: The Secret History* (Arlington, VA: Mitchell Institute Press, 2010), 2. Grant was the Director of the Mitchell Institute for Airpower Studies.

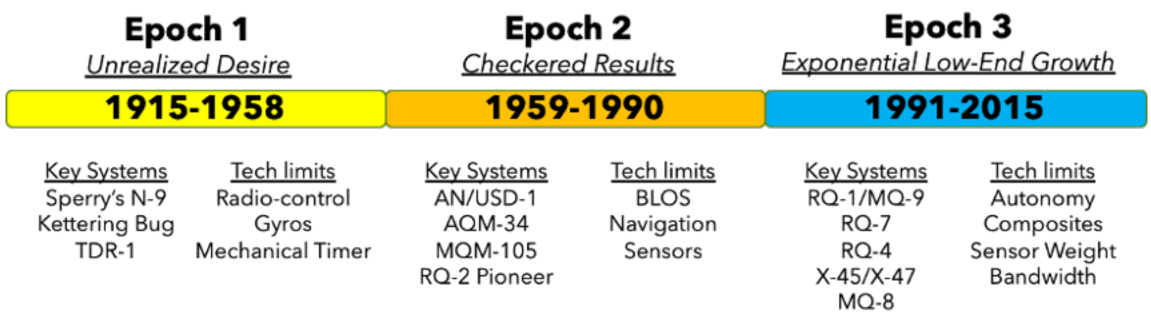

Figure 3. Epochs of the United States' UAV Development

1. First Epoch, 1915–1958: Unrealized Desire

Shortly after the inception of the airplane, the Army and Navy attempted to create unmanned aircraft. The earliest epoch of UAV invention resulted in crude cruise-like missiles, radio control, gyro stabilization, small motor development, and various launch mechanisms. Missions for these unmanned vehicles ranged from reconnaissance to penetrating strike. The U.S. military started experimentation with pilotless, self-propelled planes starting in 1915, when the Navy contracted Elmer Sperry to develop a remote-controlled "aerial torpedo" based on the Curtiss N-9 aircraft platform, seen in Figure 4.[189] By 1918, Sperry's uninhabited N-9 demonstrated a successful launch and recovery in the water. Incited by the Navy's early efforts, the Army began experimenting in 1917 with a twelve-foot-long pilotless aircraft known as the "Kettering Bug," shown in Figure 5. Named after its inventor Charles Kettering, who partnered with Orville Wright, the "bug" could carry 180 pounds of explosives and followed a pre-programmed flight profile before diving in on its intended target up to seventy-five miles away (a longer distance than field artillery at the time). Despite fifty aircraft being made, the war ended before the Army could use the "bug" for combat operations during World War I.[190] Overall, the Navy's early efforts in the 1910s drew the Army's attention to unmanned aircraft. Without the

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[189] Laurence Newcome, *Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles* (Reston, VA: American Institute of Aeronautics and Astronautics, Inc., 2004), 17–18.

[190] John W. Huston, footnote 153 in *American Airpower Comes of Age: General Henry H. "Hap" Arnold's World War II Diaries* (Montgomery, AL: Air University Press, 2002), 196.

Navy's early efforts to see its "aerial torpedo" through to fruition, the Army may have limited its nascent efforts to invent unmanned systems.

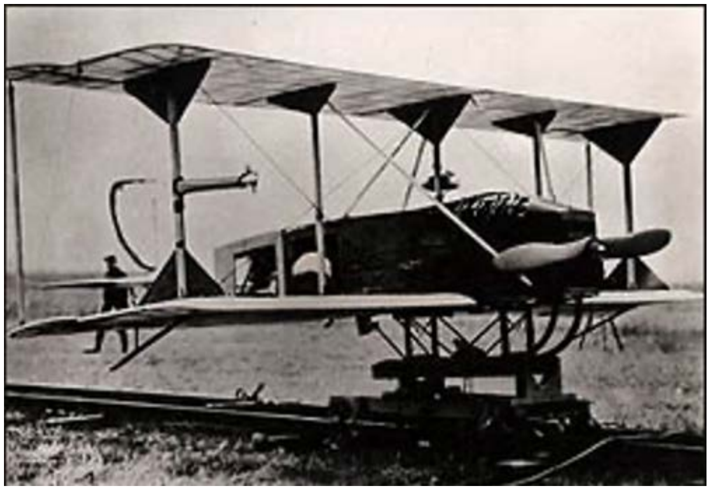

Figure 4. Sperry's N-9 "Aerial Torpedo"[191]

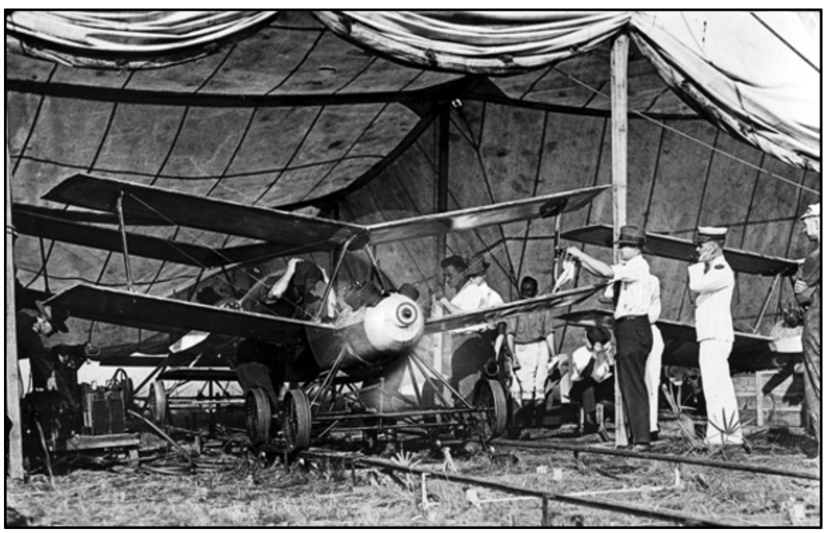

Figure 5. The "Kettering Bug"[192]

191 Source: "1910s, Sperry Aerial Torpedo," Nova, accessed February 17, 2019, https://www.pbs.org/wgbh/nova/spiesfly/uavs_03.html.

192 Source: Jimmy Stamp, "Unmanned Drones have been Around Since World War I," Smithsonian, last modified February 12, 2013, https://www.smithsonianmag.com/arts-culture/unmanned-drones-have-been-around-since-world-war-i-16055939/. Image by the United States Air Force: "The Kettering 'Bug'."

Between the wars, the American services labored to improve radio-controlled remotely piloted aircraft. Late into the interwar period, the Navy developed and adopted the TG-2 target drone and soon after assembled the first true unmanned combat aerial vehicle (UCAV)—the TDR-1 assault drone (Figure 6). Impressed with the TDR-1's potential, the Navy originally envisioned a purchase of three hundred and eighty eight TDR-1s; however, the actual procurement numbers fell far short of that goal leading up to and during World War II. Shrouded in secrecy, and with theater commanders left in the dark regarding the assault drone's successful employment record throughout 1944–1945, the Navy failed to adopt UAVs in significant numbers or change the way the service organized for war. At the beginning of World War II, the Army Air Forces built an unmanned aircraft that used radio control, but unfortunately, its limited flight range (from London to Paris) hindered further interest.[193] After the war ended, the U.S. Air Force became an independent service, adding one more bureaucratic institution vying for unmanned aircraft. Then as now, the Army and Navy always had UAV programs and made steady technological progress, increasing navigational accuracy in both remotely piloted and autonomous (gyro) controlled UAVs.[194]

Figure 6. U.S. Navy TDR-1 Assault Drone[195]

[193] Huston, *American Airpower Comes of Age*, 197.

[194] Newcome, *Unmanned Aviation*, 59–61. The Army purchased 1,445 An/USD-1 Observer aircraft in 1959.

[195] Source: "Interstate TDR-1 Assault Drone," Weapons and Warfare, last updated August 21, 2017, https://weaponsandwarfare.com/2017/08/21/interstate-tdr-1-assault-drone/.

Besides the theater commanders being left in the dark about the TDR-1, other UAV problems persisted within the Navy and Army during and after the war: requirements creep throughout the development process, extreme secrecy preventing the efficient integration of commercial technology, and senior leaders who saw the weapon as a threat more than an opportunity to the Navy institution.[196] In 1955, the company Radioplane produced a UAV prototype called the RP-71 that caught the Army's attention; the UAV showed real promise in field demonstrations in conducting reconnaissance. For the next four years, the Army worked with Radioplane to finalize a design that would eventually become the first mass-produced and adopted UAV in the U.S. inventory. Overall, the UAV systems of the first epoch represent the United States' early desire and effort to achieve operational effects through UAVs. By 1958, the Army's and Navy's aspiration to build unmanned systems throughout this epoch furnished a foundation of experience for the services and the defense industry. Having pursued UAV technology for over forty years, the U.S. and senior leadership had learned enough so to attain a modicum of success in the coming years.

2. Second Epoch, 1959–1990: Checkered Results

From 1959 to 1990, the concept of robotic aircraft evolved substantially as the Cold War heated up and the nation's security framework required ever more sophisticated reconnaissance related to nuclear deterrence and force posturing. The persistent threat of conflict with Russia and the combat engagements of the Vietnam War provided the dominant backdrop for UAV development in the second epoch. From 1959 to 1966, the Army contracted Radioplane to build 1,445 RP-71s—later designated the MQM-57A/B Falconer—as part of a surveillance drone system called the AN/USD-1 (often shortened to SD-1).[197] This medium-sized thirteen-by-eleven foot reconnaissance UAV, shown in Figure 7, would become the world's first mass produced UAV, and it remained in the Army's inventory into the 1970s. The SD-1 was a radio-controlled, radar-tracked air vehicle that took wet-film reconnaissance pictures during its thirty-minute duration flight.

[196] Newcome, *Unmanned Aviation*, 70.

[197] Dave Sloggett, *Drone Warfare: The Development of Unmanned Aerial Warfare* (Barnsley, England: Pen & Sword Aviation, 2014), 72–73.

Despite its place in the inventory, the SD-1 failed to make any substantive contribution during the Vietnam War, indicating a weak adoption at best.[198]

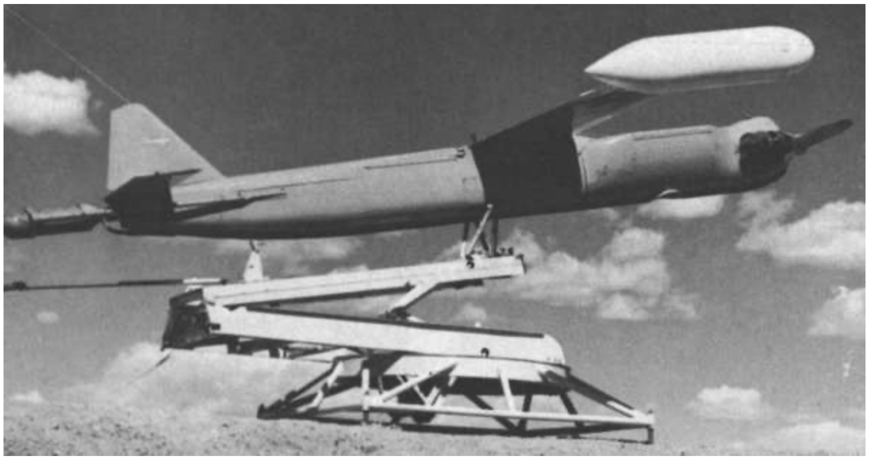

Figure 7. Radioplane's RP-71 / U.S. Army's MQM-57 Falconer[199]

The Air Force, on the other hand, created and employed a large and growing number of unmanned reconnaissance drones during Vietnam.[200] As part of a secret program between the USAF and the National Reconnaissance Office in 1960, the company Ryan Aeronautical developed a UAV prototype called Model 147. Though in early development, the United States seriously contemplated using its only two Model 147s during the Cuban Missile Crisis of 1962. Administration officers were concerned about the ability of the relatively new Soviet surface-to-air-2 air defense system to shoot down U.S. pilots conducting surveillance over Cuba. Eventually, Air Force Chief of Staff Curtis LeMay chose to not use of the Model 147s, as he was concerned that the Soviets would easily attribute the UAV flights to the United States and learn about a fledgling and

198 Andreas Parsch, "Northrop (Radioplane) SD-1/MQM-57 Falconer," Directory of U.S. Military Rockets and Missiles, accessed October 7, 2019, http://www.designation-systems.net/dusrm/m-57.html.

199 Source: Parsch, "Northrop (Radioplane) SD-1/MQM-57 Falconer." Picture from late 1950s.

200 Scharre, *Army of None*, 14.

promising secret capability.[201] Then as now, there was a balance of risk considerations that include not only casualties, but attribution and cooption of high-end technology.

Fully operational since 1964, the Model 147 evolved to become the USAF's AQM-34 Lightning Bug, shown in Figure 8. The UAV "explored virtually every subtask of intelligence collection" to include early efforts of electronic warfare.[202] The Air Force built over 1,000 aircraft and launched this multi-variant, jet-powered UAV typically from a DC-130 mothership; it was then recovered by helicopter over the ocean. The service executed over 400 such sorties each year between 1968 and 1973. As of 1972, AQM-34 sorties comprised approximately 12 percent of all U.S. reconnaissance flights in the Vietnam theater.[203] To fund this weapon system, the USAF program received much of its funding from "black" sources to include the National Reconnaissance Office and relied heavily on Strategic Air Command sponsorship for the $1.1 billion program (or $5.8 billion in FY10 dollars).[204] But, it was Tactical Air Command that employed the UAV, operating in denied areas such as heavy air defense surface-to-air missile sites.[205] The AQM-34 showcased—and foreshadowed—the utility value of a quality UAV when matched to operational needs and risk assessments dictated such tactics. For example, in the mid 1960s, the Air Force's rapid acquisition organization, Big Safari, developed Lightning Bug electronic-intelligence variants. This model picked up surface-to-air-missile radar transmissions, sending the telemetry data to off-board receivers so that the United States could build countermeasures; the drone would then act as a decoy before being destroyed.[206] The Lightning Bugs held promise as a UCAV, but the UAVs were eventually

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[201] Ehrhard, *Air Force UAVs*, 7–8.

[202] Newcome, *Unmanned Aviation*, 91. Great sources for a more detailed rendering of the Lightning Bug and its predecessor, the Firebee, is found in: Ehrhard, *Air Force UAVs* and Curtis Peebles, *Dark Eagles: A History of Top Secret U.S. Aircraft Programs* (Presidio Press, 1999).

[203] Ehrhard, *Air Force UAVs*, 28.

[204] Ehrhard, 28. Strategic Air Command drove new avenues of reconnaissance and surveillance innovation, to include UAVs, in the 1960s out of a concern over conventional and nuclear surprise attacks by the Soviet Union. For more about this history and development, see Richard Best, Jr., *Intelligence Collection Platforms: Satellites, Manned Aircraft, and UAVs*, CRS Report No. 98–495 (Washington, DC: Congressional Research Service, 1998), https://www.everycrsreport.com/reports/98-495.html.

[205] Ehrhard, 26.

[206] Ehrhard, 25.

mothballed or used as target drones after the war. Despite the Lightning Bug's seemingly proven value and wide-scale use, General Robert Marsh, the Air Force's director for UAV acquisition from 1969 to 1973, characterized the AQM-34's existence in 1972 as a "novelty,"[207] indicating the Air Force had a long way to go before it would accept and widely adopt unmanned aircraft. By the end of the 1970s, the services had few on-going UAV development efforts, and no adoption outcomes of any kind for the next several years.

This exact AQM-34L aircraft, nicknamed Tom Cat, flew "68 missions over North Vietnam before being shot down by anti-aircraft fire over Hanoi."[208] This was the most missions of any single UAV of the war.

Figure 8. Ryan Aeronautical AGM-34L over Vietnam in the Late 1960s[209]

America's procurement of UAVs stagnated in the second half of the 1970s, generally due to debates over cost, operational viability, and uncertainty with regard for UAVs.[210] Airpower historian Thomas Ehrhard channels General Marsh's sentiment,

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207 Ehrhard, 28. Backing up the General's point, a major weakness of the Lightning Bug was its navigational system that caused only 50% of the sorties in 1973 to hit their recon targets over Vietnam. Ehrhard, 24.

208 "Planes Without Pilots: SAC Remotely Piloted Aircraft (RPA)," National Museum of the United States Air Force, May 19, 2015, https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/579666/planes-without-pilots-sac-remotely-piloted-aircraft-rpa/.

209 Source: National Museum of the United States.

210 Newcome, *Unmanned Aviation*, 88.

arguing that only "the wild-eyed futurist" would have taken UAVs "in light of the tradeoffs they required" and the planning difficulties that came with them. There seemed to be truth to these practical issues, yet leaders and planner during the Vietnam War readily employed the more capable UAVs such as the AQM-34 in areas that pilots could not operate without extreme risk.[211] Then, in the late 1970s and 1980s, several experimental variants of carrier-based, rotary, and land-based UAVs matured toward the aircraft forms recognized in more modern variations. Even stealth concepts such as radar absorbent paints and coatings saw use on UAVs in the second epoch. In addition, the Air Force experienced a seismic cultural shift in the 1970s as Tactical Air Command and the fighter-generals rose to eclipse the SAC/bomber-pilots as the dominant culture in the USAF.[212] Along with this shift, Tactical Air Command successfully bid to take over the RPA enterprise from Strategic Air Command and the National Reconnaissance Office.[213] Finally, the impact of international treaties, covered in more detail below, also dampened the DOD's and USAF's aspirations for UAVs since the aircraft counted against highly-desired, nuclear-capable cruise missiles.

Between Vietnam and Operation Desert Shield/Storm in 1991, the United States fought a handful of small-scale conflicts, but none drove significant new UAV requirements. These military operations did little to influence U.S. and USAF thinking or doctrine regrading UAVs. In fact, the USAF remained focused on the pressing mission challenge of strategic-nuclear deterrence and the interdiction of Soviet forces in Europe. Two project blunders in the 1970s and 1980s also contributed to insubstantial UAV

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[211] International events backed up this view that UAVs might have an increasing role to play in air operations. The Air Force watched with great interest as the October 1973 Israeli-Arab conflict and a Soviet-designed air defense system took a major toll on Israeli air forces; Israel later used decoy drones to great effect in the 1982 Bakaa Valley conflict. Additionally, the political fallout of U.S. aircrew and pilot prisoners of war during Vietnam seem to bolster the policy reasons for UAVs to find a permanent place in America's military arsenal. Finally, a July 1970 RAND report thought so highly of the technological breakthroughs and proven use of UAVs during Vietnam that it argued that UAVs are the future of the Air Force given that air transport, air-to-air combat, and interdiction were all possibilities on the near-term horizon. (RAND hosted the symposium May 19–21, 1970, followed by reports and articles such as Barry Miller, "Remotely Piloted Aircraft Studied," *Aviation Week & Space Technology*, June 1, 1970; Ehrhard, *Air Force UAVs*, endnote 259).

[212] Mike Worden, *Rise of the Fighter Generals: The Problem of Air Force Leadership 1945–1982* (Maxwell Air Force Base, AL: Air University Press, 1998). This book provides an in-depth history of this important cultural transformation within a relatively young institution.

[213] Ehrhard, *Air Force UAVs*, 29–34.

development following Vietnam. Both failures were run by single services. The first was the Air Force/National Reconnaissance Office attempt to replace the U-2, called Compass Cope. This Boeing-led project was initiated following a 1970 RAND symposium on the future of air power in which a consensus emerged on the value of UAVs. Congress ended the project for various reasons, not least of which was budget concerns. Cost overruns, test failures, and shrinking national budgets all factored in.[214] This effort was the first of fifty years' worth of debates over the U-2, and the RQ-4 Global Hawk appears to only be the latest iteration of this fifty-year discussion to replace the U-2 with a UAV. The Army managed the second failed UAV program in the late Vietnam era called the MQM-105 Aquila. This ambitious program, originally pitched by Lockheed in the early 1970s, was designed to support artillery fires by designating targets with a laser.[215] The first full-scale aircraft rolled out in 1979, at six-by-twelve feet, with a small one-hundred-and-fifteen pound payload. The budget overruns were so egregious that by 1987 Congress killed the program. The Army's attempt to put too many unproven, cutting-edge sensors on the small platform was too much for the time.[216]

Another, less substantial, botched UAV program was the Air Force's medium-range BQM-145A, initiated in 1985 to address growing reconnaissance shortfalls. Ehrhard found that early joint acquisition structures and "Congressional pressure hindered Air Force efforts by adding requirements to the airframe design that limited its utility for its planned UAV employment concept."[217] When the Air Force's BQM program became a joint program, it faltered. At the same time when the Air Force launched the BQM-145 initiative, the Navy valued smaller tactical UAVs.[218] The navy contracted with the Israeli firm AAI Corporation to procure the Pioneer starting in 1985. The Pioneer was good enough; it was what the services could afford and Congress willing to fund. The Navy,

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[214] Ehrhard, 33.

[215] Steven J. Zaloga, *Unmanned Aerial Vehicles: Robotic Air Warfare, 1917–2007* (Oxford: Osprey, 2008), 23.

[216] Zaloga, 23.

[217] Ehrhard, *Air Force UAVs*, 41.

[218] The Secretary of the Navy, John Lehman, pushed for the AAI Pioneer based on lessons learned from the Israeli use of UAVs in the 1982 Bekaa Valley battles. Zaloga, *Unmanned Aerial Vehicles*, 25.

Marine Corps, and Army added the Pioneer in small numbers to their respective inventories by the end of the 1980s.

The DOD was not done trying to figure out how to further adopt UAVs into its arsenal, and major DOD restructuring impacted acquisition practices starting in 1986. After Congress killed the Aquila program in 1987, the new joint offices in the DOD "established a requirement for the UAV-Endurance with a range of more than 1,000 miles" and forty-eight hours of targeting large areas.[219] Subsequent to the Goldwater-Nichols Act, Congress mandated the DOD stand up a Navy-led Joint Program Office by 1989 to reduce duplicative experimental efforts across the military services;[220] this joint office was the first of its kind for UAV development in the United States. The Joint Program Office's strategic game plan introduced UAVs tiers as a means to describe strategic development requirements: Tier I (tactical endurance), Tier II (theater endurance), and Tier III (strategic endurance).[221] At the time, a limited number of Tier I Pioneer UAVs existed in the U.S. inventory, and with this categorization, the Joint Program Office gave a basis for the modern era of joint UAV development. The Air Force's Medium-Range BQM-145 program was now merged into the new Navy-led Joint Program Office as a joint USAF-USN program, and over time the aircraft design became untenable for the Air Force. The BQM-145 program ended in 1993 after ballooning "from $70 million in 1989 to $187 million in 1993."[222]

Despite waning interest in UAVs after 1975, the United States—and the Air Force in particular—exited the Vietnam era with strong UAV experiences to build upon in the future.[223] After Vietnam, target drone development and other technology demonstrators

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219 Zaloga, *Unmanned Aerial Vehicles*, 32.

220 Ehrhard, *Air Force UAVs*, 41. One might argue that the Joint Program Office structural change is the moment that the modern epoch of UAV development started; however, this important organizational move remained constrained by the pervasive Cold War mentality and grand strategy, which would give way in the 1990s, affecting the trajectory of defense budgets and security threat perceptions.

221 Newcome, *Unmanned Aviation*, 108.

222 Ehrhard, *Air Force UAVs*, 41.

223 Paul G. Fahlstrom and Thomas J. Gleason, *Introduction to UAV Systems* (United Kingdom: Wiley, 2012), 6.

kept the DOD somewhat fluent in UAVs, but without the deeper institutional infrastructure or interest, UAVs remained highly-niche assets used mostly for aerial target practice. Ehrhard suggests that UAVs succeeded during wartime with a "black" ops budget and National Reconnaissance Office support; however, UAVs in the second epoch failed once exposed to the "white-world" peacetime environment of institutional competition.[224] Therefore, the best that can be said about the period is that "technology stimulated but failed to float the RPV revolution," and the period had at best "checkered" results.[225] This rings true, as only a handful of low-end RQ-2 Pioneer UAVs existed in the U.S. inventory at the end of the "peacetime" Cold-War period from 1975 to 1990. As an ironic consequence of these systemic factors, the United States' airpower service was the only military branch to not own or operate a UAV in 1990. Overall, it is not a large leap to see that this study's rational, institutional, and cultural competing factors all had roots in the UAV programs and operations throughout the second UAV epoch.

3. Third Epoch, 1991–2015: Exponential Low-End Growth

Throughout the third epoch of UAV development the U.S. military matured specific UAV capabilities and roles as well as expanded adoption of low-end UAV types.[226] This dissertation focuses on this period. Reliability, communications bandwidth, and micro-processors all enhanced UAV utility and capability during this time period. Furthermore, the end of the Cold War altered U.S. capability strategies, especially in the high-end categories. Also, the Gulf War provided a host of lessons on the potential employment opportunities for UAVs. From 1993 through 1998, the Defense Airborne Reconnaissance Office led UAV coordination among the services, introducing Advanced Concept

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[224] Ehrhard, *Air Force UAVs*, 36.

[225] Ehrhard, 37, 46. These comments and observations derive mostly from Air Force experiences and cases, but the joint nature and impact of DOD processes strongly contributed to the overall development and outcome of UAVs in the United States.

[226] This view that the UAV epochs split in 1990 and 1991 is supported by RAND's recent study of service culture and preferences, which characterized and bound the major strategic environment periods using similar dates: Bipolarity up to 1989; Unipolar from 1990–2000; The Rise of the Non-state Actors from 2001–2014; and Great Power Competition from 2007 to today. I use the date 1991 as the start of the third UAV epoch since that is the year the collapse of the Soviet Union was fully established. Zimmerman et al., *Movement and Maneuver,* 195–216.

Technology Demonstration (ACTD) acquisition processes. This was an effort to speed up acquisition cycles and shorten the typical 7-year minimum budget allocation. As one of these ACTDs, the General Atomics' Predator flew a modest number of missions over the Balkans in the mid 1990s, showcasing the promise of near-real time surveillance streaming. After experiences in the Balkans the DOD accepted that UAVs were a more effective method of long-duration surveillance and a way to complete boring missions in permissive environments. One UAV historian accurately categorized the micro period from 1991 to 2001 as "field testing,"[227] and this perspective is further supported when compared with the status and number of UAVs in the U.S. inventory by 2000 as reflected in Table 2. In this micro-period, the DOD and its services primarily held a reconnaissance-only perspective for UAV development. With the onset of the Global War on terror, UAV use exponentially increased by a factor of forty from 2002 to 2010 as UAVs shed the prevailing perspective that UAVs must be ISR-only platforms.[228]

Table 3. Summary of UAV Outcomes in the Year 2000[229]

System	Manufacturer	Lead Service	First Flight	IOC	Number Built	Number in Inventory	Status
RQ-1/Predator	General Atomics	Air Force	1994	2001	54	15	87 ordered
RQ-2/Pioneer	Pioneer UAVs, Inc	Navy	1985	1986	175	25	Sunset system
BQM-145	Teledyne Ryan	Navy	1992	n/a	6	0	Cancelled '93
RQ-3/DarkStar	Lockheed Martin	Air Force	1996	n/a	3	0	Cancelled '99
RQ-4/G'Hawk	Northrop Grumman	Air Force	1998	2005	5	0	In E&MD
RQ-5/Hunter	IAI/TRW	Army	1991	n/a	72	42	Sunset system
Outrider	Alliant Techsystems	Army	1997	n/a	19	0	Cancelled '99
RQ-7/Shadow200	AAI	Army	1991	2003	8	0	176 planned
Fire Scout	Northrop Grumman	Navy	1999	2003	1	0	75 planned

227 John David Blom, "Unmanned Aerials Systems. A Historical Perspective," (Occasional Paper 37, U.S. Army Combined Arms Center, 2010), 126, https://pdfs.semanticscholar.org/94af/8293b07716f2b2052dd0a8315a3da934fb63.pdf.

228 Jeremiah Gertler, Summary, in *U.S. Unmanned Aerial Systems*, CRS Report No. R42136 (Washington, DC: Congressional Research Service, January 3, 2012), https://apps.dtic.mil/dtic/tr/fulltext/u2/a566235.pdf

229 Source: Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap, 2000–2025*, 6.

When the Army and Navy showed substantial movement in the development and employment of UAVs starting in the mid 1990s, senior Air Force leadership made a bid by the early 2000s to centralize the DOD's medium-to-high altitude UAV enterprise under its executive leadership.[230] The Army and Navy strenuously objected, and the Air Force was forced to drop the bid, which resulted in the DOD maintaining a service-centric model of UAV development until 2006. It is seemingly odd that the Navy once held the joint lead for UAVs from 1989–1993, but now the Air Force—charged with commanding the air domain—was denied that role. Additionally, the Secretary of Defense, Robert Gates, fired the USAF Secretary and Chief of Staff of the Air Force simultaneously in 2008, a rare and rather unprecedented move. That decision appeared to be partly based on Gates's negative views about the Air Force's slow UAV procurement rates. Gates's perceived a national security requirement and wanted to bolster the on-going counterterrorism wars in Iraq, Afghanistan, and around the world. Last, as the development for a high-end UAV capable of operating in contested airspace matured in the 2000s, the Air Force abandoned the conventional, "white"-world development of UCAVs. The Air Force appears to have continued with the small-scale development of an advanced unmanned system through black-world development channels since 2006 (e.g., the RQ-170 and RQ-180), while the U.S. Navy continued work on an UCAV concept for carrier-based applications at the direction of the U.S. Secretary of Defense until the end of the third UAV epoch.

In the latter half of this epoch, the services continued preferred UAV development efforts. The Air Force returned to the UAV world by coopting and expanding RQ-1 Predator aircraft in the mid 1990s, followed by MQ-9 and RQ-4 acquisitions. The service explored high-end UCAVs such as the X-45 for a few years before terminating the program as an open-source, "white" experimental project. The Navy has worked to develop a series of unmanned rotary and combat aircraft, to include the X-47 Pegasus, the UCLASS aircraft, and MQ-8 Fire Scout. The Navy continued work on the X-47 UCAV long after

[230] The traditional coordination altitude for direct command and control of air-breathing assets operating in a joint environment is 3,500 feet. This provides Army Aviation the airspace needed to operate, with the Air Force primarily controlling all joint aircraft activity above that altitude. Control and coordination with the Navy is more complicated, but primarily partitioned geographically with areas of responsibility.

the Air Force cancelled its sister program, the X-45, in 2006. The Navy finally ended the X-47 experiment in 2015. Additionally, the Navy procured two unique versions of the Northrop Grumman RQ-4 to improve maritime surveillance operations. The future of the next generation of advanced UAV remains uncertain, particularly for UCAVs. For now, the Navy is procuring and operationalizing the MQ-4 Triton, developing the MQ-25 Stingray as an unmanned aerial refueling platform, and continuing spiral development and adoption of the MQ-8 Fire Scout. As for the Army, their inventory boasted over 4,000 UAS systems of all sizes as of 2010, and the service continues to field three major systems within the larger UAV Groups 3, 4, and 5. Those systems include the MQ-1 Gray Eagle, the MQ-5 Hunter, and the RQ-7/FQ-7 Shadow, all assigned to the brigade and division levels of the Army.[231]

B. THIRD UAV EPOCH CONTEXTUAL CONSIDERATIONS

The strategic, economic, and historical circumstances from 1991 to 2015 provide a backdrop of permissive grounds from which to explore additional factors related to each of UAV adoption episodes and military innovation theories. This section considers the contextual factors of the third UAV epoch, accenting service perspectives, issues, and events.

1. Strategic Environment Perspectives and Guidance at the National, Defense, and Service Levels

An in-depth 2019 RAND research study on the state of "culture and the competition for influence among the U.S. military services" characterized historical strategic-environment eras using similar dates that align with this study's third UAV epoch. The article's authors presented four strategic periods, bounding the major international political trends and military shocks that impacted U.S. national security policy and strategy: "Bipolarity" up to the year 1989; "Unipolar" from 1990–2000; "The Rise of the Non-state Actors" from 2001–2014; and "Great Power Competition" from 2007 to today.[232]

[231] U.S. Army UAS Center of Excellence, *"Eyes of the Army."*

[232] Zimmerman et al., *Movement and Maneuver*, 195–216.

Reference Figure 9 for a visual depiction of the strategic eras. Overlapping this model on the third UAV epoch results in three distinct, and sometimes overlapping, national security landscapes that dominated the nation's security context for UAV development (i.e., unipolar, non-state actors, and great power competition). Slightly different from the RAND study's 1990 start date for the Unipolar moment, this paper aligns the third UAV epoch with 1991 since that is the year the collapse of the Soviet Union was fully established and the year coincides with Operation Desert Storm, a watershed moment in military strategy, service culture, and technology development that influenced how U.S. senior leaders approached the next decade and more.

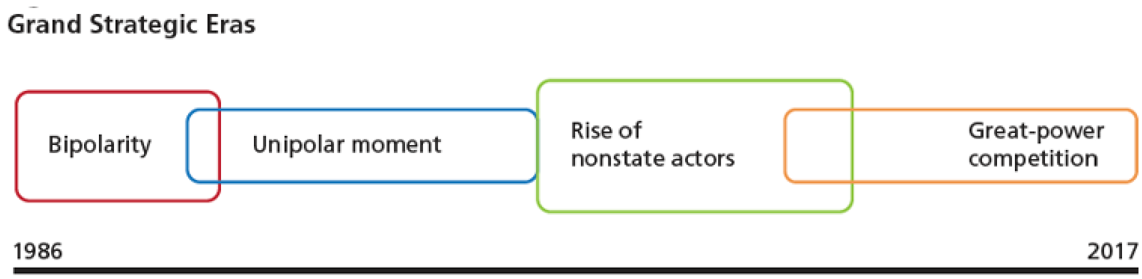

Figure 9. Grand Strategic Eras in U.S. National Security[233]

Opening the Unipolar moment in 1991, the combination Soviet Union's collapse and the United States' remarkable military display against the world's fourth largest army in Iraq rocketed the United States to a global hegemonic position, causing a drastic shift in U.S. strategic perspective. Between January 17 and February 28, 1991, U.S. airpower overwhelmed the Iraqi military and its high-end Soviet hardware, resulting in a short 4-day ground war; the comparatively low friendly casualties and the technological display of precision contributed to an emerging decrease in casualty risk tolerance.[234] Additionally, the 1991 *National Security Strategy*, released in August just six months after the end of Desert Storm, described a "new era" requiring a military strategy that could match a

[233] Source: Zimmerman et al., *Movement and Maneuver*, 190.

[234] Thomas Keany and Eliot Cohen, *Gulf War Airpower Survey Summary Report* (Washington, DC: Defense Technical Information Center, 1993); Edward C. Mann III, *Thunder and Lightning: Desert Storm and the Airpower Debates* (Maxwell Air Force Base, AL: Air University Press, 1995).

security environment that was now “ambiguous,” “volatile,” and “less predictable” than during the bi-polar Cold War.[235] The victory over Iraq was a regional problem and one that America, with a broad coalition, could solve. While not dismissing Russia outright, no other threat dominated the strategic view of the United States; regional instability and nuclear proliferation became the leading concerns for U.S. security policy. Additionally, the U.S. security apparatus could now conduct limited operations unimpeded by concerns over sparking larger conflicts from a peer competitor such as the Soviet Union. From its hegemonic perch, America waged a decade of “discretionary operations” becoming the world’s policeman and chief promoter of democratic transition in an era of *Pax Americana*.[236] At the same time, America expected to capitalize on technological advancements through an emerging, but uncertain, *revolution in military affairs*—a buzz phrase that would persist for over a decade.[237]

A time of relative peace followed the Gulf War, with no major international competitors. Instead, the United States engaged in a handful of small-scale conflicts as it sought the right policy footing for military engagements and peacekeeping/peacemaking efforts. During this unipolar period, two such conflicts had a disproportionate effect upon the United States’ operational approach to warfare. First, the peacemaking operation to capture the Somali warlord Muhammed Aideed ended with the difficult Battle of Mogadishu and cable news scenes of American soldiers being beaten and dragged in a third-world country. Second, the series of operations in the Balkans from 1993 to 1999 strengthened air strike warfare proponents; the United States achieved major military objectives without the direct insertion of ground troops.[238] Balkan operations also added to the Somali effect of casualty intolerance, when Captain Scott O’Grady was shot down

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[235] White House, *National Security Strategy of the United States* (Washington, DC: White House, 1991), 1–2.

[236] Charles A. Kupchan, “After Pax Americana: Benign Power, Regional Integration, and the Sources of a Stable Multipolarity,” *International Security* 23, no. 2 (1998), 40–79, cited in Zimmerman et al., *Movement and Maneuver*, 200.

[237] Zimmerman et al., *Movement and Maneuver*, 195; William A. Owens, “Creating a U.S. Military Revolution,” in *The Sources of Military Change: Culture, Politics, Technology*, ed. Theo Farrell and Terry Terriff (London: Lynne Rienner Publishers, 2002), 212.

[238] Zimmerman et al., *Movement and Maneuver*, 195.

over Bosnia causing a political crisis for the Clinton Administration.[239] As a result of Desert Storm, Somalia, and the Balkans, an attitude of zero casualties—whether friendly or civilian—became embedded in the U.S. approach to warfare. Subsequently, risk tolerance for U.S. forces decreased and a preference for air strikes by aircraft and cruise missiles increased throughout the 1990s.[240]

As the U.S. presidency moved from twelve years of Republican leadership, President Bill Clinton's national security strategies built upon the "Age of Democratic Peace" as conceived by his predecessor.[241] Surveying the Clinton administration's national security strategies, the evolving grand strategy emphasized regional stability, active promotion of democracy and global trade, domestic economic rebalancing, and military reconstitution. The overall theme for national security policy was "Engagement and Enlargement."[242] Developing a rubric of when and why to employ forces also became a recurring puzzle, one that never seemed to fully settle. While Russia remained an acknowledged power due to its nuclear capabilities, the real fear was in technology transfer and proliferation. Additionally, the administration set the goal of preventing China from becoming a security threat in the region by opening its foreign markets, normalizing China's role in international organizations, and promoting democracy in general.[243] Iran and Iraq were to be contained while the Middle East peace processes unfolded. Toward the end of the Clinton era, the United States security strategy described the international threat picture as a "diverse set" of states that "still have the capability and the desire to threaten our vital national interests" and a constant need to conduct crisis response around the globe

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239 John Sims, Jr., "Shackled by Perceptions: America's Desire for Bloodless Intervention," (master's thesis, School of Advanced Airpower Studies, 1997), 59, https://apps.dtic.mil/sti/pdfs/ADA391802.pdf.

240 Zimmerman et al., *Movement and Maneuver*, 201. It is interesting to note that as interest for cruise missiles as a tool of security policy increased, weaponized UAVs did not enjoy a corresponding boost.

241 George H. W. Bush, Preface to *National Security Strategy of the United States* (Washington, DC: White House, 1993), ii.

242 White House, *National Security Strategy of Engagement and Enlargement* (Washington, DC: White House, 1994), title page.

243 White House, 24; White House, *A National Security Strategy for a New Century* (Washington, DC: White House, 1997), 24.

to prevent ambiguous situations from spiraling out of control.[244] A concern of near-peer capabilities never fully dissipated, and yet, President Clinton strongly iterated that Russia and China were "former adversaries," no longer posing a threat to the United States.[245] Overall, the U.S. security approach from 1993 through 2000 can be summarize as putting America's economic house in order through globalized trade and military drawdowns while maintaining military engagement in order to prevent further disorder and regional unrest from erupting.[246]

The terrorist attacks of September 11, 2001, abruptly altered the strategic environment for the United States, ushering in period dominated by concerns over the rising power of the non-state actors.[247] This led to a radically new U.S. security policy centered on unilateralism and preemption.[248] The rogue state concerns of the 1990s added a new concern: weak states that pose a national-level threat due to the nexus of ungoverned territories, radicalism, and technology.[249] The George W. Bush administration released the 2002 *National Security Strategy* a year after 9/11, boldly declaring that the United States would embark on preemptive approaches to stop threats from materializing. The rationale for this shift in U.S. policy was that "the administration believed that using traditional concepts of deterrence would not be effective against actors whose affirmed strategies" were targeting innocents and whose motivation was martyrdom.[250] Not ignoring state threats completely, the Bush administration still called out Iran and North Korea as rogue states and terrorist clients, but he primarily focused on those nations' weapons of mass

[244] White House, *A National Security Strategy for a New Century*, 4.

[245] White House, *A National Security Strategy for a Global Age* (Washington, DC: White House, 2000), 5. The strategy still referred to a military posture able to conduct two major conflicts simultaneously but also shunned a global posture for one of engagement and small-scale contingencies. North Korea was singled out as the main threat in East Asia; any threat from Russia and China was described as benign at best.

[246] White House.

[247] Zimmerman et al., *Movement and Maneuver*, 202–208.

[248] Joseph M. Siracusa and Aiden Warren, *Presidential Doctrines: U.S. National Security from George Washington to Barack Obama* (Lanham, MY: Rowman & Littlefield, 2016), 165.

[249] White House, *The National Security Strategy of the United States* (Washington, DC: White House, 2002), preface.

[250] Siracusa and Warren, *Presidential Doctrines*, 169.

destruction and delivery capabilities as main threats.[251] Bush's infamous line categorizing Iraq, Iran, and North Korea as an "axis of evil" in his 2002 State of the Union address put the U.S. defense establishment on notice to ensure it could respond and take down those regimes' militarily if necessary. Finally, the two national security strategies of 2002 and 2006 reflect the continued efforts to persuade Russia and China to embrace internal reforms toward democracy and military transparency while emphasizing a cooperative approach with the two nations. The harshest criticism reserved for China appeared in 2002's security strategy, noting that after twenty-five years of U.S. engagement, China had yet to shed its communist legacy.

Besides the new national security strategy guidance, the Bush administration initially arrived in the White House with an agenda of technological transformation and a desire to make good on a revolution in military affairs as envisioned in the 1991 national security strategy (which, to them, the Clinton years had ignored).[252] While the events of 9/11 did not alter Bush's transformational goals, the Global War on Terror made the effort much more challenging than originally envisioned during Bush's presidential campaign. The priority to adapt capabilities for the conflicts in Afghanistan and Iraq from October 2001 through 2008 eroded U.S. long-term planning stability and budgetary consistency. The only nations driving real U.S. military development outside the Global War on Terror efforts were Iraq, Iran, and North Korea. Iran and North Korea had formidable but dated former-Soviet Union military capabilities of their own along with a mix of other assets.

Operationally, the period from 2001 through 2012 was one of enduring counterinsurgency and counterterrorism conflict around the globe—punctuated by shorter periods of major combat—which drastically altered the U.S. security landscape and military perspectives of warfare. U.S. national security authorities have used Congressional authorization laws from 2001 (targeting al-Qaeda and associates) and 2002 (Iraq) for the use of military force to justify global military operations ever since. The two-fold resulting

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[251] White House, *The National Security Strategy of the United States*, 14–16.

[252] Mark G. Czelusta, *Business as Usual: An Assessment of Donald Rumsfeld's Transformation Vision and Transformation's Prospects for the Future* (Garmisch-Partenkirchen, Germany: George C. Marshall Center, 2008).

effect was an era dominated by land-power perspectives in the U.S. security establishment and operations in almost exclusively “permissive” environments that did not pose a challenge to air or sea power after an initial wave of offensive attack. During this long period, the U.S. Army enjoyed unprecedented favor from the American public and Congress, so much so, that the Navy and Air Force started taking on “roles and missions outside the scope of its traditional preferences” and the Army’s budget saw enormous funding increases compared to other services.[253] In another example of the Army’s clout, the USAF had tried to decommission the A-10 in the early 2000s, as part of the transformation agenda, in favor of multi-mission aircraft; Congress sided firmly with the Army’s major lobbying effort.[254] The second trend during this period was long-enduring conflict against insurgents and terrorists—with extremely limited anti-air and anti-naval capabilities— operating in an otherwise friendly or neutral country posing no air or sea threats. Hence, special operations command, the Army, and the Marines became the unequivocal supported force, while the Air Force and Navy both experienced crises of relevance and concern over lost political-institutional clout.

Starting around 2007, a rising China and revanchist Russia stirred a return to great power competition predilection that has only increased since 2015 (though the United States appeared slow to categorize their national strategy as such).[255] Overall, the flourishing ground-centric perspective since 2001 began to wane as shocks from Russian and Chinese modernization appeared[256] along with the removal of ground forces from Iraq in 2011 and major drawdowns from Afghanistan starting in 2012. One of those shocks was China’s military advancements, especially as it demonstrated anti-satellite capabilities and improving missile technologies, along with a growing abundance of highly capable anti-access/area-denial weapon systems. As for Russia, Putin’s 2007 speech at the Munich Security Conference espoused deeply-held national grievances, putting the West on notice of Russia’s intentions to begin serious military modernization efforts as well as exert its

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[253] Zimmerman et al., *Movement and Maneuver*, 205.

[254] Zimmerman et al., 205.

[255] Zimmerman et al., 210.

[256] Zimmerman et al., 210.

power on the world stage.[257] Russian cyber-attacks against Estonia in 2007 and a hostile incursion into Georgia in 2008 made good on Putin's new, aggressive approach to regional affairs. Iranian efforts to acquire nuclear technology also kept the U.S. military in perpetual planning to strike if necessary.

President Barak Obama entered the White House with a grand strategy of pivoting military and diplomatic efforts to the Asian theater, ending the war in Iraq, and curtailing the United States' military presence overseas, especially in Afghanistan. The Bush Doctrine of preemption was forcefully recast by Obama's focus on international law and norms; unilateral action was not ruled out, but significant curbs were placed on military action.[258] The 2010 *National Security Strategy* acknowledged the increasing power and influence of key regional states such as China, India, and Russia, but the document took little notice of these emerging negative trends of state power. The updated U.S. policy continued to pledge cooperation in every arena possible with Russia and China, while simply offering "support" for the "sovereignty and territorial integrity of Russia's neighbors."[259] The full measure of Russia's expansionist foreign policy culminated in the 2014 annexation of Crimea. By then, Russia had successfully re-modernized, especially its anti-access/area denial systems, and China had built an arsenal of highly capable anti-access/area denial and offensive systems throughout the South China Sea. Both nations showed the ability to directly challenge U.S. might, and wargames regularly forecasted a U.S. military defeat in hypothetical regional conflicts.[260] China and Russia's state-centric, strategic initiatives catalyzed the Air Force and Navy to explore what became known as Air Sea Battle—a technological integration effort to improve operational effectiveness to

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[257] Vladimir Putin, "Wars Not Diminishing," speech to the *Munich Conference on Security Policy* (February 10, 2007); https://www.youtube.com/watch?v=U4MAsIh3zMA

[258] Siracusa and Warren, *Presidential Doctrines*, 196.

[259] White House, *National Security Strategy* (Washington, DC: White House, 2010), 44.

[260] After several years of wargaming efforts, Deputy Secretary of Defense Robert Work and key defense planner David Ochmanek commented in 2019 that "When we fight Russia and China, 'blue' [the United States] gets its ass handed to it." Graham Allison, "The New Spheres of Influence: Sharing the Globe with Other Great Powers," *Foreign Affairs* 99, no. 2 (March/April 2020): 34; A *New York Times* article summarized the China-only results: "In 18 of the last 18 Pentagon wargames involving China in the Taiwan Strait, the U.S. lost." Nicholas Kristof, "This is How War with China Could Begin," *New York Times*, September 4, 2019, https://www.nytimes.com/2019/09/04/opinion/china-taiwan-war.html.

counter tough, near-peer offensive and defenses capabilities, particularly in anti-access/ area denial environments (e.g., coastal defenses such as China, Iran, and later Russia in the Baltics).[261] This move threatened the Army's leadership status in the DOD of the past decade, prompting a fresh round of inter-service conflict.

The evolving strategic landscape and resulting policy shifts during the second half of President Obama's tenure were wide and varying, indicative of the rising complexity and uncertainty in the international security arena. The first blow to the ground-centric dominance of U.S. military policy was the end of a major U.S. presence in Iraq in 2011, when the Obama administration pulled all combat force out of the country that December. This was followed in 2012 with the Obama administration's air-centric operation in support of Libyan rebels with the goal of ousting Muammar Gaddafi; a short-lived offensive reliant upon fighter planes, helicopter, and UAVs. Combat operations lasted only a few weeks, but it gave the Navy and the Air Force a bit of relief as it harkened back to the time when airpower was ascendant in the 1990s, reminding Congress and others that U.S. defense is not unidimensional land power. Additionally, the Obama administration drastically increased its reliance on and use of UAVs to target and kill violent extremists—even outside acknowledged theaters of war.[262] This controversial trend challenged Obama's appeal to international law and norms touted early in his administration. It also exposed U.S. "doctrinal ambivalence" and "new interpretations of international legal standards governing its use-of-force" as new technologies emerge in the global security environment.[263] Then, there was the rise of the Islamic State in Iraq and Syria that challenged the existing Congressional authorizations for the use of force, exposing the institutional stagnation of Congress to weigh in on national security matters. During this time, an amateurish misstep was made by the administration over Syrian chemical weapons use, further adding uncertainty to the international security environment, and indirectly emboldening other state aggression to include Russia's 2014 invasion of Ukraine and

[261] Zimmerman et al., *Movement and Maneuver*, 210.

[262] Siracusa and Warren, *Presidential Doctrines*, 199–200.

[263] Siracusa and Warren, 203.

China's bellicose posturing against neighboring countries in and around the South China Sea.[264] Working to reframe and make sense of the unfolding security landscape in 2015, the White House acknowledged "serious challenges to our national security" and the need for renewed state-centric deterrence postures that had long been neglected or seen as passé.[265] Still, President Obama remained committed to "strategic patience," which had come to define his approach to security throughout his two terms—both praised and ridiculed as a strength and a weakness that often added to the difficulties of determining a direction for policy and budgetary processes.

a. Department of Defense UAV Guidance and Roadmaps

From 1993 to 1998, the Defense Airborne Reconnaissance Office produced the only department-level, unmanned vehicle related documentation, and these short documents amounted to little more than a highly detailed report. After a three-year hiatus without any centralized strategy for unmanned acquisitions (following the disintegration of Defense Airborne Reconnaissance Office), nor any concerted effort by the department to harness the innovative technology beyond a few systems, Congress legislated on the future UAV force. In October 2000, Congress mandated in the national defense authorization act that by 2010, that one-third of the Defense Department's operational deep strike assets must be unmanned.[266] Around the same time, the Office of the Secretary of Defense stood up a joint UAV task force and began a series of UAV "roadmap" documents to increase coordination and vision across the services. The first UAV roadmap was released in April 2001, five months after the defense bill passed. Subsequent documents were released in 2005, 2009, and 2011 and constitute some of the most importance sources of data in evaluating UAV outcomes against the military innovation perspectives in the case studies.

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[264] White House, *National Security Strategy* (Washington, DC: White House, 2015), 13.

[265] White House, preface.

[266] Floyd D. Spence National Defense Authorization Act for FY2001, Pub. L. 106–398 (October 30, 2000). https://www.govinfo.gov/content/pkg/PLAW-106publ398/pdf/PLAW-106publ398.pdf; Office of the Secretary of Defense, *Unmanned Systems Integrated Roadmap, FY2009–2034*, 5.

Common to all the roadmaps was a focus on the status of technological maturation and its gaps, along with the foreseen issues to bridging those gaps. The documents were highly descriptive in nature, making clear that the service nor industry were to take the documents as prescriptive, directive, or reflective of service concurrence. In a way, they lacked any real teeth as a coordinating mechanism, but were highly insightful regarding developmental challenges across the Defense Department—a theme that remained throughout all four documents. In 2001, the DOD created a joint Planning Task Force, reporting to the Office of the Secretary of Defense, with the responsibility of developing the first UAV roadmap. The first roadmaps sponsors, Under Secretary of Defense David R. Oliver and Assistant Secretary of Defense Arthur L. Money, sought to highlight to a broad audience on-going challenges, which included technical, political, programmatic, regulatory, and operational issues.[267] A Government Accounting Office (GAO) document praised the move as helpful, but criticized the documents for failing to provide a "comprehensive strategic plan to ensure that the services and DOD agencies develop systems that complement each other, perform all required missions, and avoid duplication."[268] The nature of the four documents facilitated information openness and coordinated current and projected states of effort across the entire DOD enterprise of research, development, testing, evaluation, and operations. The first two documents focused purely on unmanned aircraft, but the 2009 and 2011 roadmaps expanded their scope to include all unmanned systems (i.e., air, ground, undersea, and surface vehicles) as part of their guidance, improving discussions in a much more inclusive and cross-discipline fashion.

With the release of the 2009 roadmap, the services began to develop supporting UAV visions documents that nested under the DOD's general guidance, mission synchronization, and descriptions of technological development. Regardless, the services' documents seemed to lag the DOD's efforts to provide organizational guidance and

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[267] Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap, 2001–2025*, introductory memo.

[268] Government Accountability Office, *FORCE STRUCTURE: Improved Strategic Planning Can Improve the DOD's Unmanned Aerial Vehicle Efforts*, GAO-04-342 (Washington, DC: Government Accounting Office, March 2004), highlights page.

direction about UAV development and adoption efforts. Given the highly technical and detailed nature of the documents, a few key highlights are provided here, with more granular data given in the subsequent chapters where appropriate for UAV episode analysis.

The first Defense Department roadmap for unmanned aircraft, released in 2001, had few operational and developmental UAVs to survey and report on; therefore, the document was comparatively short. For instance, the only operational UAVs at the time of the April release were the RQ-1, RQ-2, and RQ-5; the latter two were already considered "sunset systems," as seen in Table 3.[269] At the time, the entire department had a combined total of 90 operational UAVs across all services, having spent $3 billion spent on unmanned aircraft since 1991; additionally, the roadmap projected that the UAV inventory would grow to two-hundred and ninety vehicles by 2011.[270] The RQ-4, MQ-8, and RQ-7 were still in development, with the X-45 and X-47 barely mentioned as highly experimental endeavors.[271] The authors suggested that the motivation for military UAV development fell into three missional bins referred to a "dull" (long-duration), "dirty" (hazardous materials), and "dangerous" (high-risk hostile action).[272] At the time, a preponderance of forecasted UAV missions and platforms fell into the dangerous bin. The technological area the report focused on current and future research included propulsion, survivability, communication, information processing, and payload sizing. The authors also took pains to acknowledge the contentious debate regarding the affordability and cost of unmanned systems compared to manned platforms, particularly the relatively poor safety record often noted at the time.[273] Yet, the authors generally made the case that UAVs were indeed a cost-savings measure, in both procurement and operations support. Forecasting a tentative procurement and initial operating capability for the programs of record, the document released the roadmap graphic shown in Figure 10 (the white vertical bar on the timelines

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[269] Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap, 2000–2025*, 6.

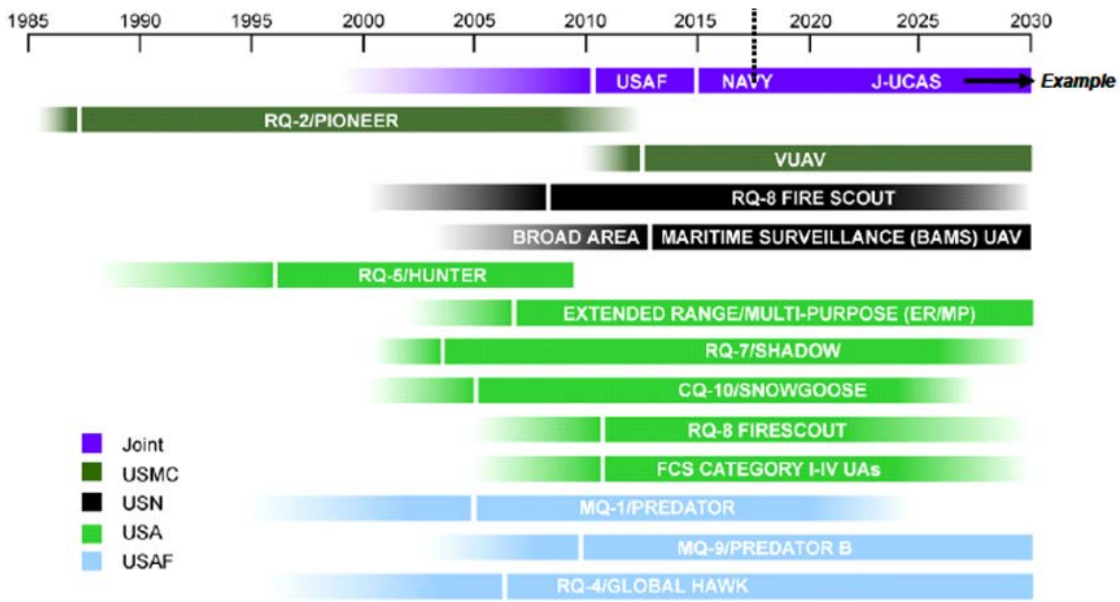
[270] Office of the Secretary of Defense, i.

[271] DARPA held the lead for the X-45 and X-47, with the Air Force and Navy in support respectively.

[272] Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap, 2000–2025*, 14.

[273] Office of the Secretary of Defense, *Unmanned Aircraft Systems Roadmap, 2005–2030*, H-1.

indicate actual/projected initial operating capability milestones). A notable weakness of the document was the lack of a DOD or service concept of operation; the roadmap lightly described experimental effort by the services and did not propose an actual employment concept.



ER/MP was a planned follow on to RQ-5. The Army extended the RQ-5 past its planned end of service date, which was around 2004 before to the wars of the early 2000s.

Figure 10. The 2005 DOD UAV Roadmap[274]

The 2005 *Unmanned Aircraft System Roadmap* reflected a country embarked in two on-going wars and that had experienced dramatic, unexcepted changes to the number and types of UAVs employed on the battlefield or in development. The tone of the roadmap shifted to one of immediacy, though it retained its forecasted planning out through 2030. The document was not only approved by the Under Secretary of Defense for Acquisitions, Technology, and Logistics, but also the Vice-Chairman of the Joint Chiefs of Staff and the Under Secretary of Defense for Intelligence, indicating a shift from unsubstantiated acquisitions in 2001 to a roadmap blessed by both operational and intelligence leadership.

[274] Source: Office of the Secretary of Defense, 72.

Additionally, the approving officials stated the goal of the document was "to guide the Department toward a logical, systematic migration to UAS mission capabilities focused on the most urgent warfighter needs."[275] Besides the change in tone, the 2005 roadmap followed the same structure and format of its predecessor, but with a much expanded list of both fielded and developmental UAVs (see Figure 8 above). A third, more sizable list was the experimental vehicles and programs in development, showcasing the commitment to the transformation vision underway in the Pentagon. Furthermore, the 2005 roadmap executive summary emphasized need to continue transformational efforts by evolving and operationally evaluating the "potential fielding" of a UCAV to conduct suppression-of-enemy-air-defense and strike missions in a "high threat environment;[276] this effort was listed at the *top* of a list of capability goals.

Between the 2005 and 2009 roadmaps, Congress once again passed specific guidance and direction for UAV acquisition process within the DOD. According to the 2009 UAV roadmap, the FY 2007 National Defense Authorization Act (passed on October 17, 2006)

> called for DOD to establish a policy that gives the Defense Department guidance on unmanned systems, some key points of which included: identifying a preference for unmanned systems in acquisitions of new systems, addressing joint development and procurement of unmanned systems and components, transitioning Service unique unmanned systems to joint systems as appropriate, the organizational structure for effective management, coordinating and budgeting for the development and procurement of unmanned systems, and developing an implementation plan that assesses progress towards meeting goals established in Section 220 of the Floyd D. Spence National Defense Authorization Act for FY2001.[277]

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[275] Office of the Secretary of Defense, approval memo.

[276] Office of the Secretary of Defense, i.

[277] Office of the Secretary of Defense, *FY 2009–2034 Unmanned Systems Integration Roadmap*, 4–5. For the original bill, see John Warner National Defense Authorization Act for FY2007, Pub. L. 109–364 (October 17, 2006). https://www.govinfo.gov/ content/pkg/PLAW-109publ364/pdf/PLAW-109publ364.pdf.

In 2009, two major changes occurred in the DOD's approach to the roadmap, which was a trend that was repeated in 2011: removal of UAV platform procurement projections and a vastly increased focus on technology-performance goals over time. Based on the increased demand signal from combatant commanders, the roadmap noted that key performance attributes" must "evolve significantly….to enable the projected missions and tasks."[278] Improving autonomy was at the top of the list of performance attributes of a long list of domain-agnostic adaptations. Here domain refers to air, ground, surface, and sub-surface. The indispensable adaptations were further categorized by first evolutionary change and revolutionary change; 2015 was the goal year marked to delineate a transition from evolutionary adaptations to those of more revolutionary nature. When considering air-domain specific requirements, the DOD identified performance adaptions needed to succeed across a variety of missions, as indicated in Figure 11. Of note, there remained significant autonomy and flight characteristic issues even by 2009.

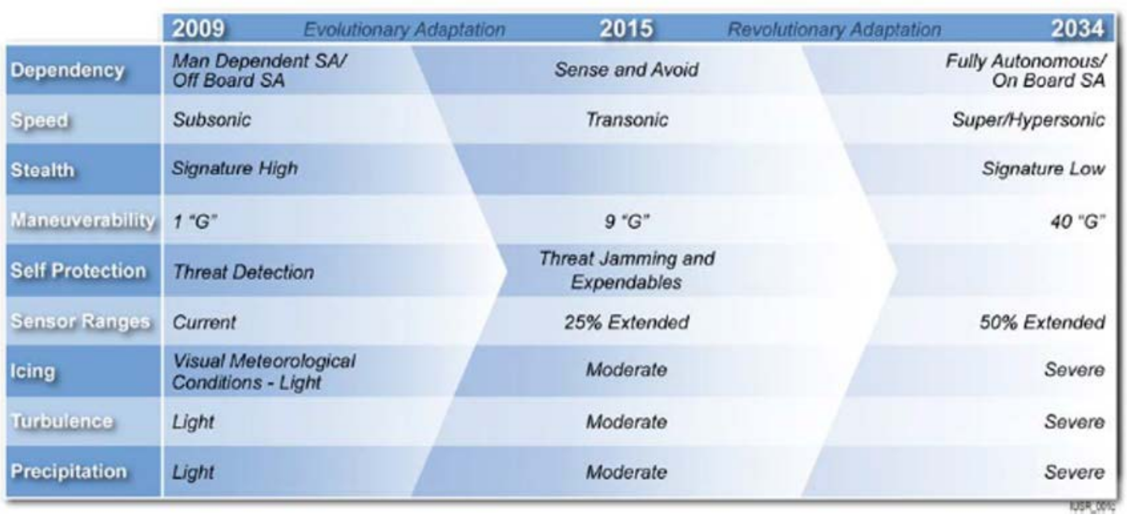

Figure 11. Air Domain Specific Performance Envelope[279]

278 Office of the Secretary of Defense, *FY 2009–2034 Unmanned Systems Integration Roadmap*, 27.

279 Source: Office of the Secretary of Defense, 30.

Finally, in 2011, the DOD released a modified roadmap that refined the 2009 version, changing the terminology of performance to capabilities and tightening the strategic forecast into technology-capability pairs. *Efficiency* initiatives colored the 2011 version, with the growing concern and uncertainty over national and DOD funding. *Affordability* was added as a key performance parameter "equal to, if not more important than, schedule and technical performance."[280]

b. USAF Strategy, Guidance, and UAV Roadmaps

A series of capability shortfalls and operational demonstrations in the late 1990s awakened USAF planners and leadership to the value of UAVs and the need to exert influence once again in the procurement of all major aircraft programs designed to operate in the Air Force's domain of responsibility. Yet, it was not until 2009 that the air service released a comprehensive UAV roadmap—or "flight plan" as the Air Force called it. The turbulence the Air Force experienced in the first decade of the 21st century regarding UAV adoption brought a deeper seriousness and a plethora of lessons that by 2009 gave the Air Force an appreciation for just how much was needed to affect change in the organization. The 2009 manuscript, titled *United States Air Force Unmanned Aerial Systems Flight Plan, 2009–2047*, emphasized a holistic "DOTMLPF-P" approach to ensure a fully integrated organizational effort toward a stronger adoption of UAVs in general.[281] While lacking a full concept of operations in the unclassified document, it did set new employment ideas such as "loyal wingmen," enlisted pilots for smaller UAVs, and set a direction for modular systems to ease technology modifications in future system iterations.[282] A major weakness of the document was its lack of specificity in its near thirty-year time horizon, offering a chronological order of development to include at least some immediate institutional and

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[280] Office of the Secretary of Defense, *Unmanned Integrated Roadmap, 2011–2036*, v.

[281] Headquarters Air Force, *United States Air Force Unmanned Aerials Systems Flight Plan, 2009–2047*. DOTMLPF stands for Doctrine, Organization, Training, Material, Leadership and Education, Personnel, Facilities, and Policy, which is a standard practice across the DOD for program planning. This document is referred to as *USAF UAS Flight Plan, 2009* from here.

[282] Loyal wingman is the idea of one or more UAVs tethered with a manned aircraft in a digital network to provide a variety of jobs such as weapons mule, intelligence, autonomous strike, and even have its own self-defense. This differs from swarm employment that is not tied to a manned platform. *USAF UAS Flight Plan, 2009*, 34.

organizational goals that would set the foundation for all future endeavors. Major transition periods were also highlighted where legacy manned aircraft would be shed, and new UAVs would feature prominently in the next generation of aircraft within that family of system.

Five years later the USAF released an even more detailed and expanded UAV strategy called Uni*ted States Air Force RPA Vector: Vision and Enabling Concept 2013–2038*. Not released until 2014, the RPA Vector made some radical changes for the organization while providing a much clearer and more detailed family of systems approach. For one, the document called for breaking cultural paradigms to allow enlisted UAV pilots—at least for the smaller unmanned aerial systems comprising Groups 1, 2, and 3. The Air Force returned to the RPA nomenclature it has clung to decades, but now specified that RPAs meant those unmanned aircraft in Groups 4 and 5—which would still be flown by rated officer pilots. The transition periods and types/families of systems were much more detailed in this document; however, the fighter recapitalization transition shown in the 2009 version was removed. Both the 2009 and 2014 documents devote considerable time detailing how to maximize and navigate the DOD coordination process to ensure effective requirements and funding throughout the years. Overall, the 2014 document is much more robust, and looks to set a comprehensive institutional and cultural foundation for UAV adoption by the service.

c. USN Strategy, Guidance, and UAV Roadmaps

The USN never produced a UAV roadmap until recently in 2018, well past the period of interest for this study. Instead, it appears the Navy relied on its S&T planning strategies, capstone service-level strategies, as well as internal guidance produced by the Navy's Program Element Office for strike weapons and unmanned aviation. (The first two categories of documents are covered in the S&T section below.) It appears that the Navy did not have a robust rationale for UAV acquisitions within the Navy during most of the Third UAV Epoch. In 1999, the Navy commissioned the National Research Council to conduct an analysis of the Office of Naval Research's UCAV program. This commission found that the only UCAV vision cast for the Navy—one developed by the Office of Naval Research's Strike Technology Division—was "unrealistic" with no grounding in anticipated future technological advancements; furthermore, it found that key UAV stakeholders within the Navy had not been included in coordination processes.[283] It recommended the Navy establish a new concept of operations. To ensure clear direction for the Navy, the Defense Secretary's 2006 quadrennial defense review directed the Navy to develop a stealthy, carrier-based UAV.[284] By 2008, the Navy still did not seem to have a coherent UAV roadmap or concept of operations for UCAVs, and the Center for Strategic and Budgetary Assessment's released a voluminous monograph by Thomas Ehrhard and Robert O. Work, which argued for the Navy to fully adopt a carrier-borne UCAV.[285] In early 2013, the Program Element Office director, Rear Admiral Mat Winter, released an internal briefing with an updated roadmap for Naval UAVs showing navy acquisitions to date and what the office anticipated in the coming ten-to-twelve years (see Figure 12).

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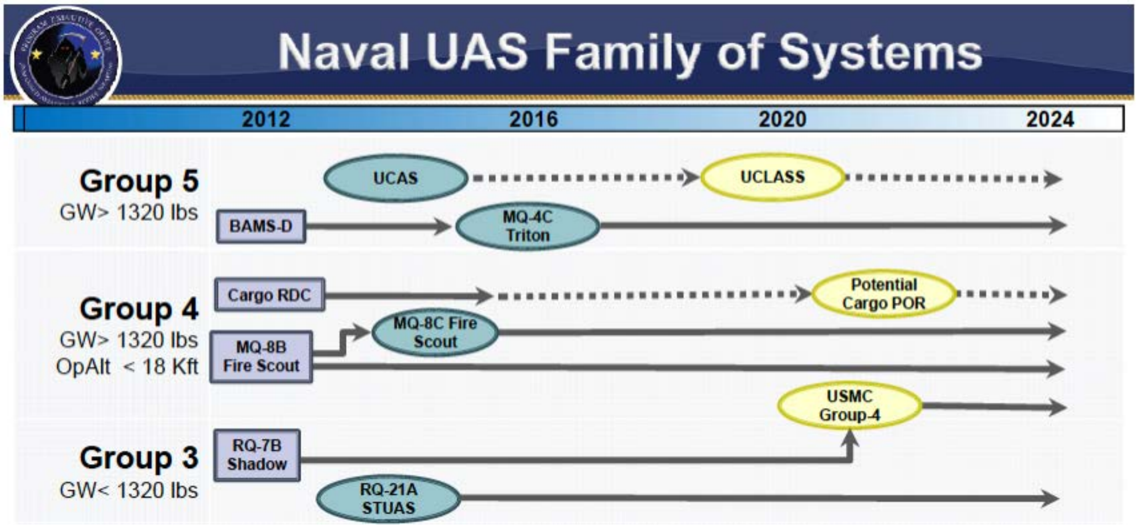
[283] National Research Council, *Review of ONR's Uninhibited Combat Air Vehicle Program* (Washington, DC: National Academy Press, 2000), 2.

[284] Office of the Secretary of Defense, *Quadrennial Defense Review Report* (Washington, DC: Department of Defense, 2006), 46. The QDR directed the DOD to "Restructure the Joint Unmanned Combat Air System (J-UCAS) program and develop an unmanned longer-range carrier-based aircraft capable of being air-refueled to provide greater standoff capability, to expand payload and launch options, and to increase naval reach and persistence."

[285] Thomas P. Ehrhard and Robert O. Work, *Range, Persistence, Stealth and Networking: A Case for a Carrier-Based Unmanned Combat Air System* (Washington, DC: Center for Strategic and Budgetary Assessment, 2008).



BAMS-D: RQ-4 Global Hawk; the RQ-21A is a Marine Corps system.

GW: Gross Weight

Figure 12. Naval UAS Roadmap, 2012–2024[286]

d. U.S. Army Strategy, Guidance, and Roadmaps

Since 1991, the U.S. Army has factored UAVs into its modernization programs, but the service produced only one UAV focused planning document. Until recently, all UAS planning and guidance fell under one of the two modernization plans: *Future Combat System* initiated in 1999 under Chief of Staff of the Army General Eric Shinseki and the 2009 Army Brigade Combat Team Modernization Program. Under the *Future Combat System's* rubric—the largest and most ambitious modernization plan for the Army in several decades—the service procured the MQ-8 Fire Scout in 2003 as a Class IV UAV. In 2007, the Army cancelled further plans for Class II and III UAVs for the *Future Combat System* due to ballooning and un-met electromagnetic spectrum and communications bandwidth requirements for the system overall.[287] By 2010, the Army had acquired over 4,000 UAV of various sizes (mostly smaller, tactical UAVs) but demand was expanding;

[286] Source: Mat Winter, "US Navy Family of Unmanned Aircraft Systems," (presentation by Program Element Office of Unmanned Aviation and Strike Weapons, NAVAIR, 13 February 2013), https://www.hsdl.org/?view&did=731454.

[287] Blom, "Unmanned Aerials Systems.," 119–122. Army classes of UAVs do not line up with the Joint definition of UAV Groups. Instead, classes progress I-IV with platoon, company, battalion, and brigade sized UAVs respectively. See *Unmanned Aerial System Roadmap 2005–2030*, 12.

the MQ-1 was already fielded as a quick reaction capability (though not yet met initial operating capability) and there was room for the Army to grow organic UAV capabilities for all echelons of command.[288] Therefore, in 2010 the Army Chief of Staff General Martin Dempsey approved a UAV-specific planning document titled *Eyes of the Army, UAS Roadmap 2010–2035*. *Eyes of the Army* anticipated only minor changes to UAV innovations in the near term from 2010–2015: upgrading the existing RQ-7, fielding the new MQ-1C, and transitioning to a common control interface. The plan extended the S&T needed for unmanned armed recon and attack until after the 2025 timeframe or later.[289] The anticipated new technologies during this period included advances in signature reduction, control of multiple vehicles simultaneously, improved vertical take-off/landing, collision avoidance, and small heavy fuel engines among other needs.[290] Figure 13 reflects the Army UAV acquisitions since 2003 through the near-term phase as envisioned in *Eyes of the Army*.

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[288] U.S. Army UAS Center of Excellence, *Eyes of the Army*, i.

[289] U.S. Army UAS Center of Excellence, 33.

[290] U.S. Army UAS Center of Excellence, 34.

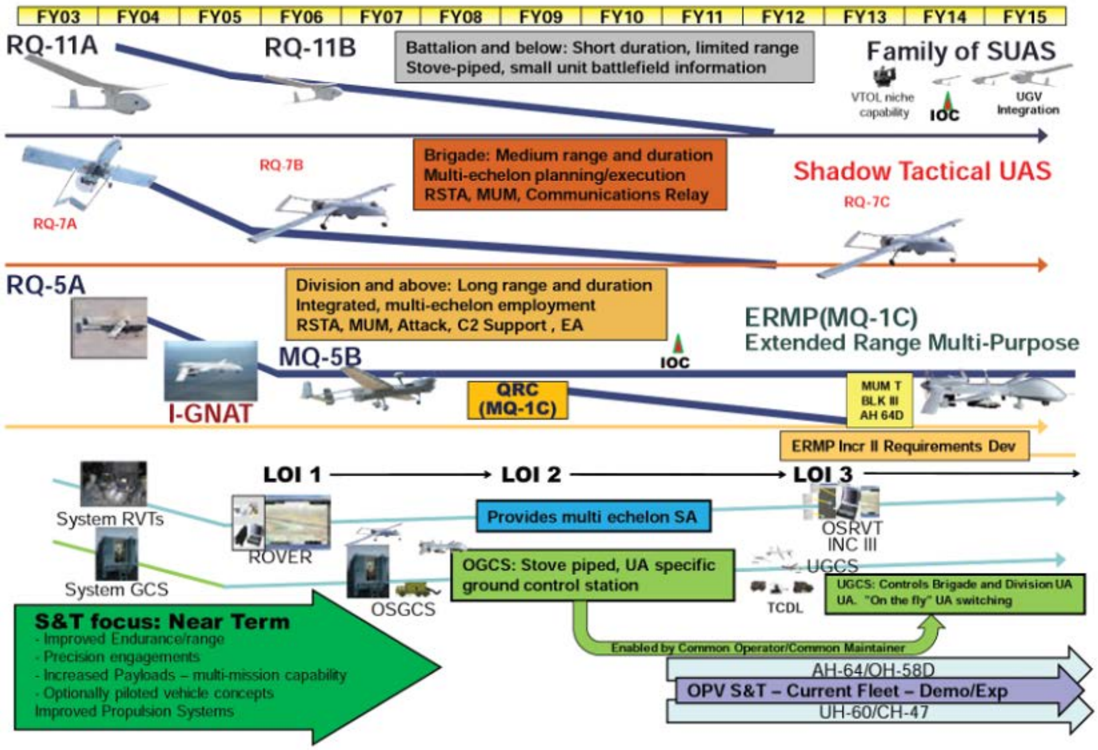

Figure 13. U.S. Army UAV Implementation through 2015[291]

e. The Impact of International Treaties on UAV Development and Adoption

International arms treaties affect UAV development, design, and adoption outcomes. The initial overlap of cruise missiles and UAV technology starting in the early 1970s had a direct impact on UAV growth that did not abate until the differences between the two technologies became clearer and treaty language made the distinction. For example, in the second UAV epoch, the *Strategic Arms Limitation Talks* treaties (I and II) between the United States and the Union of Soviet Socialist Republics confused further armed UAV development of the Lightning Bug series. As the first round of talks ended in 1972, the Soviet Union "pushed hard for limits on the emerging U.S. cruise missile capability, and the eventual agreements signed by President Jimmy Carter on June 18,

291 Source: U.S. Army UAS Center of Excellence, 47.

1979, included limits on cruise missiles under a definition that included, or captured in arms control parlance the newer BGM-34C as a strategic weapon."[292]

Though the *Strategic Arms Limitation Talks* agreements are no longer applicable today,[293] UAVs in the third UAV epoch were shaped in part by legacy arms treaties: the *Biological and Toxin Weapons Convention* of 1972, the *Intermediate Range Nuclear Forces Treaty* of 1987, and the *Treaty on Conventional Armed Forces in Europe* of 1990.[294] The first convention, signed by most nations, and followed by the *Chemical Weapons Convention* of 1993 prohibits weapons that include UAVs from being able to dispense biological and chemical agents. The Intermediate Range Nuclear Forces treaty was problematic at given its prohibition of land-based "unmanned, self-propelled vehicles" that delivered weapons at a range between five-hundred and 5,500 kilometers.[295] The U.S. distinction between cruise missiles and UAVs quickly overcame this issue for ground-launched UAVs shown not to be nuclear capable, but for a time, the United States considered the political ramifications of Russia considering all UAVs as captured by this treaty.[296] The *Conventional Armed Forces in Europe* treaty, which was updated in 1999, had the most direct impact on UAV development, as the treaty limited the number of combat aircraft each nation could have in Europe. The treaty's language purposefully covered unmanned vehicles, independent of size or mass; therefore, any UAV to include micro UAVs. For every UAV introduced into the European theater, it would count against

[292] Ehrhard, *Air Force UAVs*, 36. The SALT agreements were never ratified, but the two sides abided by them anyway until 1986, influencing UAV development. Section II, Article B of the agreement defined cruise missiles as "unmanned, self-propelled, guided, weapon delivery vehicles which sustain flight using aerodynamic lift over most of their flight path and which are flight-tested or deployed on aircraft." It further limited those capabilities to no more than 600 kilometers (372 miles). The BGM-34C had a one-way endurance in excess of 372 miles. See the archived U.S. State department site for further info: https://2009-2017.state.gov/t/isn/5195.htm.

[293] The agreements and outcomes of the Strategic Arms Limitation Talks ended in the late 1970s.

[294] Jürgen Altmann, "Arms Control for Armed Uninhabited Vehicles: an Ethical Issue," *Ethics and Information Technology* 15 (2013), 142, https://doi.org/10.10007/s10676-013-9314-5.

[295] As defined by Article II, paragraph 2. See U.S. State Department, https://2009-2017.state.gov/t/avc/trty/102360.htm. The miles equivalent is 310–3,410 miles.

[296] Altmann, "Arms Control for Armed Uninhabited Vehicles, 142. Altmann summarizes the issue as mute due to Department of State's view that UAVs do not count as cruise and ballistic missiles.

manned aircraft as well.[297] This caused a dilemma for planners and acquisition personnel. So long as the primary area of operation remained Europe, the services had to weigh carefully UCAV capabilities and quality to ensure the UCAV provided unique capabilities that manned aircraft could not or even match manned fighter/bomber capabilities—irrespective of UCAV size. For example, the Defense Airborne Reconnaissance Office, upon its launch in 1995, made conscientious efforts to show the world that it was not working on or overseeing any armed UAV programs.[298] In its inaugural annual report of August 1995, the agency produced a graphic to show the growing zone of overlap between treaties and UAV development, while emphasizing that there are no treaties banning reconnaissance-only UAVs (Figure 14). It also noted the prevailing concern of senior DOD and national security leaders, by highlighting the "inherent similarities" of UAVs and cruise missiles, which creates diplomatic concern.

[297] The total number of armed U.S. aircraft allowed in the treaty totaled 784. The definition of combat aircraft is given in Article II, paragraph 1, section K of the treaty: "The term 'combat aircraft' means a fixed-wing or variable-geometry wing aircraft armed and equipped to engage targets by employing guided missiles, unguided rockets, bombs, guns, cannons, or other weapons of destruction, as well as any model or version of such an aircraft which performs other military functions such as reconnaissance or electronic warfare. The term combat aircraft does not include primary trainer aircraft. U.S. Department of State, *Conventional Armed Forces in Europe Treaty*, https://2009-2017.state.gov/t/avc/trty/115588.htm.

[298] Defense Airborne Reconnaissance Office, *Annual Report: Unmanned Aerial Vehicles (UAVs) August 1995* (Washington, DC: Office of the Under Secretary of Defense, Acquisition & Technology, 1995), 8.

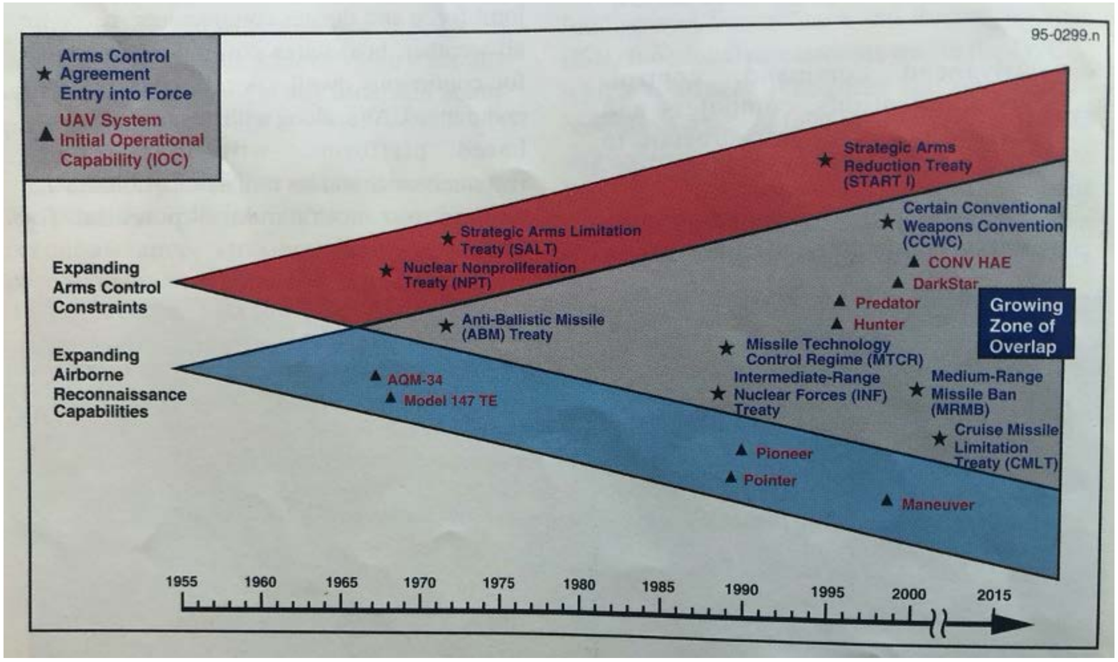

Figure 14. Arms Control Agreements versus Reconnaissance UAV Development, 1995[299]

The only modern treaty of consequence is the *New Strategic Arms Reduction Treaty*, completed in 2010 between Russian and the United States. It permits new versions of nuclear-weapons carriers, with the only obligation being that both sides notify and show them to each other. Essentially, there are no direct limitations on UAVs, yet there is a possible incentive for their development since unmanned bombers are not specified in the treaty. Ancillary to these treaties are export control agreements such as the *Missile Technology Control Regime*; this restricts UAV weapons and technology transfers of certain sizes, as well as safeguards against weapons of mass destruction capabilities and certain production technologies.[300] The only real concern regarding UAV design limitations here in the United States comes from the limiting economies of scale that this export control regime enacts. In sum, the timing and design of America's military UAV development and adoption reflect the timing, language, and spirit of international arms

299 Source: Defense Airborne Reconnaissance Office, *Annual Report: 1995*, 8.

300 Altmann, "Arms Control for Armed Uninhabited Vehicles," 142.

treaties it has signed, with advanced armed UAVs only becoming an option for development since the year 2000.

2. Budgetary Developments and Expenditures

a. Defense Funding Trends

Between 1991 and 2015 national spending on defense experienced several booms and cuts based on strategic contexts and presidential political agendas, as seen in Figure 15. As the first Bush administration wound down in 1991, defense spending continued an accelerate decline from the Reagan Buildup years as part of a peace dividend from the Soviet Union's dissolution. In the last year of the George H.W. Bush presidency, defense spending was approximately 4.5 percent of gross domestic product and just shy of $500 billion (adjusted to 2015 dollars). In 1991, for the first time since the Korean War, the defense budget fell to less than 5 percent of gross domestic product and would never be higher than 4.8 percent through today. The Clinton years sought to capitalize on the unipolar moment through an increased procurement holiday, resulting in massive military drawdowns in both structure and budget; in the first two years of Clinton's administration, the defense budget dropped around $90 billion and would finally bottom out in FY 1998 at just around $390 billion for the year (in 2015 dollars). As a percentage of gross domestic product, the defense budget fell to around 3 percent. Figure 16 shows those cuts in total as well as the impact within the services, with every service hit hard but particularly the Air Force and Navy.

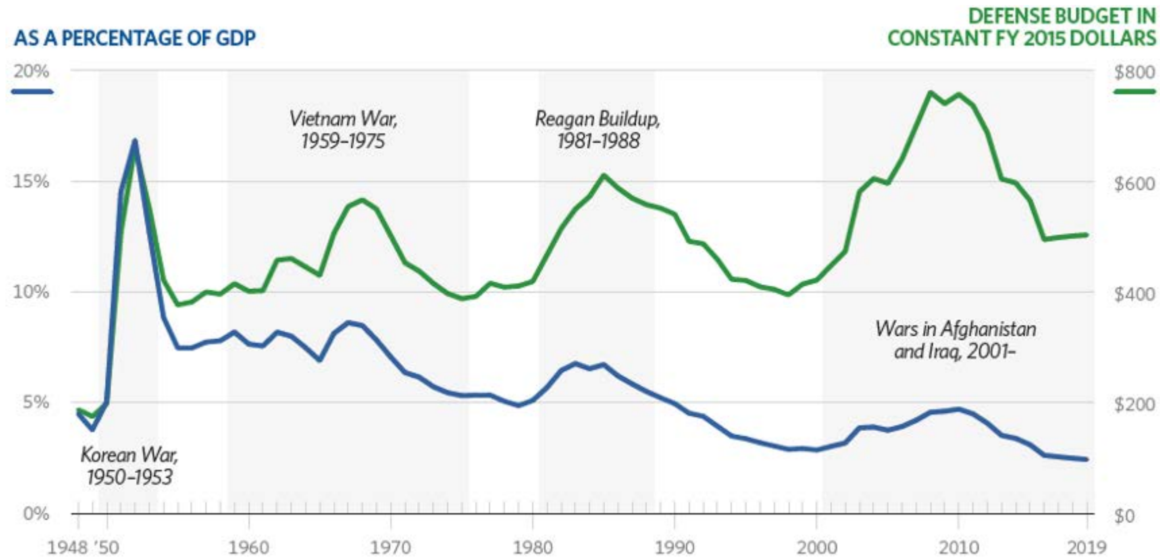

Figure 15. Defense Funding in Dollars and Percent of Gross Domestic Product, 1948–2019[301]

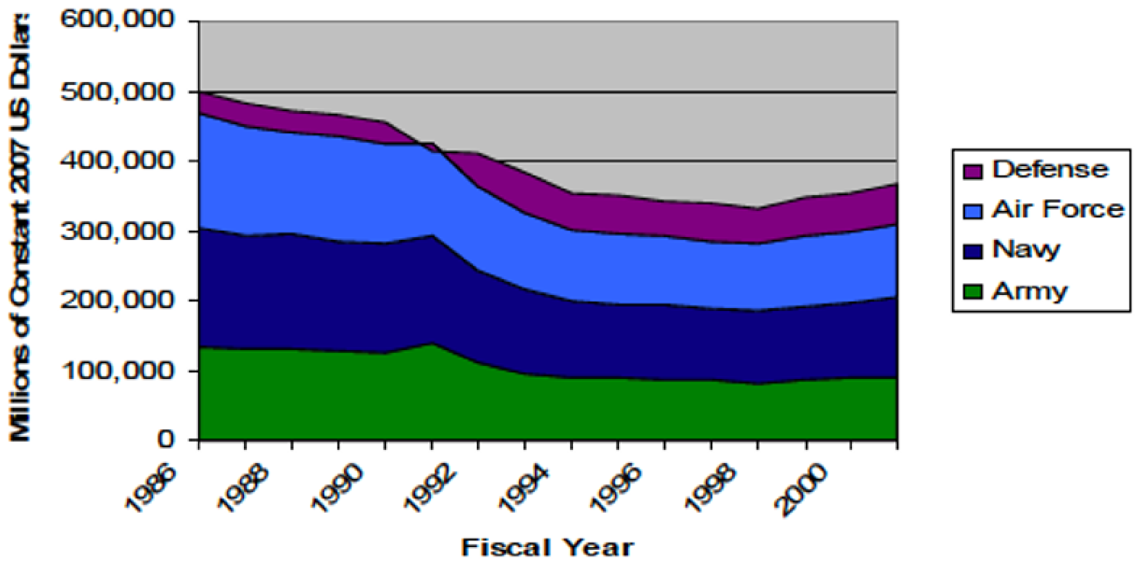

Figure 16. U.S. Defense Spending, 1986–2002 (2007 U.S. Dollars)[302]

301 Source: Diem Nguyen Salmon, *A Proposal for the FY 2016 Defense Budget*, BR 2989 (Washington, DC: The Heritage Foundation, 2015), 7, http://report.heritage.org/bg2989.

302 Source: Czelusta, *Business as Usual*, 10.

Though Clinton started to reverse the defense funding cuts the last two years of his tenure, George W. Bush entered the White House with a plan to restore funding to the military in order to facilitate a major transformation with talks of leap ahead technologies and skipping a generation of procurement. One could call it the Bush catch-up years, with the FY 2001 base budget set at just under $400 billion in 2015 dollars ($287 billion in then-year) and more planned in the future. The events and wars following September 11, 2001, propelled the defense budgets higher in pure dollar figures than ever seen in the post-World War II era. Huge portions of that funding counted as overseas contingency operations funds; furthermore, the DOD baseline budget for organizing, training, and equipping through the services rose as well, staying steady in the mid $300 billion dollar range (in then-year dollars) through Bush's first term. Figure 17 reflects these changes in detail from 2001 on. In Bush's second term, the base funds rose in the last two years to the mid $500 billion range (then-year dollars), while overseas contingency funds rose significantly to match the surge in Iraq and Afghanistan.

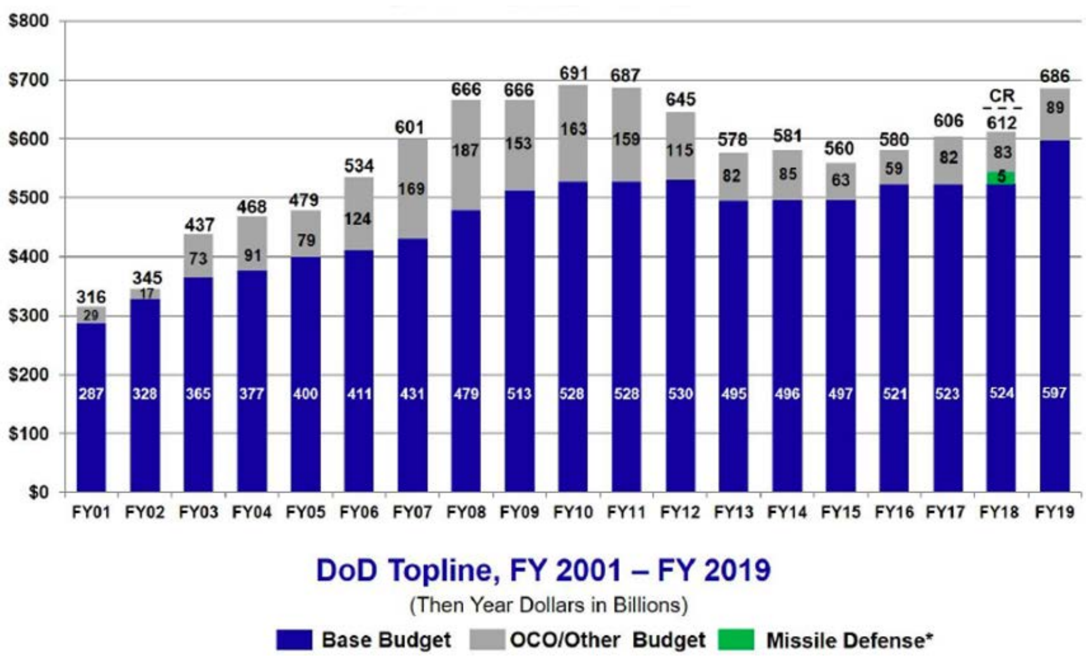

Figure 17. Historical DOD Funding since Fiscal Year 2001[303]

Under President Obama, the DOD base budget flattened, but remained at a near constant between $513 to $530 billion then-year dollars from FY 2009 to 2012; however, the overseas contingency funds remained high in the first term as Obama approved his own surge of troops for Afghanistan starting in early 2010 and ending in mid 2012. Concurrently, the Iraq War ended, and the administration pulled troops in 2011 which drove the overseas contingency funds down significantly. These additional funds remained consistently lower for the remainder of Obama's second term. Also, in Obama's second term, the defense budget again dropped, but only slightly, remaining flat at $495 then-year dollars for FYs 2013 through 2015 due in part at least to the 2011 Budget Control Act—an attempt to solve the legal debt ceiling issues.[304] The Act forced caps and sequestration of funds upon the DOD due to Congressional failure to pass a budget within the limits set

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[303] Source: Office of the Under Secretary of Defense (Comptroller), *Defense Budget Overview: United States Department of Defense Fiscal Year 2019 Budget Request* (Washington, DC: Department of Defense, 2018), 1–3, https://dod.defense.gov/Portals/1/Documents/pubs/FY2019-Budget-Request-Overview-Book.pdf.

[304] Budget Control Act of 2011, Pub. L. 112025 (August 2, 2011) https://www.congress.gov/112/plaws/publ25/PLAW-112publ25.pdf.

on discretionary spending. Congress' failure to pass a budget in early 2012 forced automatic caps on the DOD starting in early 2013, which forced a $38 billion (6 percent) unplanned cut on the Pentagon for that year.[305] The impact of sequestration continued for several more years.

b. UAV Funding Trends

At a more granular level inside the defense budget, funding for UAVs reflects strategic context, technological development, and institutional adoption patterns within the U.S. military. Two graphs (Figure 18 and Figure 19) provide insight into funding amounts invested into UAVs as a function of the acquisitions process as well as total expenditures in the DOD, which includes funds for operations and maintenance. The first graph provides then-year total dollars spent on research, development, and testing, along with weapon systems and spares. Investments in UAV S&T and procurement fluctuated wildly from 1991 through 1997, with a minor uptick around the years when the MQ-1 Predator was being tested and fielded in the 1995. The costs settled for acquisition efforts around the $300 million (then years) mark for the last couple years of the decade. Exponential growth for UAV acquisitions started in 2001 and quickly jumped each year crossing the $1 billion threshold in 2003; by 2007, the figure was over $2.2 billion, topping $4.2 billion in 2012 before entering a freefall in the remainder of the Obama years. From 1999 to 2004, Congress funded the DOD acquisition process at or above requested levels for an increase of $400 million, mostly for additional RDT&E, but also adding funds to increase the number of Predators purchased by the Air Force from seven to twenty nine in FY 2003.[306] The second graph adds to those figures the cost of operations and maintenance for fielded systems. It is consistent that from 1991 to 2010, the amount spent on operations and maintenance remained low, ranging from $50 to $250 million, with a few higher exceptions in 2005 and 2006. Then, starting in 2011, the operations and maintenance totals skyrocket $2 to $4 billion over acquisition costs.

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[305] Salmon, *A Proposal for the FY 2016 Defense Budget*, 4. That cut forced an 8.9 percent cut to procurement and an 8.7 percent cut in R&D among others.

[306] Government Accountability Office, *FORCE STRUCTURE: Improved Strategic Planning*, 2.

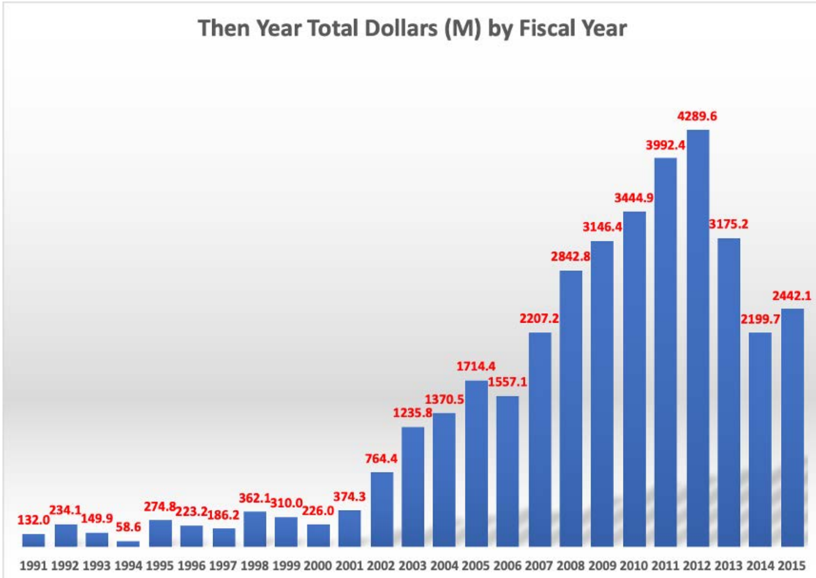

Figure 18. DOD UAS Costs for Acquisitions[307]

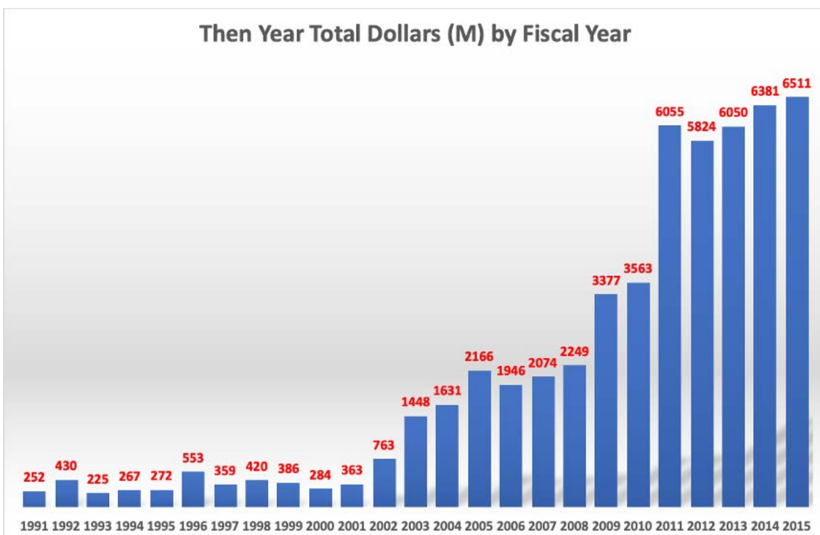

Figure 19. DOD UAS Total Costs[308]

307 Adapted from Ted Nicholas, *U.S. Military Aircraft Data Book, 2015* (Fountain Valley, CA: Data Associates, 2015).

308 Adapted from Office of the Secretary of Defense, *Unmanned Aircraft Systems Roadmap, 2005–2030*; Office of the Secretary of Defense, *FY 2009–2034 Unmanned Systems Integration Roadmap*; Office of the Secretary of Defense, *Unmanned Integrated Roadmap, 2011–2036*. Note: Data for 2006–2008, 2010, 2012–2015 are estimates based on presidential budget requests. Note: The dollar totals include operations and maintenance costs.

3. Science and Technology

It is easy for one to project current technological capabilities further back in time than is warranted. People often forget—or at least minimize—even the recent past's technological limitations. Consider, in the early 1990s, the Global Positioning System was not fully operational (though used with effect in the Persian Gulf War) nor widely available for commercial use. In 1991, the compact disc was just becoming affordable enough for a few software companies to start issuing their products on disks. Compact discs for music were still a few years away for the public, and VHS video tapes and music cassette tapes were the only commercial options. It was on August 6, 1991, that developers published the first-ever online website. Around the same time, telecommunication companies introduced 14.4 kilobits per second "high-speed internet," allowing a one-gigabyte file (for reference, movie files today are four to five gigabytes) to download in a whopping one-hundred-fifty-four hours. Intel and other microchip companies introduced the 386-computer processing unit in early 1991.[309]

Besides the state of technology in government and the marketplace, national level guidance documents provide insight into what was within the realm of possible along with the aspirational works planned out to drive technology in support of national security. The unipolar moment and its associated military operations impacted America's technological approach and thinking as well, enabling potential new avenues for UAV development. Setting the state for the third UAV epoch, the 1991 *National Security Strategy* dedicated a full section to "Defense Technology" calling for a research and acquisition agenda to achieve a generational leap in technology.[310] In terms of weapon systems, this did not pan out in the midst of military drawdowns and increased low-end engagements during the 1990s. This was followed by a George H.W. Bush administration rededicated to achieving military technological transformation in addition to insatiable operational demands for real-time surveillance of terrorist organizations on a global scale.[311] In addition to

[309] Adrian Kingsley-Hughes, "Top 10 Tech Developments of 1991," ZDNet, last modified April 17, 2011, https://www.zdnet.com/article/top-10-tech-developments-of-1991/.

[310] White House, *National Security Strategy of the United States*, 30.

[311] Czelusta, *Business as Usual*.

guidance from the highest levels of national security policymakers, the institutional services further refined national guidance into service-specific science and technology (S&T) strategies.[312] The S&T strategies theoretically then allowed the services to drive long-term research investments and match technology development efforts to future capability needs. Defense Department S&T is one part of the overall DOD Research, Development, Test, and Evaluation (RDT&E) acquisitions umbrella. The relationship of S&T within the research and acquisitions world is shown in Figure 20. The DOD budget categories 6.1 through 6.3 reflect S&T research, and the 6.4 and 6.5 categories are for system development. While the depiction uses an Air Force example of S&T management by the Air Force Research Laboratory, other service equivalents fit this model to include the Office of Naval Research and the Army Research Laboratory (which falls under Army Material Command). Many of the S&T efforts that fall under 6.3—ACTDs and Advanced Technology Demonstrations—are run by DARPA alone or as a cooperative sponsorship of DARPA and one of the services. See Appendix C for a more detailed description.

[312] The Assistant Secretary of Defense for Research and Engineering manages the Defense Innovation Marketplace, which is a repository of all current plans, strategies, and documents related to science, technology, and innovation acquisitions across the entire DOD and all services. https://defenseinnovationmarketplace.dtic.mil.

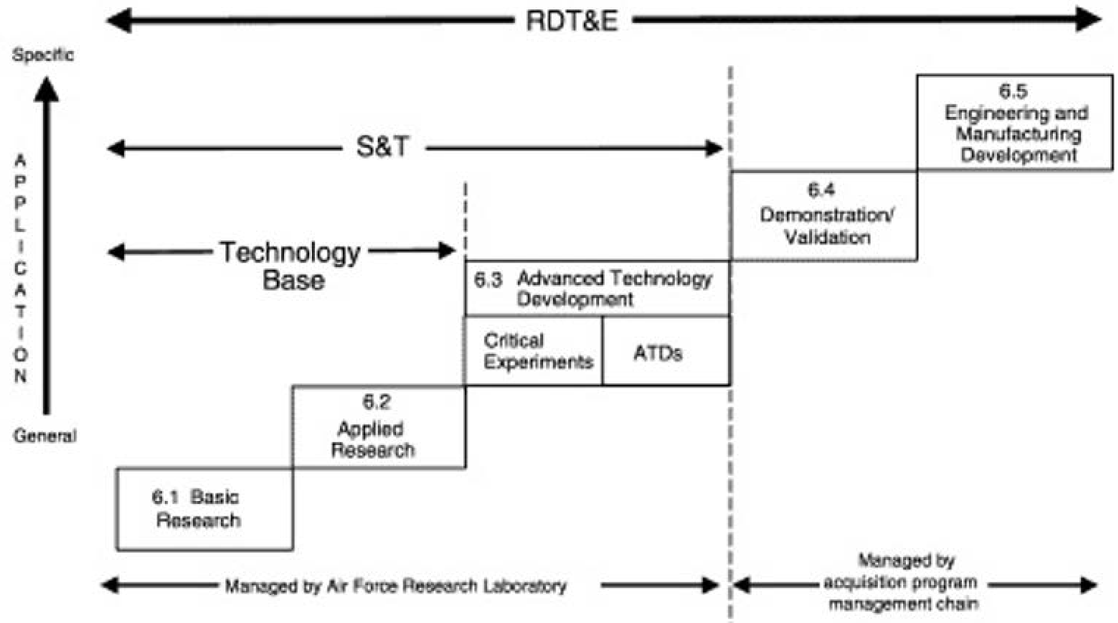

Figure 20. RDT&E Budget Categories[313]

The earliest of the S&T vision document within the third UAV epoch was a DOD effort worked in tandem with the planning stages of the 1991 *National Military Strategy*. The Pentagon submitted its *1990 Defense Department (DOD) Critical Technologies Plan* to the House and Senate Armed Services Committee, providing insight into what the military establishment considered as important and anticipated future technological innovations in the coming fifteen-to-twenty years.[314] The Air Force Institute of Technology took the DOD's plan and assessed it from an airpower perspective for science and engineering in a later document titled *Critical Technologies for National Defense*. Using the categories of deterrence, military superiority, and affordability, two goals stood out as the most pertinent for aviation and potential UAV development. One of the goals

[313] Source: T. Neighbor, "AFRL Vision," (presentation, Committee on Review of the Department of Defense Air and Space Systems Science and Technology Program, National Research Council, Washington, DC, December 17, 1999) cited in National Research Council, *Review of the U.S. Department of Defense Air, Space, and Supporting Information Systems Science and Technology Program* (Washington, DC: National Academy Press, 2001), 59, https://www.nap.edu/read/10179/chapter/12#58. Note: T. Neighbor was the Director, Plans and Programs at the Air Force Research Laboratory.

[314] Department of Defense, *DOD Critical Technologies Plan*, Government Report (Washington, DC: Department of Defense, 1990). See also: Office of Science and Technology Policy, *National Critical Technologies*. Government Report (Washington, DC: White House, 1991).

emphasized systems that could penetrate enemy defenses through signature management and electronic warfare means. A second goal desired affordable “brilliant weapons” with the autonomy to execute the full kill chain to include finding, identifying, tracking and engaging a variety of mobile and fixed targets.[315] While it is not clear if the scientists authoring the report saw UAVs as “brilliant” weapons,” the UCAV would seem to come closest. To meet these two goals, critical technologies outlined for development and exploitation included: composite and advanced materials, “semi-conductor materials and microelectronic circuits,” “machine intelligence and robotics,” and “artificial intelligence.”[316] This listing reveals not only what technologies the national defense apparatus and the services desired, but what was missing in terms of science and technology needed for UAV progress at the dawn of the 1990s. An important contribution to coordinating and integrating technological innovations for UAV use across the DOD started in 2001 with the release of the first DOD roadmap for UAVs. These roadmaps, released in 2001, 2005, 2009, and 2011, are another important source regarding the state of RDT&E maturation during the third UAV epoch; these documents, introduced above, provide important insights used in the analysis of UAV adoption episodes.

a. U.S. Air Force Science and Technology (S&T) Strategy and Investments

In 1991, Air Force investments in UAV technology was limited to basic S&T research. This left the service with only a few technologies that could even aid UAV development. Following Vietnam, Ehrhard asserts that technology “stimulated but failed to float” the UAV “revolution” of the 1970s as the Air Force succumbed to other political and bureaucratic pressures.[317] In the 1980s, the Air Force prioritized technical innovation, excluding any direct UAV developments. Instead, the USAF pursued satellite reconnaissance, precision stand-off munition, and stealth capabilities. Employing these capabilities during the Persian Gulf War, the USAF celebrated its combat success,

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[315] American Institute of Aeronautics and Astronautics, *Critical Technologies for National Defense* (Washington, DC: Air Force Institute of Technology, 1991), 2–3.

[316] American Institute of Aeronautics and Astronautics, 7–11.

[317] Ehrhard, *Air Force UAVs*, 37.

convinced these technologies tipped the balance in their favor. In addition to these advances, the USAF had improved reconnaissance cameras and sensors even further. Since the early 1970s, the development of reconnaissance UAVs competed with manned reconnaissance aircraft and satellites as satellite capabilities drastically improved.[318] What did exist for UAV technologies in the late 1980s was the legacy "command guidance" techniques that relied on radio links between the pilot and aircraft. Some industry partners made advancements during that decade developing early "autonomous guidance" to enable more accurate and reliable pre-programmed flight.[319] As the 1990s began, advances in commercial technologies enhanced UAV options and capabilities—particularly miniaturized video cameras and computer processing technology. Military research advanced GPS navigation systems and smaller satellite communication transmitter-receivers, which provided key capabilities for future UAV progress in the 1990s.[320]

The USAF produced two subsequent major S&T studies between 1991 and 2015: *New World Vistas* in 1995 and *Technology Horizons* in 2010. *New World Vistas*—written by the Scientific Advisory Board at the direction of Secretary of the Air Force Dr. Sheila Widnall and Air Force chief of staff General Ronald Fogleman—represented a return in thought to the original USAF S&T study conducted fifty years earlier, called *New World Horizons*. Commissioned in late 1994, *Vistas* authors likened the end of the Cold War period as analogous yet different from the world affairs and technological possibilities that existed in 1945 when *Horizons* was released. Summarizing *Vista's* goals, Dr. Gene H. McCall, the Chair of the USAF Scientific Advisory Board and study director, wrote that the board "endeavored to define the capabilities which will result from emerging technologies during the next three decades," in the expanding Information Age.[321] While the full study was 13 volumes, a major push throughout the *Summary* and *Attack* volumes, "uninhabited *combat* aerial vehicles" feature prominently and repetitively. So much so,

318 Ehrhard, *Air Force UAVs*, 15.

319 Ehrhard, 29–30.

320 Ehrhard, 29.

321 U.S. Air Force Scientific Advisory Board, Summary in *New World Vistas*: *Air & Space Power for the 21st Century*, Headquarters Air Force (Washington, DC: Department of the Air Force, 1995), iv.

seasoned defense policymaker and academic Eliot Cohen hailed *Vistas* as both practical and visionary, noting that the document called for "an air force composed, in large part, of unmanned aircraft."[322] As part of the overall recommendations for coming power projection capabilities, UCAVs were the top of a list of five items: UCAVs, directed energy weapons, next-generation stealth, hypersonics, and space technologies.[323] The *Vistas* study then highlighted the technologies needed to realize the leap into UCAVs: high-efficiency, supersonic engines; miniaturization; intelligent data processing; improved data links; aerodynamic control science; and, human-machine interfaces for off-board vehicle control.

Fifteen years later, and in a very different strategic environment than the one envisioned during the *Vistas* document, the USAF released *Technology Horizons* in 2010. Learning from the prognostic failures of the *Vistas* document, which admitted to a goal of prediction and forecasting, *Technology Horizons* emphasized that it's effort was *not* predictive in nature, nor was it intended as a "forecast of likely future scenarios;"[324] rather, the 2010 vision offered a "rational assessment of what is credibly achievable from a technical perspective to give the Air Force capabilities that are suited for the strategic, technology, and budget environments" of the next 20 years.[325] As its base assumption, *Technology Horizons* held that the science and technology that forms the basis of USAF capabilities had proliferated to potential adversaries who could utilize them in entire novel concepts of operation or as a "basis of entirely different war-fighting constructs."[326] America's asymmetric, qualitative advantage was eroding quickly. The document stressed several shifts in the strategic context that would drive "shifts in research emphasis" to vector "S&T in directions that can maximize capability superiority": from platforms to

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[322] Eliot Cohen, "New World Vistas: Air and Space Power for the 21st Century," *Foreign Affairs* (September/October 1996), https://www.foreignaffairs.com/reviews/capsule-review/1996-09-01/new-world-vistas-air-and-space-power-21st-century.

[323] U.S. Air Force Scientific Advisory Board, "Summary," *New World Vistas*, 60.

[324] Office of the U.S. Air Force Chief Scientist, *Technology Horizons: A Vision for Air Force Science and Technology 2010–2030* (Montgomery, AL: Air University Press, September 2011), xvii.

[325] Office of the U.S. Air Force Chief Scientist, xvii.

[326] Office of the U.S. Air Force Chief Scientist, xvii–xviii.

capabilities; manned to remotely piloted; from control to autonomy; from single-domain to cross-domain; from permissive to contested; from long system life to faster refresh.[327] Unlike its predecessor document, *Technology Horizons* did not emphasize UAVs/UCAVs to the same degree, but instead, it drove home the need for designing and building autonomous systems that could engender a greater level of warfighter trust. *Technology Horizons* identified "Trusted, Adaptive, Flexibly Autonomous Systems" as an important capability area to meeting future strategic needs, stating that "establishing trust in autonomy will thus become the central factor in gaining access to the potentially enormous capabilities that such systems can offer."[328] Additionally, the document talked about the necessary computer processing power and algorithms as a forthcoming technology, not one fully arrived yet, while at the same time, warned that an adversary who achieves and integrates this technology without the Western imperative of maintaining human in the loop decision points would have huge asymmetric advantages.[329] Equally concerning to the study's authors was the loss of guaranteed navigation capabilities and "high-bandwidth secure communications" due to advanced adversary jamming of Global Positioning System signals and other communication nodes.[330] The leaps in technology in the 1990s that allowed UAVs to overcome navigation issues and beyond line of sight control limitations—problems that had plagued UAV development advocates in the early 20th century—were threatened with obsolescence due to adversary countermeasures at the dawn of the 21st century. Comparing the two S&T visions, a shift in Air Force thinking appears to have occurred between 1995 and 2010 regarding the true state of technological maturity needed to field advanced UAVs; furthermore, a diminished view regarding adversary capabilities to impact UAV employment seems to have taken root.

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[327] Office of the U.S. Air Force Chief Scientist, xix.

[328] Office of the U.S. Air Force Chief Scientist, 75.

[329] Office of the U.S. Air Force Chief Scientist, 75.

[330] Office of the U.S. Air Force Chief Scientist, 77–80. GPS-denied environments and crowded electromagnetic spectrum communications were an increasing problem that demanded alternatives. Chip-scale atomic clocks, networking of GPS relay signals, and laser communication technology were considered important near-term developments in the next decade.

b. Navy Science & Technology Strategy and Investments

The Office of Naval Research oversees the Navy's S&T strategy, releasing an update biannually—far more frequent, but with less period change, than the USAF. Therefore, a sample of two of the documents, one in 1997 and the other in 2011, provides insight to the views of S&T strategies during the third UAV epoch. The first document is timed when UAVs development was just beginning to make headway in the DOD under Defense Airborne Reconnaissance Office during the 1990s, and the second document showcases USN thinking during a time when great power competition was increasing and the service enjoyed many successes with its X-47 experimental UCAV demonstrator.

In 1997, the Navy remained confident that it would continue conducting its core missions for the next several decades and released its S&T strategy focused on platforms and processes as the key to its S&T program forecasted out until 2035. That strategy, called *Technology for the United States Navy and Marine Corp, 2000–2035: Becoming a 21st Century Force*, leaned partially on the USAF's 1995 strategy *New World Vistas* and the Army's 1993 S&T strategy, identifying over 100 critical technologies as a base for future naval operational success. The document highlighted automation technologies as one of the major themes and emphasized the type of results it hoped to adopt: "teleoperated and autonomous UUVs [underwater unmanned vehicles] and UAVs" that will "participate in cooperative engagements against difficult targets."[331] To make this a reality the authors stated that certain technologies were necessary, to include "autonomous navigation and guidance and automatic target recognition," implying these fundamentals were not yet mature.[332] The study's panel then argued that gas turbine engine development should be the Navy's highest priority, along with small sensor payloads, low-cost communications for UAVs, the free-wing aircraft design, and vertical take-off and landing capabilities.[333]

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[331] Naval Studies Board, *Technology for the United States Navy and Marine Corps, 2000–2035*, (Washington, DC: National Research Council, 1997), 14, https://www.nap.edu/read/5863/chapter/1.

[332] Naval Studies Board, 15.

[333] Naval Studies Board, 185–186. The gas turbine engine afforded long-life, low weight-to-thrust ratios, use of heavy fuels, and low acoustic signatures. The sensors envisioned included those capable of the full spectral range from electro-optical/infrared to millimeter wave with radar and synthetic aperture radar. The free-wing design is a rotating wing that enables variable pitch to aid with platform stability but also make it stall free.

Not only were certain technologies missing from S&T, the Navy disclosed concern that it had lost its focus on long-term research and development, and instead, the trend within the service was a preoccupation for scientists and engineers on short-term applied research. Worse, S&T personnel experienced serious regulatory meddling that hindered technological progress for long-term operational success.[334]

In 2011, the Navy's S&T Corporate Board directed the Chief of Naval Research to execute a newly revised S&T strategy. The document is very different from its 1997 predecessor, in that it is much shorter and less specific, but it continued its trend of nesting with the USN's keystone vision document, *Sea Power 21*, which was released in 2002.[335] Of note, to support Secretary of Defense Rumsfeld's transformation agenda, *Sea Power 21* indicated that user needs and technology opportunities would be maximized by allowing those needs and opportunities to enter the acquisition process at any milestone stage. One of the S&T focus areas called for in the 2011 vision document was "autonomy and unmanned systems."[336] The strategic drivers for unmanned aviation and greater automation stemmed from

> increased proliferation of inexpensive lethal threats targeting individual warfighters and high-value assets, combined with continued rapid advances in computing, power and energy, robotics, sensors and position guidance technologies drives the requirement to augment expensive manned systems with less expensive, unmanned fully autonomous systems that can operate in all required domains.[337]

Unfortunately, the document is limited in detail regarding the types of technologies needed to continue forward progress in this focus area.

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[334] Naval Studies Board, 5.

[335] *Sea Power 21* was the Navy's answer to strategic visioneering that the Air Force had started to use in the 1990s. It set forth a global concept of operations, focused on transnational threats, and seeking to overturn a perception that the Navy was an enabler of operations and not fully joint integrated. It also emphasized the Bush administration's "transformation" policy for military affairs by creating new cross-cutting categories of capabilities in lieu of platform centric communities. In 2003, *Sea Power 21* projected fielding the Joint-Unmanned Combat Air System in the 2015 timeframe. Office of Chief of Naval Operations, *Sea Power 21* (Washington, DC: Department of the Navy, 2002).

[336] Office of Naval Research, *Naval S&T Strategic Plan 2011* (Arlington, VA: Department of the Navy, 2011), 34.

[337] Office of Naval Research, 15.

4. Service Culture Summary

Another major consideration of the contextual aspect of UAV adoption episodes—tied directly to this study's third hypothesis of organizational culture—are the service prevailing cultures. This section summarizes the findings of three major studies, each building upon one another. The first and third studies were produced by RAND in 1989 and 2019 respectively and bookend the period of the third UAV epoch highlighting what has and has not changed among the various service cultures since the implementation of the Goldwater-Nichols Act of 1986. The first study was Carl Builder's seminal study *The Masks of War*, published by RAND in 1989. The middle study was a doctoral dissertation written in 2013 by USAF officer Jeffrey Donnithorne, which focused on how culture shapes and predicts subsequent service preferences and positions when responding to policy changes from the President and OSD. The 2019 RAND study, *Movement and Maneuver: Culture and the Competition for Influence among the U.S. Military Services* relied heavily on the two earlier works, summarizing and incorporating their findings. This study found that Carl Builder's earlier assessment of service culture continues, with only slight or minor differences now that the joint environment had time to mature since the late 1980s. It is the third study that this section primarily used to capture the prevailing assessment of service culture since it synthesizes the earlier two works, but important differences or additions from those earlier two studies are highlighted for each of the three main services, starting with the Army.

First, the U.S. Army's cultural assumptions are rooted in its early creation in 1775 and its role in establishing the nation during the Revolutionary War. The service "sees its value to the nation as so fundamental and will ultimately undertake any role," it is confident in its current and future "institutional security" but occasionally has trouble formulating a case for resources clearly.[338] This is compounded by the fact that the Army rarely comes into full strength until needed for conflict, a facet not shared by the Air Force and Navy. The Army, therefore, competes in the inter-service arena by ensuring its inclusion and participation in a wide variety of missions and by "positioning itself as a master of

[338] Zimmerman et al., *Movement and Maneuver*, xiv.

leadership," especially operational command.[339] It further relies on the argument that ground combat is the only true decisive instrument in conflict and requires resources to avoid "unacceptable risk to the nation."[340] Operationally, the Army seeks total victories using overwhelming firepower; to do so requires all its functions and any supporting services to remain tightly synchronized and "in step" with the "massive Army machine."[341] The individual soldier is the most important building block of the Army machine, but in order to function, that solider must be incorporated into a unit with both functional and heraldic purposes.[342]

Second, the Navy's baseline cultural assumptions stem from a long practice of independent service to the nation, with many of its views imbued from British naval traditions. The Navy has long served the nation providing sea control and securing sea lines of communication that fuel the nation's economic prosperity, overseas power projection, and diplomatic influence around the globe. They preserve the nation's security, which is bound by vast oceans on either side of the country. Therefore, the Navy is keen to maintain a certain force structure, first in number of ships, and second in support infrastructure and personnel to crew the ships.[343] Fairly secure in the enduring relevance of sea control and power projection, the Navy argues for an ever present need of professional crews and ships able to concentrate firepower built around capital ships.[344] For the past twenty years or so, the Navy has spent more energy reconciling internal arguments over current versus future resource needs and the strategy underpinning those arguments. That said, the service main argument for resources remains based on a certain threshold of ships that require long lead times and constant dedication of resources to build and maintain. The service, as normal

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339 RAND Overview, *Movement and Maneuver*, accessed March 15, 2020, https://www.rand.org/pubs/research_reports/RR2270.html.

340 RAND Overview, *Movement and Maneuver*.

341 Donnithorne, "Principled Agents," 493.

342 Donnithorne, 493.

343 Zimmerman et al., *Movement and Maneuver*, xiv.

344 Donnithorne, "Principled Agents," 490–491.

practice, places less emphasis on joint integration and assignments;[345] following the 1991 Gulf War, the Navy did begin closer coordination and joint efforts with the Air Force given the increasing overlap and support the two services have in the prominent hot spots of the world (e.g., the Persian Gulf's and its surrounding countries, China's eastern seaboard, and the European theater's Baltic, Black, and Mediterranean Seas). Bottom line, the Navy competes for a unique set of roles and missions through "tightly articulated service strategies" emphasizing near-peer competitors with the goal of maintaining forward presence as a non-negotiable for the DOD.[346] If forced to choose between supporting overland missions or its domain-based roles, the choice unarguably falls to the latter.

Third, the Air Force focuses on "technology, innovation, and strategic analysis" with the aim to "make air superiority central to U.S. strategy."[347] The "Air Force was created to exploit disruptive technology" and has an enduring interest in new technology.[348] This effort, in its own eyes, would secure for the service its identity as separate from simply being an enabler of Army or Navy campaigns. This runs counter to, and exasperates, other service views that see air superiority as an enabling mission to ground and sea victories,[349] but the Air Force holds to the decisive strategic potential of the force.[350] To achieve this goal, the Air Force has spent the past thirty years investing in young talented officers—particularly pilots—and developing senior leader resource management skills. At least through 2017, the service has built an effective lobbying apparatus to compete in the resource domain of institutional rivalries, given its relative comfort "in the competition for future institutional security" and preservation.[351] The Air Force, keen to parry Army instigations of poor support and integration, often bills itself as the most joint service, but that has not translated into successful competition in joint

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[345] Zimmerman et al., *Movement and Maneuver*, xv.

[346] RAND Overview, *Movement and Maneuver*.

[347] RAND Overview,

[348] Donnithorne, "Principled Agents," 494.

[349] Zimmerman et al., *Movement and Maneuver*, xv.

[350] Donnithorne, "Principled Agents," 495.

[351] Zimmerman et al., *Movement and Maneuver*, xv.

operational leadership positions, yet. Furthermore, the Air Force adamantly champions central control of air power and should not be distributed or assigned to field commanders.[352] Since 2001, the Air Force has lost competitive ground in the roles and mission arena,[353] since air superiority, space, and cyber have not played prominent roles during the Middle East counter-insurgency/counter-terrorism wars except where those missions enhanced strike, coordination, and reconnaissance. For the Air Force, a long tradition and cultural assumption is that officers fly and fight, while enlisted personnel provide support as skilled technicians. Officer-enlisted relations generally occur away from the battlefield—unlike army and naval units.

Overall, all three services remain committed to persuading the DOD and the nation that their service and respective domain holds a central place in the security of the nation. Competition for resources remains keen—with the Navy being the only minor exception—and has only become more complicated as the joint staff and combatant commanders add evermore sway to define capability needs, resource allocation, and weapon-system adoption outcomes.

C. THE BASICS OF ACQUISITIONS—A CRASH COURSE

The complicated, iterative process of defense acquisitions is difficult to grasp even to the initiated professional. The sheer number of policymakers, institutions, agencies, and committees involved in a seemingly endless input-output and oversight cycle is mindboggling. Add to it an acronym soup and constant reform, confusion can set in. For instance, the Joint Staff's top-level document governing its lead developmental entity within the DOD—the Joint Requirements Oversight Council (JROC)—comes in at over one-hundred pages in its latest version.[354] To make things digestible, this section of the chapter introduces the key formal relationships, roles, and processes of acquisitions without bogging down in the informal aspects. Acknowledging that often it is in the informal

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[352] Donnithorne, "Principled Agents," 494.

[353] Zimmerman et al., *Movement and Maneuver*, xv.

[354] Joint Chiefs of Staff, *Charter of the Joint Requirements Oversight Council (JROC) and Implementation of the Joint Capabilities Integration and Development System*, CJCS Instruction 5123.01H (Washington, DC: Joint Chiefs of Staff, 2018).

universe that programs are shaped, those details are left to the individual UAV episodes in chapters IV and V where aspects such as media, personalities, commitments, incentives, culture, and private communication unfold. It is both the inter-organizational processes and the "cross-institutional linkages" that we are concerned with here.[355] This section introduces the broad DOD systems that work in sequential feedback loops, some major roles within the Defense Acquisition System, and an overview of the acquisitions process and milestones required. It wraps up with who in Congress provides monetary oversight to the DOD. Overall, the formal processes and regulations since 1991 all fall under the same joint rubric of the Goldwater-Nichols Act and lead by the Under Secretary of Defense for Acquisition, Technology, and Logistics.[356] Where possible, this section highlights substantive changes to the systems that occurred over time since 1991.

The Defense Acquisition System for material innovations is comprised by three integrated and deliberate processes: requirements, management, and funding. Respectively, the DOD's programs for these reinforcing efforts are the Joint Capabilities Integration and Development System; the Acquisition Process; and the Planning, Programming Budgeting, and Execution system.[357] The Defense Acquisition System is reliant upon threat forecasting and strategy documents from the national and department level of the DOD/services. Figure 21 shows how these systems overlap in relation to one another: guidance (gray), threats (red), capabilities (blue), acquisitions (yellow), and resources/funding (green). The purple oval refers to the contingency and war plans that also partially informs capability requirements. The overall "life cycle" of a program exists from initial identification of a capability need through to its final disposal.

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[355] Rebecca K. C. Hersman, *Friends and Foes: How Congress and the President Really Make Foreign Policy* (Washington, DC: Brookings Institution Press, 2000), 4–7.

[356] The Under Secretary of Defense (USD) position for Acquisition, Technology, and Logistics has at times used the title USD for Acquisition and Sustainment (A&S) as well as Acquisitions and Technology (A&T). The three are generally synonymous and have been interchanged depending on administrations.

[357] The *Defense Acquisition Guide*, managed and run by the Defense Acquisition University, is the authoritative, top-level guide for these systems and associated regulations. See: https://www.dau.edu/tools/dag.

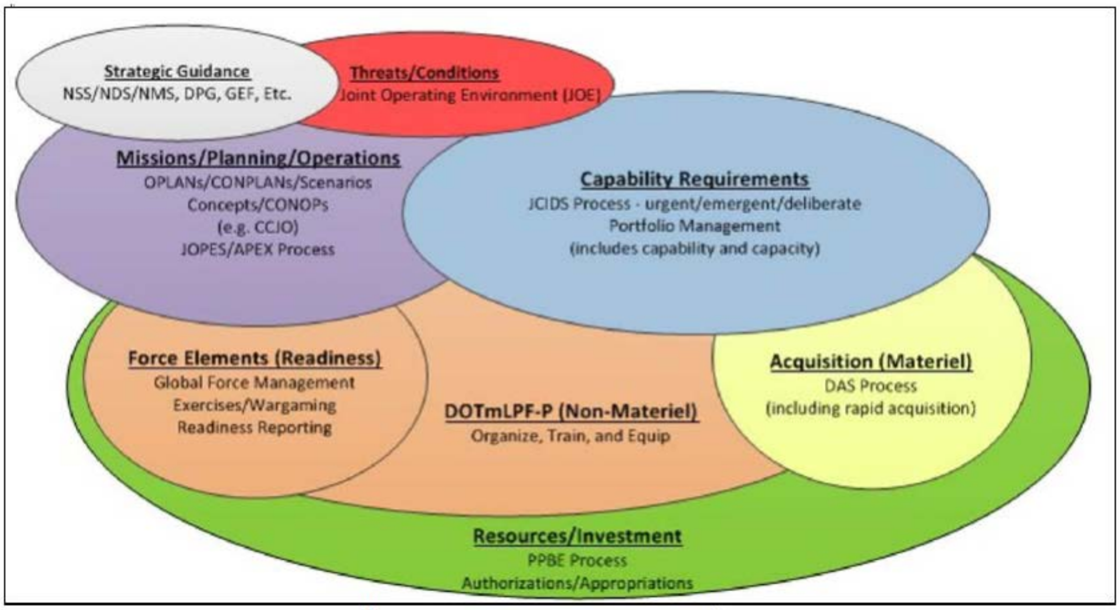

Figure 21. DOD's Major Processes and Relationships[358]

According to the Chairman's charter on Joint Capabilities Integration and Development System employment, the JROC is responsible to the President and Secretary of Defense for Title 10 responsibilities to identify and assess new joint military capabilities based on gaps; the JROC is the primary customer of the acquisition system.[359] Of note, the Joint Capabilities Integration and Development System replaced the Joint Warfighter Capabilities Assessment process used in the 1990s, in order to strengthen the joint aspects of the process; independent analysis by RAND and the GAO in the late 1990s argued that service parochialism still dominated the joint capabilities validation process. The Vice Chairman of the Joint Chiefs of Staff chairs the JROC and uses the National Defense Strategy as its keystone document for guidance in establishing, approving, and reviewing material capabilities development processes. The JROC is the highest-level body responsible for the Joint Capabilities Integration and Development System. Key members of the JROC include at least one four-star officer from each of the services, as well as other Under Secretaries of Defense for Policy, Intelligence, and Comptroller, as well as directors

[358] Source: Joint Chiefs of Staff, *Charter of the Joint Requirements Oversight Council (JROC)*, D-4.

[359] Joint Chiefs of Staff, *Charter of the Joint Requirements Oversight Council*.

from those agencies responsible for testing, evaluation, and cost assessment. Inputs to the JROC can come from the National Command Authority, combatant commanders, joint staff directorates, and the services seeking new "joint military capabilities," defined as "collective capabilities across the joint force, including joint and force-specific capabilities that are available to conduct military operations."[360] JROC conducts a Capability Based Assessment centered on subordinate board recommendations who look for " advances in technology and evolving concepts of operation needed to maintain a technological and operational superiority" of U.S. forces.[361] If the Capability Base Assessment exposes a need, the JROC produces four key documents, starting with the Initial Capability Document; this validates the need. Later, other documents include the Draft Capability Development Document, the Capability Development Document, and the Capability Production Document.[362] These documents are not static during the life cycle of the program. Bottom line, validated JROC requirements guide the Acquisition Process and inform the programming and budget process.

The Acquisition Process comprises four sequential phases of development: 1) material solution analysis, 2) technology maturation & risk reduction, 3) engineering & manufacturing development, 4) production & deployment (see Figure 22).[363] A fifth phase occurs when the weapons system moves to full operations and support. The decision to explore a material solution to a validated capability gap initiates phase one, and the forward progress of the phases is determined by three milestone decisions at the end of each of phases one through three; these are known simply as Milestone Decisions A, B, and C.[364]

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[360] Joint Chiefs of Staff, *Charter of the Joint Requirements Oversight Council,* A-4.

[361] Joint Chiefs of Staff, A-5.

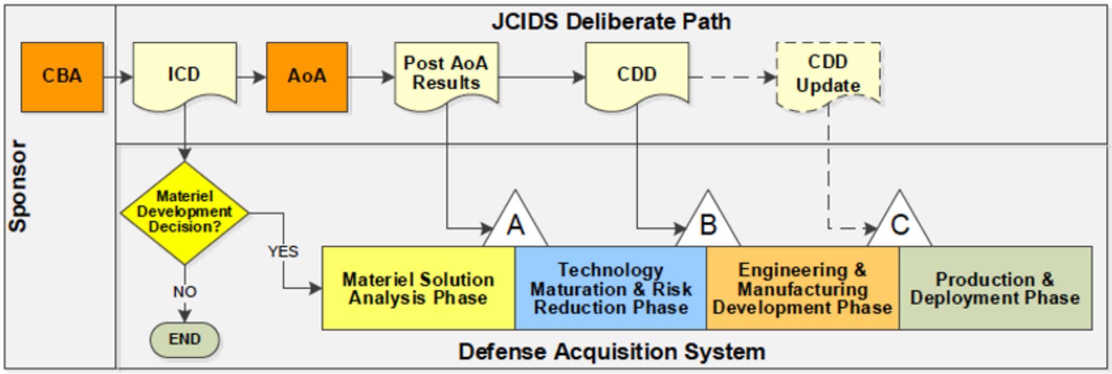
[362] The initial capability document describes the capability gap and starts the process of determining if the gap can be addressed first through non-material solutions before moving to the draft capability document that will outline the preliminary material requirements, capabilities, and parameters.

[363] Joint Staff J-8, *Manual for the Operations of the Joint Capabilities Integration and Development System*, (Washington, DC: Joint Chiefs of Staff, 2018), A-A-12.

[364] Milestone A is known as the Risk Reduction Decision, intended to assess the level of risk regarding technology maturity and the need to commit resources to mature the technology if needed. Milestone B marks the decision to award contracts to a company for development. Milestone C is the Initial Production decision that starts low-rate production, indicating a commitment of adoption by one or more of the services.

Senior DOD leadership appoints the milestone decision authority early in phase one. Also, in phase one program management conducts an analysis of alternatives for the identified capability requirement. Another decision point during phase two (not reflected in Figure 22) determines the release of request for proposal, that formally provides defense contractors what they need to design, submit, and compete their solution for the requirement. These phases and decisions unfold iteratively as the JROC approves and releases it key documents, which are represented by white rectangles in the figure below. While the DOD instruction on defense acquisition refers to this overall model as “generic,” the framework provides the basis for all hardware, software, hybrid, and rapid acquisition approaches; modifications and additions conform still to the basic framework. Program management follows a chain of command, moving upward from the Program Manager, through the Program Element Officers to the Component Acquisition Executive. For those programs that exceed a certain dollar threshold or are otherwise designated, a Defense Acquisition Executive—who is the Under Secretary of Defense for Acquisitions, Technology, and Logistics—may be installed at the top of the chain.[365] A Joint Program Office is established with a designated lead service anytime a program is being procured or funded by two or more services.

[365] That threshold changes based on regulation and legislation; the most recent number are programs that exceed research & development of greater than $480 million OR total procurement of $2.79 billion.



AoA: Analysis of Alternatives
CBA: Capabilities Based Assessment
CDD: Capabilities Decision Document
ICD: Initial Capabilities Document
JCIDS: Joint Capabilities Integration and Development System

Figure 22. Joint Capabilities and Acquisition Process Interaction[366]

There are a couple entry points into the Joint Capabilities Integration and Development System for science, technology, and innovative approaches To expedite certain "evolutionary" capabilities needed on a shorter timeline, the process is flexible enough to consider starting a program at Milestone B based on urgent or emergent operational needs for on-going operations or plans. If approved, these can generate a Rapid Acquisition Cycle in two-to-five years, as opposed to the more traditional timeline for major acquisitions that take seven-or-more years. In the past, the Acquisition System tried to speed up the acquisition and fielding of emerging technologies by conducting Advanced Concept Technology Demonstrations (ACTD). These ACTD efforts were designed to allow the earlier and cheaper adoption of advanced mature technologies for the warfighter. Often with mixed results, ACTD as a practice ended in 2006, replaced by the Joint Concept Technology Demonstration before being scrapped altogether. Since the late 2000s, the Rapid Acquisition model based on urgent operational needs has been in place. More disruptive technologies, such as those generated by an updated national defense strategy or new a Joint Operating Concept would likely dictate a fresh Capability Based Assessment from the JROC altogether.

[366] Source: Joint Staff J-8, *Manual for the Operations of the Joint Capabilities Integration and Development System*, A-A-12.

The Under Secretary of Defense, Comptroller, oversees the Planning, Programming, Budget, and Evaluation process for allocating resources to competing programs.[367] While the Joint Capabilities Integration and Development System and Acquisition Process are tightly linked as shown in Figure 22, the programming and budget process is the intervening step that resources the Acquisition Process. For any material procurement, the Joint Capabilities Integration and Development System represents the *why*, the Acquisition Process the *what*, and the fully budget process the *how* of that effort. The Planning, Programming, Budget, and Evaluation cycle is focused on the financial management, policy, and resource allocation for programs in the current year and programming for four future years. The DOD and the services run the budget cycle process as an internal decision-making process, without Congressional or White House representation. As we see in the next paragraph, Congress retains powerful oversight of budgetary process, regardless of how institutions internally manage those resources once approved in legislation. Additionally, Congress maintains policy influence at all stages of capability and program development, to include agenda setting, pushing specific programs and contractors, and other meddling due to partisanship, district-specific interests, and personal or electoral perceptions.[368] One of the early lessons for the USAF during the 1990s when it ran up against Congressional roadblocks was that it had to "work much harder at educating Congress" regarding the "long-term consequences of budgetary choices."[369] A key output after the planning and programing phases is the Program Objective Memorandum at the end of every July, which shows the resource allocation by the military departments based on DOD planning and guidance. This allows the Office of the Secretary of Defense to put together the final DOD budget request to the President in December. This informs the President's Budget to Congress, which is due on the first day

[367] Department of Defense, *The Planning, Programming, Budget and Execution Process*, DOD Directive 7045.14 August 29, 2017 (Washington, DC: Department of Defense, 2017), https://www.esd.whs.mil/ Portals/54/Documents/DD/issuances/dodd/704514p.pdf?ver=2019-06-06-145814-060.

[368] Chris Darnton, email message to author, March 20, 2020. Dr. Darnton is a professor at the Naval Postgraduate School's Department of National Security Affairs.

[369] Michael Barzelay and Colin Campbell, *Preparing for the Future: Strategic Planning in the U.S. Air Force* (Washington, DC: Brookings Institution Press, 2003), 17.

of February each year. Systemically, the three processes of Joint Capabilities Integration and Development System, Acquisitions, and Planning, Programming, Budget, and Evaluation are show in Figure 23.

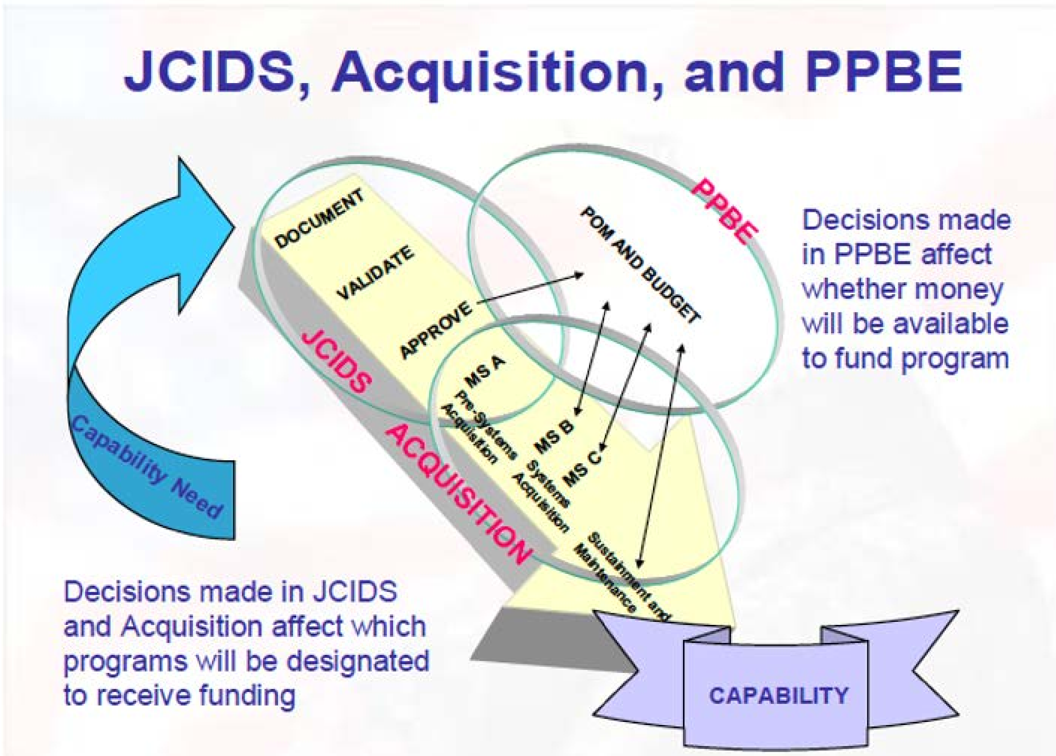


Figure 23. DOD Corporate Process for Material Capabilities[370]

Finally, acquisition processes must contend with congressional oversight, who holds the power of the purse to shape military innovation and procurement. Congress stands at the apex of an Iron Triangle issues network that involves bureaucratic institutions in one corner and interest groups in the other corner.[371] The congressional House and Senate Armed Services Committees provide the top-level oversight and funding to the

[370] Source: Air Force, *United States Air Force Unmanned Aerials Systems Flight Plan*, 63.

[371] Auburn University, "Iron Triangles," *A Glossary of Political Economy Terms*, accessed November 7, 2019, http://webhome.auburn.edu/~johnspm/gloss/iron_triangles.phtml.

bureaucracies of interest to this study: the DOD and subordinate service branches.[372] Each chamber of Congress has its own slew of sub-committees and regulations for receiving and providing input to bureaucratic institutions. Interest groups include defense industry companies and other such non-governmental organizations who have abiding interest in congressional decisions and budgeting; these interest groups lobby individual members of Congress who sit on the congressional committees to develop mutually supporting leverage. Members of Congress also wield legislative, calendar, and procedural power. For example, the Nunn-McCurdy Act of 1982 stipulates the DOD notify Congress when acquisition programs exceed cost overrun thresholds.[373] The act was put into place mainly due to the Army's cost overruns associated with the Black Hawk helicopter, Patriot missile system, and the ill-fated Aquila UAV program. Congress can use tools such as "fencing (making the expenditure of funds subject to restrictions, reporting, or notification) or cutting funding" altogether."[374] Political and foreign policy expert, Rebecca K. C. Hersman, observed that "when informal pressures are not successful, congressional members and staffs will often seek to legislate their way into executive decision making processes, by introducing procedural steps like reports, notifications, and certifications designed to force the executive [and its departments such as the DOD] to keep Congress in the loop."[375] The Government Accounting Office produces independent, "watchdog"

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[372] According to the House Armed Services Committee, Rule 4, para 1, the committee has jurisdiction for: "defense policy generally, ongoing military operations, the organization and reform of the Department of Defense and Department of Energy, counter-drug programs, acquisition and industrial base policy, technology transfer and export controls, joint interoperability, the Cooperative Threat Reduction program, Department of Energy nonproliferation programs, and detainee affairs and policy" https://armedservices.house.gov/committee-rules#0D456DEB-8D11-4DF4-A8E3-D4D778DFDA61. The Senate Armed Services Committee has similar jurisdictions according to its rules, but also includes the Panama Canal and aeronautical/space activities associated with weapons systems or military operations, https://www.armed-services.senate.gov.

[373] Those thresholds are categorized as significant and critical breeches, starting at 15 and 25 percent respectively for current baseline estimates. Congressional Research Service, *The Nunn-McCurdy Act: Background, Analysis, and Issues for Congress*, CRS Report No. R41293 (Washington, DC: Congressional Research Service, 2016), https://crsreports.congress.gov/product/pdf/R/R41293.

[374] Hersman, *Friends and Foes*, 43.

[375] Hersman, 43–44. An example of this is the case of the Advanced Medium Range Air to Air Missile case. When House staffer Tony Battista was unable to get a sufficient response from the Defense Department for Representative Smith. Smith wanted to influence the process, but when informal avenues and personal contacts failed, the congressman embarked on a successful letter writing and media campaign against the Air Force. See Hersman, 42–42.

reports to Congress examining and critiquing how tax dollars are spent with the goal of increased efficiency for taxpayers. Government Accounting Office products are a source of data for this study, along with congressional committee hearings related to UAV development.

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IV. AIR FORCE UAV EPISODES, 1991–2015

The story of the U.S. Air Force is the story of the search for…innovation.[376]

Born from mechanical marvels to give humans sustained, controlled flight, the U.S. Air Force seeks technological innovation to rule the air. Technology untethers the Airman from terrestrial constraints and creates new pathways to strategic and tactical effects on the battlefield.[377] Echoing airpower proponent General William "Billy" Mitchell's description of airmindedness in the 1920s, the Air Force looks forward in anticipation, not solely back into history, when developing solutions to military problems.[378] Additionally, the organization often concerns itself with generating effects based on risk-versus-effectiveness calculations. The Air Force's technophile ethos incorporates the development and acquisition of UAVs for a variety of missions; however, UAV adoption outcomes too often appear inconsistent and non-committal.

In November 1944, shortly before the Air Force became an independent service, the General of the Army Air Corp, Henry H. "Hap" Arnold, requested an assessment of scientific developmental requirements over the next twenty years. As part of his guidance to the Army Air Corps' Scientific Advisory Group, Arnold stated that a "fundamental principle of American democracy is that personnel casualties are distasteful" and that the strategy of future warfare would trend towards mechanical wars as opposed to manpower wars.[379] From the outset, key airpower leadership such as Arnold's prioritized casualty avoidance to the maximum extent possible. In response to Arnold's requested study, Dr.

[376] Chairman of the Joint Chiefs of Staff, Admiral Mike Mullen, U.S. Navy, as quoted in Chief of Staff of the Air Force, *Global Vigilance, Global Reach, Global Power for America* (Washington, DC: United States Air Force, 2013).

[377] Headquarters Air Force, *The World's Greatest Air Force—Powered by Airmen, Fueled by Innovation* (Washington, DC: Department of the Air Force, 2013), https://www.af.mil/Portals/1/documents/af%20events/2015/Vision_Brochure_PRINTresolution.pdf.

[378] William "Billy" Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power--Economic and Military*. 1925. Reprinted with Forward by Robert S. Ehlers, Jr. (Tuscaloosa, AL: The University of Alabama Press, 2009), 20.

[379] Theodore Von Kármán, *Towards New Horizons: Science, Key to Air Supremacy* (Washington, DC: Army Air Forces Scientific Advisory Group, 1945), v.

Theodore Von Kármán, head of the Air Force's Scientific Advisory Group, emphasized continuous and rapid technological adaptations in order to maintain global air supremacy.[380] Additionally, four-out-of-ten summary conclusions for future research and development declared pilotless aircraft as an important goal to pursue. The report proposed that "a global strategy for the application of novel equipment and methods, especially *pilotless* aircraft, should be studied and worked out" (emphasis added).[381]

From its foundation, the Air Force and its senior pilots have looked to unmanned aircraft as a viable option to meet operational challenges and preserve life, yet the Air Force's UAV adoption outcomes have been underwhelming for most of that history. Only in recent years could the Air Force claim that enough UAVs now exist to enable the organization to conduct sixty-five UAV air patrols simultaneously. Still, the organization struggles to maintain that requirement and remains precariously postured to continue providing those capabilities despite an ever-increasing demand from combatant commanders and national leaders.

The Air Force is an important component to this study, because the USAF has the greatest institutional and cultural stake regarding UAVs as the service created to conduct war in the air. In 1991, the Air Force did not have an operational UAV in its inventory, but it did possess vast experience with an established cultural ethos. The Air Force provides several pertinent UAV episodes from 1991 to 2015 that illuminate how, when, and why rational, institutional, and cultural factors impacted UAV adoption results. Based on the selected high-, medium-, and low-end UAV case types introduced in Chapter I, the sample UAs within the Air Force include the RQ-3 DarkStar, X-45 UCAV, RQ-4 Global Hawk, MQ-9 Reaper, and R/MQ-1 Predator. The USAF eventually cancelled both the RQ-3 and X-45 following their demonstration periods yet adopted the other three UAs in varying degrees. To explore and examine why the programs ended in adoption or not, the sections

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[380] Von Kármán, *Towards New Horizons,* xi. Note: Dr. Theodore von Karman was a renown physicist and aeronautical engineer of Jewish-Hungarian descent who moved to the United States in 1930 to teach at Caltech. He was invited by General Arnold to start the Scientific Advisory Group in 1944 in order to study, plan, and guide aeronautical technologies for the Army Air Corp (and later U.S. Air Force).

[381] Von Kármán, *Towards New Horizons,* ix-xiii.

below describe the selected UAV programs/episodes that comprise each UAV case type; from there, the case type is examined through the three main hypotheses introduced in Chapter II (i.e., rationalism, institutionalism, and organizational culture). The chapter ends with a cross-case synopsis and analysis overall within the service.

A. HIGH-END UNMANNED AIRCRAFT (RQ-3, X-45)

While different in aircraft design and mission purpose, the RQ-3 and X-45 are the two high-end UAVs that the Air Force pursued between 1991 and 2015, with neither program making it beyond the demonstration phase of development.[382] Both platforms shared a similar design goal to incorporate newer technology to enabled survivable operations in high-threat environments: the RQ-3 as a low-observable, high altitude endurance reconnaissance vehicle and the X-45 as a strike penetrator against highly lethal enemy air defenses. Both programs sought to incorporate cutting-edge autonomy and control. In the end, though, the RQ-3 and X-45 failed to cross the "valley of death" from S&T to procurement, precluding the systems from truly becoming innovations for the Air Force.[383] Nonetheless, the programs represented such a leap in technology and design that both aircraft earned a coveted spot at the National Air and Space Museum in Washington, D.C.[384]

1. RQ-3A DarkStar Program Overview

Since the mid-1960s, the United States defense establishment has sought to build and procure a high-end reconnaissance UAV to operate in dangerous and politically sensitive arenas, and the Lockheed Martin RQ-3 DarkStar, shown in Figure 24, represents the latest iteration of that effort. In the late 1960s and early 1970s, the Central Intelligence

[382] The "R" is the DOD designator for reconnaissance aircraft, the "X" signifies experimental, and the "Q" signifies unmanned, remotely piloted vehicles.

[383] Richard Shipe, Monte D. Turner, and Douglas P. Wickert, *Innovation Lost: The Tragedy of UCLASS* (Washington, DC: The Eisenhower School for National Security, AY2015–2016), 1.

[384] Richard Whittle, *Predator: The Secret Origins of The Drone Revolution* (New York, NY: Henry Holt and Company, 2014), 309; For the latest status of the aircraft on display at the museum, see also: https://airandspace.si.edu/collection-objects/lockheed-martinboeing-rq-3a-darkstar; https://airandspace.si.edu/collection-objects/boeing-x-45a-joint-unmanned-combat-air-system-j-ucas.

Agency commissioned the D-21 Tagboard, a futuristic and expendable UAV designed to launch from an A-12 host aircraft, overfly sensitive sites in China, and then eject its reconnaissance pod for recovery after a mission as the aircraft body crashed into the ocean. After four failed operational missions, the CIA shelved the program.[385] Determined to achieve an advanced, unmanned reconnaissance capability due to the political sensitives and risk of using the manned U-2 and SR-71 over Russia, China, and their proxies, the DOD initiated a secret program called the Advanced Airborne Reconnaissance System in the early 1980s. As sponsors, the Air Force and the National Reconnaissance Office pushed technological boundaries to include automatous flight, sensor capabilities, and stealth, all which eventually drove per-aircraft cost estimates to over $500 million each. This unacceptable budgetary reality and loss of sponsorship from the Air Force's Strategic Air Command—which was being disbanded—led to the Air Force pulling the plug altogether in December 1992.[386]

Figure 24. Lockheed Martin/Boeing RQ-3 DarkStar UAV[387]

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385 Zaloga, *Unmanned Aerial Vehicles*, 15.

386 Ehrhard, *Air Force UAVs*, 15–17.

387 Source: "Lockheed Martin/Boeing RQ-3 DarkStar," National Museum of the United States Air Force, October 9, 2015, https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/195774/lockheed-martin-rq-3-darkstar/.

Within just a couple years of Advanced Airborne Reconnaissance System's demise, the Office of the Secretary of Defense launched the DarkStar concept in 1994 as a DARPA advanced concept technology demonstrator for a low observable, high altitude endurance reconnaissance platform. At the time, the DOD classified such UAVs as Tier III aircraft—a new UAV development category the Joint Program Office created in 1993 describing UAVs with a high-altitude flight profile and long endurance, which was measured as twenty four hours or more. The DOD constrained DARPA to a very limited per-aircraft budget of $10 million due to the prohibitive cost overruns from its predecessor program;[388] additionally, the program was designated as a tactical (regional) commander, long-dwell asset to be free from national tasking interference and national-strategic design requirements from agencies such as the National Reconnaissance Office.[389] While starting as a DARPA-only ACTD, like many such programs, the RQ-3 quickly became a co-sponsored program with the Air Force, and the RQ-3 was eventually handed to Air Force management in a later ACTD stages.

The ACTD platform was a modified, shrunken version of the Advanced Airborne Reconnaissance System, dubbed the flying clam.[390] With a 69-foot wingspan and a main body twelve-by-fifteen feet, the RQ-3 sported a single turbo-fan engine and a somewhat diminished stealth capability, while retaining a near autonomous ability to take off, fly, and land. It had a flight radius between five-hundred to six-hundred nautical miles,[391] a greater than 45,000-foot operating altitude, and a twelve-hour endurance. The RQ-3's 1,000-pound payload capability limited the aircraft to one low probability of intercept sensor package—

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[388] "RQ-3A DarkStar Tier III Minus," Federation of American Scientists, accessed January 10, 2020, https://fas.org/irp/program/ collect/darkstar.htm.

[389] Ehrhard, *Air Force UAVs*, 18.

[390] All ACDTs include ten selection criteria: 1) "Technology sufficiently mature"; 2) "Significantly increased military utility"; 3) "Likely to be affordable"; 4) Time frame of 2-to-4 years; 5) "User commitment to full ACTD involvement (but not committed to procurement)"; 6) "Developer ready with a plan that covers all essential aspects/issues"; 7) "Risks identified, understood, and accepted"; 8) "Funds budgeted to complete the planned demo program" and review of progress; 9) "Cost-effective demonstrations focused on principle issues"; 10) "RDT&E funding to support two years of operations in the field." Defense Airborne Reconnaissance Office, *Annual Report: 1995*, 11. A robust discussion of what and how an ACTD program works is found in Defense Airborne Reconnaissance Office, *UAV Annual Report, FY 1997* (Washington, DC: Department of Defense, 1997), 16–17.

[391] 1.0 nautical mile (nm) equals 1.151 miles; 500nm equals 575.5 miles; 600 nm equals 690.6 miles.

either synthetic aperture radar or electro-optical sensor payloads, but not both at the same time. As for the ground station and imagery processing backend, a Common Ground Segment developed by the Raytheon and E-Systems companies combined mission planning, communications, launch and recovery, mission control, and sensor control into two militarized transportable containers; the ground elements were designed as a common backend system for both the RQ-3 DarkStar and RQ-4 Global Hawk to create commonality and interoperability for the family of systems.

From a programmatic perspective, DARPA's management progressed along several key milestones over the course of four years. In August 1994, DARPA awarded the contact to Lockheed's Skunk Works. This initiated phase one program definition and prototyping with two air vehicles; ACTD goals included four vehicles (two engineering and two demonstration), a launch and recovery station, and a refined concept of operations.[392] This single-source contract resulted in Lockheed's rollout of the first air vehicle in June 1995, thus moving to phase two test and evaluation. The first flight took place on March 29, 1996; however, the second flight test on 22 April ended shortly after takeoff when the air vehicle's pitch oscillated uncontrollably resulting in a high stall and subsequent crash.[393] The second engineering air vehicle underwent software changes and testing, allowing the program to resume flight tests in the third quarter of 1997. In preparation for phase three (engineering, fabrication, and user demonstrations),[394] which was slated to begin in FY 1999, the contractor produced two additional air vehicles in 1997 and 1998. The user demonstration portion of the phase, for a variety of reasons, was delayed for almost two years from its originally slated start in FY 1997. Demonstrations were delayed again until the second air vehicle's resumption of flight in early 1998, which pushed back milestones planned for FY 1999. Overall, the program received defense-wide funds: $61.2 million in 1995; $65.3 million in 1996; $55.1 million in 1997; and, $54.6

[392] Defense Airborne Reconnaissance Office, *Annual Report: 1995*, 24.

[393] Defense Airborne Reconnaissance Office, *UAV Annual Report, FY 1996* (Washington, DC: Department of Defense, 1996), 22.

[394] Phase three nomenclature has changed over time, but the effects within the phase are the same. It is a also commonly referred to as the engineering, manufacturing, and demonstration phase.

million in 1998 for a total of over $236 million in RDT&E funding.[395] The Air Force took over from DARPA in late 1997, but by fall 1998, the DarkStar program lost Pentagon favor, resulting in OSD's cancellation of the program in January 1999.[396] Around the same time, the full handoff to the USAF occurred, DARPA and the Air Force initiated the other high-end UAV in this study, the X-45.

2. X-45 Unmanned Combat Aerial Vehicle Overview

Thomas Ehrhard, a retired Air Force colonel whose doctoral dissertation focused on Air Force UAV adoptions until the mid-1990s, views UCAVs in general as the technological peak of unmanned flight;[397] the X-45 represented the Air Force's attempt at reaching this technological peak in the third UAV epoch. The U.S. military's ongoing desire to employ an "assault" unmanned vehicle with kinetic-kill capabilities emerged as early as 1918, starting with the Army's maiden flight of the gyro-controlled Kettering Bug; the Bug could carry one-hundred-eighty to two-hundred pounds of explosives.[398] More like an irretrievable cruise missile or Flying Bomb whose bi-wing ejected, the Kettering Bug gave way twenty years later to the Navy's radio controlled UAV, the Curtis N2C-2. This converted, full-sized aircraft, subsequently called the TG-2, was controlled by a "mother" aircraft 20 miles away; armed with a torpedo that separated from the aircraft, the TG-2 scored a direct hit on its target in the first successful test in 1941.[399] Besides one successful operation in late World War II,[400] few UCAV developments occurred from 1945 through to the end of the Vietnam War, as reconnaissance UAVs took center stage for many reason, chief among them the U.S.-Soviet Union arms-control treaties that conflated the distinction between proven, nuclear-capable cruise missiles and unproven,

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395 Defense Airborne Reconnaissance Office, *Annual Report: 1995*, 24; Defense Airborne Reconnaissance Office, *FY 1996*, 22; Defense Airborne Reconnaissance Office, *FY 1997*, 34.

396 Ehrhard, *Air Force UAVs*, 54.

397 Zaloga, *Unmanned Aerial Vehicles*, 43.

398 Newcome, *Unmanned Aviation*, 24–26.

399 Richard M. Clark, "Uninhabited Combat Aerial Vehicles: Airpower by the People, For the People, But Not with the People," College of Aerospace Doctrine, Research and Education Paper No. 8, August 2000 (Maxwell Air Force Base, AL: Air University Press, 2000).

400 Zaloga, *Unmanned Aerial Vehicles*, 8.

conventional-only UAVs. Based on the successful Ryan Model 147 Lightning Bug reconnaissance UAV from the Vietnam era, the most successful of the UCAV test programs was the Teledyne Ryan BGM-34C, which showcased the ability to conduct strike, reconnaissance, and electronic warfare missions from 1974 to 1977. By 1979, all of the U.S. Air Force's "air-launched recoverable UAVs and UCAVs of various configurations" were mothballed due to the Air Force's choice to keep high-speed antiradiation missiles, cruise missiles, and tactical strike aircraft during a time of shrinking budgets.[401] In the late 1990s, the DOD strove once again to achieve a UCAV capability within the U.S. inventory.[402] That effort started in 1997 with a DARPA-initiated UCAV Advanced Technology Demonstration contract, which eventually led to the Boeing X-45, as shown in Figure 25.[403]

Figure 25. The Boeing X-45A Unmanned Combat Aerial Vehicle[404]

[401] Clark, "Uninhibited Combat Aerial Vehicles," 28.

[402] Ehrhard, *Air Force UAVs*, 43.

[403] Clark, "Uninhibited Combat Aerial Vehicles," 37.

[404] Source: Jim Ross, "X-45 Unmanned Combat Aerial Vehicle," NASA, last modified August 7, 2017, https://www.nasa.gov/centers/dryden/multimedia/imagegallery/X-45A/ED02-0295-5.html.

The purpose of the Advanced Technology Demonstration was to establish if a cost-effective UCAV system could conceivably achieve operational status in a 10-year timeframe. Consisting of two phases, the initial $4 million[405] first phase sought assessment and technology plans from several contractors to "demonstrate the technical feasibility for a UCAV to effectively and affordably prosecute 21st century" enemy air defenses and other strike mission.[406] Based on the submitted plans, DARPA awarded Boeing the phase II, $110 million, forty-two month contract in March 1999 for the development of the X-45 ATD.[407]

The three-and-a-half-year phase two began with the design and production of the X-45A, which had a similar shape and design as the B-2 bomber, though much smaller. Boeing built two X-45A demonstration air vehicles, with the first air vehicle achieving a fourteen-minute test fight in May 2002. The contractor designed the aircraft to be fully autonomous—to include taxi, take-off, and landing but with the option for pilot control. The internal bays could carry "multiple" advanced munitions to include up to eight small diameter bombs, and included an actively electronically scanned array, synthetic aperture radar.[408] Another key design feature included the ability to transport up to six air vehicles in a single C-17 cargo transport plane, making the weapons system rapidly deployable. The X-45A demonstrator flew a total of sixty-four demonstrator flights over the course of its programmatic growth and changes. During this time period, Boeing and the USAF paved the way for the next phase of development.

In 2003, the USAF earmarked funds through 2007 for a larger engineering and operational variant. Therefore, in October 2004, DARPA, with Air Force concurrence, awarded Boeing a $767 million contract to produce three prototypes and two mission

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[405] "Boeing X-45," Jane's by IHS Markit, May 4, 2011, https://janes.ihs.com/Unmanned Aerial/Display/juav9091-juav.

[406] Defense Advanced Research Projects Agency, *Unmanned Combat Air Vehicle Advanced Technology Demonstration (UCAV ATD)*, March 9, 1998, cited in Clark, "Uninhibited Combat Aerial Vehicles," 37.

[407] Ehrhard, *Air Force UAVs*, 56. In contrast, Jane's by IHS Markit states the contract as 56-months and $191 million of which Boeing contributed $21 million.

[408] Jane's, "Boeing X-45."

control stations for concept demonstrations through summer of 2011; the first vehicle was due in 2006 with maiden flights scheduled for 2007. Halfway through the design phase for an X-45B model, Boeing and DARPA chose to scrap the X-45B plans in favor of a slightly larger X-45C model, shown in Figure 26, that could meet new joint requirements, which added Navy specifications to the design parameters. Aircraft specifications included a sub-sonic (.8 Mach) flight profile with an operating altitude of 40,000 feet and combat radius of over 1,200 miles. It could carry 4,500 pounds in ordnance, and the aircraft's dimensions were thirty-nine feet long by forty-nine feet wide. In July 2005, the Air Force spent another $2.65 million dollars to extend flight testing through December 2012, but then in an abrupt move in 2006 as the program officially transitioned from DARPA to a joint endeavor between the Navy and the Air Force, the USAF cancelled the X-45C contract and exited the program. One plausible explanation is that the Air Force purposely quit the X-45C in order to move development and production into a top secret, or "black," status.[409] Since then, the Air Force has released limited acknowledgement of the smaller and more limited RQ-170 Sentinel and RQ-180 programs that look to be at least a partial adoption of a high-end UAV capability following the failed RQ-3 DarkStar or X-45 program.[410]

[409] Tyler Rogoway, "The Alarming Case of the USAF's Mysteriously Missing Unmanned Combat Aerial Vehicles," The Drive, 9 June 2016. https://www.thedrive.com/the-war-zone/3889/the-alarming-case-of-the-usafs-mysteriously-missing-unmanned-combat-air-vehicles; See also, Zaloga, *Unmanned Aerial Vehicles*, 43.

[410] Jane's, "Boeing X-45."

Figure 26. Boeing X-45C Test Flight[411]

3. Innovation Perspectives and Factors Analysis

a. Rational Factors

The first hypothesis in this study states that a service will adopt high-end innovations that alter an organization's traditional solutions for critical missions when external threats exceed current organizational capacities. This postulate is tightly wedded to two of Grissom's criteria for innovation introduced in Chapter I: changing the way the military functions in the field and generating greater military effectiveness. The USAF's two high-end UAV episodes generally supported this hypothesis, as well as met Grissom's innovation criteria.

First and foremost, the RQ-3 and X-45 systems met no compelling military need despite their intended purpose to surveil adversary movements in a high-threat environment. Put simply, from 1995 through 2005, America's security and intelligence apparatus held no unified assessment of such a threat posed by adversarial states, to include advanced anti-access/area denial systems. In 1996, the GAO's report to Congress on U.S. combat air power concluded that "aircraft and air defense forces of potential adversaries have not been substantially improved and do not pose a serious threat to U.S. air power's

[411] Source: Tyler Rogoway, "The Alarming Case."

successful execution of its mission."[412] Ten years later during the height of the Global War on Terror, the 2006 quadrennial defense review referred to all other regional powers as emerging, going so far as to label Russia as a nation still in turmoil and "transition." It acknowledged China as rising military force in its region, with advancing air defense capabilities, but the tenor of the document suggested this was more a trend to watch than to respond to. Therefore, the quadrennial defense review called for a more complex conventional deterrence posture to deal with rogue states, terrorists, and near-peer competitors. Overall, the DOD's vision and guidance for joint aviation capabilities weighed long-term needs against highly capable anti-access/area denial systems but put that need out to the 2025 horizon.[413]

While the X-45 contended against manned fighter-bombers for a place in the suppression of enemy air defense mission set, DarkStar saw competition from satellites and manned reconnaissance. Satellites, manned aircraft, and UAVs have respective strengths and weaknesses for any given mission, and the factors of that mission determines what platform would be most effective. The post–Cold War environment afforded a more permissive environment for manned aircraft, taking the incentive away for UAVs acquisition in the high-end spectrum of conflict. Furthermore, technology improvements vastly advanced satellite quality, size, and cost to the point of making them much more viable than during the 1970s and 1980s; not to mention the increasing available and use of commercial satellite imagery.[414] While UAVs like the DarkStar had the advantages of removing pilots from harm's way, while maintaining the elements of surprise and unpredictability associated with manned reconnaissance, the UAVs were vulnerable to intercept. Finally, the X-45 and RQ-3 offered only a modicum of reliability and ease of employment, compared to other assets, especially regarding communication and networking.

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[412] Government Accountability Office, *COMBAT AIR POWER: Joint Mission Assessments Needed Before Making Program and Budget Decisions*, GAO/NSIAD-96-177 (Washington, DC: Government Accountability Office, 1996), 6.

[413] Office of the Secretary of Defense, *Quadrennial Defense Review Report*, various.

[414] The major limitations of satellites included their fixed orbits, lack of responsiveness, and predictable timing of when they would be overhead an adversary position.

In addition to the threat and utility factors, the underlying logic of X-45 requirements and purpose was not consistent, which led to programmatic ambiguity and technological overreach. The GAO assessed that the Air Force had inconsistent requirement for the X-45. Between 2000 and 2002, the USAF attempted to add more capabilities while shortening the timeline to operationalize the X-45.[415] The USAF's original schedule in 2000 envisioned a technology and demonstration period lasting until 2007, with product development starting in 2007 so to field systems by FY 2011. The requirements and program schedule changed three times between 2000 and 2002, as shown in Table 4. There appears to be a correlation between the early George W. Bush/Donald Rumsfeld era—the administration's push for a generational revolution in military affairs—with these USAF program timeline changes. Ironically, the enthusiasm and support for leap-ahead technology seems to have hindered rather than helped the X-45 program's adoptions in the long-term. In sum, the X-45 was a high-end capability in search for a high-end mission at a time when the country and its Air Force had no major state competition within a future acquisition cycle or two.

Table 4. Chronology of Changes to the Air Force UCAV Acquisition Program Schedule[416]

Program strategy as of	End of technology and military utility demonstrations (FY)	Start product development (FY)	Initial deliveries (FY)	UCAV capabilities
2000	2007	2007	2011	Preemptive SEAD; reactive SEAD
2001	2006	2005	2010	Preemptive SEAD; reactive SEAD
Explanation of change: To meet Air Force expectations for delivering capabilities to the war fighter earlier than 2011, the product launch date was moved up by 2 years to 2005 and initial delivery up 1 year to 2010.				
2002	2006	2003	2007	Preemptive SEAD
Explanation of change: The schedule was changed by direction of the Office of the Secretary of Defense to further accelerate delivery of initial operational UCAVs to the customer. The program attempted to balance this decision by deferring the most challenging requirements for conducting reactive SEAD against mobile targets to a future version of UCAV.				
Late 2002	2006	2004	2007	Preemptive SEAD; Electronic attack; Extended range
Explanation of change: The timeline was changed to address added requirements for electronic attack and extended range. While 1 year was added to the start of product development, the date for initial deliveries did not change.				

SEAD: Suppression of Enemy Air Defense

[415] Government Accountability Office, *DEFENSE ACQUISITIONS: Matching Resources with Requirements Is Key to the Unmanned Air Vehicle Program's Success*, GAO-03-598 (Washington, DC: Government Accountability Office, 2003), 2.

[416] Source: GAO, *DEFENSE ACQUISITIONS, Matching Resources with Requirements*, 11.

Another important factor under the rationalist lens is the ability to adopt an innovation with technology mature enough not only to justify fielding the new capability, but technologies that improve upon existing weapon systems to solve the independent variable in this hypothesis—a specified threat. DarkStar's flight control problems, novel stealth design, and the vehicle's small size prohibited quality sensors and communication suites, much like the Army's Aquilla a decade earlier. In 2003, Stan Kasprzyk—Boeing's program manager for the UCAV—admitted that the aircraft remains in an "adolescent phase,"[417] indicating there was a lack of technological maturity needed to advance the program within a reasonable budget or time cycle. The X-45, according to Kasprzyk, lagged due to unreliable aerodynamic performance, limited duration missions, weather problems, and a vulnerability to enemy attacks.[418] Kasprzyk assessed the aircraft's autonomy at a level one to two, out of ten, with an immediate ability to get to a level four or five.[419] DARPA's director of the Joint-Unmanned Combat Air System program (after it transitioned into the joint program), Michael S. Francis, agreed. Francis observed in 2005 that the most difficult part of the UCAV development was its operating system and the ability of the UCAVs to communicate with each other and with manned platforms; the developers had confidence in the aerial refueling, sensor integration, and flight autonomy aspects of the program.[420]

Further evidence of the technological problems with the X-45 were highlighted by a scathing GAO report in 2003, which showed the program had moved technologically from a low-risk to a medium-high risk development schedule based on the gap between resources and requirements. In this case, resources included mature technologies underpinning the requirements. In 2000, the Air Force's plan required the development and maturity of 15 key technologies to meet the mission design of conducting "preemptive"

[417] Sandra I. Erwin, "Unmanned Combat Aircraft Still in 'Adolescent Phase'," National Defense, last modified October 1, 2003, https://www.nationaldefensemagazine.org/articles/2003/10/1/2003october-unmanned-combat-aircraft-still-in-adolescent-phase.

[418] Erwin, "Unmanned Combat Aircraft Still in 'Adolescent Phase'."

[419] Erwin.

[420] John A. Tirpak, "Toward an Unmanned Bomber," *AIR FORCE Magazine* (June 2005), last modified May 17, 2008, https://www.airforcemag.com/article/0605bomber/.

(i.e., preplanned) strikes against air defenses. The GAO assessed that all 15 of the immature key technologies underpinning the program constituted a low risk to achieve so long as the program remained on its original eleven-year timeline. The USAF's 2002 changes to requirements, to include extended ranges, electronic attack, and reactive suppression of enemy air defenses, as well as a shortened delivery date of 2007 compounded the risk. Based on the induced risk to the technologies, the GAO rated likelihood of failing to meet requirements as high. Also, the estimated risk for the fifteen technologies in 2002 was now rated as one high risk, twelve medium risk, and two low risk.[421]

Lastly, the Air Force did not fully nest its transformational S&T vision with the on-going and likely future national-level strategies. The *Toward New Vistas* document had an extremely futuristic, almost science fiction quality—that while not bad in and of itself as a technologically oriented organization—did not match the dominant strategic direction of the nation. *Vistas* was a bold vision at a time when America had the capacity to enact such advances and national defense strategies remained anchored on concerns over smaller regional conflicts and weapons proliferation—two aspects that seemed on a positive trend for U.S. outcomes. On December 20, 2019, the author spoke with former Chief of Staff of the Air Force General Ronald Fogleman (1994–1997), who expressed frustration over the lack of implementation of the keystone *Vistas* document; he remarked that all the air power ideas needed or enacted for the past twenty years were contained in that document. The seeming lack of attention of the document at the national level at least partially stemmed from the divergent issues taking national leaders' attention in a different strategic direction. What Fogleman got right, though, as a "visionary," was the general success of UAVs in the Global War on Terror campaigns; it was Fogleman who "pressed the case for unmanned aerial vehicles…against some opposition during his stewardship of the Air Force."[422] Finally, in a highly-redacted declassified memorandum on December 21, 2000, the Under Secretary of Defense for Acquisitions, Technology, & Logistics certified that the X-45 ACTD did not violate international treaties. The compliance review group certified the

[421] Government Accountability Office, Highlights to *DEFENSE ACQUISITIONS, Matching Resources with Requirements*.

[422] Barzelay and Campbell, *Preparing for the Future*, 8.

UCAV would not breach the *International Nuclear Forces* treaty, *Strategic Arms Reduction Treaty*, or *Conventional Armed Forces in Europe* treaty. Though, if the DOD desired to introduce UCAVs to Europe in the future, further approvals would be necessary. Thus, for the first time in decades, DARPA and the USAF were cleared to openly pursue armed UCAVs.

b. Institutional Factors

The second hypothesis tested by the study postulates that unless a common base of support forms across service leadership, Congress, the Secretary of Defense, and defense industry companies, a service will not procure a high-end innovative system. For both the RQ-3 and X-45, few of these stakeholders aligned in full support of the two projects.

Stephen Rosen contends that budgets hold less causal influence on innovations than certain other factors surrounding an innovation. His theory becomes problematic when applied to the aircraft procurement strategies of the RQ-3 and X-45. Take for instance the testimony and guidance of GAO's director, Louis Rodrigues, to Congress in 1997.[423] He criticized DOD aircraft procurement strategy in general, for failure to alter its aircraft procurement strategy based on realistic funding projections—coordinated with Congress—as opposed to questionable assumptions about future available funds. Here, we see an episode where the DOD and Congress, as key components of the Iron Triangle, were not aligned for procurement efforts; furthermore, the GAO, on behalf of Congress, strongly suggested that budgets should drive procurement strategy, and not the other way around. The DOD operates, generally, from the reverse perspective, instead desiring that strategy drive budgets, and by extension procurement, based on the joint capabilities integration and Planning, Programming, Budget, and Evaluation processes covered in Chapter III. Based on those processes and the resultant Presidential Budget Estimate product, it was important that the DOD obtained presidential (i.e., executive agencies and key players of the executive branch) buy-in, as well as make a compelling operational narrative that

[423] Louis J. Rodrigues, *Testimony, DEFENSE AIRCRAFT INVESTMENTS: Major Program Commitments Based on Optimistic Budget Projections*, GAO/NSIAD-97-103 (Washington, DC: Government Accountability Office, 1997), 9.

convinces Congressional stakeholders to fund DOD planning and programming efforts. Narrowing in on the RQ-3, the DOD had spent $326.9 million in RDT&E for the air vehicles alone by 1997.[424] Additionally, by December 1998, the DarkStar's per vehicle cost had risen to $13.7 million, well above the $10 million per copy goal.[425] These budgetary issues (as well as the technological issues mentioned above) contributed to the DarkStar's termination in January 1999. The GAO assessed that the DOD made the right call to end the program during the ACTD phase two of test and evaluation without moving to a phase three engineering fabrication and user demonstration because the cost was prohibitive and not likely to improve. Finally, these decisions were concurrent with the lowest year of the Clinton-era defense budgets, which bottomed out in 1998.

Avant argues that intra- and inter-group politics play a significant role in the outcomes of innovation adoption episodes, and the high-end UAV episodes both bear witness to this theory. First, Air Force intra-group politics contributed to ongoing uncertainty surrounding the RQ-3's acquisition process. This is due in part to service's reorganization in the early 1990s following the demise of the Soviet Union—the most drastic organizational change in thirty years. For instance, the dismantling of Strategic Air Command, "long viewed as the crown jewel of Air Force organizations," sought to streamline operational airpower, removing the connotative separation between strategic versus tactical platforms and battlefield effects.[426] Another major change that caused consternation for roles and processes was the merger of Air Force Systems Command and Air Force Logistics Command; the former oversaw RDT&E and acquisitions, the latter managed aircraft logistics support. The new combined command was called Air Force Material Command. Former Systems Command leader, General Lawrence A. Skantze,

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[424] Louis J. Rodrigues, *Testimony*, *UNMANNED AERIAL VEHICLES: DOD's Acquisition Effort*s, GAO/T-NSIAD-97-138 (Washington, DC: Government Accountability Office, 1997), 13. Note: The Common Ground Segment, or ground control station development was shared with the Global Hawk development, costing $272.6 million as of 1997 (page 12). Added together, the DarkStar program had cost $599.5 million.

[425] Government Accountability Office, *UNMANNED AERIAL VEHICLES: DOD's Demonstration Approach Has Improved Project Outcomes* (Washington, DC: Government Accountability Office, 1999), 5, https://www.gao.gov/assets/230/227915.pdf.

[426] Rebecca Grant, "End of the Cold War Air Force," *AIR FORCE Magazine* (July 2012), 42, https://www.airforcemag.com/article/0712coldwar/.

observed that the two old organizations had very different philosophies, causing a renegotiation of intuitional political power and processes.[427] The merger marred acquisition capabilities, leaving long-lasting impacts that took a long time to repair.[428] Add to it the insertion of the Defense Airborne Reconnaissance Office (an external organization), and the roles and responsibilities became even more challenged. General Fogleman felt that the demise of the Defense Airborne Reconnaissance Office was deserved, having served its purpose of sorting through the early unmanned intelligence, surveillance, and reconnaissance (ISR) policy issues and forcing the services to think harder about UAVs. In the end, though, Fogleman attested that the reconnaissance office struggled because there was limited thought on how to support systems programmatically—an Air Force institutional high-interest item—and so Congress ended the experiment. The DOD's and the Air Force's reorganization efforts in the 1990s sowed intra- and inter-service confusion and took the better part of the decade to smooth out the new processes and relationships.

Second, both intra- and inter-group changes led to heightened, and sometimes fraught, political negotiations between civilian and military leadership for the Air Force. In August 1990, President Bush emphasized the need for "not merely reductions but restructuring" of the services.[429] Civilian leadership drove change in this instance, and the Air Force Chief of Staff and Secretary of the Air Force embraced the directive. As those changes unfolded, General Merrill A. McPeak, the Air Force Chief of Staff, reflected that early in the changes occurring across the Air Force and broader DOD, the Air Force "lost [its] deputy chief of staff for R&D" since the authority transferred to an assistant secretary of the Air Force for acquisitions.[430] McPeak and the Secretary of the Air Force, Donald

[427] Grant, "End of the Cold War Air Force," 44. General Merrill McPeak, Chief of Staff of the Air Force from 1991–1994, sought to create "one commander responsible for life-cycle weapon system support." It was a noble and likely right goal in hindsight for efficiency sake, but it took a toll in sorting out the implementation for years to come and likely has influenced all acquisition processes for most of the third UAV epoch.

[428] Grant, "End of the Cold War Air Force," 44.

[429] Grant, 41.

[430] Grant, 44.

Rice, sparred over weapons system design authorities and the detailed requirements being transferred to civilian-led offices. In McPeak's words, he challenged Secretary Donald Rice, asking "You mean to tell me you want civilians saying how sharp the bayonet has to be?"[431] According to journalist Rebecca Grant, the Air Staff regained the lead on setting requirements shortly after McPeak's objection. In addition to the externally driven call for change by President Bush, Congress forced the creation of the Defense Airborne Reconnaissance Office upon the DOD a few years later in 1993.[432] While minimizing some duplication of effort for ISR UAV programs, this move exacerbated an already-destabilized Air Force acquisition command. The new defense-level office removed incentives—intended or not—as the service lost control of the requirements and programming process.[433] In all these instances, leaders drove top-down change, which impacted the acquisition programs in the 1990s in general.

The research indicated that while Congress was generally supportive of the X-45, consternation over a lack of cross-service efficiencies and shifting requirements and timelines compelled congressional intervention.[434] First, there was pressure and guidance to consolidate similar service projects to gain efficiencies; in this case, the X-45 and the Navy's X-47 merged into the Joint-Unmanned Combat Air System. Yet, as shown in the rationalism section above, Air Force leaders were not consistent with their requirements and concept development, making it more difficult for Congress to align with the common goal of fielding the X-45. The original vision of for the X-45 was a "light, semidisposable craft used to suppress enemy air defenses."[435] The requirements then changed in 2002 to a larger aircraft with greater range to loiter deep in adversary territory and conduct such missions as electronic attack and close air support. By 2005, the Air Force Chief of the Staff, General John Jumper, an early supporter of the X-45, began questioning the purpose

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431 Grant, 44.

432 Best, *Intelligence Collection Platforms*, 19.

433 Best, 18.

434 Best, 19.

435 Tirpak, "Toward an Unmanned Bomber."

of the X-45's capabilities.[436] Jumper did not see the X-45 being able to dogfight; he wanted the mission to determine the size and shape of the machine, not the other way around. In the end, the Defense Secretary's 2006 Quadrennial Defense Review emphasized a new USAF task: to develop long-range strike capabilities. Intentional or not, the secretary ended Air Force and Navy interservice competition between the X-45 and X-47, a typical driver of innovation. The USAF followed this new top-down directive for bomber development, and the Secretary of Defense gave justification for the USAF to end its pursuit of the X-45. The Air Force was content to let the Navy take the lead and assume the risk on the UCAV project as the USAF turned its attention to its larger priorities of the time,[437] such as the F-22, F-35, tanker, and search and rescue recapitalization efforts.

Research interviews revealed that senior leaders in the Air Force, regardless of time period, assessed that institutional factors played a supporting role shaping UAV adoption episodes. One key finding was that institutional missions, not threats, often drove Air Force innovation efforts as the primary logic, especially in evolutionary-type scenarios. According to General Fogleman, senior leaders look at mission sets within which to evolve capabilities. When a weakness or gap widens in a mission area occurs, it is often a confluence of bureaucratic and institutional phenomena—not necessarily threat-based assessments—that determines the direction of a new or emerging technology. For instance, the capabilities of the USAF's tactical reconnaissance mission waned as the F-4 Phantom retired and stand-off capabilities improved. The Gulf War exposed the dearth of tactical reconnaissance assets at first, and that was later again exposed in the Balkans. So, mission tasks and not threat can cause iterative evolution to a capability, not just threats. A second finding was that the Air Force has minimized UAVs for many missions and scenarios. On January 15, 2020, the author interviewed Colonel Scott Campbell, A-10 pilot and former UAV wing commander; Campbell commented that USAF institutional biases have swayed the USAF from aggressively pursuing UAV innovation into mission sets beyond ISR and counter-insurgency operations, such as interdiction, air superiority, and higher-end conflict

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436 Tirpak.

437 Shipe, Turner, and Wickert, *Innovation Lost: The Tragedy of UCLASS*, 25–26.

scenarios. The institutional friction he described is that between the Air Force staffing functions of the A2 (ISR) and A3 (operations) divisions. This split inherently produces friction, and the A3 traditionally takes precedence in agenda setting for USAF staffing and operational processes; furthermore, assets are often thought of dichotomously as either belonging to the A2 or the A3, making it challenging to design and employ a platform that integrates the needs of both functional divisions within the staff. Tasking authority—who gets to task the asset, for what reasons, and when—is often under negotiation, especially for multi-role assets. This institutional legacy endures at various levels.

c. Organizational Culture Factors

When considering the RQ-3 and X-45 episodes outcomes, the study tests a third hypothesis of military innovation, namely that a service's prevailing organizational preferences emerging from the dominant culture, determines adoption outcomes. Theo Ferrell argues—and Kier, Terriff, and Adamsky support—that "culture sets the context for military innovation, fundamentally shaping the organization's reaction to technological and strategic opportunities."[438] Assessing the rational and institutional issues in comparison to the cultural factors, culture cannot be said to have determined outcomes, as much as having had a conditioning affect.[439]

Faced with the prospect of on-going and long-range flat budgets,[440] where pressures mandated cuts in keystone organizational programs such as the F-22 and F-35, the Air Force's organizational culture inclined the service to choose comparatively tepid investments into unmanned research and development for high-end UAVs. It also chose to prioritize congressional lobbying with the goal of maintaining its core air superiority capabilities. These capabilities underpin the USAF's presumption and conditioned solution to problems: manned aircraft, especially fighters and tactical reconnaissance aircraft. Even with over five years vested into the X-45 development—along with concurrently adopting

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[438] Farrell and Terriff, *The Sources of Military Change*, 12–17.

[439] This observation counters Kier and Mankhan's assertions that culture is the overriding and mostly determinant factor of innovation outcomes.

[440] Rodrigues, *Testimony, DEFENSE AIRCRAFT INVESTMENTS*, 9.

the Predator UAV—the USAF provided extremely little information in its 2004 United States Air Force Posture Statement regarding the current or future role of UAVs, particularly in the section on modernization and recapitalization. Instead, then Air Force Chief of the Staff General Jumper and Secretary of the Air Force James G. Roche touted the F-22 and F-35 as central weapon systems necessary to "find, fix, track, and target fleeting and mobile targets" and provide the joint force with close air support.[441]

The RQ-3 DarkStar did not present a direct threat to the USAF's dominant subculture, the fighter pilots, but the cancellation of DarkStar also fit cultural normative practices in acquisitions. The DarkStar, as an ISR-only asset, fell squarely into the responsibility of the Air Force A2, ISR staff community. Top leaders and programs have always been fighter and bomber pilots within the USAF. Reconnaissance pilots, while not glamorous in the same way as fighter culture, are generally still honored for the dangerous position and storied career paths well established since the 1950s. But in terms of cultural frameworks, the Air Force regularly bins people and assets into carnivore and herbivore characterizations.[442] Compounding those frameworks is a fluctuating bias of strategic-versus-tactical missions and assets that depend on the prevailing wartime/crisis context. The Air Force has swung repeatedly between these two contexts, resulting in cultural changes and cultural solutions to prevailing problems. In the Cold War, strategic missions operated in the background as all important, while the Korean and Vietnam Wars heightened Air Force sensitivities and normative solutions towards tactical assets and communities.[443] Reconnaissance missions, people, and assets generally fall into the herbivore support bin, and the prevailing context at the time of the RQ-3 was one of indecision between strategic and tactical prevalence. The Air Force has a history of relinquishing and abandoning ISR development when there is no compelling strategic or tactical catalyst, unlike the service's constant drive to evolve both existing and future

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[441] Department of the Air Force, *United States Air Force Posture Statement, 2004* (Washington, DC: Department of the Air Force, 2004), 31–32.

[442] Robert Stiegle, "Is the Air Force Serious About Intelligence, Surveillance, and Reconnaissance?" War on the Rocks, last modified June 25, 2019, https://warontherocks.com/2019/06/is-the-air-force-serious-about-intelligence-surveillance-and-reconnaissance/.

[443] This is one of the reasons the AQM-147 Firefly succeeded during the Vietnam War.

fighter and bomber capabilities even in the absence of threats. This is an interesting phenomenon given the informal and formal aspects of the Air Force's ISR missions, which it creatively employed at its inception during World War I,[444] and later obtained officially as a military department in 1947.[445]

Based on recent RAND analysis of the service the past twenty-plus years, the USAF experienced an identity crisis that arose during the early campaigns in Afghanistan and Iraq; such a crisis left the Air Force looking to reclaim its "identity beyond enabling" other services and to "make air superiority central to U.S. strategy" once again.[446] Operations Enduring Freedom and Iraqi Freedom changed institutional dynamics towards ground-favored perspectives in the DOD.[447] So, when the Secretary of Defense called for the Air Force to pursue a next-generation bomber in 2006—and altered the Joint-Unmanned Combat Air System project to a navy-led program—the Air Force easily fell in line.[448] This direction was far more in tune with traditional cultural assumptions about not only piloted solutions to warfare but also played to the Air Force's cultural identity that is more comfortable with missions and assets geared toward either strategic, global attack or air superiority. Such missions remain central to the Air Force's justification for service existence. For further support to this argument, senior Boeing representatives lamented in the mid 2000s that there was significant "operator resistance" that was unprepared for a shift towards greater UAV autonomy.[449] The 2006 quadrennial defense review emphasized the Air Force's own long-term goal for long-range strike, calling for a strike

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[444] Tyler Morten, "Manned Airborne Intelligence, Surveillance, and Reconnaissance: Strategic, Tactical…Both?" A*ir & Space Power Journal* 26, no. 6 (November–December 2012), 36–37, https://www.airuniversity.af.edu/Portals/10/ASPJ/ journals/Volume-26_Issue-6/ASPJ-Nov-Dec-2012.pdf.

[445] Warren A. Trest, *Air Force Roles and Missions: A History* (Washington, DC: Air Force History and Museums Program, 1998), 116–117, https://apps.dtic.mil/dtic/tr/fulltext/u2/a476454.pdf. The National Security Act of 1947, along with Executive Order 9877, gave the Air Force responsibility for strategic strike and reconnaissance. See also Chief of Staff of the Air Force, *Global Vigilance*.

[446] RAND Overview, *Movement and Maneuver*.

[447] Zimmerman et al., *Movement and Maneuver*, 205–206.

[448] Office of the Secretary of Defense, *Quadrennial Defense Review Report*, 46. This is in line with Donnithorne's findings on policy preferences based on cultural norms.

[449] Erwin, "Unmanned Combat Aircraft Still in 'Adolescent Phase'." This was in spite of the capability to raise the X-45's autonomous algorithms to a mid-level capability.

force increase of 50 percent and the "penetrating component of long-range strike by a factor of five by 2025," but to have unmanned aircraft comprise at least 45 percent of those assets.[450]

Finally, Air Force leaders and seasoned fighter pilots sense that the UAV's control interface can impact cultural receptivity to UAVs as a whole. For instance, the RQ-3 and the UCAV control interface required only programming on the ground and removed stick and rudder controls from the control vans. This design departure from other UAVs, such as the Predator, shifted the high-end, more automated UAVs away from a traditional pilot-vehicle interface, according to Colonel Campbell, and toward a mission operator concept.[451] This is reminiscent of the early astronaut confrontations with NASA administrators and engineers for astronauts to have more control and flight interface of the space capsules, starting with the Apollo program in the late 1950s. For the RQ-3 and X-45, the mission operator concept of control brought with it contested views not only what a UCAV should be (a remotely piloted aircraft versus an autonomous UAV) but also created divergent views of personnel and training best practices in the institution. Two former UAV wing commanders from the last decade, both whom flew fighters in their career, saw the pilot-vehicle interface issue differently. Colonel Campbell argued that only a true pilot-vehicle interface that looks like a cockpit will provide the training transfer and comfort of skills across all UAVs needed for the Air Force to culturally adopt UAVs. A second former Air Force UAV wing commander and F-16 pilot, Colonel Houston Cantwell, was interviewed on February 11, 2020. Cantwell suggested that until the Air Force adjusts its lexicon and moves away from the 'remotely piloted aircraft' terminology, the pilot-vehicle interface cannot grow beyond the traditional stick and rudder; more importantly, the Air Force will not be able to realize unmanned systems' full potential. Once the UAV is viewed as a system not bound by traditional pilot interface and aircraft design, Cantwell added, the Air Force will experience real innovation in the cultural

[450] Office of the Secretary of Defense, *Quadrennial Defense Review Report*, 46. Interestingly, now in 2020, none of these numbers have been even close to being met, especially the unmanned aircraft strike force of 45 percent.

[451] Erwin, "Unmanned Combat Aircraft Still in 'Adolescent Phase'."

frameworks of the service and adopt UAVs in general, to include high-end autonomous one such as the RQ-3 and X-45.

B. MEDIUM-END UNMANNED AIRCRAFT (RQ-4, MQ-9)

The medium-end UAVs developed by the USAF between 1991 and 2015 include the General Atomics-Aeronautical Systems MQ-9 Reaper and the Northrup Grumman RQ-4 Global Hawk. The Air Force employs both platforms today, having acquired the weapons systems in the early-to-mid 2000s. Like the RQ-3 and X-45 discussed above, these medium-end UAs each have different missions—the MQ-9 for strike, the RQ-4 for surveillance. In fact, the MQ-9's strike role makes it akin to the X-45 in purpose; the RQ-4 shares the RQ-3's unarmed surveillance role. The "M" nomenclature signifies a multi-mission aircraft, indicating that the MQ-9 performs multiple missions, particularly strike and reconnaissance. Yet, the medium-end UAVs harness less exotic technology than the RQ-3 or X-45. A lack of stealth and other protective design features for non-permissive environments reflect the most obvious differences between the medium-end and high-end UAs. In the end, the Air Force strongly adopted the MQ-9 Reaper, while only weakly adopting the RQ-4 as the Global Hawk competes with other existing surveillance capabilities such as satellites and the USAF's U-2 Dragon Lady aircraft.

1. RQ-4 Global Hawk Program Overview

Touted as a "fly before buy" endeavor, this DARPA-managed ACTD program was designed as a Tier II+ conventional high-altitude endurance UAV.[452] The RQ-4 was a sister program to the RQ-3's low observable, high altitude endurance effort—partly in competition with, as well as a complementary system, to the RQ-3. The Defense Airborne Reconnaissance Office described the RQ-3 and RQ-4 as "ACTDs of two technologies in high-altitude endurance UAV roles,"[453] both with the target goal of costing $10 million or

[452] Defense Airborne Reconnaissance Office, *Annual Report: 1995*, 11.

[453] Defense Airborne Reconnaissance Office, 13.

less in average fly-away costs per aircraft (1994 dollars).[454] Designating the RQ-4 as a Tier II+ was a compromise to show that the RQ-4 would not have the ability to operate in a high-threat environment like the RQ-3, but would also far outperform the medium-altitude endurance UAVs under development. DARPA stipulated the RQ-4 operate above 45,000 feet in accordance with high altitude endurance requirements, but with a much longer dwell period than medium altitude endurance aircraft that fell squarely into the Tier-II category (i.e., the MQ-1 Predator, which is described in the next section). The program requirement for the conventional high-altitude endurance RQ-4 envisioned an operating range of about 3,000 nautical miles. See Figure 27 for a depiction of the aircraft.

Figure 27. Northrop Grumman RQ-4 Global Hawk[455]

In June 1994, DARPA released a phase I request for proposal and design study. Five contractor teams bid on the Tier-II+ UAV requirement, and though DARPA originally intended to have a two-team competition, a funding-cut decision forced DARPA to award

[454] Fly away costs factor only production and production tool costs. Secretary of the Air Force Financial Management Board, *FY 2009 Budget Estimates: Aircraft Procurement, Vol 1*. (Washington, DC: USAF, February 2008), 55. Other measures of cost include procurement cost, which includes initial spares and factors in RDT&E costs plus military construction and ammunition (if used). Ted Nicholas and Rita Rossi, *U.S. Unmanned Aircraft Systems, 2011* (Fountain Valley, CA: Data Search Associates, July 2011), 4–2.

[455] "RQ-4 Global Hawk," United States Air Force, October 27, 2014, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104516/rq-4-global-hawk/.

only one company the $164 million, thirty-one month phase two contract in June 1995 for development and flight testing. Teledyne Ryan Aeronautical, as lead contractor, went to work designing and assembling the first RQ-4A, with a planned first flight in Spring 1997.[456] The ground control element was still tied to the RQ-3's Common Ground Segment as a means for controlling both the RQ-3 and RQ-4. Due to funding and technical issues with software development and sub-system integration problems, the first air vehicle did not roll out until February 20, 1997, behind schedule, finally making its maiden flight a year later in February 1998.[457]

Defense department budget changes between 1996 and 1997 led DARPA to alter the milestone dates, cut the number of air vehicles planned, and reduce the duration of phase three engineering, fabrication, and demos. First, the budget changes in RDT&E funding shifted significantly as the ACTD competed with other programs and changing national budgets. The planned $177 million in funds for 1996 turned into only $55.4 million when the final budget was written. While nowhere near as drastic, the change from the 1997 pre-planned funds and the final funds was only $3.4 million, dropping from $71.2 million to $67.8 million.[458] Second, phase two proved more expensive and took longer than planned.[459] Subsequently, the milestone timelines shifted to a planned first flight in early 1998, almost a year later than originally planned. The number of ACTD phase two vehicles dropped as well, from eight down to five. Finally, the phase three duration, which started on October 1, 1998, was reduced from twenty-four to fifteen months in order to maintain overall ACTD-planned timeline to finish on December 31, 1999.[460] Teledyne Ryan produced two more vehicles in phase III. Program management transitioned to the

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[456] "Northrup Grumman RQ-4 Global Hawk," in *Unmanned Aerial Vehicles and Targets*, ed. Kenneth Munson and Martin Streetly (Alexandria, VA: Jane's Information Group, 2006), 223. With contributing information from the Defense Airborne Reconnaissance Office, *Annual Report: 1995*.

[457] Jane's, "Northrup Grumman RQ-4 Global Hawk," 226.

[458] Defense Airborne Reconnaissance Office, *Annual Report: 1995*, 22; Defense Airborne Reconnaissance Office, *FY 1997*, 32; Defense Airborne Reconnaissance Office, *FY 1996*, 20.

[459] John G. Drew, Russell Shaver, Kristin F. Lynch, Mahyar A. Amouzegar, and Dan Snyder, *Unmanned Aerial Vehicle End-to-End Support Considerations* (Santa Monica, CA: RAND, 2005), 57.

[460] Defense Airborne Reconnaissance Office, *FY 1997*, 32.

Air Force when phase three began in October 1998,[461] and Northrup Grumman acquired Teledyne Ryan the next year in 1999. Following phase three, the Air Force continued demonstrator flights in early 2000, taking Global Hawk to several U.S. and international exercises, making a strong impression on Air Force and joint decision makers. In September 2000, the U.S. Joint Forces Command recommended to the Defense Acquisition Board that Northrup Grumman's Global Hawk enter production as part of a new engineering, manufacturing, and development phase, which officially started in March 2001.[462]

The aircraft's design came in two variants, an A and a B model; since the Air Force procured only seven A models, the capabilities and characteristics of the B model provide a better description of the primary vehicle in the inventory. The large RQ-4B aircraft sports a wingspan of one-hundred-thirty-one feet, which is significantly larger than even a modern Boeing 737 commercial airliner whose wingspan is ninety-five feet.[463] The length and height are forty-eight and fifteen feet respectively. Originally intended to have an endurance of over twenty-eight hours, the RQ-4B's single turbo-fan jet engine and composite composition enables a maximum on-station endurance of thirty-five hours at an operating altitude of 60,000 feet, an airspeed of three-hundred-and-ten knots, and a total range of over 9,500 nautical miles.[464] The B-model also carries a 3,000 pound payload weight, expanding its sensor capabilities to include electro-optical/infrared and synthetic aperture radar in both wide-area and spot imagery, plus a signals intelligence package. The larger B model, furthermore, provided an increased fuel load, new self-defense capabilities, and a higher operating altitude.[465]

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461 Government Accountability Office, *Unmanned Aerial Vehicles: Progress Towards meeting High Altitude Endurance Aircraft Price Goals*, GAO/NSIAD-99-29 (Washington, DC: Government Accountability Office, 1998), https://fas.org/irp/gao/nsiad-99-029.htm. See footnote 2. Published on December 15, 1998.

462 Jane's, "Northrup Grumman RQ-4 Global Hawk," 224.

463 Drew et al., *Unmanned Aerial Vehicle End-to-End Support Considerations*, 59.

464 Jane's, "Northrup Grumman RQ-4 Global Hawk," 226.

465 Drew et al., *Unmanned Aerial Vehicle End-to-End Support Considerations*, 59.

Adoption and production of the RQ-4 began in February 2003 with the Air Force's award of a $101.3 million contract to Northrup Grumman for a low-rate initial production that included five "lots." Lot one included two RQ-4As and a mission control element, all delivered between August and December 2003. Lots one, two, and three produced a total of seven RQ-4A variants and one RQ-4B, for a total of eight air vehicles. The entire low-rate initial production totaled 19 aircraft, delivered between August 2003 and 2006; these aircraft represented the Air Force's initial operating capability, and they were assigned to the newly formed 12th Reconnaissance Squadron, Beale Air Force Base, California. During the opening salvos of the Global War on Terror in November 2001, the Air Force sent Global Hawks to a base in United Arab Emirates to support Operation Enduring Freedom. In 2006, the DOD and USAF spent a combined total of $3.4 billion, of which $2.1 billion went to RDT&E.[466] The unit cost per aircraft fluctuated over time based on number of aircraft ordered and sensor capability improvements. By 2006, average unit costs equaled $71 million,[467] but that cost climbed to $123 million by the FY 2016 Presidential Budget Estimate released in early 2015.[468] For comparison, the Congressional Budget Office estimates replacing a U-2 aircraft would cost approximately $100 million in 2018 dollars.[469]

By October 2014, the Air Force procured 33 RQ-4s in four different "blocks" and added a second operational squadron, the 348th Reconnaissance Squadron at Grand Forks Air Force Base, North Dakota. All RQ-4As were designated as "Block 10," while Block-20, -30, and -40 aircraft used the RQ-4B platform to house various payloads associated with the different blocks. For instance, Block 10 were all imagery intelligence assets only, and were retired from the inventory in 2011. Block 20 aircraft also housed imagery-only

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466 Nicholas, *U.S. Military Aircraft Data Book, 2015*, 5–19.

467 Nicholas, 5–19.

468 Department of Defense, "RQ-4A/B Global Hawk Unmanned Aircraft System," *Selective Acquisition Report* (Washington, DC: Department of Defense, 2015), 36, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected Acquisition Reports/15-F-0540_RQ4AB_Global_Hawk_SAR_Dec_2014.PDF.

469 Congressional Budget Office, *The Cost of Replacing Today's Air Force Fleet* (Washington, DC: Congress of the United States, 2018), 17, https://www.cbo.gov/system/files/2018-12/54657-AirForceAviationFunding.pdf.

sensors, but had better aircraft performance, communications, and self-defense features. Block 30, which the Air Force declared an initial operating capability in August 2011, introduced the synthetic aperture radar sensors as well as signals intelligence capabilities; the USAF had eighteen aircraft in the inventory as of late 2014. All eleven of the Block 40 RQ-4Bs include a moving target indicator radar in addition to improved signals intelligence sensors. The Block 40 entered initial operating capability status in 2015.[470]

2. MQ-9 Reaper Program Overview

In 2000, General Atomics-Aeronautical Systems, Inc.,[471] initiated a "company-funded venture" program to develop a larger proof-of-concept aircraft based on the successful MQ-1A Predator (also known as Predator A).[472] The company was looking to capitalize on its earlier success of the Predator from the mid 1990s and overcome the service's perceived limitations of the MQ-1 such as altitude ceiling, weapons payloads, and overall survivability.[473] General Atomics also hoped that the new UAV's expanded capabilities would expand its potential customer base both within the U.S. government and foreign countries. General Atomics referred to the new demonstration aircraft as the Predator B, and by February 2001, the first prototype took flight. The aircraft strongly resembled a larger version of the MQ-1 with a few modifications, namely the V-tail flight control surfaces moved from the bottom to the top of the aircraft. These company-designated "B-001" and "B-002" aircraft also used two different engines as part of the test—a turboprop and a turbojet to expand its operating envelopes. Seeing the Predator B's potential for atmospheric and payload testing, the National Aeronautics and Space

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[470] All data in this paragraph derived from: "RQ-4 Global Hawk," United States Air Force.

[471] Referred to in a shortened manner as simply General Atomics from here on.

[472] "GA-ASI MQ-9 Predator B and Mariner," in *Unmanned Aerial Vehicles and Targets*, ed. Kenneth Munson and Martin Streetly, 96.

[473] Drew et al., *Unmanned Aerial Vehicle End-to-End Support Considerations*, 76. A higher operational ceiling would place the Predator B/MQ-9 above the bad weather conditions that impacted MQ-1 operations, as well as raise the operating altitude above many of the man-portable air defense surface-to-air missile systems.

Administration contributed funds early to General Atomics to develop the UAV.[474] According to the National Museum of the United States Air Force, Congress directed the service in October 2001 to acquire two prototype Predator Bs from General Atomics to test and develop a more robust medium altitude, long endurance UAV capability that increased weapons capacity.[475] The Air Force bought the two existing prototype aircraft B-001 and B-002, designating the aircraft the YMQ-9 in early 2002. The Air Force finally had its first true, dedicated "hunter-killer" combat UAV with "deadly persistence."[476]

Development and operational use progressed concurrently as the USAF took charge of the program. The Air Force took most of 2002, following its procurement of the two YMQ-9 prototypes, to determine a way forward as a Quick Reaction Capability program.[477] In December 2002, the Air Force paid $68.4 million[478] to General Atomics to start production on two pre-production aircraft, whose maiden flight occurred in October 2003. Between 2003 and 2006, the Air Force procured a total of eight aircraft[479] for testing and training, and authorized the name change to "Reaper" in 2006.[480] By February 2008,

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474 General Atomics Aeronautical Systems developed the Altus UAV as part of NASA's Environmental Research Aircraft and Sensor Technology program. The Altus was the precursor to the Predator B, which was later renamed Reaper by the Air Force. NASA selected the Altus as the winner of the Environmental Research Aircraft and Sensor Technology UAV contest. Altus exhibited endurance at higher altitudes and could carry atmospheric radiation measuring equipment. Newcome, *Unmanned Aviation*, 122–124.

475 "General Atomics Aeronautical Systems YMQ-9 Reaper," National Museum of the United States Air Force, May 18, 2015, https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/196042/general-atomics-aeronautical-systems-ymq-9-reaper/.

476 "GA-ASI MQ-9 Predator B and Mariner," *Unmanned Aerial Vehicles and Targets*, 196. ("Y" is the designator for experimental aircraft.)

477 The Air Force's annual test and evaluation report for 2002 indicated that Congress directed the Air Force to procure two turboprop and one jet powered Predator B aircraft. The USAF remained certain that a jet-powered aircraft would have limited endurance, though. Office of the Director, Operational Test and Evaluation, "MQ-9 Predator B Unmanned Aerial Vehicle System," *FY2002 Annual Report* (Washington, DC: Department of Defense, 2002), 283–284.

478 Nicholas and Rossi, *U.S. Unmanned Aircraft Systems, 2011*, 1–18.

479 James C. Reuhrmund Jr. and Christopher J. Bowie, *Arsenal of Airpower: USAF Aircraft Inventory 1950–2016* (Arlington, VA: The Mitchell Institute for Aerospace Studies, February 2018), 63. http://www.mitchellaerospacepower.org/single-post/2018/02/22/Arsenal-of-Airpower-USAF-Aircraft-Inventory-1950-2016.

480 "'Reaper' Moniker Given to MQ-9 Unmanned Aerial Vehicle," United States Air Force, September 14, 2006, https://www.af.mil/News/Article-Display/Article/129780/reaper-moniker-given-to-mq-9-unmanned-aerial-vehicle/.

the Air Force approved the MQ-9, shown in Figure 28, for full production, starting with Block 1 models. Of note, the FY 2007 President's Budget funded the MQ-9 program from 2005 through 2011 for a total of thirty-seven aircraft. Due to ever-shifting demands from the field and the DOD, that number grew to an approved total number of four-hundred-and-one aircraft in the presidential budget of FY 2013.[481] As budgets adjusted through sequestration and the objectives in the Global War on Terror shifted, the Air Force's recorded contract with General Atomics stood at two-hundred-twenty-five aircraft as of February 2015.[482]

Figure 28. GA-ASI MQ-9 Reaper[483]

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481 U.S. Department of Defense Inspector General, *Air Force Did Not Justify the Need for MQ-9 Reaper Procurement Quantities*, Report No. DODIG02014-123 (Washington, DC: Department of Defense, 2014), 4, https://media.defense.gov/2018/Jul/24/2001946126/-1/-1/1/DODIG-2014-123.PDF. Note: Published on September 30, 2014.

482 Department of Defense, "MQ-9 Reaper Unmanned Aircraft System," *Selected Acquisition Report* (Washington, DC: Department of Defense, 2015), 7, https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/15-F-0540_MQ-9%20Reaper_SAR_Dec_2014.pdf.

483 Source: "MQ-9 Reaper," United States Air Force, September 23, 2015, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104470/mq-9-reaper/.

The Air Force's MQ-9 operational employment began in secret but expanded quickly into unclassified employment while procurement numbers ramped up. In August 2004, the Air Force deployed the MQ-9 to an undisclosed location for concept development and testing, using one of the pre-production aircraft.[484] Following the establishment of the 42d Attack Squadron at Creech Air Force Base in late 2006,[485] the USAF started conducting sustained MQ-9 combat operations over Afghanistan in October 2007 in order to meet the commander of Air Combat Command's March 2006 directive for "early fielding to meet operational needs."[486] This decision sped up procurement and operational employment from the original planned 2009 production timeline; by the end of 2015, the Air Force had one-hundred-sixty-five Reapers in its inventory with that number expected to climb well over two-hundred Reapers in the coming few years.[487]

Though similar in shape, the MQ-9's capabilities outstripped its predecessor's MQ-1 performance in size, power, payload, speed, operating altitude, and weapons assortment, making it more versatile but still relatively affordable. At twelve feet high and thirty-six feet long, the MQ-9 looked more like a small fighter-sized aircraft. Thanks to its turboprop engine, the thrust power of the MQ-9 is almost eight times that of the MQ-1, giving it over twice the cruise speed at two-hundred knots. Able to carry 3,750 pounds of payload and weapons, the sixty-six foot wing-span and higher operating ceiling of up to 50,000 feet boosted flight duration to 1,150 miles, twice the range of the MQ-1. The ground control station uses two operators, like the MQ-1. Besides the Hellfire anti-tank missile, which the MQ-1 can carry, the MQ-9 can employ larger stand-off munitions such as the laser-guided Paveway II and Joint Direct Attack Munitions. For intelligence, surveillance and

[484] "GA-ASI MQ-9 Predator B and Mariner," *Unmanned Aerial Vehicles and Targets*.

[485] Dan Gettinger, *The Drone Databook* (Annandale-on-Hudson, NY: The Center for the Study of the Drone at Bard College, October 2019), 223, https://dronecenter.bard.edu/projects/droneproliferation/databook/.

[486] Department of Defense, "MQ-9 UAS Reaper," *Selected Acquisition Report*, RCS: DD-A&T(Q&A) 823–424 (Washington, DC: Defense Acquisition Management Information Retrieval, December 31, 2010), 4, https://www.globalsecurity.org/military/library/budget/fy2010/sar/mq-9-uas-reaper_sar_25-dec-2010.pdf.

[487] Reuhrmund and Bowie, *Arsenal of Airpower*, 67. The primary source for these numbers is the Air Force Magazine's annual "USAF Almanac".

reconnaissance, the MQ-9 employs a suite of infrared and TV camera full-motion video sensors, as well as a laser range finder/designator. After 2015, the MQ-9 will incorporate synthetic aperture radar capabilities.

3. Innovation Perspectives and Factor Analysis

a. Rational Factors

Rational factors of military innovation stimulated the medium-end UAVs developed by the USAF from 1991–2015 and provide modest support for the rationalism-based hypothesis. It is a reasonable to conclude that threat-based feedback loops, strategic and tactical gaps driven by conflict, and low-risk technology approaches all contributed the adoption outcomes of the RQ-4 Global Hawk and MQ-9 Reaper. First, the demise of the RQ-3 as a high-altitude endurance UAV, then categorized as a Tier III program, left the RQ-4 Global Hawk as the only on-going program to full-fill the wide-area surveillance ISR gaps and limitations within the Air Force and the joint force. It was broadly acknowledged that the need for more ISR assets, following the regional conflicts in Europe and the Middle East, would only grow. The U-2 is aging, and has its own inherent limitations, as good as it is.[488] This put pressure on the Global Hawk program to perform better and for the USAF to adopt it. With Global Hawk performing adequately as an ACTD, and later a program of record under Air Force management (within a lower-risk acquisition cost and strategy), the RQ-4 expanded global coverage required by the joint force's strategic planning and operations. While the RQ-4 eventually contributed in 2007—and still does today—to the conflicts in and around the Persian Gulf, the RQ-4 fleet and capabilities expanded to fill critical global ISR needs; senior and tactical warfighter demand for more remains unquenched.[489]

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[488] The U-2's sensors outclass the Global Hawk in many ways; however, the U-2 has a fraction of the flight time of a RQ-4. As a contributor to warfighter needs, the U-2 remained unmatched in responsiveness and capability compared to the RQ-4. Global Hawk added greater volume of ISR production in the wide-area surveillance needs; however, until the RQ-4 could match or exceed the ISR production value, the U-2 would remain in demand over the Global Hawk. Richard Whittle, "A Freed Hostage: ACC Commander's Parting Shots," Breaking Defense, last modified September 17, 2014, https://breakingdefense.com/2014/09/freeing-the-hostage-acc-commander-outspoken-on-the-even-of-retirement.

[489] This observation comes from many years working within tactical and operational planning cells around the world, including Korea, the Indo-Pacific Command, Europe, and Afghanistan.

A different set of more urgent requirements drove MQ-9 development. While initially industry conceived and drove the Reaper in 2002, the demonstrated capabilities of the then Reaper provided a significant capability increase over the MQ-1's performance in Afghanistan and other hotspots. The Pentagon's official *Selected Acquisition Report* for the MQ-9 highlights that "in March 2006, the Commander of Air Combat Command … directed early fielding to meet operational needs."[490] This document emphasized that Air Combat Command, the Air Force agency responsible for equipping warfighters, drove an accelerated acquisition pace by declaring the MQ-9 a Quick Reaction Capability program with a fully operating Program Office; uniquely, the program office ran "concurrent capability development, procurement, combat operations, and support."[491] The MQ-9's increased payload, munition type and storage, range, altitude, and endurance—with the same footprint as an MQ-1—typified a war-time adaptation offered by industry and driven internally from the top-down.

Both the Global Hawk and RQ-9 leveraged more mature technology and utilized basic or already proven aircraft and system design. According to the GAO's Louis Rodrigues, Global Hawk was a "conventional aircraft design, offering no special protection from enemy radar systems"; it was instead, intended only for "low-to-medium risk environments."[492] The technology for the Global Hawk was fairly advanced for UAVs, but not for general flight and warfighting capabilities. The RQ-4 had developmental advantages in its Common Ground Segment, which it had shared with the now defunct RQ-3. Additionally, the high-altitude endurance UAV utilized an advance mission planning and control program that made control straight forward and simpler. The Global Hawk's sensor development remained its greatest weakness, but its acquisition program deliberately planned a block or spiral upgrade approach to address these limitations. The MQ-9 has often been described—first by the manufacturer, and later Air Force officers—as simply a larger version of its predecessor, the MQ-1 Predator. Drawing on decades of

490 Department of Defense, "MQ-9 UAS Reaper," 6.

491 Department of Defense, 6.

492 Rodrigues, *Testimony, UNMANNED AERIAL VEHICLES*, 5.

UAV design and employment lessons by General Atomics and its lead Predator designer, Abe Karem, the MQ-9 brought the best of the features from the MQ-1 while improving the Predator's weaknesses, particularly in the areas of power, altitude, over-the-horizon control, and weapons selection. General Atomics reported that the Reaper was the first UAV controlled by satellite communications as well as the first to provide voice communication from the platform to other in-vicinity aircraft and troops; eventually the MQ-9 would be the first UAV to employ air-to-air weapons, a testament to its design and foundational capabilities.[493]

b. Institutional Factors

Of the three innovation hypotheses examined, the factors within the institutional hypothesis show the strongest conditional effects on the outcomes for the Air Force's medium-end category of UAVs, the Global Hawk and Reaper. The strong alignment among the key stakeholders for both programs that ensured the eventual adoption—that is, innovation—for these two systems, though the Reaper was much more strongly adopted. The Global Hawk had enough aligned support across the DOD, industry, Congress, and civilian leadership at critical moments to ensure its weak adoption. Comparatively, the Reaper maintained sustained support for its development and adoption since 2002, with the only institutional challenges arising over how many MQ-9s to purchase and how to grow the system's workforce effectively.

The Global Hawk enjoyed the institutional factors and conditions needed to ensure its selection, adoption, and development sustainment. After suffering a budget slash in 1996 as a young ACTD at the height of the Clinton-era budget drawdowns, funding returned to need with $370.7 million for the Global Hawk ACTD by mid 1997.[494] Financially, the Global Hawk had tacked close to its 1994 goal of a fly-away cost of $10 million, though Congress and the GAO remained concerned the cost would grow. Still,

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[493] Michael V. Cannon, "USAF MQ-9 Predator B 'Reaper' Program," accessed November 10, 2020, mromarketing.aviationweek.com/programexcellence/files/2010/Sys%20lvl%20prodSus%20GAAS%20MQ-9.pdf. Note: Company's entry sheet for the 2010 Aviation Week Program Excellent Initiative.

[494] Rodrigues, *Testimony, UNMANNED AERIAL VEHICLES*, 5. In 1996, the final presidential budget suddently slashed Global Hawk funding by almost two-thirds.

from 1999 until 2003, congressional funding met or exceeded DOD's requests for UAVs,[495] as Congress rewarded the ACTD methodology. Case in point, the DOD requested a total of $2.3 billion during those five fiscal years, and Congress appropriated $2.7 billion to "encourage rapid employment" and procure systems faster than originally planned.[496]

In 2006, Secretary Rumsfeld and the Chairman of the Joint Chiefs of Staff signaled strong institutional support for the Global Hawk,[497] while simultaneously retiring the U-2 fleet by 2012.[498] This is in line with Rumsfeld's creation of defense-level transformation offices, as well as the broad push to realize a revolution in military affairs. Congress and theater commanders intervened to keep the U-2 flying and in the inventory (due to its yet unmatched sensor capabilities by the RQ-4), but the pressure for the U-2's demise in favor for the RQ-4 never went away. As Air Combat Commander, General Hostage vented in 2014, he finally capitulated to Air Force calls to retire the U-2 out of ongoing sequestration and budgetary uncertainty.[499] Hostage remained concerned over undue risk to warfighters due to the U-2 cuts but knew the budget issues were real enough.

The programs also had sustained broad support among cross-institutional stakeholders. Within the DOD, the Under Secretary of Defense for Acquisitions, Technology, and Logistics took personal interest and involvement in the Global Hawk program throughout the early 2000s, insisting on an "evolutionary approach" that fielded versions of increasingly capable aircraft with cost constraints that were not onerous, but

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[495] Government Accountability Office, *FORCE STRUCTURE: Improved Strategic Planning*, 7.

[496] Government Accountability Office, 7–8. Note: The Air Force in 2003 asked for money to procure 7 Predators, but Congress approved a 470 percent increase to twenty-nine Predators. Of the 2.7 billion, $1.8 billion (roughly 67 percent) went to RDT&E, and $880 million to procurement for Predator, Global Hawk, and the Army's Shadow UAVs.

[497] Office of the Secretary of Defense, *Quadrennial Defense Review Report*, 46. The Quadrennial Defense Review specifically called for accelerating planned RQ-4 purchases in order to double the amount of then global coverage capabilities.

[498] Amy Butler and David A. Fulghum, "USAF Not Ready to Retire the U-2," *Aviation Week*, last modified August 26, 2008, https://web.archive.org/web/20121208145701/http://www.military.com/features/ 0,15240,174427,00.html.

[499] Whittle, "A Freed Hostage."

deferred more advanced sensors for later versions.[500] The undersecretary retained the Milestone Decision Authority as well, and designated it a "special-interest program," from 2002 until 2012.[501] For the MQ-9, Congress called for early USAF involvement in the program, and the Chief of Staff of the Air Force threw full support behind the Reaper in 2006 calling it a critical warfighter need; subsequent Air Force Chiefs appeared to continue such support. Finally, General Atomics purposely designed the MQ-9 to broaden appeal to other government agencies and foreign military sales and had an enduring commitment to the program. In all, there was alignment of Air Force, industry, Congressional, and civilian leadership in majority favor for the Reaper, which catalyzed its strong adoption.

On November 19, 2019, the author spoke with Michael Donley, Secretary of the Air Force from October 2008 to June 2013, who provided unique insight into the institutional factors at work for both the RQ-4 and the MQ-9, amongst other programs at the time. Donley's relationship with the DOD and USAF spanned several decades, and presidents, even before his stint as the Air Force's top civilian: as DOD Director of Administration and Management from May 2005 to June 2008 and as Comptroller and Assistant Secretary of the Air Force from late 1989 to January 1993. Looking back on all this experience, Donley remarked that from the early 2000s through to the end of his tenure as Secretary of the Air Force, resources were as unlimited as you could get. He corroborated the earlier findings that Congress was adding to and increasing the MQ-1 and MQ-9 (and other UAV programs) funding[502]; Donley recollected that Capitol Hill held General Atomics and its programs in high regard. That said, the Air Force was in an institutional battle for its resources and overall inventory, as the Air Force and Navy both

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[500] Neal P. Curtin and Paul L. Francis, *Testimony, UNMANNED AERIAL VEHICLES: Major Management Issues Facing DOD's Development and Fielding Efforts*, GAO-04-530T (Washington, DC: Government Accountability Office, 2004), 16, https://www.gao.gov/products/GAO-04-530T. Curtin was Director of Defense Capabilities and Management; Francis was Director of Acquisition and Sourcing Management. Testimony was before the Subcommittee on Tactical Air and Land Forces, Committee on Armed Services, House of Representatives, March 17, 2004.

[501] U.S. Department of Defense Inspector General, *Air Force Did Not Justify the Need for MQ-9 Reaper Procurement Quantities*.

[502] According to the Secretary of Defense in 2009, Robert Gates, "Congress just kept stuffing more C-17s into the budget to in order to preserve the jobs on the production line. The Air Force didn't need more, didn't want more, and couldn't afford more." Robert M. Gates, *Duty: Memoirs of a Secretary at War* (New York, NY: Alfred P. Knopf, 2014), 458.

shrank even after 9/11 due to base budget situations. Add to it, institutional demands from the DOD and the Army upon all aspects of the Air Force was unparalleled. Donley recalled that when Robert Gates took over the DOD as Secretary of Defense, the pressures only increased. Donley remarked that Secretary Gates had very strong views in place regarding UAVs, set institutional mechanisms up to that end, and drove the changes he wanted in acquisitions, the institutions, and culture.

This is not to say that the Reaper, particularly, did not have shortfalls in the internal institutional factors that slowed adoption outcomes. Two issues stand out: pilot shortfalls and general cost. The Air Force stood up its first Reaper squadron, the 42nd Attack Squadron, in November 2006, with the first aircraft assigned in March 2007.[503] As reported by Rachel Cohen for *Air Force Magazine*, manning was in perpetual crisis from early on, having to pull from other career fields, operate at a perpetually dangerous personnel and operations tempo, and forego many institutional career developments for the Reaper unit's operators.[504] Secretary Donley added further detail to the institution's pilot issues. Having non-volunteered many pilots, to include fighter pilots, into the MQ-1, MQ-9, and RQ-4 workforce early on, the Air Force's retention rates quickly declined due to personnel stress, workload, and morale issues. Focusing on retention, Donley and other senior Air Force leaders attempted to assuage the problem with added incentive pay and awards. Donley remarked that the awards system flunked twice before gaining traction due to opposition by the Army and the DOD leadership; the joint community had little appetite for rewarding similar medal to UAV pilots as those warfighters deployed and risking their lived in Iraq and Afghanistan. Once again, the prevalence and preference for the ground-centric perspective, introduced in Chapter III, dominated the period. Thus, interagency perspectives negatively shaped the internal working to adopt UAVs, making it harder on the Air Force to achieve the goals of the Defense Secretary. Gates leveraged enormous amounts of pressure on the Air Force to build the number of UAV orbits (i.e., "caps") in

[503] Office of the Secretary of Defense, *FY2009–2034, Unmanned Systems Integration Roadmap*, 67.

[504] Rachel S. Cohen, "MQ-9 'Get-Well Plan' Status," *AIR FORCE Magazine*, September 1, 2019, 24, https://www.airforcemag.com/issue/2019-09/.

the Middle East, and as Donley reminisced, personnel arguments held little sway with Gates.

Corroborating and expanding on Cohen's report, the Reaper's home wing commander, Colonel Stephen Jones, stated in 2019 that most MQ-9 pilots were finally direct accessions into the Air Force's 18X career field—those personnel exclusively trained as USAF pilots from the time of service entry. Furthermore, costs for the Reaper was on par or even greater than similar-sized fighter aircraft to build and operate, as revealed by the analysis of Winslow Wheeler, a Time Magazine reporter.[505] The DOD's 2015 *Selected Acquisition Report* for the MQ-9 bears this out, indicating the average cost of a single Reaper was $26 million.[506] Financial savings cannot be counted as a positive contributing factor under the institutional hypothesis for either the Reaper or the Global Hawk. Despite these budgetary issues and concerns, both programs prevailed as adoption outcomes due to Gates's use of the defense-level ISR Task Force which funded many UAV acquisition efforts through overseas contingency operations budget authorizations.[507] The contingency budgets were in addition to base budgets, which as noted earlier, tightened for the Air Force from the mid-2000s on. These findings support Rosen's argument that time, data, personnel, and other factors held greater impact on innovation than just budgets and money. Additionally, Donley indicated that the Air Force simply had a capacity problem to onboard Reapers, Predators, and Global Hawks any faster than it was doing. Basing and infrastructure limitations impeded the adoption rates. With cost and capacity combined, the Reaper episode provides strong evidentiary support for Horowitz's adoption-capacity theory of military innovation and adoption. Bottom line, resources are important, but external leadership, direction and persistent interest play more critical roles.

Interservice rivalries persisted in the ISR UAV enterprise and across the DOD—one of the key contextual facets motivating this study's puzzle. As early as the mid 1990s,

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[505] Winslow Wheeler, "The MQ-9's Cost and Performance," *Time Magazine*, February 28, 2012, http://nation.time.com/2012/02/28/2-the-mq-9s-cost-and-performance/.

[506] Department of Defense, "MQ-9 UAS Reaper," 31. Fighters typically range from $15-25 million each.

[507] Gates, *Duty*, 457. For example, the overseas contingency operations fund in FY2011 was $159 billion.

the Army and the Air Force were at loggerheads regarding the Predator. According to former Air Force Chief of the Staff Ron Fogleman, he and other Air Force leaders had strong concerns over how the Army was managing the Predator ACTD, and so, he made a strong bid to take over the program. Secretary Donley indicated that the Army and Air Force remained at odds over control and use of all ISR UAV assets in the inventory, noting that the Army would keep many of its useful assets in storage stateside, since they were tied to lower echelon units like battalions and brigades. The most telling and senior perspective came from Secretary Gates, in his autobiography:

> There was an unseemly turf fight in the ISR world over whether the Air Force should control all military drone programs and operations. The Army resisted, and I was on its side; the Air Force was grasping for absolute control of a capability for which it had little enthusiasm in the first place. I absolutely loathed this kind of turf fight, especially in the middle of ongoing wars, and I was determined the Air Force would not get control.[508]

Essentially, from 2006–2011, Gates exerted immense influence over the Air Force adoption outcomes and the institutional relationships, having significant effect on Air Force internal processes, programs, and results.

Finally, one theory of institutional adoption, Terry Pierce's theory about military innovation, differentiates between sustaining and disruptive programs. He argues that depending on the type of innovation attempted, a greater degree of institutional resistance will ensue, requiring the disruptive program to be disguised by its innovation champions as a sustaining project. In other words, Pierce views sustaining as an innovation for well-established military roles versus a disruptive innovation that indicates a new performance trajectory.[509] The Reaper was an interesting mix of both sustaining and disruptive within the USAF; it sustained prominent institutional preferences for fighter-sized aircraft design and fit normative perceptions of organizing, training, equipping, and employing. The Reaper was disruptive in that it was a full-size UAV that could operate much like modern attack fighters, but without the pilot onboard. The Reaper become the first mass-adopted,

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[508] Gates, 129.

[509] Pierce, *Warfighting and Disruptive Technologies*, 4.

organically driven aircraft, and there was no hiding its adoption as a purely sustaining effort. The Air Force did much to normalize the Reaper within institutional structures (personnel, organization, etc.) as if it was a sustaining innovation to meet the needs of current operations. Nevertheless, the disruptive nature of the Reaper innovation forced the Air Force to grapple with its first fully capable UCAV that could effectively replace conventional manned sorties on near-equal terms, even if it was only suited for low-to-medium threat environments.

In the end, the USAF laid the groundwork and went through the growing pains during the third UAV epoch to institutionalize the MQ-9 in a strong manner. The RQ-4 was much the same, but its more direct competition with the U-2 manned system, plus its growing cost, resulted in the Air Force's much weaker adoption overall.

c. Organizational Culture Factors

Depending on where one sits in the DOD, cultural factors both impeded and advanced Air Force adoption of the Global Hawk and Reaper platforms; the study's cultural hypothesis that the dominant subculture's attitudes and norms determine adoption outcomes was only generally supported throughout the medium-end UAV episodes. While broader cultural resistance existed, that resistance was rooted in operational employment norms and expectations. Negative cultural reactions to the Reaper, to the extent that they existed, did not determine the outcome. In fact, a cultural willingness to innovate and apply the organization's cultural norm of constant tactical improvement—and apply lessons from the Air Force's general disappointment with the Predator—actually cultivated organizational patience to get the Reaper right in the end that resulted in a stronger adoption outcome for the MQ-9. Of course, there were individual and local issues that cast the Global Hawk and Reaper into cultural disdain, but they were not onerous. In the end, cultural issues from across a variety of communities within the Air Force impacted the trend and trajectory of micro-development and adoption, but the cultural norm of adapting air power with technology prevailed in the macro sense for the MQ-9 episode, though less so for the RQ-4.

From the DOD and Army's perspective, the Air Force exhibited cultural resistance to the adoption of UAV in general, but this is not as clear cut as some would make it. Air Force Secretary Donley had the sense that the Secretary of Defense, Robert Gates, felt the Air Force had been lagging in adoption of the UAVs in general, and with the MQ-1 particularly (addressed in the next section). Robert Gates's autobiography, *Duty*, bears witness to this frustration.[510] Gates chastises the Air Force's cultural preference for manned aircraft, noting that the "Air Force made clear to its pilots that flying a drone from the ground with a joy stick was not as career-enhancing as flying an airplane in the wild blue yonder."[511] Furthermore, Gates insinuates the Air Force had "little enthusiasm" for less-capable ISR UAVs, insinuating a cultural bias.[512]

General Fogleman, the Air Force's top fighter pilot and leader from 1994–1997, forcefully defended the Air Force's interest in UAVs as a practical application of warfighting and the general stewardship of air power. After 50 years of aeronautical service to the nation, Fogleman alleges that arguments suggesting that the USAF rejects UAVs due to cultural biases are strongly misinformed, and the Air Force is not threatened organizationally by UAVs. The assessment of other senior fighter and attack pilots supported this view, to include Campbell and Cantwell, while acknowledging a broader cultural undercurrent whose sacred cows remain a detracting factor to wide-spread acceptance of UAVs within the Air Force's warfighting communities. Colonel "Slider" Cantwell, F-16 fighter pilot and UAV pilot—now the vice-superintendent of the U.S. Air Force Academy—conceded that there are some USAF sub-groups who stifle UAV development and adoption, while other groups promote UAVs. The Air Force is not a black or white monolith with one voice or view. Cantwell sees that at the lower ranks, many officers have immense respect for the growing capabilities of the Reaper, but he also says many senior leaders do not see the weapon system as valid and credible. Part of the issue is a wartime cultural mentality that leaves little room for experimentation and growth, even

510 Gates, *Duty*, 239.

511 Gates, 129.

512 Gates.

for a promising capability like the Reaper and Global Hawk. One instance Cantwell offered in support of this view is the insatiable drive for lethal effects on the post-9/11 battlefield to meet military campaign objectives[513]; this singular focus warps cultural adoption by demanding UAVs be as effective as manned platforms in that task, almost singularly.

The interview with Colonel “Soup” Campbell adds further support to these cultural nuances. Colonel Campbell spent the first 18 years of his career as an A-10 pilot, before qualifying in the Reaper. One of the Air Force principles common to most interviews was that a platform’s/community’s credibility emerges after demonstrated efficiency in executing effects on the battlefield—especially lethal effects. Colonel Campbell explained the many attitudes and cultural perceptions for the Reaper—and UAVs in general—were established due to poor introduction MQ-9 at Nellis Air Force Base, Nevada. The Air Force’s premier tactics, weapons development, and warfighting exercises take place at Nellis and in the large airspace complexes that cover the southern one-third of Nevada. MQ-9s often hindered quick and efficient weapons employment from manned systems due to embryonic MQ-9 tactics and poor integration knowledge across the force; furthermore, the premature MQ-9 concept of operations added to the ambiguity and negative stereotypes. This can partially be explained by the air combat command’s expedited acquisition of the platform. That said, the Reaper’s capabilities grew, and operators became better versed in integration expectations and employment concepts.

Even after the UAV incentive programs built during Secretary Donley’s tenure, adverse cultural perceptions about UAV subgroups became so ingrained that Headquarters Air Force at the Pentagon launched a Cultural and Process Improvement Program in 2015.[514] The goal of this program was to achieve a healthier institutional work-life balance for UAV operators, as well as career incentives such as basing variety, money, and broadening tours for staff and other educational opportunities that had largely been missing since the mid-2000s.[515] While these institutional variables provided relief within the UAV

[513] There was not a value judgement here, but an observation.

[514] Cohen, “MQ-9 ‘Get-Well Plan’,” 24.

[515] Cohen, 24.

community to a degree, it is cultural preferences for rank and representation that held significant value in the Air Force. By 2019, a career '18X' (pure UAV) pilot had ascended to a squadron commander position.[516] Campbell also saw great value in the 18X career field, as it gave the community a cadre of pilots vested in the success of the program from the start. Additionally, Colonel Jones, commander of the main Reaper wing at Creech Air Force Base, touted the expectation that soon the community would have a pure remotely-piloted-aircraft pilot in the rank of colonel,[517] which in the Air Force remains a big deal. With rank comes foundational representation and an entry-level of credibility. As General McPeak, Air Force Chief of the Staff from 1991–1994, remarked during the major cultural and institutional reorganizations of his time that "rank is the best sign of sincerity in the military."[518] Little seems to have changed in twenty-five years.

C. LOW-END UNMANNED AIRCRAFT (R/MQ-1)

The MQ-1B Predator is the DOD's best-known UAV.[519] Since 1991, it is also the least sophisticated of all the mid-to-larger-sized UAV aircraft associated with the Air Force. This UAV, produced by General Atomics-Aeronautical Systems, Inc., (the same upstart company that produced the MQ-9), was the brainchild of former Israeli aircraft designer Abraham Karem. Karem did not originally intended for the MQ-1 to employ kinetic weapons, but upon being armed in early 2001 to kill fleeting high-value targets, this unique and unassuming aircraft transformed UAVs in general from being a niche technology into a capability of extraordinary potential and demand. Richard Whittle, a long-time defense correspondent and historian, argues convincingly in his 2014 book *Predator*, that the MQ-1 ushered in the "drone revolution" of the early 21st century.[520] In 1995, the Air Force sought exclusive rights from the Secretary of Defense to operate the RQ-1, and by 2008 the Air Force built up the MQ-1 inventory to a total of one-hundred-

[516] Cohen, 24.

[517] Cohen, 24.

[518] Grant, "End of the Cold War Air Force," 44.

[519] Gertler, *U.S. Unmanned Aerial Systems*.

[520] Whittle, *Predator*, 6.

twenty-one aircraft.[521] The service then ended the program after purchasing a total of one-hundred-seventy-four aircraft by 2011.[522] The MQ-1 Predator, shown in Figure 29, no longer exists in the USAF inventory; the Air Force weakly adopted the platform into its organization. The Air Force shut down all operational units in early 2018 and mothballed the aircraft for good; the service fully transitioned combat UAV operations to the MQ-9 Reaper the same year.

This aircraft, tail number 97-3034, now resides in the National Air and Space Museum. It was the first to test-fire a Hellfire missile on January 23, 2001; the first U.S. aircraft over Afghanistan on September 12, 2001; and the first UAV to fire a Hellfire in combat on October 7, 2001.[523]

Figure 29. General Atomics-Aeronautical Systems MQ-1 Predator[524]

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521 How many of that total the USAF employed operationally is unclear, but circumstantial evidence seems to indicate it was less than one would hope or expect.

522 Reuhrmund and Bowie, *Arsenal of Airpower*, 68. The charts by Reuhrmund and Bowie indicate that the USAF procured 160 aircraft between 2006 and 2011, which is at odds with a detailed Jane's reports covering the exact contracts, aircraft ordered, and delivery dates. The total number of 174 aircraft in the Reuhrmund and Bowie document is corroborated by a 2012 Congressional Services Report titled *U.S. Unmanned Aerial Systems*, which is referenced elsewhere in this paper.

523 As recounted by Lt Gen (ret.) David Deptula on the aircraft's dedication day at the National Air and Space Museum. Whittle, *Predator*, 310.

524 Source: "MQ-1B Predator," U.S. Air Force, September 23, 2015, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104469/mq-1b-predator/.

1. The R/MQ-1 Predator Program Overview

The RQ-1's route to becoming an operational UAV was anything but conventional, and the program is one of the most interesting episodes of innovation adoption this paper examines. So unconventional and yet so consequential, the program has been called "the anti-joint UAV",[525] a small simple "glider with an Austrian racing snowmobile engine,"[526] and "the drone that changed the world."[527] The Predator traces its lineage from DARPA's early attempts in the 1980s at endurance UAVs using Leading System's Amber and General Atomics' Gnat-750 UAVs, shown in Figure 30. Abe Karem was the design genius behind these aircraft. While all three aircraft (Amber, Gnat-750, and Predator) had a single-source designer, there was not a single-service customer for the MQ-1, per se; the Predator came about with "virtually no service input"[528] at a time when the services' interest in drones "was nearly nonexistent."[529] Additionally, shrinking defense budgets after the end of the Cold War, combined with strategic uncertainty generated by the emerging New World Order of the early 1990s, exacerbated typical interservice rivalries and parochialism.

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525 Ehrhard, *Air Force UAVs*, 49.

526 Walter J. Boyne, "How the Predator Grew Teeth," *Air Force Magazine*, July 2009, 42, https://www.airforcemag.com/PDF/MagazineArchive/Documents/2009/July%202009/0709Predator.pdf

527 Daniel Terdiman, "The History of the Predator, the Drone That Change the World (Q&A)," CNET, last modified September 20, 2014, https://www.cnet.com/news/the-history-of-the-predator-the-drone-that-changed-the-world-q-a/. Interview with Richard Whittle, authority on Predator development who also commented that the Predator "changed the world" in his book *Predator*.

528 Ehrhard, *Air Force UAVs*, 49.

529 Whittle, *Predator*, 67.

The Amber and Gnat-750 clearly show the resemblance to the successor RQ-1. The Amber and Gnat-750 were much smaller than the RQ-1; the Amber was fifteen-feet long with a wingspan of twenty-eight feet, the Gnat was only about fourteen feet in length with a wingspan of twenty-four feet. In contrast, the Predator expanded the dimensions to twenty-seven feet long with a massive fifty-five foot wingspan.

Figure 30. Leading System's Amber in 1988 (top) and the General Atomics Gnat-750 in Approximately 1992 (bottom)[530]

[530] Top photo: "UAVs," DARPA, accessed May 25, 2020, https://www.darpa.mil/about-us/timeline/amber-predator-golden-hawk-predator. Bottom photo: J.P. Santiago, "Genesis of the Predator UAV," *Tails through Time*, last modified February 26, 2011, http://aviationtrivia.blogspot.com/2011/02/genesis-of-predator-uav.html.

From 1988 to 1994, changes in leadership, organization, and operational conditions led to new concepts and relationships that set the stage for the "anti-joint" Predator to emerge.[531] In 1988, the DOD stood up a UAV Joint Program Office and placed the Navy in charge of the organization, seeking to centralize DOD's UAV efforts after a series of Army and Navy UAV project disasters starting in the 1980s.[532] Between 1989 to 1993, international political change—the Soviet Union's crumbling control over Eastern Europe and other former client states—created turmoil and uncertainty as the Cold War ended. Correspondingly, the American voters lifted a young democrat, Bill Clinton, to the Oval Office in January 1993, shifting away from the republican-dominated, defense-oriented establishment of the past twelve years. With a fresh administration, new leadership reset the tone and tenor within the defense department. In April 1993, the Pentagon established a new undersecretary position of defense for acquisitions and technology, placing John M. Deutch in charge. Deutch was a UAV enthusiast and believed that the DOD was behind on UAV acquisitions given the technological advances occurring the past five-to-ten years.[533] Within the Air Force, the career path of General John Jumper meant he held key position later in the decade to take advantage of Deutch's thrust for UAV. Jumper influenced, or made directly, important decisions about the Predator as it transitioned from an ACTD into the operational inventory. Jumper held the Air Force's most-esteemed operational command at the time, the command position of U.S. Air Forces, Europe, from December 1997 to February 2000; then, he became commander of Air Combat Command until

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[531] The best historical account of the Predator's development is Whittle's *Predator*. The other authoritative historical source that includes analysis from a military innovation studies perspective is Thomas Ehrhard's *Air Force UAVs*; and, Michael R. Thirtle, Robert V. Johnson, and John Birkler, *The Predator ACTD: A Case Study for Transition Planning to the Formal Acquisition Process* (Santa Monica, CA: RAND, 1997), https://www.rand.org/pubs/ monograph_reports/MR899.html. These accounts bring together disparate data and new interviews to piece together a much clearer and nuanced telling of the factors leading to the Predator's status as an ACTD and eventually an operational platform with full acquisition status.

[532] The 1988 defense appropriation's bill directed the creation of the Joint Program Office. The Army's tactical UAV project known as Aquilla ballooned into a billion-dollar, decade-long disaster that did not go unnoticed by Congress, and all funding for the project was ended with 1988 defense bill. The Navy was still attempting, along with the Army, to get the Pioneer UAV on more solid footing as well. The Air Force had not shown any real interest in UAVs for several years. Whittle, *Predator*, 58–63.

[533] Whittle, *Predator*, 58. From 1986 through April 1993, the office was simply called the Undersecretary of Defense for Acquisition. The Clinton administration added on the "and Technology" to the office, with the acronym OSD (A&T).

September 2001. Air Combat Command is the pinnacle agency in the USAF for organizing, training, and equipping the combat air forces of the United States. Finally, Jumper assumed the Chief of Staff of the Air Force position from September 2001 until his retirement in September 2005.

Once the Navy-led Joint Program Office awarded the $37.1 million contract to General Atomics in January 1994,[534] the program was formally designated an ACTD and given thirty months to produce ten air vehicles, build three ground control stations, and participate in key demonstrations by mid 1995. Some of the first air vehicles deployed to the Army's Roving Sands exercise in April and May 1995.[535] From July through November the same year, the Army deployed Predator to support contingency operations over Bosnia, with promising results and key lessons learned despite the loss of two air vehicles. The results were so promising that the Air Force stood up the 11th Reconnaissance Squadron at Indian Springs (later Creech Air Force Base) in Nevada in preparation to make a bid to procure the Predator and shape its overall development.[536] From September 2, 1996, on, the 11th Reconnaissance Squadron controlled Predators over Bosnia, followed by the activation of the 15th Reconnaissance Squadron on August 1, 1997. Over the course of the full ACTD, the president's budget in then-year dollars included $61.4 million in 1995, $44.9 million in 1996, and $7.8 million in 1997,[537] for RDT&E and the total procurement of twenty-seven ACTD UAVs (two of which crashed over Bosnia) and six ground stations.[538] On August 8, 1997, the Defense Acquisition Board approved the MQ-1 for low-rate initial production through the Navy Program Element Office and under the auspices of Defense Airborne Reconnaissance Office. The Secretary of Defense at the same time delegated the Air Force as the milestone decision

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534 "GA-ASI MQ-1 and RQ-1 Predator," *Unmanned Aerial Vehicles and Targets*, 195.

535 Having already flown a sortie of forty hours and seventeen minutes in testing, the Predator then flew twenty-five days of Roving Sands exercise, imaged over two-hundred targets, and provided 85 percent of the imagery collected. Newcome, *Unmanned Aviation*, 109.d-

536 Defense Airborne Reconnaissance Office, *FY 1997*, 10.

537 Defense Airborne Reconnaissance Office, *Annual Report: 1995*, 20; Defense Airborne Reconnaissance Office, *FY 1996*, 18 and 30.

538 "GA-ASI MQ-1 and RQ-1 Predator," *Unmanned Aerial Vehicles and Targets*, 195.

authority for development and gave the Air Force sole operational control of all Predator aircraft.[539]

The Predator does not look drastically more robust than its Gnat-750 predecessor or other smaller UAVs such as Pioneer and Hunter of the same time period. But a combination of size, materials, and design tradeoffs made the Predator the best medium altitude, endurance UAV of the 1990s and then 2000s. The aircraft was designed to meet the Tier II specifications, carrying between four-hundred to five-hundred pounds of payload for electro-optical, synthetic aperture radar, and infrared sensors, operating between 15,000 and 25,000 feet in altitude, and flying for greater than twenty-four hours and over five-hundred nautical miles. Predator produced these parameters by using graphite epoxy composites and a small four-cylinder Rotax 912 piston engine.[540] Flying at speeds just over 100 miles per hour, the Predator's slight, long wings helped it stay airborne with minimal fuel consumption. Karem designed a bulge in the forward section of the fuselage, with the idea of holding a satellite dish. The biggest drawbacks of the whole design were that it would not be able to operate above typically problematic weather at 15,000 feet, the engine could not produce a great amount of power to run the on-board sensors and communications equipment, and the motor was extremely loud, sounding like a large mosquito. The Predator was progressively improved during the ACTD and early production to include rudimentary de-icing, UHF/VHF two-way radios for air traffic control voice communications, laser designator/range finders, and Mode IV friendly identification systems. The ground control station requires a pilot and a sensor operator and provides relief-on-station so that a single control team can control two aircraft simultaneously when needed. Later models included an upgraded engine with a tilt rotor to maximize speed, loiter time, and reliability at higher altitudes above 15,000 feet. The concept of operations, while initially line-of-sight only from the launch site, expanded quickly with the successful introduction of Ku-band satellite communications, which allowed remote-split operations. These remote-split operations allow for a launch and

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[539] Defense Airborne Reconnaissance Office, *FY 1997*, 30.

[540] Whittle, *Predator,* 83–84.

recovery unit perform aircraft take-off and landing at the deployed base but then to hand off the aircraft for beyond-line-of-site command and control from the United States.

2. Innovation Perspectives and Factor Analysis

a. Rational Factors

The legacy of the Predator would not belong to the Air Force without certain necessary rational factors present: a new strategic environment in the mid 1990s, well-established UAV technology, and senior leader support. Absent these factors, the Predator would have remained a niche capability for the Central Intelligence Agency and, likely, the Army.[541]

The strategic environment moved decidedly away from near-singular focus on Soviet peer competition in most facets except the nuclear arena. The uncertainty and ambiguity, reflected in from the national security strategies on down, rippled through the services. Russia and China were deemed "former" adversaries, and as such no state had the sophisticated defenses to remotely challenge the United States. Iran, Syria, and North Korea, problematic as they were, offered tough but not daunting air defenses. The Air Force was one of the first services to effectively employ strategic visioning to produce the first service-specific mission and vision in answer to the question asked by the USAF deputy chief of staff in 1990, Lieutenant General Jimmie V. Adams: "What role will the Air Force play in the new world order?"[542] In June of the same year, Secretary of the Air Force Rice and Air Force Chief of the Staff General McPeak answered the question in a short paper titled, *The Air Force and U.S. National Security: Global Reach, Global Power*. Besides expanding the focus of the Air Force beyond Russia and eastern Europe, the USAF signaled a more global and diverse mission and purpose across the spectrum of conflict. According to Rebecca Grant, the paper provided a structure for air power emphasizing conventional

[541] When surveying the MQ-1 against the three military innovation perspectives, vital sources of information included the works of Richard Whittle, Walter Boyne, Secretary of Defense Robert Gates, and Government Accountability Office reports. Vital interviews included Air Force Secretary Donley and Chief of Staff Fogleman.

[542] Grant, "End of the Cold War Air Force," 40.

forces and a new variety of scenarios such as humanitarian operations, regional conflicts, as well as major combat operations.

After the U.S. military's failure and embarrassment in Somalia, the United States was pressured to either invigorate its small wars capabilities or avoid such conflicts altogether. The latter was not an option, as ethnic strife erupted in the Balkans in 1992 and 1993 resulting in a Serbian blockade of Bosnia and attacks on United Nations peacekeepers. According to Whittle's history of the Predator, President Clinton wanted to end the blockade, and the president "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."[543] Whittle also found that satellites and manned reconnaissance jets struggled to answer the need due to limited passes over the area by satellites (and Serbians concealing their activity based on known overflights) and cloud coverage that stymied U-2 still-photo cameras. The White House demanded an answer and fast. The emerging strategic environment of regional conflict and the tactical problem of the Balkans required new capabilities, quickly. The strategic stage was set for the Predator's capabilities. This demand signal from the White House catalyzed the DOD toward finding a way to provide the needed real-time, enduring surveillance in the Balkans. General Colin Powell, then Chairman of the Joint Chiefs of Staff, had a meeting in early 1993 at the White House concerning the lack of intelligence on Serbian activity; Powell engaged the joint staff's director of intelligence to procure a system to meet the gap.[544] This led to discussions with DARPA and the Central Intelligence Agency, where the Gnat and the Predator programs were taking shape.

Besides events in the Balkans, the trials of 9/11 provided another shift in the strategic environment and set permissive conditions for further Predator's acquisitions beyond the Air Force's initial modest purchases. The current commander of Global Strike Command, General Timothy Ray, reflected on almost thirty-five years of service during an interview with the author on December 17, 2019; Ray remarked that structural barriers

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543 Whittle, *Predator*, 71.

544 Whittle, 73.

within the institution often requires a galvanizing event such of such strategic imperative and implication to overcome the status quo. The terrorist attacks of 9/11, like its predecessor events to include the Cuban Missile Crisis and World War II, provided an immanently higher threat than continuing with the status quo, so innovative change occurred. From the start of Operation Enduring Freedom, three events drove a rapid spiral of innovation to include the Predator and other UAVs; two events were threat-based, the third was a technology-capability limitation. Cantwell stated that the first event was the recurrent missed opportunity to target and kill senior Al Qaeda leadership once identified and tracked using the Predator. The second was the ever-evolving threat of terrorist activity in Afghanistan—and later in Iraq. The need for more ISR matched with readily available lethal effects drove innovation. Third, the Afghanistan terrain forced the Predator to operate at altitudes not fully designed into the airframe and engine combination. Furthermore, line of sight issues due to the rugged terrain drove communications needs as well. While the Predator performed well enough in the near sea-level testing ranges of the Yuma proving grounds in the early development as an ACTD, operational employment in more challenging environments revealed the platform's deficiencies, which stemmed from its origin as an industry-led experiment instead of an institutionally led program using requirement and design parameters. Still, the Predator performed "good enough"—a utilitarian theme that permeates the operator community according to Colonel Cantwell—especially in wartime.

Since the Predator's technology was mature for what it was initially designed to do, the program became operationally effective in a short amount of time; however, new threats and operational environment fostered innovative change. Based on the mature technology established by the Gnat predecessor, the RQ-1 went from contract to demonstration flights in a few short months in 1994.[545] The Predator's endurance capability was a major breakthrough, along with an increased ability to receive commands

[545] Government Accountability Office, *UNMANNED AERIAL VEHICLES*, 3.

and send data off-board real time.[546] The Predator project exemplified and matched ideas put forth by the 1991 *Critical Technologies for National Defense* report produced by the Air Force Institute of Technology (see Chapter III).[547] First, the evolution of new critical technology resulted when military requirements combine with an increase in mature technology. Second, that innovation succeeded when technology development runs in parallel with concept of operations development. Put another way, the outcome of innovation resulted when institutions and organizations integrate technology development with military doctrine development. The ACTD nature and employment of the Predator enabled improvements to be made using already mature and available technology to meet a concept of employment that produced results earning favor of senior military and civilian leaders all the way from service members to the president.[548] Finally, the Predator proved robust enough as a platform, technologically, to incorporate a weapons capability for which it was not originally designed. While still a low-end platform without cutting-edge technology, the MQ-1 was sturdier than the other contemporaneous UAVs such as the Pioneer. With the approval for UAV weapons testing by the Under Secretary of Defense for Acquisitions, Technology, and Logistics despite years of treaty concerns,[549] the MQ-1 had the technological capability to become the U.S. military's first hunter-killer.

b. Institutional Factors

The institutional hypothesis—characterized by concurrence among civilian leadership, the service military leadership, industry, and Congress—varied in stakeholder

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546 Frank Strickland, "The Early Evolution of the Predator Drone," *Studies in Intelligence* 57, no. 1 (March 2013): 3, https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/csi-studies/studies/vol.-57-no.-1-a/vol.-57-no.-1-a-pdfs/Strickland-Evolution%20of%20the%20Predator.pdf. Frank Strickland was a senior officer in the Central Intelligence Agency's directorate of Science and Technology in the early 1990s.

547 American Institute of Aeronautics and Astronautics, *Critical Technologies for National Defense*, 1–2.

548 President Clinton and President Bush were both pleased with the intelligence that the Gnat and Predator UAVs provided for the Balkans and Afghanistan respectively. Whittle, *Predator*, 82 and 264. See also, Bob Woodward, *Bush at War* (New York, NY: Simon & Schuster, 2002).

549 G.R. Gansler, "Compliance Certification of Predator Tests and the DARPA/USAF X-45A," (official memorandum, Washington, DC: Director, Strategic and Tactical Systems, 2000), https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Other/14-F-0267_Doc_01_Compliance_Certification_of_Predator_Tests_and_DARPA-USAF-X-45A.pdf.

alignment throughout the 1990s, and the Air Force adoption outcomes would not have occurred to the degree that they did without significant civilian and congressional advocacy. The components of the Iron Triangle remained weakly aligned due to an inconsistent commitment by the Air Force institutionally. The research data exposed valid institutional concerns that partially account for the USAF's wavering commitment to the Predator program.

First, the industry component, General Atomics, had a unique origin backstory well chronicled by the historian Richard Whittle.[550] The genius behind the Gnat and the Predator, Abe Karem, never stopped pursuing his UAV vision even after immigrating from Israel to America. A pair of aviation entrepreneurs partnered with Karem to develop prototypes and used their well-heeled connections to the DOD to push the company's line of UAVs, working contracts initially with DARPA and the Central Intelligence Agency. As the Predator became an ACTD—flying agency missions, run by the Army, and flown from time to time with Air Force pilots—General Atomics was known for its efforts to accommodate and innovate throughout the process. Air Force Chief of Staff, General Fogleman, pointed out that General Atomics played a substantial role not only designing and marketing its inventions but was also successful in garnering DOD support. Needless to say, the industry component of the institutionalist hypothesis not only was dedicated to its product (as most companies are) but General Atomics remained ahead of the times by anticipating the needs of the DOD and then leveraged its growing good reputation across the defense establishment, Congress, and civilian leadership.

Throughout the Predator's life cycle, the quality and consensus of cross-service and civilian-military relationships was so turbulent that it is surprising at times that the Air Force eventually procured as many Predators as it did. Starting in 1994, the Army had operational control of the Predator ACTD in support of the mission in the Balkans. Seeing the UAV's promise,[551] Fogleman insisted the Army was not approaching the Predator's use effectively or efficiently. To ensure the Predator's operational relevancy for the long-

550 Whittle, *Predator*. See also Frank Strickland, "The Early Evolution of the Predator Drone."

551 Whittle, "The History of the Predator."

term, Fogleman worked to get the DOD to name the USAF as the rightful owner and steward of the program.[552] It was an interservice coup of sorts.

Besides the concern over Army stewardship of the RQ-1, Fogleman indicated that what drove the decision to acquire the Predator was not just interservice politics, nor international security threats. Instead, Fogleman saw the Predator as a promising addition to a flagging tactical reconnaissance capability within the institution. The Air Force learned during the 1991 Gulf War that its mission to provide tactical reconnaissance on the battlefield was inadequate, at least in quantity, if not quality. With massive drawdowns, aircraft end of life service dates approaching, and other budgetary limitations, the Predator could be part of the solution to regaining a healthier tactical reconnaissance capability that matched the emerging strategic environment of the post-Cold War era. It was also a first step in realizing Fogleman's S&T vision that was emerging in 1995, known as *New World Vistas*; this vision emphasized UAV development—an institutional desire since the late 1940s "Hap" Arnold era. Fogleman directed the institution to begin figuring out the organizational and manpower requirements plus stood up the first operation squadron in the fall of 1995. The USAF's decision to force pilots into these new squadrons quickly is not surprising; it had little choice. The fact that this model persisted for so long became problematic, as discussed in the MQ-9 analysis section. Over ten years later, in the mid 1990s, the Air Force failed to get the institutional solutions in place to facilitate a stronger UAV adoption, and the Secretary of Defense responded forcefully.

If Fogleman drove acceptance, it was the Air Combat Command leader, Gen John Jumper who drove improvements to fit institutional structures and evolve the capability. General Jumper, another career fighter pilot and future Air Force Chief of the Staff, set about improving the Predator by turning to the secret Air Force rapid technology unit known as Big Safari. With their help, Jumper and the Air Force set about rectifying the many limitation they saw in the Predator and worked with General Atomics to make the Predator a more robust system that included new hardware, software, new communication

[552] Whittle. With the help of Colonel James "Snake" Clark and other allies, Fogleman succeeded in his goal to take ownership of the Predator.

architecture, and ways to exploit the intelligence feeds faster. In other words, the Air Force applied its years of innovation and flight know-how to make the Predator more lethal from the air. One small example includes de-icing systems; a more serious issue was the Predator's lack of sensor to see through cloud cover.[553] Another brainchild was to arm the Predator: with Jumper's enthusiastic support and backing, the Air Force began the process to organize and obtain the ordinance to test the Predator with the Army's Hellfire missile.

One institutional factor, investigated by Avant, revolves around the impact of domestic bureaucratic politics which often affect the outcome of emerging innovations, which the research revealed as having an impact on the Predator episode. Colonel Campbell highlighted the various administrations' indeterminant timelines and shifting troop levels in Iraq and Afghanistan; these political machinations wreaked havoc on the force projections and estimated cap requirements in both theaters. Short-term surge capacity versus sustained manpower, infrastructure, training, and organization had widely different answers, making institutional consensus hard to generate with how many resources were required and at what level of risk to the institution's other concurrent missions, priorities, and investments. Besides the target goal of sixty caps laid down by Secretary Gates, no one could say for sure how long these forces were needed, and if they would ever be valuable again once the bulk of U.S. forces exited the combat theaters. Domestic politics of wartime strategies, conflict termination dates, and on-again, off-again withdraws/troop levels kept the Air Force off balance as to what inventory and force posture was needed now and in the future. Fogleman characterized this time from roughly 2002 through 2011 as a period lacking strategic thinking, which drove ad hoc decision for DOD and Air Force programming. And, it was not just the UAV systems, but the entire force structure behind the Predator: communication networks and bandwidth, intelligence personnel and systems to process data output, and more. Compounding all the operational, organizational, and logistic ambiguity was what Secretary Gates characterized in his

[553] Government Accountability Office, *UNMANNED AERIAL VEHICLES*, 4.

autobiography, *Duty*, as “near-perpetual financial uncertainty” from 2006–2012.[554] Gates adds that this “madness played havoc with the acquisition programs.” Gates goes on and takes to task even the president regarding budget agreements with the Pentagon, especially from 2009–2011. The Defense Secretary, he remarked, “I felt that agreements with the Obama White House were good only for as long as they were politically convenient.”[555] Domestic politics influenced the outcomes of acquisition programs and the services institutional stances time and again. The Air Force, and all the services, had compounding institutional factors that coexisted, making it difficult to separate out individual variables for correlation assessment, much more, causation of a specified degree.

As further evidence of these compounding institutional factors, the internal structure of the Air Force exacerbated prioritization and budgetary concerns. A division exists institutionally between ISR and operations directorates, knows as the A2 and A3 respectively. It is a classic case of competing priorities on the battlefield when an asset straddles this divide: does the asset utilize its specialized sensors to fulfill the ISR collection deck and long-term pattern-of-life surveillance, or does the A3 operators own the asset for tasking to respond to events such as time sensitive targets? Colonel Campbell suggested that as an institution, the USAF has seen the Predator and the Reaper as an ISR asset, belonging to the A2 for tasking. However, he added, there is deep institutional (and cultural) views that unless the A3 operators lead, the USAF will fail to set the right hierarchy of needs and taskings.

Finally, the principal-agent relationship between Secretary Gates and the Air Force showed significant strain regarding both the speed of adoption of the Predator and the service’s commitment to institutional adaptation. The Secretary of Defense, as the principal, lost faith in the Air Force to adopt the MQ-1, an innovation he deemed most

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[554] Gates, *Duty*, 453. Gates commented that “For all its bleating from Congress about defense acquisition reform, tighter management, reducing waste, and auditable accounting, the made it nearly impossible to manage the Pentagon efficiently.” Not one defense budget in this time period was enacted on time, and the Pentagon had to operate most of the time with continuing resolutions, meaning that until the budget actually passed, the Pentagon operated with the exact same amount of money as the previous year and could not start any new programs.

[555] Gates, 464.

critical to prosecute and win the Global War on Terror. Gates argues that with the USAF, he "encountered a lack of enthusiasm and urgency" in the matter of ISR.[556] Subject interviews for the study corroborated Gates's view in that the Air Force negatively considered the Predator a "one trick pony" for highly permissive counter-terrorism settings that would not be a lasting part of its inventory. Gates, therefore, developed what Avant referred to as civilian incentives to entice, persuade, or coerce the agent to adapt—a key factor to innovation adoption. As part of the enticement, Gates authorized an increase to the Air Force's base budget by $2 billion to adopt and implement fifty MQ-1s caps.[557] Gates used coercive measures, as well, to overcome what he saw as impediments to his demands starting in mid 2007. The secretary said at the time, the Air Force operated eight Predator caps which consisted of six crews totaling eighty people operating each cap. Gates pushed the USAF hard for the next twenty-four months to develop, present, and execute plans to expand to eighteen caps within a year, and later to sixty caps of various types of UAVs. It got so bad, Gates traveled to Nevada, Afghanistan, and Iraq to see firsthand the operating locations; he found what he thought of as excess capacity sitting at all these locations, adding that he did not understand why he was having such a hard time persuading USAF leadership to adopt the UAVs.[558] In view of all these issues, along with the fight for the F-22, F-35, a next generation bomber, and an eroding nuclear enterprise, there is strong support once again for Horowitz's adoption-capacity theory.

c. Organizational Culture Factors

Gates offers one unique view of Air Force culture as a senior government official across several decades and as one who also served in the Air Force as a young officer. Gates disparages Air Force culture as intransigent against UAVs. As CIA director in 1992, Gates attempted to partner with the Air Force on "developing technologically advanced drones" for ISR, but the Air Force rebuffed him; Gates expounds, claiming the Air Force "wasn't interested because, as I was told, people join the Air Force to fly airplanes and

[556] Gates, 127.

[557] Gates, 318.

[558] Gates, 131.

drones had no pilot."[559] Almost fifteen years later as the Secretary of Defense in 2006, Gates added that the "Air Force mind-set had not changed." Furthermore, whether purely culture-based, or based in long-standing institutional policy, the Air Force insisted that rated pilots operate the controls (in whatever form those controls took) of remotely piloted vehicles.[560] The USAF was not interested in exploring the Army's solution by allowing warrant officers to operate their own version of the Predator, called Warrior. First, the Air Force has not traditionally operated with warrant officers; second, the Air Force maintained that in order to execute lethal rules of engagement, as well as the complicated aspects of flight in certain classes of airspace, fully rated pilots were the correct answer. It is hard to assess the degree of bias in Gates's view outside his own words in his autobiography; however, there are several who critique his excessive singular focus on current wars at the expense of the broader security framework that spanned other levels of conflict, then and in the future. Perhaps Gates's motivations for succeeding in current wars can be excused and understood; yet, unfavorable biases are a much harder factor to assess and account for.

Expanding on the Air Force stance that rated pilots are the only officers qualified to operate RPAs/UAVs, the issue of operating in national airspace also factored into Air Force thinking. As of September 2005, the Federal Aviation Administration released new UAS policy declaring that any UAV greater than fifty-five pounds required a visible registration number in order to operate in national airspace.[561] The larger the aircraft, the more accountability, and hence training, UAV operators required to function in the airspace. This bolstered the USAF's qualified pilot argument for large UAVs, just as external DOD pressures were building against the USAF's position. Additionally, the Air Force cultural divide of officers and enlisted is vastly, uniquely, different from the other

[559] Gates, 128.

[560] The term 'rated pilots' has a double meaning. First, *rated* is a skill set deemed through the award of an *aeronautical rating*—someone who flies. Second, rated, is a position or career field, which only a few career fields are deemed rated—those officers who have an aeronautical rating; only rated officers can command units that have a flying mission or aircraft assigned within the unit (squadrons, groups, wings, Air Forces, major commands). The rated career fields include pilot, remotely piloted aircraft pilot, combat systems officer, and air battle manager.

[561] See Chapter III.

services.[562] Calls like Gates's to use enlisted pilots for UAVs—which the Army has always done—went against a long-standing USAF institutional construct that, while not iron-clad, has endured since 1942.[563] Gates thought the USAF's stance on enlisted pilots was both an institutional structure and cultural norm that needed breaking.

Part of the factors creating cultural drag upon UAV adoption within the Air Force stemmed from views held within the air superiority fighter community. This community of F-4, F-15, and now F-22 pilots has long held a preponderance of USAF leadership positions ever since the "rise of the fighter generals" during and following Vietnam.[564] Using an Air Force jargon term, Campbell highlighted that the "fighter mafia" has tended to esteem a view of international conflict that favors strategic peer competition. Offering personal anecdotal experience operating within and around the community, a favorite saying was that the solution to any military problem was a four-ship of F-15 Eagles.[565] Of course, this was offered a bit tongue-in-cheek and with a dash of bravado, but it was also based on a bit of doctrinal truth: the DOD and the USAF has long experienced and maintained that a key to American military success starts with gaining air superiority over the enemy. So, there is a modicum of understanding that such a vital role would become the cultural heartbeat of the organization. Yet, the interview research exposed a more nuanced and complex cultural milieu. Harkening back to Carl Builder's implication that the Air Force is enamored with air assets as exquisite toys, General Fogleman countered such notions by emphasizing the programmatic details and industry support needed to build and maintain an air force. Aircraft, when treated with a motor pool or truck mindset such as the Army's approach to UAVs, the aircraft's failure and reliability suffered at

562 See Chapter III, on culture.

563 Gates, *Duty*, 129. Opportunities for enlisted pilots ended in 1972 with the Flight Officer Act. Oriana Pawlyk, "Air Force May Approve Enlisted Pilots for First Time in 75 Years," Military.com, March 31, 2018, https://www.military.com/daily-news/2018/03/31/air-force-may-approve-enlisted-pilots-first-time-75-years.html. An official history of enlisted pilots, and how the Air Force finally capitulated to start enlisted pilot programs for UAVs, see Amber Millerchip and José Davis, "The Epic Return of the 'Flying Sergeants,'" Air Education and Training Command, last modified February 16, 2017, https://www.aetc.af.mil/News/Article-Display/Article/1085814/the-epic-return-of-the-flying-sergeants/.

564 See Chapter III.

565 Author's own observations as a rated officer for 20 years.

unacceptable rates. In other interviews, early pilots and adopters of UAVs reminisced that the drive was to make UAVs as much like manned aircraft as possible—to add an air of cultural credibility. For instance, minor, monetary fines were levied against those in the Predator and Reaper communities if they referred to the ground control station as anything other than a "cockpit," stated Cantwell. At the same time, Cantwell added, leaders in the UAV community strove to get the Air Force to stop thinking of UAVs as aircraft sitting on a ramp, but instead, as an entire system, with the electromagnetic spectrum as the foundation of UAV success. In the end, it is important to note that it was fighter pilots from the air superiority community that not only drove initial adoption, but also early evolutionary innovation, of the Predator. From there, the RQ-1 took a more winding and difficult path to achieve further adoption and iterative innovations. Overall, the episode suggests that while subgroup and organizational cultural biases exist, the strength of subgroup biases eased over time as the officers' allegiances and biases shifted from the subgroup to a wider institutional and organizational perspective. This dynamic would ebb and flow depending on rational and institutional permissive factors.

Lastly, institutional problems related to the timing and method of UAV introduction into the force exacerbated cultural perceptions. This phenomenon peaked between 2002 and 2012 with the Predator primarily, but also with the Reaper. As discussed with the Reaper, fighter and bomber pilots were exposed to the slow moving, unformed tactics of the Predator in wartime over Afghanistan and Iraq. This hyper-focused environment of lethal effects in war fashioned an early negative view of UAVs.[566] First, the Predator forced the creation of restricted operating zones around which manned fighters had to avoid. These factors, starting in 2002 but exacerbated in the mid 2000s when significant numbers of UAVs started deploying to theater, impacted certain pilots' negative view of UAVs, which added to the background cultural issues exerting sway on innovation outcomes and the strength of overall adoption. This added transit time when fighters attempted to get to a time sensitive target—a metric the Air Force was being graded on

[566] Personal experience attests to this, as well as the Campbell interview. As noted in Chapter I, the focus is on Groups 3, 4, and 5 UAVs that operate above the coordinating altitude, typically set at 3,500 feet.

strongly by itself and the joint force. This aggravated pilots to no end. Second, if a UAV was present in the vicinity of where a manned fighter needed to operate in order to engage enemy ground forces, it was often an unacceptably slow process to coordinate movements with the UAV operators due to communication limitations or the slow speed of the UAV itself. This supports Colonel Cantwell's observation that it took ten years for UAVs—namely the Predator and Reaper—to gain cultural credibility once tactical issues were ironed out. He remarked that by 2012, UAVs were reliably doing key missions sets that other systems could not do with near the efficiency or effectiveness.

D. CONCLUSION

Comparing the hypotheses analysis from across the high-, medium-, and low-end cases within the USAF service, several critical findings and trends emerge for the rational, institutional, and cultural perspectives.

Staring with the rationalism hypothesis, the stronger the perceived gap in capabilities to address a threat, the Air Force generally tended to adopt UAVs proportionately. As a corollary, the weaker the rational factors contributing to adoption outcomes, the other perspectives' factors caused timeline extensions and mission creep. The DarkStar and X-45 UCAV programs failed to break through to an adoption outcome given the lack of consensus regarding a compelling military need. Subsequently, the defining requirements for the programs remained ambiguous, as the institutional and cultural factors were able to exert influence on competing needs/desires for what the programs should accomplish. The concept of operations for the programs were not mature, and the strategic and tactical requirements were neither aligned nor coherent in the Air Force and JROC's estimation. In fact, General Jumper, the Air Force Chief of Staff from 2001–2005 remarked in early 2005 shortly before the X-45's termination that "I want to get on with this," to generate an asset that "gets beyond being a novelty and gets to what is truly…responsive to real requirements."[567] Had the revolution in military affairs proceeded base on maintaining a qualitative military advantage against the then-modest,

[567] Tirpak, "Toward an Unmanned Bomber."

but growing, anti-access/area denial adversary systems, the X-45 and RQ-3 (or another version of it) would have likely prevailed in a modified form. We see today that the RQ-170 looks like a blend of the high-end programs, though much is not known about it, including the numbers procured; furthermore, systems such as the XQ-58A Valkyrie loyal wingman UAV concept in development since early 2019.[568]

The medium-end UAVs facilitated capability gaps for on-going operational ISR (RQ-4 and MQ-9) and attack (MQ-9) mission tasks. The Global Hawk supported growing demands for longer wide-area surveillance capabilities in response to growing regional instability. While this demand signal was strong, the need was offset by extending the life cycle and capabilities of the manned U-2 and satellites; thus, the RQ-4 was only weakly adopted. On the other hand, the MQ-9 was classified an urgent operational need, in response to the terrorist and insurgent activities in Afghanistan, Iraq, and other emerging hotbeds of non-state actor activity such as Africa and the greater Middle East. The MQ-9 was a direct answer to MQ-1 Predator shortcomings such as range, speed, altitude, and weapons payload, particularly in Afghanistan but also elsewhere. The strategic and operational threat environment of the mid 1990s had a direct and singular effect on the initial adoption outcomes of the MQ-1, though institutional and cultural factors would dampen that adoption, even in the aftermath of 9/11. The follow-on operations in response to 9/11 galvanized further MQ-1's adoption outcomes, but only to the degree that top-down civilian intervention forced the issue.

Considering the role of technology and the origin of innovation, the high-end episodes followed a legacy model of military-led technology efforts, despite the national security strategies and other senior strategy documents indicating that the era of military derived technology was waning, and commercial industry was where advanced technology would soon reside. Technology maturity, combined with current threat environment needs, propelled the RQ-4 forward despite its rising average fly away cost that increased in 1999 by 50 percent and would eventually top $123 million by 2015. Its sister aircraft, the RQ-3

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[568] Dave Axe, "The Air Force's Mysterious XQ-58 Valkyrie Drone is Almost Ready," *The National Interest*, last modified November 9, 2019, https://nationalinterest.org/blog/buzz/air-forces-mysterious-xq-58-valkyrie-drone-almost-ready-93401.

found no such favor given its technology and design problems, combined with limited threat rationale or concept of operations. The medium-end and low-end UAV programs both leveraged low-risk, established—or near established—technologies that balanced the many competing systems and engineering factors for UAVs. The MQ-1 and MQ-9 were successfully applications of industry-led, emerging technology in the smaller regional conflicts and counter-terrorism fights that dominated America's security posture for nearly twenty years and counting.

The episodes reveal a few theoretical takeaways. First, Posen's argument—that militaries do not seek major adaptation on their own and instead choose to focus on tactical level evolution—requires further conditioning. The DarkStar was an evolutionary concept for high-altitude endurance ISR, at least in the aspect of transitioning the U-2 mission space to an unmanned platform and evolving the aircraft design with the Air Force's technology of choice for operating in anti-access/area denial environments, stealth. So, in a way it was an attempt at evolutionary adaptation at the tactical level, in line with Posen's argument. Nevertheless, the work towards unmanned aircraft in and of itself is a major adaptation, much like the intercontinental ballistic missile addition to the Air Force in the 1950s and 1960s. The rational-based perspective that civilians must drive innovation certainly appeared confirmed, especially within the low-end episode. Second, the RQ-3 and X-45 episodes support the overall hypothesis that a rationalist view of technology adoption contributed to the rejection of the high-end UAV episodes. The high-end programs support the GAO conclusion that the "DOD's process for selecting program candidates does not include adequate criteria for assessing the maturity of proposed technology and has resulted in the approval of projects that included immature technologies."[569] But not so the low-end UAVs. The least advanced of all the Air Force UAVs explored here, the Predator arrived at the right time, right place, and with the right set of initial capabilities to meet an operational gap in both Bosnia and later Afghanistan. This episode supports Dahl's observation that timing is critical for innovation adoption to occur; a unique and

[569] Government Accountability Office, *BEST PRACTICES: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, DC: Government Accountability Office, 1999), 56, https://www.gao.gov/products/NSIAD-99-162.

groundbreaking capability requires the right conditions for militaries to take risks on cutting-edge technology that alters how the organization functions in the field. The utility of effectiveness is one such conditional factor.

Next, the episodes proved to generally support the institutional hypothesis, which requires consensual agreement across the four key stakeholders of an innovation for adoption to occur; however, strong adoption outcomes often required disproportionate leverage from civilian and senior military leaders. In addition to this general finding, the episodes provided strong correlation to Horowitz's adoption-capacity theory.

The high-end episodes failed in part because of weak support from one of the stakeholders. For the medium-end episodes, institutional factors had the strongest conditional effects on the outcomes. The RQ-4 had alignment at the right times to achieve a weaker adoption outcome, unable to overcome its sensor limitations and non-competitive cost margins. And, while seemingly reluctant at first, the Air Force eventually gave the MQ-9 favored status; once that occurred, the alignment across the main stakeholders propelled the MQ-9 to a strong adoption outcome. The MQ-1, as the lone low-end episode, enjoyed strong support from senior Air Force leaders, but the broader institutional barriers prevented a strong adoption. Even after the Secretary of Defense forced the issue with the Air Force, to procure the asset in volume, the service abandoned the MQ-1 by 2015, never strongly adopting it institutionally or culturally.

Another interesting and key finding within the institutional perspective was that programming and budgets supported innovations and improvements that protected pilots over UAV programs. Improvements and programs that could be sold as further insurance protection to human pilots generally took priority over UAV innovations or incremental improvements funds. This dynamic revealed an ironic tension in the institutional system: UAVs provide protection to pilots by removing them from the forward battlespace. This action prevents loss of life and stops adversaries from gaining strategic advantages in the information operations space. Yet, the Air Force did not prioritize the funds to speed UAVs fielding.

Additionally, internal institutional priorities and structures shaped outcomes significantly. First, the USAF did not want to be saddled with a fleet of single-environment, low-end systems that hampered institutional needs/priorities such as next general fighters, bombers, tankers, and space systems. The political machinations of Afghan and Iraqi withdraws disincentivized the Air Force from wanting to make commitments beyond the minimum necessary. Second, internal institutional structures, which drove budget prioritization, had a strong effect on outcomes, namely the ISR versus operational turf wars split between the A2 and A3 staff divisions.

External to the service, but internal to the DOD, the concept of jointness and developing joint solutions remained problematic for decades after the GWNA and the later introduction of the JROC. In 1998, RAND researchers assessed that the Joint Warfighting Capabilities Assessment entity of the JROC had not penetrated the service's "investment strategies" and choices; instead, the services remained tied to stove-piped perspectives.[570] Getting services to find efficiencies with other services was challenging. The pendulum swing between institutional centralization and decentralization played out across the many years. Also, the Air Force was not guilty of ignoring the UAV innovation, given the fact that Generals Fogleman and Jumper, both senior fighter pilots, fought hard for Air Force ownership of UAVs—particularly the Predator—and provided the vision and institutional push to arm the Predator in the first place. But the Air Force was institutionally slow and unenthusiastic (or culturally for that matter) to bring on such disruptive technologies and employment concepts. The Air Force did not move as quickly as needed for wartime adaptation, so the civilian leadership and Congress intervened. But, once the technology was in the inventory, the Air Force embraced the Reaper as its own organic solution. Debates continue to rage regarding UAV adoption speed, the types of UAVs desired, and the general trajectory of UAV design; however, the Reaper shows that despite an amazingly complex set of innovation factors across the three main perspectives—rational, institutional, and cultural—a successful innovation took place.

570 Leslie Lewis, John Schrader, William L. Schwabe, and Robert A. Brown, *Joint Warfighting Capabilities (JWCA) Integration, Report on Phase I Research*, Report DASW01-95-C-0059 (Santa Monica, CA: RAND, 1998), 44.

Last, the organizational culture factors across the Air Force episodes did not neatly follow the organizational culture hypothesis that the dominant subgroup would determine adoption outcomes. The Air Force's identity crisis during the first ten years of the Global War on Terror gave impetus to seeking solutions that honed closer to a traditional view of the Air Force, impacting the X-45 result; however, rational and institutional factors bear much of the correlational impact on the UCAV's outcome. While it is easy to point to Secretary of Defense Gates's characterization of USAF culture as the dominant factor impeding UAV adoption, that view appears potentially biased when laid against the other rational, institutional, and even cultural considerations. Instead, the research reveal ed that cultural factors at the organizational level tended to favor innovation and a vision for an Air Force that included UAVs. The fighter pilot culture/mafia exists, but the higher the position and rank of senior pilots, the less such subgroup norms and views persist.

Instead, the organizational culture had more of a conditional effect on the speed and quality of adoption, but not innovation proper. The USAF's predilection for making flying machines conform to manned-fighter norms and culture shaped, for better and worse, the organization's general response to UAVs. Furthermore, the way the medium- and low-end UAVs were introduced to the Air Force's warfighting community resulted in likely avoidable cultural backlashes over the skies of Afghanistan, Iraq, and the training grounds of Nevada. Also, the Air Force lexicon focused on remotely piloted vehicles partially constrained innovative perspectives and creative organizational options for developing and improving UAVs as a core Air Force competency across many institutional missions and tasks. Additionally, many senior leaders sent conflicting, and negative, cultural views of UAVs, as assessed by Cantwell and Campbell. On one hand, leadership at the general-officer level implied that UAV employment was easy compared to fighter employments (which many UAV operators with experience in both fighter and UAV platforms contend is not necessarily the case), and on the other hand, general officers inferred that those fighter pilots chosen by the Air Force to break leadership barriers within the USAF community—and bestow credibility to the UAV force—would take a career hit by doing something for the institutional service that was actually undesirable culturally.

As the Air Force made institutional changes in personnel policies and infrastructure, corresponding changes followed. With the introduction of the 18X career field, and with pure 18X pilots starting to earn senior officer rank, the cultural adoption of UAVs increased. As Colonel Campbell highlighted, until the USAF committed to fielding a dedicated and deliberate UAV force, the organization remained in a negative cyclical relationship first culturally, and second as a bureaucratic institution.

The adoption episodes indicated that the USAF authentically wrestled with UAV innovation across the rational, institutional and culture factors. The Air Force warfighter remained pragmatic, was not averse to innovation, and guarded against any reduction in warfighting capability prudently. Here the psychological and sociological aspects factored in, as a judicious guard against unnecessary loss of life. There was both a biological and an ethical component to preserving life. Technology that made human warfighters more lethal tended to find less cultural resistance; technology that completely removed the human, instead of simply aiding or enhancing human performance, struggled against a higher threshold of acceptance. If the innovation did not advance the capability against current threats, but instead represented only an iterative step towards a theoretical future threat, subgroup communities (e.g. ISR, operations, mobility, etc.) demanded the current capability stay intact, especially in an ongoing conflict. Therefore, in perpetual conflict circumstances, disruptive technologic inventions were probabilistically more likely to not be adopted. Furthermore, Congress held significant sway over episode outcomes, but without a confluence of rational, technological, institutional, and cultural support, no amount of directives (to include the 2001 Defense Authorization Act that set the goal that UAVs would comprise one-third of the DOD's deep-strike force)[571] will result in the desired congressional outcome.

In the twenty-five years since the Predator first arrived over the skies of Bosnia, initially under Army control and at a time when the USAF owned zero UAVs, the Air Force procured hundreds of medium- and large-sized UAVs but has not settled on a future direction for innovation. The results of the UAV episodes suggests that a holistic view of

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[571] Pub. L. No. 106–398, Sec. 220 (2000).

military innovation studies, with antagonism across rational, institutional and cultural competing priorities, will drive the Air Force to reconsider its future path: a) stake airpower on manned, fighter-centric platforms aided by unmanned assistants that off-load burdensome tasks that saturate attention and induce greater risk, or b) see airpower holistically, not defined only by manned fighter aircraft perspectives, but a twenty-first century airpower with fighters as part of new ecosystem of domain effects in which the hierarchy of the fighter pilot is not presumed to be the pinnacle of warfighter decision making and prowess. The Air Force has wrestled with these two visions of itself not only throughout the third UAV epoch, but for the past eighty years since General of the Air Force, Henry H. Arnold saw unmanned aircraft as the likely evolution of airpower starting in the 1940s. The path forward will likely not be one or the other, but an innovative mix. In response to entrepreneur Elon Musk's pronouncement that the age of the fighter was over in early 2020 and that autonomous drone warfare is the way of the future,[572] Major General Darryl Burke, a senior reconnaissance pilot, offered this assessment:

> I think it's safe to say fighter aircraft will be flying for decades to come and that no nation is near retiring their fighter fleet. More importantly, the reality is that America's current fighter fleet is obsolete and recapitalization efforts are not happening fast enough. The F-35 must rapidly scale as the backbone of America's air superiority force. The distant promise of autonomy must not be confused with meeting the clear and present threats of today and tomorrow.[573]

This realist, near-term perspective is counter-balanced with an institutional drive for innovation to ensure dominance in the future. The current four-star general in charge of Air Combat Command, Mike Holmes, projected a seriousness about the Musk's assertion, "Will I want to replace [F-16s] with F-35s? Or will I start cutting in something else, like

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572 Rachel S. Cohen, "The Fighter Jet Era Has Passed," *AIR FORCE Magazine*, April 1, 2020, https://www.airforcemag.com/article/the-fighter-jet-era-has-passed/.

573 Darryl Burke, Linked In commentary. https://www.linkedin.com/feed/update/urn%3Ali%3Activity %3A6640423820756865024/?midToken=AQETfDNia1CeOw&trk=eml-email_notification_digest_01-notifications-27-null&trkEmail=eml-email_notification_digest_01-notifications-27-null-null-uvf36%7Ek7leax7v%7Eg6-null-voyagerOffline.

Elon is talking about?"[574] It appears the Air Force's top fighter pilots and senior leaders are taking sincerely the innovative efforts towards an unmanned force.

574 Cohen, "The Fighter Jet Era Has Passed."

V. NAVY UAV EPISODES, 1991–2015

> We may stand, then, at an important watershed in the evolution of carrier aviation, one reflecting not only the nation's current financial crisis but the changing nature of the threats to, or constraints on, American sea power, as well as . . . the advent of a new era of unmanned air and sea platforms of all types [August 2011].
>
> — Carnes Lord, the Director of the Naval War College Press, 2011[575]

The Navy has employed airpower as one of its main instruments of warfare since the advent of the airplane and has the distinction of being the first U.S. service to experiment with unmanned aerial vehicles. Early naval research and development efforts sought to create UAVs to attack adversary ships, much like our modern cruise missiles, though never with much success initially. By the end of World War I, the Navy was aware of the growing usefulness of the airplane in military operations on a broader scale, and U.S. naval leadership gradually introduced aircraft carriers in the 1920s and 1930s. Throughout these two decades, the battleship remained the Navy's capital ship of choice.

Then, in the early years of World War II, the Navy stridently adopted aircraft carriers for a couple key reasons.[576] First, the Navy was slowly transitioning away from its previous focus on defending or attacking commercial sea lines of communication. After World War I, the Navy started slowly adapting to become a major power projection force.[577] Second, the Navy learned valuable lessons from the Japanese's aircraft carrier employment, particularly following the bombing of Pearl Harbor in December 1941. The adoption of the aircraft carrier marked a paradigm shift within the Navy regarding the

[575] Thomas C. Hone, Norman Friedman, and Mark D. Mandeles, Forward to *Innovation in Carrier Aviation.* Naval War College Newport Papers, 37 (Washington, DC: U.S. Government Printing Office, 2011), xiii.

[576] By 1942, "the ability of carrier aircraft to kill ships and defend carriers was incontrovertible as was the vulnerability of battleships to air attack. The revolutionary effect of naval aviation had become clear." Jan M. Van Tol, "Military Innovation and Carrier Aviation—The Relevant History," *Joint Forces Quarterly* (Summer 1997): 87, https://ndupress.ndu.edu/portals/68/Documents/jfq/jfq-16.pdf.

[577] Philip A. Crowl, "Alfred Thayer Mahan: The Naval Historian," in *Makers of Modern Strategy from Machiavelli to the Nuclear Age,* ed. Peter Paret (Princeton, NJ: Princeton University Press, 1986), 458–461.

relationship of airpower to sea power, and that new paradigm persists today. For now, the Navy remains wedded to the aircraft carrier as the primary means of projecting force and achieving command of the sea.

Likewise, the composition of the carrier air wing has morphed drastically over time as technology, such as jet engines and improved steam catapults, enabled greater efficiency and effectiveness for aircraft to fulfill mission sets. Over the past thirty years, a small part of the story of the naval carrier air wing included the development, experimentation, and limited acquisition of UAVs aboard carriers. Interestingly, the Navy has more shore-based UAVs than carrier-based UAVs as of 2019. Surveying the Navy's UAV adoption outcomes since 1991, the service had fewer strong adoption outcomes compared to the USAF. Yet, the Navy remained more committed to high-end UCAV development long past the Air Force, with no convincing explanation why from the military innovation studies community.

Next to the Air Force, the Navy is an equally important component to this study. Since the aircraft carrier revolution in the 1940s, the Navy now conducts a significant portion of its mandated mission through the employment of tactical fighter planes. While friendly rivalries between the Navy and Air Force persist, the communities share more in common than not regarding their sub-cultures and views of airpower. A naval flight officer and professor at the Naval Postgraduate School, Navy Commander Kathleen Giles, provided key insights to the author in an interview on January 3, 2020. She reflected on a career of joint employment and testing that the Air Force and Navy both generally see aircraft as exquisite platforms and not just tools of the trade. Personal experience has shown that in operational planning, the Navy and Air Force approach the employment of airpower in a similar manner and are generally willing to explore a give-and-take of assets to best match the desired effects on the battlefield. More importantly, there is an underlying mutual trust between the Navy and Air Force that airpower will target—in an unbiased and prioritized manner—tactical threats to the two services, given their mutual dependency of airpower. Despite these similarities and general cultural affinities, the requirements and design of aircraft remain vastly different between the Air Force and the Navy, making joint procurement endeavors challenging.

Returning to the main research questions, this chapter seeks to understand what accounts for UAV innovation adoption variation and patterns; the Navy provides several valuable episodes that included stand-alone and interservice UAV programs from 1991 to 2015 that provide further insight into innovation dynamics when examined through the rational, institutional, and cultural lenses. Based on the selected high-, medium-, and low-end UAV case types presented in Chapter II, the study explores five naval UAVs: the rudimentary RQ-2 Pioneer, the stealthy X-47 Pegasus and its follow on the Unmanned Carrier-Launched Surveillance and Strike (UCLASS), the MQ-8 Fire Scout unmanned helicopter, and Northrop Grumman's R/MQ-4 that was developed in two similar but separate versions. The Navy eventually rejected both the X-47 and UCLASS projects, while weakly adopting the Pioneer. The service found some success with the Fire Scout, slowly adopting it into the inventory. Finally, the Navy initially weakly adopted the RQ-4 Global Hawk in its initial Broad Area Maritime Surveillance (BAMS) version, but since 2015, the service has made moves to more strongly adopt a robust version called the MQ-4 Triton.

A. HIGH-END UNMANNED AIRCRAFT (X-47A/B, UCLASS)

Since 1999, the Navy has continuously endeavored to develop, test, and procure a high-end, low observable, and strike-capable UAV for operations from an aircraft carrier. This effort started as a pitch in 1999 by DARPA to the Chief of Naval Operations for a Unmanned Combat Air Vehicle-Navy based on Boeing's nascent X-45.[578] The Unmanned Combat Air Vehicle-Navy has gone through several name changes as the program unfolded as joint ventures first with DARPA only, then the Air Force, and finally as a single-service project after 2006. Shortly after DARPA awarded Northrop a service-unique contract for a demonstrator vehicle in the year 2000, Northrop's air vehicle became known as the X-47A/B Pegasus, a name that has remained through 2015 despite the program management changes. The Navy ended the X-47B demonstration program in mid-2015 with only two air vehicles ever made.

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[578] Naval Studies Board, *Review of ONR's Uninhabited Combat Air Vehicles Program* (Washington, DC: National Academy Press, 2000), 29. Also, the Navy and DARPA regularly used two versions of the acronym for Naval Unmanned Combat Air Vehicle: UCAV-N and N-UCAV.

As the X-47 demonstrator program racked up successes in the late 2000s, the JROC and Navy launched a new UCAV effort known as UCLASS in 2011 in order to capitalize on previous experimental and demonstration efforts and to create a full-fledged operational platform. The JROC's initial capabilities development document captured requirements and the noted capability gap to conduct long-range reconnaissance and strike from carriers. By 2013, the Navy received proposals from four main contractors. Despite the initial findings and commitment by the Navy, the JROC, and the contractors, the UCLASS program managers have had a turbulent time deciding how to exactly proceed. Over time, the Navy all but stripped the UCLASS of any serious strike capabilities and eventually ended the program altogether a few years later. What remained of UCLASS fed the Navy's 2016 Carrier-Based Aerial Refueling System program; Boeing eventually won that competitive bid with its MQ-25 Stingray, triumphing over Northup Grumman's entry, which was based on their recently retired X-47B. Once again, as of the end of 2016, the Navy no longer had an active high-end UCAV development or procurement program. Efforts to develop a sea-based UCAV went back to DARPA exclusively.

1. X-47 Pegasus Program Overview

The Navy's UAV Executive Steering Group, created in 1998, released a long-range plan in that year that did not include serious UAV fielding options until the fiscal year 2015 to 2025 timeframe; therefore, the X-47 started not as a requirement-driven program, but a proposal from DARPA to the Chief of Naval Operations based on another service's experimental efforts—the Air Force's X-45—in order to develop an advance technology demonstrator for a carrier-based UCAV. The Chief at the time, Admiral Jay L. Johnson, accepted DARPA's proposal, focusing on a Navy-specific UCAV design for shipboard operations.[579] In June 2000, DARPA awarded Northrop Grumman a $2.3 million contract

[579] Naval Studies Board, *Review of ONR's Uninhabited Combat Air Vehicles Program,* 29.

to build upon the prototype the company had already funded on its own[580]; the phase IA development goal focused on an affordable Advanced Technology Demonstration aircraft capable of the suppression of enemy air defenses, strike, and surveillance while operating from a carrier. What resulted was a tailless, small fighter-sized stealth platform designed for kinetic strikes in protected airspace that the contractor called Pegasus, as shown in Figure 31.

Figure 31. Northrop Grumman X-47A Pegasus[581]

Following the completion of phase 1A in March 2001, which ended with a concept of operations and roll out of Northrop Grumman's diamond shaped Advanced Technology Demonstration mock-up, the contractor received a phase-1B contract from the DARPA/ Navy team worth $25 million. According to Dr. Tony Tether, the Director of DARPA in 2002, this first phase focused on "preliminary design, analysis, and technology risk

580 "Northrop Grumman X-47," *Unmanned Aerial Vehicle and Targets,* 227. According to pp Grumman, the company funded, designed, and built the Pegasus initially to show the promise of rapid prototyping and composite materials and fabrication for a stealthy, carrier-launched aircraft. "Northrop Grumman's X-47A Pegasus First Flight Achieves Milestone in Autonomous Control," Northrop Grumman, February 23, 2003, https://news.northropgrumman.com/news/releases/northrop-grumman-s-x-47a-pegasus-first-flight-achieves-milestone-in-autonomous-control.

581 Source: "X-47 Pegasus UCAV," Air Force Technology, accessed January 22, 2020, https://www.airforce-technology.com/projects/x47/. Note: photo taken June 2001.

reduction."[582] DARPA and the Navy awarded Northrop $10 million in March 2002 to start the phase-2A study, with the objective of developing a detailed design and fabrication of a flyable Unmanned Combat Air Vehicle-Navy air vehicle. Concurrently, the Navy officially designated the experimental aircraft the X-47A.[583] The second phase, conducted at China Lake, saw the first autonomous engine start and shut down, taxi, and on February 23, 2003, the first flight.[584]

Just prior to the successful flight of the X-47, the Office of the Secretary of Defense issued a directive to consolidate DARPA's two separate, service-centric programs, the X-45 and X-47, into a single program called the Joint-Unmanned Combat Air System; funding was adjusted accordingly with a target end date of September 2009. Secretary of Defense Donald Rumsfeld's office released the directive in a program decision memorandum dated December 31, 2002, seeking to gain efficiencies from the two programs while still supporting both services' needs.[585] Reminiscent of the Defense Airborne Reconnaissance Office days, the DOD sought to centralize aircraft development for two similar weapon systems under the continued leadership of DARPA. The consolidated requirements called for a combat radius of 1,500 nautical miles, a 4,500-pound payload, and the ability to loiter for two hours over a target 1,000 miles away.[586] In late 2005, the program reins transitioned from DARPA to the Joint Program Office at Wright-Patterson Air Force Base, Ohio, and the timeline for completion of the project was extended to December 2011.

Then, in an interesting move halfway through the Joint-Unmanned Combat Air System program, the 2006 quadrennial defense review singled out the joint program for

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582 *Testimony Submitted to the Subcommittee on Emerging Threats and Capabilities*, Senate Armed Services Committee (April 10, 2002), 5 (statement of Tony Tether, Director, Defense Advanced Research Projects Agency), http://www.darpa.mil/attachments/TestimonyArchived (April%2010%202002).pdf.

583 "Northrop Grumman X-47," Jane's by IHS Markit, December 4, 2018, https://janes.ihs.com/Janes/DisplayFile/JUAV9306.

584 Jane's, "Northrop Grumman X-47."

585 Jeremiah Gertler, *History of the Navy UCLASS Program Requirements: In Brief*, CRS Report No. R44131 (Washington, DC: Congressional Research Service, 2015), 2, https://www.everycrsreport.com/reports/R44131.html.

586 Jane's, "Northrop Grumman X-47."

termination.[587] The review report, instead, called for the Air Force to start work on a replacement bomber and the Navy was charged to "develop an unmanned longer-range carrier-based aircraft capable of being air-refueled to provide greater standoff capability, to expand payload and launch options, and to increase naval reach and persistence."[588] Essentially, the Navy was being told to continue its effort, developing even more robust capabilities. Thus, the X-47 became a true single-service effort, and the Navy formed the Navy Unmanned Combat Air System program; as a part of that umbrella program, the Navy began the Unmanned Combat Air System-Demonstrator to demonstrate the "technical feasibility of operating unmanned air combat systems from an aircraft carrier."[589] Contractually, the program was extended out through 2011 (and would be extended even further in the future).

On August 3, 2007, the USN selected and awarded Northrop Grumman a six-year contract worth $635.8 million to conduct the Unmanned Combat Air System-Demonstrator program.[590] Two years later in October 2009—and with the addition of over $30 million more—the first X-47B air vehicle rolled out in its final design at Northrop Grumman's Palmdale, California facility. The aircraft had a distinctive new design that strongly resembled the company's B-2 Spirit design for the USAF and with vastly improved capabilities over the previous Pegasus X-47A version (see Figure 32). Of note, the first air vehicle forwent its stealthy coating and some of its key mission systems in order to focus on carrier compatibility trials.[591] The high sub-sonic capable aircraft used a single Pratt & Whitney engine and retained its tailless, low observable planform to provide some stealth features. At just over thirty-eight feet long, the X-47B aircraft was roughly half the length of the F/A-18E/F Super Horner, while the wing width, at sixty-two feet, came in slightly wider that the Super Hornet (though when folded, the wings had the same width). The

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587 Office of the Secretary of the Department of Defense, *Quadrennial Defense Review Report*, 46.

588 Gertler, *History of the Navy UCLASS Program Requirements*, 3.

589 Gertler, 3.

590 "Northrop Grumman X-47," *Unmanned Aerial Vehicle and Targets*. Both Boeing's X-45 and Northrop Grumman's X-47B competed for the Unmanned Combat Air System-Demonstrator program, with the latter being selected.

591 "Northrop Grumman X-47," *Unmanned Aerial Vehicle and Targets*, 229.

vehicle could fly over 40,000 feet high, and met, or almost met, the original 4,500-pound payload requirement. The aircraft's systems and payload bays were designed to be able to carry an extremely wide variety of munitions from the U.S. inventory, and the sensor suite included an advanced active electronically scanned radar, signals intelligence and electro-optical/infrared packages, and even electronic attack.[592] Finally, the surface was an all-carbon composite manufactured by Scaled Composites, Inc., and the launch and recovery center could control up to four aircraft simultaneously. Overall guidance and control during the mission provided pre-programmed, automated, and limited autonomous options for flight management.

Figure 32. Northrop Grumman X-47B Pegasus[593]

Under the Navy's stewardship, the Unmanned Combat Air System-Demonstrator program and its two X-47B air vehicles repeatedly made aviation history through the end of the program. In fact, the aircraft's success propelled the program much longer than

[592] Rick Ludwig, "X-47, J-UCAS Overview," (PowerPoint presentation, San Diego, CA, October 2005), https://ndiastorage.blob.core.usgovcloudapi.net/ndia/2005/systems/thursday/ludwig.pdf. Rick Ludwig was Northrop Grumman's Director of Unmanned Systems Strategy and Development for the Joint Unmanned Combat Air System.

[593] Source: Sam La Grone, "Navy could test aerial refueling on X-47B in 2015," USNI News, last modified December 9, 2014, https://news.usni.org/2014/12/09/navy-test-aerial-refueling-x-47b-2015. Note: photo credited to Northrop Grumman.

originally envisioned, until it finally terminated in late 2015. The first X-47B first flew in February 2011, with the second air vehicle making its maiden flight in November of the same year. From that point on, the advances came quickly. In May 2012, the aircraft completed its first autonomous wave-off touch-and-go landing at Edwards Air Force Base, and a year later the first X-47 launched successfully by catapult onboard the USS *George H.W. Bush* aircraft carrier (landing at nearby Naval Air Station Patuxent River). Two months later, in July 2013, an X-47B accomplished its first arrested landing aboard the same ship, as shown in Figure 33. Soon after on another test flight, the vehicle sensed a malfunction in the navigation system and diverted to a nearby air base in Virginia. This event validated the X-47's autonomous safety logic. The pair of air vehicles then deployed to the USS *Theodore Roosevelt* in November 2013, this time performing "26 total touchdowns, 21 precise touch-and-goes, 5 arrested landings, and 5 catapult launches;"[594] five commanded and two autonomous wave-offs also occurred. In April 2014, the Unmanned Carrier Air System-Demonstrator team earned the National Aeronautic Association's prestigious 2013 Robert J. Collier Trophy for achievements in aeronautics, specifically for "developing and demonstrating the first unmanned, autonomous air system operating from an aircraft carrier."[595] Additional funding in 2014, in the amount of $63 million, gave Northrop the funding needed to move into post phase-2 demonstration activities that focused on integrating the Pegasus into carrier operations. In August 2014, an X-47B conducted carrier flight pattern maneuvers proving manned and unmanned aircraft operating simultaneously could keep the Navy's standard of a 90-second launch-and-recovery interval.[596] On April 22, 2015, the USN announced that the first-ever autonomous aerial refueling of a UAV occurred during a sortie, when the X-47B received fuel from a K-707 refueling aircraft; this event completed the test objectives for the Unmanned Combat Air System-Demonstrator demonstration program. In July 2015, the

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594 Jane's, "Northrop Grumman X-47."

595 "US Navy, Northrop Grumman and Industry Recognized for Outstanding Achievement in Aeronautics," Northrop Grumman, last modified April 10, 2014, https://news.northropgrumman.com/news/releases/photo-release-legendary-collier-trophy-awarded-to-x-47b-team.

596 Jane's, "Northrop Grumman X-47."

two X-47Bs were moved to storage for possible future endeavors, with the USN having invested more than $1.4 billion over the course of the entire program.[597]

Figure 33. The X-47B's First Landing on the USS *George H.W. Bush*[598]

2. UCLASS Program Overview

While the Unmanned Combat Air System-Demonstrator program continued, the USN wanted to turn the demonstration effort into an acquisition program by issuing a request for information in March 2010. On June 9, 2011, the JROC approved the UCLASS Initial Capabilities Document by issuing the JROCM 087–11 memorandum, which laid out the requirement for a persistent ISR and strike asset operating from a carrier.[599] Based on its initial requests to the JROC, the Navy desired an operational platform capable of operating in a highly-contested environment protected by anti-access/area denial coastal

[597] Gertler, *History of the Navy UCLASS Program Requirements*, 3.

[598] Source: "US Navy, Northrop Grumman and Industry Recognized for Outstanding Achievement in Aeronautics," Northrop Grumman, April 10, 2014, https://news.northropgrumman.com/news/releases/photo-release-legendary-collier-trophy-awarded-to-x-47b-team. Note: This photo by Alan Radecki captured the first-ever UAV autonomous landing onboard an aircraft carrier.

[599] "The Initial Capabilities Document replaced what had been called the Mission Need Statements" in earlier acquisition programming, "which provides the basis of a system's desired capabilities." Gertler, *History of the Navy UCLASS Program Requirements*, 4.

defense cruise missiles and integrated air defenses.[600] The Navy's acquisition strategy laid out a two-year requirements and preliminary design phase from 2011 to 2013 and broke the program into three key components: the air vehicle segment, the aircraft carrier segment, and the control segment. Defense contractors begun speculative internal aircraft design and development based on the Navy's request for information and the JROC's memorandum, despite no official kickoff of a competition.

Then, in December 2012, the JROC revised the UCLASS requirement in preparation for the fiscal year 2014 budget proposal.[601] Of all the changes, the most significant ones included modifications to the type of operating environment and primary mission of the UCLASS air vehicle. The JROC memorandum 086–12 and 196–12 now called for the aircraft to operate in a permissive airspace primarily focused on ISR collection.[602] Using the updated requirements issued by the JROC, the Chief of Naval Operations signed a UCLASS capabilities development document in April 2013, putting the program's acquisition on better strategic footing that before; subsequently, the Navy awarded four companies preliminary design review contracts at $15 million each in August 2013.[603] Initially, the Navy sought to select one of the designs at the Milestone A decision, which was initially scheduled for mid-2014.[604] Just prior to this decision point, the Navy released a classified draft of the UCLASS request for proposal on April 10, 2014, to the four competing contractors—Boeing, Lockheed Martin, General Atomics Aeronautical Systems, and Northrop Grumman. In July the same year--as the contractors begun modifying their design solutions—the JROC once again started a review of the UCLASS

[600] Government Accountability Office, *UNMANNED CARRIER-BASED AIRCRAFT SYSTEM: Navy Needs to Demonstrate Match between Its Requirements and Available Resources*, GAO-15-374 (Washington, DC: Government Accountability Office, 2015), 3, http://www.gao.gov/assets/680/860010.pdf.

[601] Gertler, *History of the Navy UCLASS Program Requirements*, 4.

[602] Dave Majumdar and Sam LaGrone, "UCLASS Timeline," U.S. Naval Institute News, April 29, 2014, https://news.usni.org/2014/04/29/uclass-timeline.

[603] Government Accountability Office, *UNMANNED CARRIER-BASED AIRCRAFT SYSTEM*, 3.

[604] Government Accountability Office, *DEFENSE ACQUISITIONS: Navy Strategy for Unmanned Carrier-Based Aircraft System Defers Key Oversight Mechanisms*, GAO-13-833 (Washington, DC: Government Accountability Office, September 2013), 7, https://www.gao.gov/assets/660/658236.pdf.

requirements partly because of Congressional criticism and because of questionable USN design and acquisition concepts. The final request for proposal was put on hold and "repeatedly delayed from the summer of 2014, to the spring of 2015, to the fall of 2015, and finally early 2016."[605] The Navy never conducted a Milestone A review nor awarded a UCLASS contract to a defense company to start the integration and demonstration phases of acquisition. Ongoing disagreements never resolved among Congress, the USN, and the DOD over threats, capability gaps, and how to integrate UCAVs into the carrier air wing, and in the fiscal year 2017 defense budget, Congress and the DOD eliminated all UCLASS funding, instead replacing it with funds to transition efforts to the Carrier Based Aerial Refueling System.

3. Innovation Perspectives and Factor Analysis

a. Rational Factors

The research pointed to a very limited role for the rationalism hypothesis in the episodes for the X-47 and its successor the UCLASS. First, the Navy's versions of the UCAV remained a system in search of a mission as opposed to a program in response to a threat or capability gap. For twenty years starting in the mid 1990s, the nation and U.S. Congress largely accepted a strategic view that "potential adversaries' air defense capabilities cannot…prevent U.S. air power from achieving military objectives;" furthermore, those adversary capabilities will increase only slightly through 2006.[606] When the Navy decided to start the X-47 in partnership with DARPA, there was no definitive capability gap or threat the Navy was trying to solve. During interviews, several senior naval leaders and aviators agreed on this perspective. Foremost was Vice Admiral Ann E. Rondeau who remarked in a January 22, 2020 interview with the author that the Navy did not really develop an overarching vision on how and why to integrate UAVs for anti-surface warfare; the tactics of the programs often made sense, but an operational- or strategic-level concept of operations remained elusive. On December 17, 2019, naval Captain Markus Gudmundsson candidly suggested in an interview with the author that

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605 Shipe, Turner, and Wickert, *Innovation Lost: The Tragedy of the UCLASS*, 11.

606 Government Accountability Office, *COMBAT AIR POWER: Joint Mission Assessments*, 9.

aviation equipment acquisitions in general—manned or unmanned—most often did *not* flow from a logical reaction to external threats. So, what drove the Chief of Naval Operations and DARPA in 1999 to start the program remains unclear other than it was not a response to a definitive threat but maybe an opportunity to create institutional synergy between the Air Force and the Navy toward a futurist, leap-ahead technology.

Furthermore, the assessed threat picture did not worsen for several more years; at least not in an appreciable way to drive navy UCAV outcomes. Not until 2008 (after the X-47 program transitioned to the Joint Combat Air System-Navy) did the director of national intelligence, James Clapper, declare China's military to have the capability and willingness to project force throughout the South China Sea and the Middle East. Later in 2012, he assessed that China's military capability goals had resulted in "impressive military might."[607] Clapper also characterized Russia's modernization movement as strong, albeit economically challenged, saying it would take over a decade for real change to occur. Bottom line, in the estimation of America's top intelligence officer, Russia's conventional military would remain defensive in nature and was not a threat anyone other than those nations immediately on Russian borders. In 2014, that assessment appeared mostly correct; however, the strength of Russian defensive anti-access/area denial assets caused NATO to rethink the defensive-only nature of Russia's strength given such assets could enable offensive action as well. So, between 2006 and 2014, adversary air defense capabilities and intent to use them remained contained to traditional regional hotspots; however, since then, those assumptions have come into question. The need for a capability to address anti-access/area denial problems became more acute, yet the X-47/UCLASS remained a demonstration asset with no future. Through 2015, rationalist perspectives do not seem to have swayed the Navy toward UCAV inventions worth adopting.

The X-45 and UCLASS programs also suffered changing requirements due to ambiguous concepts of operation and a myriad of technological challenges associated with carrier operations. First, under the Joint-Unmanned Combat Air System program, the X-

[607] James R. Clapper, *Unclassified Statement for the Record on the Worldwide Threat Assessment of the U.S. Intelligence Community for the Senate Select Committee on Intelligence*, January 31, 2012 (Washington, DC: U.S. Congress, 2012), 13.

47 requirements grew to mandate a larger airframe to extend range, payload, and capability. Later, as the UCLASS program of record took over from the X-47 demonstrator, the Navy initially envisioned the UCLASS vehicle to operate in a *non-contested* environment, and planned to add technological capability for *non-permissive* missions in the future for anti-access/area denial environments.[608] In a December 16, 2019, interview, Navy Captain Edward McCabe, the air warfare chair at the Naval Postgraduate School and P-3 aviator, commented that throughout the naval requirements planning apparatus, there was little focus on building a high-end force structure—especially not one that looked like a revolution as opposed to evolution of carrier air power. In fact, the JROC accepted the Navy's change of program to a spiral development approach in 2015, and Congress generally supported that decision.

In 2005, the status of technology maturity for the Joint-Unmanned Combat Air System appeared on track for a low level of risk, with six critical technologies projected to be sufficiently ready by the target production date of FY 2010, according to a GAO report on weapons systems status.[609] The GAO report further assessed, based on program manager inputs, that the targeting and autonomous operations technologies were the most mature, but carrier operations technology and the common operating system needed significant improvement. Another highlighted applied science problem was the reliable availability of bandwidth for communication nodes and datalinks.[610] Low bandwidth capacity limited in the number of simultaneously airborne UAVs that could share command and control information [611]; furthermore, the GAO, in April 2006, deemed the

608 Shipe, Turner, and Wickert, *Innovation Lost: The Tragedy of the UCLASS*, 10.

609 Government Accountability Office, *DEFENSE ACQUISTION: Assessment of Selected Major Weapons Programs*, GAO-05-301 (Washington, DC: Government Accountability Office, 2005), 88. Those six critical technologies were geared towards operating in a contested environment with persistence: signature reduction; advanced targeting; secure robust communications; force integration, interoperability, and information integration; adaptive autonomous operations; and, operations in carrier-controlled airspace.

610 The DOD pursued an effort known as the Global Information Grid in 2004 to build a new information system like the internet for sharing threat data and employing effects. The DOD spent nearly $21 billion on this effort by 2010. Government Accountability Office, Highlights page to *DEFENSE ACQUISTIONS: The Global Information Grid and Challenges Facing Its Implementation*, GAO-04-858, July 2004 (Washington, DC: Government Accountability Office, 2004), https://www.gao.gov/assets/250/243640.pdf.

611 Office of the Secretary of Defense, *Unmanned Aircraft Systems, 2005–2030*, 49–50.

cost to increase bandwidth options as significant since the defense department had "not established standards requiring unmanned aircraft or sensor payloads to be reprogrammable from one band to another."[612] One problem with the GAO's critical assessment is that most of the UAVs up to this time, except for the Joint-Unmanned Combat Air System, had started as ACTDs (which the GAO generally praised) and the services had very limited input to how the ACTDs took shape. Part of why the services objected to ACTDs was that they had to establish standards for the ACTD vehicle in retrospect to make it operationally worthy of some mission. Retrofitting system requirements in a platform already established in size, shape, and components (as well as usually with a fixed budget cost) made ACTDs challenging to alter.[613] The DOD designed ACTDs to provide mature technology to the warfighter, both relatively cheaply and without requiring major alterations that would drive up costs. While the technology was somewhat mature for the X-47 and the UCLASS in basic requirements, it took a lot of effort and funds to get the most challenging technological aspects correct for carrier operations. The X-47 program succeeded in overcoming carrier operational deficiencies, which led to major recognition by the DOD and industry, but other factors had a greater influence on outcomes: a lack of consensus over operational threat leaving other innovation factors to weigh heavily on the Navy's high-end UAV episodes.

b. Institutional Factors

Starting in the mid 1990s, the Navy committed to the proven and evolutionary F/A-18E/F Super Hornet, characterized as an improved fourth-generation aircraft like its Air Force F-15 and F-16 counterparts. As the centerpiece of naval aviation and power projection, the Super Hornet's acquisition plans influenced all other aircraft programs for decades to include the plan to complement it with the advanced high-end Joint Strike Fighter. In 1996, the Navy had planned for an $81 billion investment to procure 1,000 Super Hornets, on top of a yet to be approved Air Force-Navy combined purchase of around

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612 Pickup and Sullivan, *UNMANNED AERIAL SYSTEMS*, 10.

613 Fahlstrom and Gleason, *Introduction to UAV Systems*. This assessment is the general gist of Gahlstrom and Gleason's book.

2,900 F-35 Joint Strike Fighters; F-35 costs to the Navy would be even more than for F-18s.[614] Ten years later, between 2007 and 2008, Gates incentivized overhead savings for the services, but directed how the services could use the savings: for the Navy that was "additional ships, F/A-18s, and unmanned strike and surveillance aircraft."[615] Gates attempted to drive the Navy towards UAVs, though the Navy had internally set its institutional preference and budgetary process to acquire manned platforms. Captain McCabe corroborated this view, highlighting that the vast preponderance of aviation funding in the DOD goes to the F-22 and F-35; anything else, to include UAVs, are niche programs, at least from a budgetary perspective. For reference, as of September 2004, the Navy had spent $4.04 billion on X-47 RDT&E, with a projected additional $3.7 billion through 2009 (which was a loss of over $1.1 billion in planned funds due to DOD restructuring and budget changes).[616] By the time the X-47 and UCLASS ceased to exist in Navy budgeting and acquisition programmatic processes around 2016, the Navy had spent several billions of dollars over sixteen years of experimentation and demonstrations. Compared to the Super Hornet, F-22 Raptor, and Joint Strike Fighter budgets, the amount spent on UCAVs in general pales in comparison. Navy commander and permanent military professor of acquisitions, Dr. Katy Giles, agreed, noting that when it comes to technology experimentation and RDT&E, budget issues dominate the decision landscape making it difficult to introduce new technology or platforms because of unknown safety records. Therefore, the institution is incentivized to pursue small programmatic successes even for favored programs to ensure credibility at the tactical level of leadership. The Navy institutionally pursued the UCAV concept longer than the Air Force but ended with the same result—no innovative adoption.

The USN did not adopt the high-end UCAV capability because stakeholders argued over the program's direction and the X-47/UCLASS competed directly for manned fighter

[614] Government Accountability Office, *COMBAT AIR POWER: Joint Mission Assessments*, 10.

[615] Gates, *Duty*, 464.

[616] Government Accountability Office, *DEFENSE ACQUISITION*, 88. These figures do not include the nearly $500 million on service-specific projects prior to the merger of the X-45 and X-47 programs.

procurement plans,[617] all during an era of unstable federal budgets and sequestration battles. Multiple senior aviators and naval leaders raised, during author interviews, interesting budgetary and institutional concerns that also contributed to the lack of enthusiasm, or at least challenges, for the UCLASS. The carrier has precious little space to devote to unique aircraft spares, maintenance systems knowledge, storage, and skill sets associated with aircraft. The more commonality across platforms, the better the carrier can maintain independent operations even in a combat or other degraded environment. The introduction of UCAVs adds significant burden to a carrier now operating F/A-18E/F Super Hornets, F-35s, E-2s, helicopters, and more. The UCLASS would have to bring something very special, something very powerful in closing a clear capability gap to justify its inclusion, while at the same time, choosing what capability—what aircraft—would be offloaded to make room for the UAV.

Support alignment among the key stakeholders—both intra- and inter-institutional—never coalesced, dooming the UCLASS to rejection despite almost two decades of effort beginning with the X-47 UCAV program. The battle began early with the X-47/Joint-Unmanned Combat Air System. With a push for more joint synergy, Congress punished the fledgling Joint-Unmanned Combat Air System program in 2005, reducing funding over concerns that the program "had not properly coordinated with the two services" concerning the integration of both services' requirements.[618] As the Navy began its transition to the UCLASS program for its high-end carrier-based UCAV, an ideological struggle for the institution's power projection needs split between ISR-centric versus penetrating strike views. This contest had stakeholders on both sides of the divide, within and across multiple institutions. In favor of a more affordable, quicker timeline focused on ISR capabilities—with *limited* strike capability—in a permissive environment were Admiral James Winnefeld, vice-chairman of the Joint Chiefs of Staff and JROC chair; Mr. Sean Stackley, assistant secretary of the Navy for research, development, and acquisitions;

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617 Dave Majumdar and Sam LaGrone, "UCLASS Requirements Shifted to Preserve Navy's Next Generation Fighter," USNI News, last modified July 31, 2014, http://news.usni.org/2014/07/31/uclass-shifted-preserve-navys-next-generation-fighter.

618 Government Accountability Office, *DEFENSE ACQUISITION*, 88.

Rear Admiral Mat Winter, the Program Element Office director for Unmanned Aviation and Strike Weapons and, the Navy staff's N98 aviation requirements and N2 intelligence/information dominance branches.[619] On the side that supported the more robust strike UCAV capability designed for a non-permissive environment were congressional leaders in the armed services committees, particularly John McCain and Randy Forbes; the naval secretary Ray Mabus and Chief of Naval Operations Admiral Jon Greenert; academics such as Thomas Ehrhard and others on the National Defense Panel; and key Pentagon leadership to include the undersecretaries of defense for policy, for intelligence, and the deputy defense secretary Robert Work.[620]

In 2013, the JROC set an aggressive timeline for initial operations capability, wanting to field twenty-four UCLASS vehicles by 2020. To meet that objective, the institution would be forced toward a less-capable, ISR-focused UCLASS design. Supportive Navy stakeholders worked to sway Congress to the JROC's positions. Having learned the lesson from the X-47 program to garner early congressional support, naval leadership delayed the release of the UCLASS's request for proposal. The postponement totaled over twenty months in 2013 and 2014 as the Navy attempted to "solidify Congressional [sic] support behind the Navy's less capable UCLASS design."[621] That support did not materialize according to Richard Shipe of the National Defense University.[622] For example, Senator John McCain sent a March 24, 2015, letter to Secretary of Defense Ashton Carter, stating that McCain "strongly believe [s] that the Navy's first operational unmanned combat aircraft must be capable of performing a broad range of missions in contested environments as part of the carrier air wing, including

619 Majumdar and LaGrone, "UCLASS Requirements Shifted to Preserve Navy's Next Generation Fighter."; Dave Majumdar, "US Navy Grapples with Different UCLASS Philosophies," FightGlobal, last modified September 29, 2013, https://www.flightglobal.com/civil-usavs/us-navy-grapples-with-different-uclass-philosophies/111219.article.

620 Majumdar and LaGrone, "UCLASS Requirements Shifted to Preserve Navy's Next Generation Fighter."; Majumdar, "US Navy Grapples with Different UCLASS Philosophies." Ehrhards support shines in the co-authored monograph with Bob Work cited earlier: Ehrhard and Work, *Range, Persistence, Stealth and Networking: A Case for a Carrier-Based Unmanned Combat Air System*.

621 Shipe, Turner, and Wickert, *Innovation Lost: The Tragedy of the UCLASS*, 11.

622 Shipe, Turner, and Wickert.

precision strike as well as intelligence, surveillance and reconnaissance."[623] Depending on the camp, tradeoffs in design could not support both goals, namely that a design focused on endurance ISR support to the carrier would preclude survivability aspects in contested airspace as well as limited weapons payload capacity. Many of these argument stem from the lack of consensus regarding the operational and strategic environment discussed under the rationalism factors above. Unsuccessful in changing the Navy's course, Congress utilized its oversight tools at that point attempting to drive the USN to pursue a UCLASS designed for to strike in a high-end, non-permissive environment. Congress even doubled the UCLASS's budget in the 2016 National Defense Authorization Act as incentive to do so. One year later, with key proponents still pushing a less-capable aircraft, Congress and the Navy abandoned the UCLASS in favor of a solution that both stakeholders seemed to support: an unmanned refueling UAV.[624]

Finally, the pendulum swings between more and less program centralization did not foster a favorable environment for the X-47/UCLASS. Between 2004 and 2006, the centralized Joint-Unmanned Combat Air System office tried to reconcile differing service needs into a joint platform, once again forcing the design requirements of two different services into a single platform. The solutions resulted in unfavorable compromises and added expenses to accommodate both competing needs: for the USAF, the priority was suppression and attack of enemy air defenses and for the USN, the priority was for carrier-based UAV that could provide persistent armed surveillance. The hope of synergizing these efforts to achieve cost savings through interoperability and common sensors, weapons, and subsystems[625] set up several issues leading to both services' growing frustrations with the status of the program by 2005. It appears both the Air Force and the Navy welcomed the

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[623] John McCain, letter to Secretary of Defense Ashton Carter, March 24, 2015. "Document: McCain Letter to SECDEF Carter on UCLASS," USNI News, last modified March 24, 2015, https://news.usni.org/2015/03/24/document-mccain-letter-to-secdef-carter-on-uclass. Representative Randy Forbes wrote similar language in a letter to the Chief of Naval Operations, arguing that "UCLASS must include a requirement for aerial refueling, survivability, lethality and payload to have enduring utility in tomorrow's threat environment. Dave Majumdar, "Forbes Writes in Support of a High End UCLASS," USNI News, last modified February 19, 2014, https://news.usni.org/2014/02/19/forbes-writes-support-high-end-uclass.

[624] Shipe, Turner, and Wickert, *Innovation Lost: The Tragedy of the UCLASS*, 10–12.

[625] Government Accountability Office, *DEFENSE ACQUISITION*, 88.

Defense Secretary's 2006 direction for the Air Force to end its Joint-Unmanned Combat Air System participation and liberation for the Navy to pursue the X-47 as a pure demonstration platform with its goal of solving the toughest technical challenges: carrier operations on and around the ship in tandem with other aircraft. Once committed to that more limited goal as a single-service program, the X-47 achieved significant milestones as an RDT&E project.

c. Organizational Culture Factors

Unlike the Air Force, the Navy's organizational culture stems from two dominant subgroups, both of which impacted the outcome of high-end UAV adoption: surface warfare officers and naval aviators. This lends itself to an interesting dynamic that does not fit neatly into the dominant subgroup perspective of the organizational culture hypothesis. Instead, the overarching organizational culture must also be considered when analyzing cultural impacts upon innovation, and culture had a significant effect on X-47/UCLASS adoption outcomes.

Surface warfare officers, according to Giles, present a hybrid of cultural opinions regarding UAV missions and requirements, but if an asset can be shown to bolster anti-surface and sub-surface warfare, then the ship-driver community will tend to favor innovations toward that end. Navy UAV adoption aboard carriers calls into question the future utility of aircraft carriers, with naval officers taking staunchly opposite points of view. Some see the carrier's future credibility tied to the UAV, while others see only an ancillary role at best given then cultural issues at work. This study agrees with Richard Shipe, Monte Turner, and Douglas Wickert's suggestion that the Navy's identity crisis was beginning in the mid-2000s as it faced questions about its aircraft carrier viability in the midst of growing anti-access/area denial threats and so "likely had more motivation to take up the charge" to develop the Joint-Unmanned Combat Air System as a long-range means to deal with high-threat, mobile anti-access/area denial systems.[626]

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[626] Shipe, Turner, and Wickert, *Innovation Lost: The Tragedy of the UCLASS,* 26.

As for the naval flying community, two of three senior naval aviators and two younger career aviators all stressed the strong impact that culture had on UAV outcomes. Captain McCabe characterized the naval aviator subgroup as having fought the X-47 and UCLASS procurement until it went away. This started early on with the X-47, which became the Joint-Unmanned Combat Air System after 2006. An anonymous senior Navy official revealed to defense reporters that it is common for naval aviation personnel working on the Joint-Unmanned Combat Air System to purposefully mangle its acronym name to 'jackass'.[627] But more than nomenclature, pilot culture in the Navy revolves around the mythos and grading of carrier landings, according to Captain Gudmundsson. For naval aviators, your grades for landing on a ship—which are marked every time—become a point of pride and identity as prowess for accomplishing one of the most difficult things for a human to do. If UAVs show an autonomous capability to land on ships, this would directly threaten this ethos and call into question the special nature of the naval aviator community. Gudmundsson further explained that a sort of groupthink set into the community in this regard.

The one counter to this perspective was offered by Captain and former carrier air wing commander Michael "Norm" Wallace in an author interview on March 1, 2020. Wallace felt strongly that fighter pilots and the general aviation community were not adamantly or emotionally opposed to the X-47 and UCLASS. Instead, he suggested that a utilitarian mindset at the tactical level drove attitudes and assessments. In his experience, neither UCAV offered a compelling epiphany that the UAV was absolutely needed because of a certain capability; furthermore, aviators found the technology exciting, but a vision and concept of operations was missing. Wallace was quick to agree that naval aviators would welcome an asset that could off-load high-risk tasks such as engaging anti-access/ area denial threats directly or other task-shedding support. One example of the carrier air wings being fully vested in integrating with UAVs occurred over Afghanistan and Iraq. When the capability for Air Force MQ-1 and MQ-9 sensors and video to feed directly into the cockpit of F/A-18s became available, the air wing was fully supportive and welcomed

[627] Erwin, "Unmanned Combat Aircraft Still in 'Adolescent Phase'."

the combination. Finally, with thirty-eight years of active duty naval service, a background qualification as a surface warfare officer, and multiple tours in the joint community, Vice Admiral Rondeau that the Navy, as well as the Air Force, strongly favors manned aircraft approaches as a culture and generally lacks a belief that UAVs will take over aircraft mission tasks.

B. MEDIUM-END UNMANNED AIRCRAFT (R/MQ-8, R/MQ-4)

These two aircraft, while vastly different in design, represent the Navy's foray to adopt medium-end UAVs. The first, the R/MQ-8 Fire Scout, owes its roots to a predecessor vertical-takeoff and landing platform from the 1950s era. The Navy saw the Fire Scout as a natural follow on to the medium-end Pioneer UAV that served the Navy's ISR missions since the mid 1980s. There is great appeal in the vertical-takeoff and landing design when it comes to landing on a moving ship deck, plus there is no special equipment the ship needs like netting to recover the UAV; this reduces weight and storage needs on already cramped ships. There is little wonder the Navy returned to a helicopter, vertical-takeoff and landing platform after decades without it. The second, the RQ-4 BAMS and MQ-4 Triton, are modifications to the successful Air Force RQ-4 Global Hawk UAV initiated in the late 1990s. The RQ-4 represented a proven capability with a stable cost profile and held promise to supplement or replace the Navy's aging P-3 Orion ISR aircraft. The BAMS and Triton models are land-based aircraft, never intended for ship-borne take offs or landings. These UAVs do not incorporate any advanced aircraft design, nor require stealth or intricate autonomy beyond what was mature at the time. Both UAVs utilize solid and proven platforms respectively: a helicopter and the large, glide-body design of the Global Hawk/U-2.

1. The MQ-8 Fire Scout Program Overview

The MQ-8 Fire Scout is not the first UAV based on a rotary-wing platform, having conceptual and operational roots going back to the Navy's much earlier adoption of the Gyrodyne QH-50 Drone Anti-submarine Helicopter,[628] shown in Figure 34. Gyrodyne

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[628] Operators often referred to this UAV simply as the DASH.

developed the simple-looking aircraft in the late 1950s, and the Navy employed the QH-50 on-board the USS *Buck* in January 1963 to conduct antisubmarine warfare operations; the QH-50 carried its own on-board sensors and torpedoes to prosecute submarines beyond the organic sensors of destroyers, while being controlled from a console aboard the ship.[629] The Drone Anti-submarine Helicopter provided destroyers with their first beyond the horizon real-time video surveillance capability, extending battlespace awareness. According to historian Laurence Newsome, the Navy built a total of seven-hundred-and-eighty-six QH-50s, losing about half that number employed during the Vietnam War; furthermore, the Navy terminated the QH-50 program by 1971 when concerns grew that the UAV presented competition and a threat to the emerging manned antisubmarine helicopter. Still, the QH-50 set important UAV milestones, was an automated UCAV, and set many notable firsts[630]:

- The first rotary wing UAV produced
- The first UAV to take off and land back aboard a vessel at sea
- The first hunter-killer UAV, employing sonobouys and torpedoes from the same platform)

[629] Newsome, *Unmanned Aviation*, 87.

[630] Newsome, 88. The list is produced, and modified, from Newsome's list.

Figure 34. Gyrodyne QH-50D, with Two Torpedoes[631]

From these foundational firsts, the MQ-8 Fire Scout is a return to the QH-50 legacy, with similarities in size but also newly added autonomous capabilities. Why the Navy took so long to re-adopt a proven system is part of the puzzle explored in this study.[632] Today, the Navy is finding renewed success, albeit slowly, with the Fire Scout program. Begun as a company-funded prototype in 1999, Northrop Grumman fielded two RQ-8A Fire Scout vertical-takeoff and landing aircraft based on the Schweitzer 330 helicopter, one manned and one unmanned. The Navy, in its search for a replacement to the aging and limited RQ-2 Pioneer, developed requirements to shift to a vertical-takeoff and landing capability, particularly on board destroyers and cruisers, but also on carriers to save space.[633] Interested in Northrop Grumman's prototype, which showcased autonomous, GPS-guided flight by January 2000, the Navy conducted a competition among three bidders, ultimately selecting Northrop Grumman.

631 Source: Bill Giovino, "Look! Up in the Sky! It's an Autonomous Vehicle!" last modified April 25, 2018, https://microcontroller.com/news/military_autonomous_vehicles.asp.

632 Instead in the past, the Navy adopted manned antisubmarine helicopters—and the RQ-2 Pioneer UAV in later years.

633 Sandra I. Erwin, "Navy Poised to Select New Combat Drone," National Defense, last modified December 1, 1999, https://www.nationaldefensemagazine.org/articles/1999/11/30/1999december-navy-poised-to-select-new-combat-drone.

Despite a fast issuance of the initial contract of the UAV Group 4 system, the Fire Scout program has ebbed and flowed based on technical issues and varying leadership and budgetary decisions that resulted in a more drawn-out acquisition phase than originally envisioned. The February 2000 contract, costing $93 million covered initial development of two air vehicles in a planned forty-two month engineering and manufacturing Development phase of the program, to be completed by December 2003.[634] In November 2000, the first prototype vehicle crashed due to a faulty radar altimeter, but by September 2001, Northrop Grumman delivered the first engineering, manufacturing, and development phase's Fire Scout. Despite this progress, the Navy did two things in 2001 that countered each other. It approved a low-rate initial production of three air vehicles and two ground-control stations intended for the Marine Corps, and at the end of that year, the Navy drastically cut the RDT&E budget for the 2003 POM to almost zero, electing to not aggressively pursue development and acquisition at the time. From 2003 through 2005, aspirations of acquiring up to 162 Fire Scout vehicles for the Navy and Marine Corps waned, and according to National Defense magazine reporter Frank Colucci, the Navy and Marines in mid 2004 were "no longer committed to full production," which resulted in RQ-2 Pioneer inventory and operations extension through fall 2008.[635] After an initial investment of $166.3 million from 2000 through 2002, the budget for Fire Scout RDT&E dropped to $39 million and $36 million in 2003 and 2004 respectively; at the same time, Northrop Grumman modified, in collaboration with the Schweizer helicopter company, the Fire Scout to generate a new rotor configuration (from 3 rotors to 4) and increased the vehicles payload capacity, speed, range, altitude, and endurance; the new designator for the aircraft became the RQ-B. Based on this, the Army, in late 2003, selected the modified RQ-8B for its own future force designs, and by 2005, the Navy recommitted to the Fire Scout, awarding the defense contractor another $28 million to continue engineering, manufacturing, and development evaluation, build control stations, and conduct ship-board

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634 "Northrop Grumman RQ-8A and MQ-8B Fire Scout," Jane's by IHS Markit, January 9, 2017, https://janes.ihs.com/Janes/DisplayFile/JUAV9179.

635 Frank Colucci, "Schoolhouses for UAV Pilots Up and Running," National Defense, May 1, 2004; https://www.nationaldefensemagazine.org/Articles/2004/5/1/2004May%20Schoolhouses%20for%20UAV%20Pilots%20Up%20and%20Running.

testing.[636] In 2005, the RQ-8B was re-designated the MQ-8 based on its evolving requirements and capabilities beyond surveillance and reconnaissance mission designs. The UAV has progressed in autonomy, with the ability to conduct takeoffs, landings, and flight.

The concept of employment for the Navy's MQ-8B system on board Littoral Combat Ships consists of three air vehicles and two tactical control stations, to enable at least a twelve-hour mission on-station time utilizing all three aircraft. The air vehicle, shown in Figure 35, has an overall length of almost twenty-three feet, a rotor span of 27.5 feet, and a payload capacity of six-hundred pounds. The designed flight characteristics include a 20,000-foot ceiling, a one-hundred-fifty nautical-mile radius with a maximum payload, and an endurance of over five hours depending on loadout and mission; its cruise speed is eighty knots. Its sensors include electro-optical and infrared imaging, a laser designator, plus a multi-mode radar. Weaponized first during testing in 2005, the MQ-8 has evolved to carry unguided and laser-guided rockets as well as the Advanced Precision Kill Weapon system, a small missile intended for personnel and other high-value targets. Overall, the system has a significant payload advantage compared to the Pioneer that it is intended to replace, but for now does not possess a much larger endurance and flight radius capability.

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[636] Jane's, "Northrop Grumman RQ-8A and MQ-8B Fire Scout."

Figure 35. Northrop Grumman MQ-8B Fire Scout[637]

The program has slowly progressed since 2005, reaching the low-rate initial production decision in 2009, and costing a total of $3.06 billion dollars in research, procurement, and operations (part of that money is U.S. Army RDT&E).[638] Originally desiring one-hundred-sixty-eight vehicles, the Navy cut that number to one-hundred-thirty-one by 2008,[639] and finally settled on a mixed purchase of 96 MQ-8Bs and its forthcoming upgrade version, the MQ-8C. As of 2014, the Navy procured 32 MQ-8s (22 operational),[640] and ceased further orders in 2013. The MQ-8's biggest shortcomings include its limited flight time/radius and its loud noise signature, and the Navy ended procurement in 2012, stopping at twenty six. In 2013, the Navy felt the MQ-8 was still too limited in its range to meet current special operations needs and future ship needs, so Northrop Grumman proposed to start an upgrade program that included a larger, previously manned platform, the Bell 407. Using 90 percent of the same software but having twice

[637] Source: U.S. Navy, (presentation, Navy Information Dominance Industry Day, June 22, 2010), https://www.afcea.org/mission/intel/documents/IndustryDay-Kraft.pdf.

[638] Government Accountability Office, *DEFENSE ACQUISTIONS: Assessments of Selected Weapons Programs*, GAO-15-324SP (Washington, DC: Government Accountability Office, March 2015), 125, http://www.gao.gov/assets/670/668986.pdf.

[639] Office of the Secretary of Defense, *Unmanned Systems, FY2009–2034*, 66.

[640] Dan Gettinger, *The Drone Handbook*, 218.

the flight radius and three times the payload, the Navy designated the future version the MQ-8C, and flight testing started in October that same year.

Operationally, the MQ-8B has proven somewhat useful since 2009 in both land-based and ship-based environments. In 2009, three MQ-9s were sent to Afghanistan to fill an urgent needs request for Navy SEALs and later operationally deployed for the first time on the USS *McInernery*, a frigate. The next year, a Fire Scout successfully intercepted an illicit drug smuggler boat in the Pacific Ocean. In 2011, the Marine Corp employed Fire Scouts over Libya during Operation Unified Protector, losing one to enemy ground fire. In 2012, two separate incidents resulted in a critical malfunction and a forced crash, causing the Navy to set limits on the Fire Scout's employment.[641] The MQ-8 is flown by members of the composite MQ-8/MH-60 community and fielded by Helicopter Maritime Strike and Helicopter Sea Combat squadrons.[642] In November 2014, an MQ-8 and MH-60 deployed together on the Littoral Combat Ship USS *Fort Worth*, the first composite deployment for the Navy. Based on the *Naval Aviation Vision* endorsed by the Navy's Commander of Naval Aviation in 2015, the MQ-8B will continue support to Littoral Combat Ships until the MQ-C can join the LCS mission sometime in 2019 or 2020.

2. The RQ-4A BAMS and MQ-4C Triton Overview

The RQ-4 Broad Area Maritime Surveillance (BAMS) is a derivative of Northrop Grumman's RQ-4B Global Hawk, built for the Air Force as a Group 5 UAV. Looking for its own organic, high-altitude, long-endurance ISR platform to augment the maritime patrol mission, the Navy awarded Northrop Grumman an initial half-million dollar contract in 2000 to design a maritime version of the RQ-4A, with the intent to operate as an adjunct to the P/EP-3 Orion patrol aircraft; the Navy referred to this early effort as the Global Hawk Maritime Demonstration, which later morphed to the BAMS-Demonstrator. Northrop unveiled the prototype in 2002, and the Navy committed funds in Fiscal Year 2003 for two

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[641] Dan Parsons, "Navy's Fire Scout Fleet Not Grounded, Only Curtailed," National Defense, last modified April 17, 2012, https://www.nationaldefensemagazine.org/Articles/2012/4/12/Navys%20Fire%20Scout%20Fleet%20%20Not%20Grounded%20Only%20Curtailed.

[642] Naval Aviation Enterprise, *Naval Aviation Vision: 2016–2025* (Patuxent River, MD: Naval Air Systems Command, 2016), 63, https://www.navy.mil/strategic/Naval_Aviation_Vision.pdf.

RQ-4A Block 10 systems as part of the second low-rate initial production lot in conjunction with Air Force buys. Northrop delivered the two demonstrator models in 2005, which the Navy tested during Exercise Trident Warrior in November of that same year. Further participation in exercises throughout 2006 showcased the BAMS ability to expand maritime interdiction operations and wide area surveillance to find ships at sea.[643]

The BAMS system consists of two air vehicles, based on the RQ-4A Block 10, a Mission Control Element, two launch and recovery elements, plus one Tactical Auxiliary Ground Station.[644] Except for the same external shape and size, Navy requirements dictated different sensor, subsystems, and ground stations that the Air Force's Global Hawk program.[645] The BAMS air vehicle remained a large aircraft with a length of forty-four feet, a height of just over fifteen feet, and a massive wingspan of one-hundred-sixteen feet (see Figure 36). Flight characteristics are the same as covered under the Air Force Global Hawk section. Since 2003, the Navy procured only a total of four BAMS-Demonstrator air vehicles.[646] Until the pivot and decision to commit to the BAMS follow-on MQ-4C, this study characterizes the BAMS/Triton episode as a very weak adoption outcome.

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643 "Northrop Grumman RQ-4 Global Hawk," Jane's by IHS Markit, August 9, 2019, 15–16.

644 "BAMS-D," Naval Air Systems Command, accessed April 2, 2020, https://www.navair.navy.mil/products/BAMS-D.

645 Michael J. Sullivan, *Testimony, DEFENSE ACQUISTIONS DoD Could Achieve Greater Commonality and Efficiencies Among Its Unmanned Aircraft Systems*, GAO-10-508T (Washington, DC: Government Accountability Office, 2010), 8, https://www.gao.gov/assets/130/124311.pdf. Note: Testimony was before the Subcommittee on National Security and Foreign Affairs, Committee on Oversight and Government Reform, U.S. House of Representatives, on March 23, 2010.

646 Naval Air Systems Command, "BAMS-D."

Figure 36. Northrop Grumman RQ-4A BAMS-Demonstrator[647]

From deployed testing to operations, the BAMS-Demonstrator relentlessly supported combatant commanders around the globe. The demonstrator conducted its first operational trials as part of 5th Fleet in the Middle East since 2009, providing “high-resolution tactical imagery in support of combat operations.”[648] The BAMS-Demonstrator flew in support of exercises in the Pacific theater starting in 2008, to test its capabilities and integration concepts, with the launch and recovery element in California and mission control at Patuxent River, Maryland. When natural disasters struck the United States that same year—wildfires in California and Hurricane Ike in the Gulf coast—BAMS supported with sensor imagery to assess the landscapes. In December 2008, the Secretary of Defense ordered BAMS-Demonstrator to support Fifth Fleet in the Middle East, where the RQ-4A remained for several years in support of maritime patrol activities in the Persian Gulf. Of note, Iran shot down an RQ-4A BAMS-Demonstrator in June 2019 in the Gulf of Oman.

[647] Source: Stefano D’Urso, “US Navy RQ-4A Surveillance Drone Damaged During Takeoff in the Middle East,” The Aviationist, last updated December 14, 2019, https://theaviationist.com/2019/12/14/u-s-navy-rq-4a-bams-d-surveillance-drone-damaged-during-takeoff-in-the-middle-east/. Note: Photo by Erik Hildebrandt for NAVAIR. The photo captures the RQ-4 BAMS-Demonstrator taking off over Patuxent River, MD in 2013.

[648] Naval Aviation Enterprise, *Naval Aviation Vision: 2016–2025*, 70.

Lessons from the RQ-4A BAMS-Demonstrator contributed to the Triton's development, and while it still looks like the RQ-4B Global Hawk, the Navy contends it is an "entirely different aircraft because it is engineered to operate in the maritime environment."[649] According to Jane's, in April 2008, the USN selected the Block 40 version of the RQ-4B as its future BAMS aircraft, in a planned $1.2 billion systems development and demonstration program that set a target date of summer 2013 to achieve initial operational capability. The aircraft now has a one-hundred-thirty foot wingspan and is slightly longer and taller than the RQ-4A version. Its service ceiling remained in the 60,000 foot or greater range. The Navy intended to use the Triton version of BAMS, seen in Figure 37, for "persistent ISR on a global scale where no other naval forces are present" and to base the system at five different locations: Hawaii, Diego Garcia, Florida, Japan, and Italy.[650] From these main and forward operating locations, five-to-six BAMS per site could provide twenty-four hour coverage of areas up to 2,000 nautical miles from the base. Seeking efficiencies with the Air Force's Global Hawk development and training, the DOD's *2011 Unmanned Systems Integrated Roadmap* reported that the USAF and USN service chiefs signed a memorandum of agreement in July 2010, to "increase transparency between systems and a common work environment for both USAF and Navy operators."[651]

[649] Sandra I. Erwin, "Triton Will Test Navy's Commitment to Drones," National Defense, last modified April 6, 2013, https://www.nationaldefensemagazine.org/articles/2013/4/6/triton-will-test-navys-commitment-to-drones.

[650] Jane's, "Northrop Grumman RQ-4 Global Hawk, 8.

[651] Office of the Secretary of Defense, *Unmanned Systems Integration Roadmap, 2011–2036*, 73; Erwin, "Triton Will Test Navy's Commitment to Drones."

Figure 37. Northrop Grumman MQ-4C Triton[652]

Still, Northrop and the Navy did not achieve the initial operational capability in 2013, and instead, the developmental aircraft achieved its first flight that year as it moved forward with testing after the Milestone B approval. The program hit further snags, though, when issues arose for the wing construction and the sense and avoid radar, particularly the necessary miniaturization of this subsystem; funding halted to the sub-contractor in August 2013. Flight and operational assessments continued the next two years, and the program received Milestone C approval in February 2016. Between 2015 and 2016, the USN awarded Northrop a $255 million contract in September 2016 to start the low-rate initial production of three aircraft, along with earlier 2015 purchases that covered $39 million for air-to-air sub systems, a $60 million ISR development package, and $49 million for long-lead procurement contract of key parts and material for a future second lot of aircraft.[653]

As of 2015, the Navy acquisition and operational plan for the Triton slated a new initial operating capability for 2018, with an upgraded multi-intelligence capability

[652] Source: "MQ-4C Triton," Naval Air Systems Command, accessed May 25, 2020, https://www.navair.navy.mil/product/MQ-4C. The color scheme is unique to the MQ-4C, with a full white upper half of the fuselage; the Air Force version only colors the front half of the fuselage white.

[653] Jane's, "Northrop Grumman RQ-4 Global Hawk," 9.

entering the fleet in 2020.[654] The Navy's concept and acquisition strategy calls for an overall $11 billion program; cost per aircraft stands at $189 million as of 2013.[655] The planned purchase has fluctuated from anywhere between forty-eight and sixty-eight aircraft. Furthermore, there is both competition and collaboration of the Triton with manned platforms, just like the Air Force analysis between Global Hawk and the U-2. For the Navy, the discussion revolved first around the manned P-8 Poseidon, which entered service at the end of 2013, and the greater suite of capabilities represented in the UCLASS and MQ-8.[656] The Navy is now planning to acquire fewer Poseidon anti-submarine aircraft meant to replace the aging P-3 Orion since it is buying more Tritons that can aid in maritime domain awareness—which the Navy sees as a force multiplier working in tandem with the P-8 and other platforms.

3. Innovation Perspectives and Factor Analysis

a. Rational Factors

For the Triton and Fire Scout episodes, threat assessments did not contribute significantly to the outcome of these middle-end UAVs, but technology issues slowed the MQ-8. The Navy's broad evaluation of peer competitors convinced it that it had no real threat for most of the 1990s and 2000s. Instead, like the MQ-1, the Navy took a methodical and reserved approach to explore and adopt the MQ-4 and MQ-8 as assets to accomplish certain mission tasks inherent in naval operations. The MQ-8 Fire Scout provided limited over-the-horizon surveillance and targeting support to the fleet, while the MQ-4 added unique capabilities of broad maritime domain ISR and expanded maritime patrol capability to enhance and work in tandem with the P-8 Poseidon aircraft.[657] As a land-based, forward deployed asset to provide wide-area coverage, the MQ-4 received positive reports from

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654 Naval Aviation Enterprise, *Naval Aviation Vision: 2016–2025*, 70.

655 Erwin, "Triton Will Test Navy's Commitment to Drones."

656 Sydney J. Freedberg, Jr. "Triton, Poseidon, & UCLASS: the Navy's ISR Balancing Act," Breaking Defense, last modified October 1, 2014, https://web.archinve.org/web/20141004133434/http://breakingdefense.com/2014/10/triton-poseidon-uclass-the navys-isr-balancing-act.

657 Naval Aviation Enterprise, *Naval Aviation Vision: 2016–2025*.

field commanders and warfighter, and overall the MQ-4 has shown operational value providing enhanced maritime domain awareness and cueing.

The enthusiasm generated by the end of the Cold War and then the George W. Bush administration's technology thrust for revolutionary capabilities sparked Navy experimentation, but those short-lived efforts gave way to a steadier, evolutionary pace of acquisitions. Contributing to the steadier innovation pace was a combination of poor strategic guidance and no compelling peer threat until the early 2010s. Captain McCabe added to that list the service's tension to balance open water versus littoral combat concerns within an ambiguous strategic environment (i.e., "blue water" versus "brown water" engagements). Highlighted in Chapter III, the Navy did not experience the strategic pull of the Global War on Terror to alter its core missions or question its service strategies. Carriers remained the bulwark of operational contributions to the war on terror, flying combat missions into Afghanistan and Iraq. The contribution to the littoral issues remained focused on critical maritime chokepoints around the world as well as anti-piracy efforts around the Horn of Africa. Neither operational environment, Captain McCabe suggested in an interview, offered a compelling or logical rationale for innovation beyond what was already within the Navy's capability set. By 2009, the specter of Chinese anti-access/area denial and growing naval projection forces began altering the rationalist calculus;[658] that time period is right at the end of this study's time window, but bears a future look at how the Navy has or has not used that emerging context as an impetus for innovation.

While the Navy was interested in transformation in conjunction with the early 2000s push for leap-ahead technology, naval officials and academics criticized an "absence of clearly articulated transformation guidance from the Secretary of Defense and the Chairman of the Joint Chiefs of Staff" that hindered all services' transformational efforts.[659] Furthermore, the findings from the same GAO report indicated that even the Defense Science Board called for a more explicit strategy for transformation starting in

[658] Zimmerman et al., *Movement and Maneuver*, 210–213.

[659] Government Accountability Office, *MILITARY TRANSFORATION: Navy Efforts Should Be More Integrated and Focused*, GAO-01-853 (Washington, DC: Government Accountability Office, 2001), 7, https://www.gao.gov/products/GAO-01-853.

1999. Moving in its own direction, then, the Navy deliberately focused its force structure improvements and technology efforts on evolutionary approaches from the late 1990s through the late 2000s. Network-centric warfare was given the priority effort; the transformational goal for much of the 1990s and 2000s was to tie ships' command, control, and communications together for better synergistic effects.[660] There was a UAV component to this effort as well (besides the waffling X-47 program), called the Tactical Control System. The director of the joint UAV program office in 2001, Navy Captain Roy Rogers, said this system was intended to address the difficult task of joint interoperability and the ability to command and control UAVs from all services.[661] It was lofty goal that matched the Navy's pursuit of network-centric solution as a technological panacea, but it failed to materialize even several years later.[662] The USN's other strategic priority, a redesign of ships for littoral warfare, remained in constant limbo, despite identifying this mission need in 1994. With the slow and uncertain littoral ship design and adoption outcomes, UAVs were left to fit onto existing platforms that did not have a compelling, rationalist logic for their adoption, nor did the organization have the capacity to absorb UAVs without considerable institutional changes.

b. Institutional Factors

For medium-end UAVs, the institutional hypothesis did not play a significant role, in that issues related to stakeholder relationships were not huge factors in determining outcomes; however, the research revealed unique institutional perspectives on resource use and bureaucratic political dynamics. First, unlike the inventive and experimental ACTD

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[660] Government Accountability Office, *MILITARY TRANSFORATION: Navy Efforts Should Be More Integrated and Focused*, 8.

[661] Roxana Tiron, "War Urgency Drives Decisions on U.S. Deployment of Drones," National Defense, December 1, 2001, https://www.nationaldefensemagazine.org/articles/2001/11/30/2001december-war-urgency-drives-decisions-on-us-deplouyment-of-drones.

[662] Sharon Pickup and Michael J. Sullivan, *Testimony, UNMANNED AIRCRAFT SYSTEMS: Improved Planning and Acquisition Strategies Can Help Address Operational Challenges*, GAO-06-610T (Washington, DC: Government Accountability Office, 2006), 11, https://www.gao.gov/new.items/d06610t.pdf. Note: Sharon Pickup was the Director, Defenses Capabilities and Management and Michael Sullivan was the Director, Acquisition and Sourcing Management. Testimony given before the Subcommittee on Tactical Air and Land Forces, Committee on Armed Services, House of Representatives, on April 6, 2006.

projects of the 1990s, the MQ-8 and RQ-4C Triton followed a standard acquisition process, and the institutional challenges reflected this reality. In 2001, Northrop Grumman officials observed that before the MQ-8, there had not been a UAV program to successfully start as a traditional acquisition project and to finish the engineering, manufacturing, & development phase and move to procurement; all adopted UAVs to that point had been demonstrations.[663] Since the mid 2000s, the Navy's medium-end UAV programs transitioned from RDT&E projects to become major programs of record that competed directly against large budget programs such as the Air Force's F-22 and the F-35 Joint Strike Fighter. Much of this dynamic was covered under the X-47/UCLASS institutional section. Nevertheless, specific to the RQ-4 BAMS and its successor the Triton, McCabe opined that the Navy's general assessment, especially within the maritime patrol community, was that there was not a capability gap so long as the P-3C Orion was maintained, which for years added to institutional drag upon the adoption of the R/MQ-4. The Navy committed to the MQ-4 as the P-3 replacement, but the P-3 continued to prove its worth and capabilities in the Middle East and other non-maritime environments; this dragged the P-3's retirement out beyond its original plan. Also, the R/MQ-4 directly competed against the manned P-3C aircraft's upgrades and life cycle management funds. Budget and infrastructure capacity to absorb three programs associated with maritime patrol and reconnaissance (e.g. MQ-4, P-3, and P-8) simultaneously, hindered adoption outcomes, at least in the speed of procurement. Once again, these episodes support Horowitz's adoption-capacity theory.

The Navy is one of the first services to consider buying fewer manned aircraft because of investments in UAVs. Vice Admiral Mark Skinner, principal military deputy to the assistant secretary to the Navy for research, development, and acquisitions, said in 2013 that the Navy, "bought fewer P-8s because we were going to buy Tritons."[664] While cross-service competition and economies of scale have impacted service-specific decisions in other episodes, this was not the case for the Triton. When the Air Force decided to end its

663 Tiron, "War Urgency Drives Decisions."

664 Erwin, "Triton Will Test Navy's Commitment to Drones."

Global Hawk Block 30 production—which was the same line the Triton was using for production—it did not have an impact on Navy's planned purchase of MQ-4s, according to Skinner. The MQ-8, on the other hand, has suffered programmatic momentum when the Army ended its in MQ-8 procurement plans when the Future Combat System strategy suffered budget shortfalls and technological difficulties with communications bandwidth. In all, the $11 billion Triton program for approximately sixty-eight air vehicles has found other collaborations, which Congress looked upon favorably.[665] One of those key collaborations was that Northrop Grumman agreed in 2011 to tie its product lines into a common, open product line, with a joint mission-planning-mission-control system" to create "synergy and collaboration between Broad Area Maritime Surveillance and Global Hawk" UAVs.[666] This was possible since 78 percent commonality by weight existed between the Navy's BAMS/Triton and Air Force's Global Hawk.[667] Another synergy that evolved was a 2011 memorandum of agreement between the Air Force and Navy to maximize joint efficiencies between the Triton and Global Hawk programs. Disappointingly, this agreement lacked joint training initiatives. According to Navy lieutenant and MQ-4C operator, Lieutenant Andrew Scherer, interviewed by the author on April 17, 2020, there has not been cross-service training opportunities, which would aid both services' budgeting and training efforts.

Avant's layered argument concerning the role of intra-group politics upon adoption outcomes within an institution was displayed in an interesting way through these medium-end UAVs. The Navy's evolving strategy and acquisition outcomes for new ships created intra-group differences of preference that impacted the medium-end UAVs politically. Nothing quite like this issue exists in other services, to the degree that aircraft are tied in tandem to other major acquisition program outcomes—in this case, to ship design and requirements. Besides the technology focused effort of network centric warfare, the USN's other priority since the 1990s—new littoral warfare ships—had spotty progress even a

[665] Erwin, "Triton Will Test Navy's Commitment to Drones."

[666] Office of the Secretary of Defense, *Unmanned Systems Integration Roadmap, 2011–2036*, 41.

[667] Office of the Secretary of Defense, *FY2009–2034, Unmanned Systems Integration Roadmap,* 55.

decade after identifying this mission capability as critical in 1994;[668] this directly impacted decisions related to the MQ-8. With the slow and uncertain littoral ship design and adoption outcomes, UAVs were left to fit onto existing platforms that either did not have the organization or capacity to absorb UAVs without considerable institutional structural changes. As the Littoral Combat Ship finally progressed from the mid 2000s on, the need for UAVs slowly increased proportionately. With a limited number of manned helicopters overall in the fleet, the Navy's expansion with the new ships created a gap in number of helicopters needed to support the new ships; therefore, the MQ-8 received a boost toward further acquisition, with one-hundred-sixty-eight vehicles planned, tied to the new littoral ship procurement efforts. Additionally, the Navy chose a personnel and organization approach to incorporate the MQ-8 in a way that did not threaten the helicopter pilot community. First, the missions the MQ-8 would fly did not compete directly with the extant SH-60 Seahawk helicopter taskings. Second, the helicopter pilots were not being asked to also fly the MQ-8 UAVs.[669] Last, the early version of the RQ-8A underperformed in requirements related to duration and overall mission capabilities, which led to two spiral upgrades over the course of a decade. Each upgrade moved successively to a larger, more powerful platform; in short, the original design consistently underwhelmed with its small frame and conservative design, drawing out any decision to move past Milestone C in the acquisitions process until 2011.[670] In comparison, the X-47/UCLASS UCAV episodes did the exact opposite: the UAV competed for the same mission tasks and the pilots were being asked to fly/monitor the UCAVs instead of, or in addition to, their manned aircraft.

Lastly, a senior naval flying officer and former commodore of an air wing, Captain McCabe, opined that while UAVs offer many tactical advantages, the real savings is strategic political gain on the domestic front. In this way, the medium-end UAVs buffered against negative domestic bureaucratic politics, which Avant identified as a factor of

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668 John H. Dalton, Frank B. Kelso, II, and Carl E. Mundy, Jr., *Revolutionizing Our Naval Forces: 1994 Posture Statement* (Washington, DC: Department of the Navy, 1994), 38.

669 This changed after 2015, according to Naval Aviation Enterprise's *Naval Aviation Vision: 2016–2025*.

670 Office of the Secretary of Defense, *Unmanned Systems Integration Roadmap, 2011–2036*, 18.

military policy choices to include doctrine and investments. For example, almost the entire conflict in Libya was flown and supported by UAVs. In 2012, the Navy had a total of nine Fire Scouts, but employed them in support of Operation Unified Protector. One MQ-8 was shot down by enemy fire. Also, Iran has shot down a few MQ-1s, an RQ-170, and most recently, an RQ-4A BAMS from the Navy inventory. McCabe noted that all these events resulted in zero grieving families and no public outcry against those military operations. The non-story events of these medium-UAVs provided a strong incentive to civilian leaders to continue supporting such UAV development through budgetary rewards and other institutional investments.

c. Organizational Culture Factors

In the Navy's medium end UAV episodes, organizational cultural factors hindered adoption outcomes, as well as the direction programs took once adopted. Most interviewees expressed excitement for unmanned aircraft potential and how UAVs could revolutionize tactical problem solving. There was equally a cultural bias for manned flight that consciously and subconsciously affected how people approached the work. Looking at the MQ-8, the interviews revealed little cultural bias against the MQ-8 itself, as the Fire Scout did not constitute a mission threat to the SH-60 pilots. What caused cultural bias to set in was the view that the Fire Scout initially was an asset in search of a mission. As Gudmundsson assessed it, that mission came after the fact, once the Littoral Combat System made acquisition progress.

As for the MQ-4C barriers to program acceptance, once it entered the inventory, barriers emerged from the manned pilot culture, according to Lieutenant Scherer. Yet, frustration with the Triton's level of technology and the mission-control/pilot interface grew within the Triton community; as Scherer put it, the technology seemed more like turn of the century equipment instead of something built in 2015. This became a significant drag upon cultural acceptance. Finally, the Navy's institutional decisions to force P-3 pilots to transition to the MQ-4 stoked cultural resistance, much like what happened with the Air Force during the 2000s. This problem has become more acute as the Navy has finally started adopting large UAVs in any significant numbers by 2013; the Navy in that year had a combined total of twenty-one medium-end UAVs.[671] Therefore, seasoned aviators, to include Wallace and others, are just now asking the hard questions. What is the best institutional and cultural answers to developing a career path, and what does it look like? Who is going to monitor the strategic integration of UAVs as a whole?

C. LOW-END UNMANNED AIRCRAFT (RQ-2)

The Navy procured the RQ-2 Pioneer UAV during the second UAV epoch, and for the most part, its adoption falls outside the scope of this study; however, knowing the background of this platform's procurement is valuable in learning why the Navy ultimately shed this innovation, especially given that it did not acquire the platform in significant numbers. The analysis of this platform will therefore focus on the demise of the platform and the Navy's election to start shedding this UAV despite not having a fully ready replacement—particularly the nascent MQ-8 Fire Scout.

1. The RQ-2 Pioneer Program Overview

For all the glory and name recognition earned by the Predator UAV, the RQ-2 Pioneer led the way for the U.S. military to adopt and employ UAVs at the end of the Cold War. Though the RQ-2 Pioneer's initial adoption into the Navy in January 1986 occurred in limited quantities during the second UAV epoch (see Chapter III), significant programmatic upgrades and other events since 1991 contributed to an increased inventory and use. That initial purchase consisted of seventy-two Pioneers at a cost of $87.7 million.[672] Not until the early 2000s did the Navy shed the Pioneer. Admittedly, it is difficult to separate the RQ-2 Pioneer as a purely Navy program, given the acquisition eventually included the Marine Corps and the Army, but the Navy initiated the purchase for itself and the Marine Corps. The Army followed suit shortly after the Navy committed to the Pioneer; in 2002, the Navy transferred its Pioneer systems to the Marines.

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[671] Under Secretary of Defense for Acquisition, Technology, and Logistics, *Report to Congress on Future Unmanned Aircraft Systems Training, Operations, and Sustainability* (Washington, DC: Department of Defense, 2012), 2.

[672] "Pioneer RQ-2A UAV," National Air & Space Museum, accessed May 25, 2020, https://airandspace.si.edu/collection-objects/pioneer-rq-2a-uav/nasm_A20000794000.

Inspired by a Marine Corp at-sea, proof-of-concept ACTD in 1985 using the Israeli Mastiff MK II UAV,[673] the Navy held a short competition between two contractors; the service then inked a contract in January 1986 with a dual-company partnership between Israeli Aircraft Industries and AAI, Inc. (of later Predator fame).[674] The Navy valued the Pioneer's over-the-horizon target spotting and fashioned a fresh concept of operation to outfit aging battleships with the new capability. The early RQ-2A version, shown in Figure 38, had an airframe consisting of fiberglass, fabric-covered wings, Kevlar, and balsa wood.[675] The twin-tail boom included a push-propeller design. A Pioneer's sensor package was limited to a seventy-five pound capacity and was initially either a forward-looking infrared or day-time television camera depending on mission. The airframe dimensions make the UAV relatively small but large enough to still be considered a Group 3 UAV: a wingspan of sixteen feet, a fourteen-foot length and a height of just under four feet. As the RQ-2 went through two iterations of airframe upgrades starting in 1990, the size did not change, but weights and performance improved, which enabled advances in sensor capabilities. The upgrades introduced all-composite wings and fuselage. In 1997, the Pioneer added an option for an electro-optical/infrared imaging sensor as well as a new engine. The mission of the Pioneer remained intelligence, but payload options expanded over time to include chemical detection, communication relay, and laser designator/range finder capabilities. Performance wise, the Pioneer could climb to a maximum altitude of 15,000 feet, fly on average for five-and-a-half hours, and cruise at eighty knots. The maximum radius of the vehicle's employment was limited due to line of sight of the datalink utilized for tracking and real-time relay of on-board sensor information.

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[673] Newcome, *Unmanned Aviation*, 97.

[674] In 1991, these two companies would stand up a combined new subsidiary company call Pioneer UAV, Inc., which would oversee all Pioneer development, user support, and sales from that year on.

[675] National Air & Space Museum, "Pioneer RQ-2A UAV."

This RQ-2 one of the first acquisition models, shown here launching from the battleship USS *Iowa* in November 1986.

Figure 38. AAI/IAI Pioneer RQ-2A/B[676]

The first two systems purchased went to the Navy, one as a training unit and the second was installed on the World War II-era USS *Iowa*.[677] Each system cost $17.2 million in FY 2004 dollars, with a per-aircraft cost of $650 thousand.[678] System lots three through five went to the Marine Corps, and in 1989, the Navy installed the sixth, eighth, and ninth delivered system on the battleships USS *New Jersey*, USS *Missouri*, and USS *Wisconsin*.[679] The Pioneer made a name for itself flying over three-hundred sorties during Operation Desert Storm in 1991, employed by the Navy from its battleships for target spotting.[680] One fabled aircraft saw a group of Iraqi soldiers surrender to it after the Iraqis became conditioned to know that if they saw the Pioneer overhead, shelling from 2,000-pound munitions would soon start landing precisely on their position; that Pioneer vehicle

676 Source: "RQ-2 Pioneer UAV," Olive-Drab, accessed April 25, 2020, https://olive-drab.com/idphoto/id_photos_uav_rq2.php.

677 "AAI/IAI RQ-2 Pioneer," Jane's by IHS Markit, February 5, 2010, 5.

678 Office of the Secretary of Defense, *Unmanned Aircraft Systems, 2005–2030*.

679 Jane's, "AAI/IAI RQ-2 Pioneer," 6.

680 A total of six Pioneer systems deployed for the war: three Marine Corp, two Navy, and one Army. Jane's, "AAI/IAI RQ-2 Pioneer," 6.

now hangs in the Smithsonian Air & Space Museum.[681] Following the Gulf War, Pioneers contributed to U.S. missions in Somalia and Operation Allied Force in the Kosovo theater in 1999 before the Navy and Marine Corps employed the UAVs in Afghanistan and Iraq in the early 2000s.

The RQ-2 evolved from an analog system to a digital system but remained only a pre-programmable asset with a remote piloting option. The control system required two operators to pilot, observe, and track the UAV. Naval UAVs initially had an autopilot and gyro system for the first decade of employment, which the Navy upgraded to a digital flight-control system. Launching the UAV had three options: a runway, rocket-assisted launch; a pneumatic catapult; or a rocket-assisted launch from a ship deck. All ship-borne launches for the Navy used the rocket-assisted method, shown in Figure 38. Recovery on board a ship required special equipment, netting, and exceptional pilot skills to hit the net, as seen in Figure 39. In 1995, the Pioneer's contractor developed a Common Automatic Recovery System to enable automated recovery using the netting system instead of pilot skill. This new system reduced the number of recovery accidents and stretched its all-weather performance envelope.[682]

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[681] This event marked the first time in history that "humans surrendered to a robot in combat." National Air & Space Museum, "Pioneer RQ-2A UAV."

[682] National Air & Space Museum, "Pioneer RQ-2A UAV."

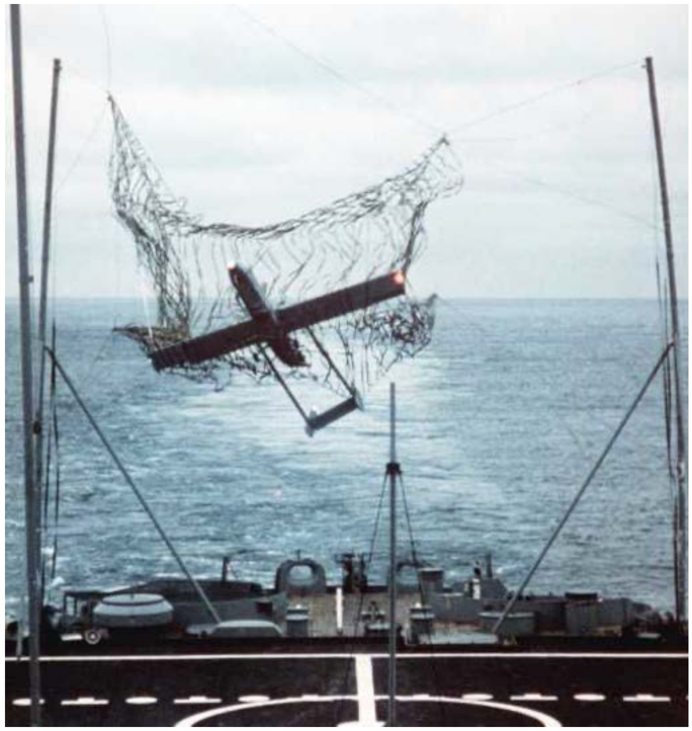

Figure 39. An RQ-2B Recovery Method on Navy Ships[683]

For the USN, end strength of the Pioneer inventory reached fifty-five vehicles (of the total 175 built for the three service)[684] in mid 1997, and in 1998, all Marine Corps Pioneer systems were placed under the Navy as it drew down its total Pioneer force to six systems by 2000 (of which, four were operational).[685] In fiscal year 2002, the Navy ceased field operations with the Pioneer, transferring most of its remaining assets to the Marines for use in Iraq and the Middle East in general. The Navy had already begun testing and development of the MQ-8 to replace the RQ-2. Eventually the Army and Marine Corp would do the same, replacing the RQ-2 with the RQ-7 Shadow. The near twenty-year operational span of the Pioneer is a testament to its design and reintroduction of UAVs into the Navy, Marine Corps, and Army at a time when these services either had none or very

[683] Source: Olive-Drab, "RQ-2 Pioneer UAV."

[684] Office of the Secretary of Defense, *Unmanned Aircraft Systems, 2005–2030*.

[685] Jane's, "AAI/IAI RQ-2 Pioneer," 6.

few. In the end, the Pioneer's design influenced future, more advance, and larger UAVs: the MQ-1 Predator and U.S Army's RQ-7 Shadow.[686]

2. Innovation Perspectives and Factor Analysis

a. Rational Factors

While the Navy did not develop the RQ-2 as a solution for a *direct* threat, the ground-breaking UAV enhanced battlefield effects and emerging ISR needs as the strategic and operational environment evolved throughout the 1990s. The Navy summarized the service's view of the strategic environment, and the Navy's changing role it, when it released its 1994 Posture Statement titled *Revolutionizing Our Naval Forces*. The document emphasized that the "threat of global war has passed" and that the security environment dangers of the 1990s and foreseeable future focused on nuclear proliferation, threats to democracy in eastern Europe, and regional and economic instability.[687] Future missions would not be defined by warfare, but crisis response, humanitarian aid, and deterrence that would require forward presence around the world. The Pioneer had shown great synergistic effect as a gunnery spotter for offensive fires from the battleships in the 1991 Gulf War. The Pioneer then supported contingency operations launching from both land and sea in Bosnia, Haiti, and Somalia starting in 1994.[688] In these missions, the Pioneer provide real-time imagery and showcased the ability for dynamic retasking. With such successes, the Pioneer began the early trend within the third UAV epoch of growing support from civilian leadership; Dick Cheney praised the Pioneer in a report to Congress, saying "UAVs proved to be an excellence reconnaissance asset…to attack enemy targets…and respond quickly to changing situations and provide real-time information."[689]

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686 Newcome, *Unmanned Aviation*, 99.

687 Dalton, Kelso, and Mundy, *Revolutionizing Our Naval Forces*, 1.

688 Defense Airborne Reconnaissance Office, *Annual Report: 1995*, 16. See also Richard Major, "RQ-2 Pioneer: The Flawed System that Redefined U.S. Unmanned Aviation" (master's thesis, Air Command and Staff College, 2012), https://apps.dtic.mil/dtic/tr/fulltext/u2/1022933.pdf.

689 Dick Cheney, *Conduct of the Persian Gulf Conflict: Interim Report to Congress* (Washington, DC: Department of Defense, 1991), 308, https://apps.dtic.mil/dtic/tr/fulltext/u2/a249270.pdf. Note: released July 1991.

The technological design limitations to operate in a maritime environment became the prime determinant in the Navy's decision to terminate the Pioneer for its own use (though it supported the Marine Corp's continued use for land-based support and littoral ISR). The Navy made the decision, in coordination with the Defense Airborne Reconnaissance Office, to fully remove the Pioneer from the Navy's inventory by FY 2000.[690] Naval operators lamented the cumbersome launch and retrieval systems that required major modification to the ships from which the Pioneer operated; furthermore, the system required a sizable footprint of equipment and personnel on the ships. The use of nets to capture the aircraft threatened to damage the aircraft every time it ended a sortie, and it was a challenging operator task to get it right.[691] Additionally, the Pioneer was famously loud, giving off a tell-tale signature to adversaries as it flew in vicinity of emerging targets. Even with the known drawdown of Pioneers looming, the Navy and the Defense Airborne Reconnaissance Office continued to support sensor and engine upgrades for the Pioneer first as a testbed for introducing new technology,[692] and second, since it was still making valuable contributions to the joint and service-specific commanders.

b. Institutional Factors

Overall, there is little evidence that the RQ-2 did not possess general support from key stakeholders such as Congress, the DOD, civilian leadership, and industry. However, the Pioneer also never garnered a strong consensus of support, either, since its limited capabilities, weak adoption, and interim status set the stage for its demise. First, the Navy did not prioritize UAVs as an important facet of naval aviation throughout the 1990s. In the service's 1994 posture statement, the result of a bottom-up review emphasized a mix of aircraft that included F-18E/Fs, AV-8B modifications, F-14 upgrades, eliminating older P-3s, and what would become the F-35. Conspicuously missing was any mention of

690 Defense Airborne Reconnaissance Office, *Annual Report: 1995*. This decision would eventually be extended to FY 2003.

691 Erwin, "Navy Poised to Select New Combat Drone."

692 Defense Airborne Reconnaissance Office, *FY 1997*, 20. The Defense Airborne Reconnaissance Office built onshore recovery devices, upgraded electro-optical/infrared sensors, and ran competitions to try and improve the engine in 1997.

UAVs.[693] The one mention of UAVs, under a joint surveillance section, indicated the Navy's desire to replace the Pioneer with a yet to be determined joint system with the Army and intended for aircraft carrier use.[694] Second, there was no Navy-specific UAV in the experimentation portfolio with the Defense Airborne Reconnaissance Office in the mid 1990s. The one joint program the Navy was involved in with the Army, the Hunter Joint Tactical UAV, ended without naval adoption since the Navy favored a future vertical takeoff design. Therefore, the Navy decided in FY 1996 to extend the Pioneer's phase out by three years from 2000 until 2003.[695] It follows then that not only was the USN slow to consider a replacement for the RQ-2, even though it knew it needed a more capable system, but also the RQ-4 and UCAV in the late 1990s as well.

Internal politics and restructuring also contributed to the Navy's weak adoption of the RQ-2. In line with evolving thoughts on commercial-military integration in acquisitions, the Navy sought to reform its acquisition processes in the 1990s to take advantage of civilian business practices, emerging technology, and the shift of the DOD from technology leader to technology follower in the military-industrial complex arena. Additionally, the service initiated efforts across a host of organizations to meet President Bush's charge to reorganize, not just cut, the services following the end of the Cold War. There is little proof that these restructuring and acquisition reform efforts made progress throughout the 1990s as the military-industrial base shrank and recapitalization efforts slowed as budget cuts set in. For example, many unnamed naval officials in a 2001 GAO report to Congress complained that the "Navy's innovation activities are not well coordinated or tracked between different organizations," and that innovation activities need better tracking across the service.[696] The burden of coordination with the Defense Airborne Reconnaissance Office added to the Navy's cross-institutional challenges; the

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693 Dalton, Kelso, and Mundy, *Revolutionizing Our Naval Forces*, 16.

694 Dalton, Kelso, and Mundy, *Revolutionizing Our Naval Forces*, 43–44. This UAV-Short Range would fail in its adoption, leaving the Navy without an RQ-2 replacement until the MQ-8 program was adopted as the new Pioneer replacement effort.

695 Defense Airborne Reconnaissance Office, *FY 1996*, 10.

696 Government Accountability Office, *MILITARY TRANSFORMATION: Navy Efforts Should be More Integrated and Focused*, 15.

Navy had lost full control over the acquisition process for its fleet, and so lost internal institutional collaboration to control its own force design to a joint process.

c. Organizational Culture Factors

A Navy officer, pilot and acquisition expert, Commander Giles reflected on years of operational, acquisitions, and academic experience, commenting that the Army approaches UAVs as toys while the Navy (and the Air Force) approach aviation assets as exquisite platforms. This results in a different risk calculus for the services for both testing and operations; risk is vastly more conservative in the Navy, and so acquisition failures are securitized more closely, which can have a dampening effect on experimentation with new technologies.[697] Additionally, operational reliability factored into cultural acceptance of the Pioneer. The Pioneer was initially very unreliable compared to manned aircraft, so it took its outlook among the operators took a cultural hit.[698] In 2003, the president of the Association for Unmanned Aerial Aircraft put it this way:

> According to several senior [military] officers, who wouldn't admit it publicly, the reason they were against the use of some of these platforms, including Global Hawk, was reliability. It isn't just a matter of cost. It boils down to a matter of capability. If you only have two, and you lose one, there goes 50 percent of your capability.[699]

Essentially, a culture of expectations arose to shape UAV adoption views. One should also keep in mind the Navy's cultural resistance to jointness,[700] particularly as it relates to the relationship it had to maintain and work through with the Defense Airborne Reconnaissance Office from 1993 to 1997. The institutional burden of joint programmatic

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697 This view was also emphasized by Dr. Oleg Yakimenko, a distinguished professor and subject matter expert on UAVs and acquisitions during an interview, January 3, 2020.

698 Michael Peck, "Pentagon Unhappy About Drone Aircraft Reliability," National Defense, last modified May 1, 2003, https://www.nationaldefensemagazine.org/Articles/2003/5/1/2003May%20 Pentagon%20Unhappy %20About%20Drone%20Aircraft%20Reliability. The RQ-2A Pioneer had a mishap rate of 363 per 100,000 hours, but that declined with the RQ-2B down to 139. An acceptable traditional rate of mishaps is 15–25 per 100,000 hours.

699 Peck, "Pentagon Unhappy About Drone Aircraft Reliability." The quote is attributed to Brad Brown.

700 RAND overview, *Movement and Maneuver*. RAND summarized the Navy's culture as "Institutional Resistance to Jointness." This is in line with both Donnithorne's and Builder's assessments as well.

undoubtedly weighed on cultural norms and acceptance of programs coming out of the centralized office. While no correlation can be made, it seems that this cultural proclivity against jointness likely contributed to the service-only UAV endeavors that followed in the 2000s with the MQ-8, X-47/UCLASS, and the slow uptake with the RQ-4 Global Hawk despite immense commonalities.

The Navy viewed the RQ-2 as an interim, bridging solution to expanding ISR needs on battleships and other smaller destroyers and cruisers. While the RQ-2 was weakly adopted for niche operational use—and drew positive reviews—the Pioneer did not create significant cultural momentum toward broad UAV adoption outcomes. However, the small Pioneer made a big enough impact that the Navy knew it would want a replacement sooner or later. The vertical takeoff and landing UAV—what would eventually become the MQ-8—was what the Navy intended as a follow on once the Joint Tactical UAV ACTD fell through. The transition to a replacement for the RQ-2 did not go smoothly. The USN retired the Pioneer in 2002 from the few naval ships the UAV served upon, despite the Navy missing a replacement capability as the Pioneers transitioned to the Marine Corp for tasking in the Global War on Terror. A lack of cultural commitment and indecision, at least partly, contributed to the situation where the Navy was content with the capability gap.

The fact that the Navy's identity was not threatened or challenged in the opening campaigns of the Global War on Terror contributed to the attitude that the RQ-2 was not critical in any way to the Navy's contribution to the post-9/11 security environment since the Marine Corps could use the assets in a new way. Overall, some naval officers became proponents of ship-born UAVs, seeing the positive contributions to operations throughout the early and mid 1990s. Admiral David E. Jeremiah, chair of the JROC in 1993, remarked "[Pioneer] proved that the utility of the unmanned aerial vehicle can be decisive in future battle."[701] Therefore, the Navy—and the DOD in general—continued efforts toward a more capable ISR asset to replace and expand the capabilities that the Pioneer re-taught to the U.S. military about UAV contributions.

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[701] Defense Airborne Reconnaissance Office, *FY 1996*, 17.

D. CONCLUSION

Across the three types of UAV cases—low, medium, and high—the rationalist hypothesis was strongly contributory in only the high-end UAVs; furthermore, that correlation came as a negative condition, one where an absence of a threat consensus correlated with a rejected adoption. Utility and effectiveness factors did contribute as well to the medium- and low-end type cases, though. The outcome revealed the underlying tension between consensus about threats versus actual adversary capabilities. Absent a consensus, the probability of other, stronger innovative factors from the institutional and cultural perspective driving outcomes rises. The medium- and low-end episodes showed that for the Navy, the development—and shedding—of these capabilities hinged on improving mission tasks or accepting risk in certain mission task areas to offset other priorities and resource constraints. Absent a convincing threat needed to take revolutionary risks in technology and capabilities, the Navy defaulted to an evolutionary approach by rejecting the X-47/UCLASS outright, while committing to a slower, more traditional acquisition process and timeline for the MQ-4C and MQ-8. Finally, because there was not a strong rationalist-based factor for the MQ-2 Pioneer to remain in the inventory despite solid contributions to the DOD mission, the MQ-2 slowly faded out of the inventory, receiving an end-of-life extension for a few years to enable limited ISR collection for the Navy. As a rational response to the Global War on Terror, the RQ-2 served longer than originally planned with the Marine Corps, given the operational benefit the Pioneer provided for counter-terrorist and anti-piracy operations.

Technologically, the unresolved consensus regarding UAV systems architecture added to the difficulty of getting to positive, strong adoption outcomes, especially regarding “man in the loop” concerns. It cannot be stressed enough that unmanned aircraft are a family of systems, not just the vehicle, and are dependent upon the electromagnetic spectrum to maintain “man in the loop” operations.[702] The competing technological choice of air-centric versus ground-centric architecture meant drastically different design

[702] Curtin and Francis, *UNMANNED AERIAL VEHICLES: Major Management Issues*, 17.

challenges,[703] but either way, communication and information networks remained the common design challenge. An air-centric model required a more autonomous vehicle with an advanced system logic and computational capability, which in turn meant a smaller ground footprint with downlinks from the UAV to users; a ground-centric approach meant a more simple UAV feeding sensor information to users constantly and would be heavily reliant upon centralized ground nodes for almost all aspects of flight and mission control. From a purely utilitarian perspective, an air-centric model would fit better on to a carrier, but with that came additional institutional and cultural burdens.

Finally, the last major finding from a rationalist perspective was the overarching critique that the Navy has not rationally thought deep enough about the role of UAVs from the strategic to tactical level. Former carrier air wing commander Captain "Norm" Wallace and Vice Admiral Rondeau offered similar criticisms, noting that the Navy had been guilty of not thinking through the strategic-to-tactical rationale for UAVs in all their forms and capabilities, as well as the whole-of-institution changes needed to facilitate such changes. In other words, there must be a common thread and logic extending from the strategic capabilities all the way down to the design of the carrier air wing itself, holistically. Piecemealing in assets or capabilities will only likely result in negative adoption outcomes at worst or ad hoc capabilities at best. For instance, the research revealed there were better questions that needed answers instead of the tactical-level arguments surrounding what missions and capabilities the UCLASS should exhibit. If holistic questions of strategic through tactical level design were better employed, the effort would likely uncover that both ISR-centric and strike-centric proponents were right; making it a seemingly dichotomous choice doomed the project to outright rejection. An anonymous congressional staffer in 2014 provided the fog-cutting statement, declaring "perhaps both camps are right and there is a compelling case for pursuing both UCLASS options."[704]

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[703] Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap, 2000–2025*.

[704] Freedberg, "Triton, Poseidon, & UCLASS." Note: Anonymous congressional staffer offered this quote to a reporter.

Moving to the institutionalist hypothesis, the research discovered that the consensus of stakeholders generally existed and aligned across the episodes, but many of the stakeholders remained weak in their commitment overall. This resulting in programs continuing for longer periods of RDT&E and acquisitions even when barriers arose. Additionally, internal bureaucratic politics wreaked havoc on resource and institutional prioritization. Finally, there was a unique dynamic that structurally created competing preferences across DOD institutions at the strategic and operational levels of warfare; with varying priorities and needs depending on the institutional level of agency.

Starting with the internal bureaucratic issues, two factors weighed more heavily on outcomes than others: personnel policies and institutional self-preservation concerns rising from aircraft carrier employment decisions. Regarding personnel policies, the Navy as an institution has not had the deep workforce issues that the Air Force experienced since it has progressed more slowly. It was able to use a blended approach to integrate operators to fly the Pioneer and MQ-8. With the MQ-4 Triton, there were more struggles akin to the Air Force squadrons since it is standing up squadrons and leveraging both volunteers as well as mandating certain pilots cross flow to the MQ-4; however, because it has been a gradual buildup, the institutional problems have not been as pronounced. The adoption has been slow enough to adjust to the changes but is also not leveraging the EP-3 community like it could to maximize the transition.

Starting around 2009, the Navy entered a period of institutional turbulence compounded by budget strain and questionable management of aircraft carriers; these issues induced an institutional self-preservation mode that pulled the Navy off its acquisition priorities, according to Captain Wallace. In a nutshell, the carriers were starting to experience major system degradations to include reactors, catapults, and elevators. Around the same time, senior naval leadership began extending the rotation schedules and between depot-level maintenance periods. This created a second order effect of strike-fighter shortfalls since aircraft were now also deployed longer and more frequently. While on paper the Navy had ten carrier air wings across the fleet, the operational reality was something more akin to half that capability. Layer onto these resource problems the Obama-era slide in budgets, followed by the uncertainty induced by the period of sequestration, and institutional wherewithal waned to keep incrementally evolving UAV programs. It is little surprise then that the MQ-8 and MQ-4 stretched out the timeline for acquisition and that the UCLASS never earned naval leadership's full backing, leading to its demise.

Next, the cultural hypothesis showed correlation across the UAV episodes, when constrained to the Navy's various pilot communities. There was strong consensus from those interviewed, as well as in other credible reports, that a cultural bias for manned aircraft shaped adoption outcomes in both the micro and macro sense of program development. Additionally, aviation communities' opinions were intensely stove-piped across mission sets (e.g., helicopters/MQ-8s, P-3s/MQ-4s, UCLASS/F-18s). Institutional decisions helped keep cultural issues from festering early on, but those issues became more prevalent as more UAVs were either adopted and/or directly competed for manned platform missions. Interestingly, for the RQ-2 and MQ-8, the Navy did not stand up a unique squadron of UAV operators to compete against manned aircraft units. For the X-47 and UCLASS, that action would have been premature, according to Wallace, since the program remained in RDT&E, but the model was under serious debate and never fully settled by 2015. Since the UCLASS straddled two operator communities—ISR and strike—it had the most variance in cultural acceptance. While tactically there was great interest UAV capabilities that could decrease a pilot's task burdens and take on the highest-risk missions, UAVs also presented a threat to aviator culture steeped in the bravado and skillset of landing on a carrier. Anything seen as automated landing would be stealing landing grades and status from individual aviators. Lastly, the dynamic of a surface warfare officer/naval aviator split within the organization added a unique cultural dynamic that prevented sub-group dominance as a single-dimension driver. With naval leadership wedded to the imperative of ship warfare, any UAV seen as enhancing that mission directly found favor among the surface warfare community; if the UAV's contribution was more indirect, the support unsurprisingly fell proportionately.

Finally, the research interviews revealed another strong factor that did not fall neatly within the three main hypotheses; instead, the factor belonged more to the fourth consideration of the study—sociological factors. Captain McCabe reflected on the Navy's strong sociocultural consensus that technology inherent in a UCAV must be foolproof; that is, ensure a "man in the loop" so long as weapons are a part of the vehicle payload. Anything short of perfection, anything that could cause a loss of communications, makes the UCAV unpalatable to the military professional and most civilians as well. Thinking through that stance, it seems there is a matter of trust and comfort in the computational logic of the system that is a matter of degrees. At what point is relinquishing "man in the loop" controls acceptable, given the many other weapons systems employed that have zero, or very limited, callback capability once released? The point of comfort comes in knowing, it seems, in that a weapon fired against an intended and deliberately identified target is the only target that a released weapon will engage (even if the human errs as part of the fog and friction of war). Any chance that a weapon might engage or destroy targets without immediate and final release authority coming from a human remains the threshold that UCAVs are held up against.

Overall, the Navy has shown an abiding interest in UAVs, outlasting the Air Force in organic efforts to create higher-end UAVs; however, the Navy comparatively has played it safe institutionally and culturally, eschewing the more controversial UAVs that challenge more powerful stakeholders and more deeply entrenched cultural norms. The MQ-4, the MQ-8, and the MQ-25 Stingray aerial refueler all represent less threatening, evolutionary advances that provide the institutional and cultural space to continue thinking through the implications and rationale for innovations related to unmanned aircraft systems. In every case, rationalist drivers of innovation had less of an impact on Navy decisions, but as peer-competition from China becomes unavoidable, the Navy will be faced with ever more uncomfortable decisions on UCAV adoption.

VI. ANALYSIS AND CONCLUSION

> There always comes a moment in time when a door opens and lets the future in.
>
> —Graham Green[705]

This study began with two motivating questions in mind. *Why, despite abundant material resources, mature technology, and operational need, are the most capable UAVs not in the inventory across the services? Put more succinctly, what accounts for UAV innovation adoption variation and patterns?* The study defined innovation as organizational adoption of an invention—in this case, it started with a technological invention as an independent variable; innovation also meant an invention met Adam Grissom's two standards of altering the way the military functions in the field while generating better military effectiveness. The chief inference from the research revealed that capability gaps, mature technology, and consistent funding were common to all adoption outcomes and work in tandem as key drivers. Additionally, of all the perspectives, institutional factors exerted the most powerful influences that structure, propel, and limit innovation pathways and adoption outcomes. The most compelling determinant in overcoming institutional momentum and structure was a crisis-level threat or capability gap. These materialist drivers act in a more immediate fashion upon innovation adoption outcomes, vivifying the process. Organizational culture and sociocultural aspects became additive in nature to the pathways to innovation, often impacting the strength or degree of adoption. Significant ideational facets included cultural consensus building, identity fit, and the broad trust that a new weapon system fits prevailing sociocultural norms.

This chapter returns to the four representative hypotheses for a structured cross comparison from Chapters IV and V. Following the theory assessments, the chapter provides suggestions for new ways to consider the explanatory power and the relationship among mechanisms of military innovation; furthermore, the chapter considers practical implications for the services and the nation's overarching defense apparatus. These

[705] Graham Green, quoted in Defense Airborne Reconnaissance Office, *FY 1997,* 0.

suggestions are based upon the resulting key driver mechanisms, their relationships, and the contextual variables that influenced adoption outcomes across the UAV case types (high-, medium-, and low-end).[706] Finally, this chapter offers an assessment regarding limitations of the study as well as recommendations for future research.

A. RESEARCH OBJECTIVES

The dissertation established two key research objectives: theory testing and heuristic building. Theory testing, identifies and describes the causal factors from the existing theoretical lenses within and across cases. Heuristic building seeks to ascertain potential new mechanisms, relationships among mechanisms, and the contextual conditions that shape or activate combinations of mechanisms leading to innovation outcomes.[707]

The study executed theory-testing as within-case inference and employed process tracing to analyze causal mechanisms in their own perspective pathways in the USAF and Navy chapters. Process tracing provided a means to test individual UAV case types and episodes against the causal factors from the rational, institutional, and cultural lenses, along with their respective hypotheses. Considering the causal factors from Table 1, the study searched and weighed overall patterns of mechanisms, when mechanisms clustered, and under what circumstances the mechanisms emerged. The analysis below moves to cross-case comparisons inferring key findings within each innovation perspective while considering the relationship of these factors to one another and the contextual element from Chapter III.

1. Theory Testing: The Hypotheses and Factors

At the start of this dissertation, the military innovation studies literature was categorized along its broad schools of thought: rational, institutional, and organizational culture. A fourth area of consideration included sociological aspects. This study then

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[706] Adoption outcome categories are *rejected*, *weakly adopted*, and *strongly adopted*.

[707] George and Bennett, *Case Studies and Theory Development*, 75; See also, Gerring, *Social Science Methodology, A Criterial Framework*, 118–124. As set forth in Chapter I, this dissertation attempted a theory-proposal as well based on causal mechanisms and their contexts. Van Evera, *Guide to Methods*, 90.

assigned representative hypotheses to the various perspectives, while not losing sight of the several theories and subfactors that nest under the overarching perspective. These perspectives and hypotheses constituted the prevailing causal mechanisms, or pathways, that military innovation scholars offered as means for an invention to become an innovation. Moving from the within-case data and analysis conducted in the chapters, this section focuses on a "structured, focused comparison" across UAV cases and UAV episodes to analyze the hypotheses holistically and in competition to one another.[708]

a. The Logic of Rationalism

The first hypothesis focused on rationalist arguments and factors: To accept high-end innovations that alter a service's historical solutions to critical mission area problems, an external threat must exist and be beyond current organizational capacities to solve. The focus within the rationalism perspective is a pragmatic one, emphasizing empirical, data-driven processes associated with choices about utility. Its premise is based on knowable and external feedback loops that, as Farrell and Terriff describe, demand a rational response. The research exposed a weakness of the hypothesis, in that it required an important qualification: the word threat was too narrow in function and had to be expanded to include a gap or problem, whether at the strategic, operational, or tactical level of mission employment. Throughout the episodes two key drivers stood out under the rational perspective: a problem to solve and sufficiently mature technology. Combined, these two key drivers constitute a *utility of effectiveness* mechanism as a prerequisite for innovation.

The hypothesis was confirmed in all of the case types, whether from a negative or positive application of the proposition that "problems" drive adoption outcomes. There was no compelling military threat, nor gap in mission task capability to justify further work to develop and adopt the RQ-3, X-45, and X-47 at the time of their early RDT&E phases. The Navy's UCLASS had more compelling operational requirements but suffered from other opposing factors: competing visions of employment, institutional barriers such as confined aircraft carrier design, meager or non-existent integration plans, and challenging

[708] George and Bennett, 63.

concurrent budgetary environments exacerbated by core institutional and identity weapons systems like the aircraft carrier. The MQ-1, MQ-9, and to a much lesser degree the MQ-8 and R/MQ-4, met needs and requirements—whether at the joint or service levels. In cases of positive adoption, the inventions filled a niche requirement and brought value to the effectiveness or efficiency of gaining advantages in the field (whatever the level of war) and achieving military objectives.

The maturity of the technology comprising the UAVs also showed strong associations to adoption outcomes. Those projects begun in the 1990s had several issues associated with technology risk, especially when timetables for procurement were shortened or unit cost of a system was arbitrarily constrained. The RQ-3 suffered many technological short comings given its unstable and highly experimental vehicle shape and software autonomy goals. The X-45, and later the X-47, were more capable and less risky technologically when having a longer time period to meet the technology to the desired requirements; however, the technology could not match the requirements within the rapid pacing of the program from 2001 to 2006. The X-47 and UCLASS showcased incredible technological capability by 2013–2015, but did not lead to adoption, at least as envisioned originally. The X-47 was a demonstration program for most of its life-cycle, and the UCLASS was its follow-on procurement program. Plagued by an absence of consensus regarding requirements/purpose and other concurrent institutional burdens, the UCLASS did not get adopted in its planned design and form. Nevertheless, the emerging MQ-25 Stingray air refueler incorporates a remarkable amount of the same technology, design, and autonomy shown by the UCLASS. A direct thread can be traced from the 1999 X-47 to the late 2010s MQ-25, marking an adoption outcome that is still unfolding but growing stronger now that the technology and requirements are solidifying simultaneously.

The one caveat to the mature technology driver is that the technology has to be considered holistically, not only in its reductionist forms of subsystems and components. Just because all individual systems and components are mature or low-risk technology, does not equate to systemic mature technology for complex UAVs that can perform militarized mission tasks and requirements to the level expected by the services in combat. The Air Force's esteem of the Predator was tarnished because the system showed systemic shortcoming that sprang from the nature of the program and its design.[709] Those shortcomings included maintenance enterprise planning, effective subsystems for all-weather operations, logistics enterprise planning to include fuel types and compatibility, and end-to-end training systems, among many other issues. The employment issues that come out in testing and demonstration phases highlight why the military services struggled to accept ACTDs as a praiseworthy approach, while the GAO and Congress tended to favor the ACTD as low risk, low waste.

b. The Logic of Institutionalism

The second hypothesis proposed that without collaborative support from a service's leadership, Congress, the Secretary of Defense, and defense industry, a service would not procure a high-end innovative system. This perspective focused on domestic factors of innovation, as well as official institutional policy, structure, composition, resources, and the official roles and mission assigned to the institution. Additionally, it focused on theories and factors related to inter- and intra-group bureaucratic posturing and relationships.

The episodes that succeeded in becoming adopted innovation, again, had general and sustained alignment among institutional and industrial stakeholders at key points in the acquisition life cycle. This is not a surprising revelation. Yet, what prevailed in all instances was institutional and congressional resource prioritization toward a particular innovation program. That did not always mean large sums of money, but it did mean enough to ensure unceasing progress. When money disappeared or dropped significantly for more than a single fiscal year, the projects inevitably went through requirements and expectation changes. *Sufficient budgetary consistency* remained a practical and essential function of technological adoption. This finding is in direct odds with Rosen's findings in the late 1980s and early 1990s that budgetary factors did not hold significant sway on innovation outcomes.

A few other institutional factors held strong permissive sway over adoption strength and timelines: the completion of complementary or corroborating projects, institutional

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[709] Government Accountability Office, *UNMANNED AERIAL VEHICLES*, 4.

consensus regarding problems to be solved or task gaps in capabilities, and macro-level personnel policies especially related to career progression, training pipelines, and rank. Finally, of the competing mechanisms that influence innovation outcomes, institutional factors rose to primacy in peacetime and perpetual wartime environments. The sway of institutional mechanisms lessened slightly in high-magnitude crises for a relatively short period—months, not years—when rationalist threat factors, strategic risk, and civilian attention outmatched institutional priorities.

Of the challenges examined across the episodes, one of the greatest institutional issues revolves around oversight channels and constructs and the degree of centralization versus decentralization of programmatic efforts. The ability of centralized organizations to direct or shape adoption outcomes, such as the Defense Airborne Reconnaissance Office, the JROC, or other joint program offices, hinged on the spectrum of advisory versus authoritative power given to these structures. Likewise, the more authority a centralized bureau had, the more institutional resistance emerged—but only when a service's requirements started to become ignored or when the service's long-range fiscal stability and sway was threatened through poor program design. The research also showed the limits of Congress to dictate the procurement strategies for defense organizations.

c. The Logic of Organizational Culture

The third hypothesis avowed that a service's prevailing organizational preferences, emerging from the dominant culture, determines adoption outcomes. The research indicated that ideational factors have permissive effects on adoption related to the strength of the adoption outcome (i.e., strong or weak) by improving tactical effectiveness of the technology while garnering bottom-up support. Core organizational identity was not as monolithic as some scholars argue, such as Adamsky and Kier. Organizational culture also was not as deterministic of which technologies were considered, much more, adopted, as Mahnken would suggest. The research further supports Theo Farrell's argument that "culture sets the context for military innovation, fundamentally shaping organizations' reactions to technological and strategic opportunities"[710]; furthermore, that it took strong visionary leadership to break subgroup cultural resistance to organizationally threatening inventions. The addendum added by the research on UAVs in this study is that visionary leadership was vital not only at the senior rank levels, but also the mid-grade levels of the organization. When respected mid-level officers of the predominant subculture began leading units with the newly adopted innovation, the level of credibility and acceptance rose significantly. Additionally, once officers from new career fields (or branches) gained significant rank, acceptance increased.

Across the two cases, core identity challenges to the service arising from the Global War on Terror amplified USAF reactions in the cases of the MQ-1 and MQ-9, but the absence of institutional identity challenges allowed the Navy to go slower on UAVs. This allowed technology to mature and naval personnel policies to be more deeply negotiated and planned. As a subgroup, USAF pilots and the associated subcultures were not as entrenched against UAVs as compared to the Navy. Poor institutional choices on behalf of the Air Force, along with the methodology of introducing the new systems at the tactical level, exacerbated and amplified apparent cultural rejection in the Air Force. On the other hand, the Navy's institutional split between surface warfare officers and aviation officers partially hid naval aviation's cultural animosity for longer at the institutional level.

d. Sociocultural Factors

Finally, the fourth approach sought to consider how and why sociocultural factors impacted general attitudes and norms either supporting or constraining UAV adoption of weapons that had the appearance—real or perceived—of autonomous, robot-like employment. While not a major component of the research, interview questions and contextual data revealed several facets that bear consideration. First, the sociocultural norms that emerged following the 1991 Gulf War and early experiences in crisis intervention in Somalia and elsewhere shifted risk to life thresholds for the American populace and caused a recalculation in the acceptable levels of costs for both operations

[710] Theo Farrell and Terry Terriff, *The Sources of Military Change*, 12–17, cited in Shipe, Turner, and Wickert, *Innovation Lost: The Tragedy of the UCLASS*, 26.

and threats to life—both friendly and enemy. These top down, permissive factors conditioned new moral norms of warfare in general, lending an amplification to a demand for unmanned systems in modern warfare.

At the same time, as unmanned systems took on lethal roles, a whole other level of social concern emerged in the realms of ethics, conventions for the employment of state-sanctioned force, and even resistance in other federal agencies. To start, the connotative response to the common-practice of using the word *drone* as a descriptor of these systems has not stimulated fact-based discussions. Instead, the word drone has biased peoples' perceptions, whether warranted or not, rather than relying on the actual technology and methods of employment for UAVs. Collaborative federal agencies in the UAV enterprise also slowed the adoption of UAVs out of sociocultural concerns about risk and safety. As John Tirpak, executive editor of the Air Force's flagship association magazine said in 2005, "the world is still uncomfortable with the idea of an armed machine flying around without a human controller on board."[711] To make his point, he offered the fact that even filing a standard flight plan for the unarmed Global Hawk was more a negotiation than a simple administrative act.

Overall, the amount of social *trust* imparted to a weapons system—to perform as programmed with ethical algorithms and an ability to recall the weapon—appeared to hold significant sociocultural weight both internally to military organizations and to the broad society as well. Like cultural factors, the ideational aspects of the sociocultural perspective—with the driver being trust—conditioned the strength or weakness of adoption, the speed of procurement, and user perspectives on reliability. Finally, sociocultural arguments surrounding biological and gendered determinism exist, and warrant further consideration, but the research data did not reveal this as a major factor to UAV adoption.

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[711] Tirpak, "Toward an Unmanned Bomber."

2. Heuristic Building: Mechanisms and Relationships

One of the most interesting findings of the study pertained to civilian-military relations, which bridged the rationalist and intuitionalist perspectives in various ways. The civilian role did not always function in ways the literature suggests, at least not without major adjustments. Secretary Gates' behavior seemed consistent with Barry Posen's view of civilian leadership within an institution and Eliot Cohen's theories of civilian importance to overall military direction. Posen argued that the state evaluates threats and directs its military institutions to change accordingly—innovation happens as part of a rationalist process. But, in these cases, the Navy and most particularly the Air Force did not fully adapt to what the civilians wanted. In fact, in the case of Gates, the charge was laid that Gates' thrust for rapid UAV adoption for ISR, and his other directives over Air Force programs, showed a lack of strategic thinking in the character of warfare in the long term. General Fogleman commented that during much of the early- and mid-years of the Global War on Terrorism, strategic thinking was limited at best, instead focusing on tactical level counter-terrorism and counter-insurgency procedures. The implication of Fogleman's observation was that a lack of strategic thinking at the national defense hampered strategic planning and programming for innovative and strategic-capabilities procurement at the institutional level at an alarming degree.

Technologist and futurists tended to be overconfident in their projections of what a technology can do, what effect it will have on the nature of warfare, and the implications for the nature of war itself. Accordingly, the UAV cases and episodes indicated that a type of hindsight bias exists among the innovation studies literature, with theorists such as Kier making pronouncements about culture's influence on outcomes that instead have significant technological limitations. The vast majority of cases used to study military innovation focus on large programs that end in adoption and forego smaller cases of innovation, those cases that evolve slowly, or those that were never adoption. This study sought to rectify that, albeit modestly. Additionally, technology revolutionist in general have oversold these movements. Throughout these cases and episodes, both services' programs went askew despite civilians' push and championing of revolutions in technology. Narratives of generational leaps seem overstated at best; the cases in this study suggest that such narratives catalyzed the opposite intended effect, leading to rejection of programs instead of the intended generational leaps. This is not meant to condemn failures to adopt as a whole, as the broad literature on innovation shows that failure is often the proverbial mother of invention, especially when the technological envelope is pushed and leads to future breakthroughs.

Across all the UAV types and episodes, one technical challenge stood out that directly confronts organizational cultures and sociocultural dynamics: connectivity to maintain a man in the loop, especially for UCAVs and high-end UAVs of all types that contain national-technical secrets. The technical difficulty presented by data links, bandwidth, and communications will persist and only become more challenged as adversaries strengthen their ability to contest the electromagnetic spectrum.[712] This point was raised by several interview participants and is rooted in the S&T design decisions of ground-centric versus air-centric architectures. Ground-centric architectures will likely not survive, but until sociocultural norms and service culture finds the trust and comfort in ever-higher degrees of autonomy, high-end UAVs will only be adopted weakly or not at all. Hence, narratives and concepts that emphasize manned-unmanned teaming are growing stronger in the military innovative space today, but the question of future UAV innovation hinges on either the ability to guarantee electromagnetic dominance or a broader sociocultural norm approving of air-centric autonomous UAVs.

Additionally, culture is not monolithic to an organization, rather there are macro and micro cultural aspects that past studies within the military innovation field ignored. Researcher and practitioners often give cultural arguments favor or primacy over rationalist or institutionalist factors. One insidious reason people fall prey to this error is that cultural factors often line up concurrently with causal factors and mechanisms from rational and institutional perspective. People fall for the cultural pathway explanation due to a "judgement heuristic" that employs emotional responses or other simpler assessments to arrive at answers quickly.[713] Instead, it was found that cultural factors have macro and

[712] Government Accountability Office, *DEFENSE ACQUISITIONS*, highlights page.

[713] Daniel Kahneman, *Thinking, Fast and Slow* (New York: Farrar, Straus, and Giroux, 2011), 91.

micro components that then often become inflated by practitioners and academics alike, thinking that culture is a monolithically-driven explanation, when it is the exact opposite. Additionally, the research exposed the danger of examining innovation episodes in reductionist methodology instead of holistically across all four perspectives. This has led to recent spate of practitioners misperceiving cultural permissive causes—real as they are—as immediate causes.

Another small issue gleaned through the research was that the first research question was off mark regarding the maturity of technology in certain instances, falling subject to some of the technology hindsight biases discussed above. The framing of the question hinted at its own technophile biases, assuming that in the high-end cases, certain necessary technologies were more mature than actually was the case. The GAO reports often criticized UAV development efforts and DOD/service timelines for this reason. The error in the question was not comprehensive, though, because most of the underlying technology shortfalls certainly could have been developed more aggressively or matured over time had resources been applied.

Finally, the literature review revealed concerns that military innovation studies field has stalled for a variety of reasons; this study suggests that in part of the reason for the mire is because the research agenda lacks a true multidisciplinary approach choosing instead the safe harbor of single discipline explanations. As Vice Admiral Rondeau suggested in our interview, cross-discipline work is controversial, but essential. Single discipline work supports purist, reductionist explanations are neat but not generalizable. Such reductionist views bring result that are so localized or seemingly like common sense that it becomes unimportant or unremarkable. Likewise, unconstrained academic and theoretical research usually produces little in explanatory power that is so loosely generalizable as to be of almost no use to any discipline. There must be a sweet spot struck in the research agenda so that visualization of the innovation phenomenon does not become constrained into irrelevance. Multi-method research, including more quantitative approaches, is needed.

B. RESEARCH LIMITATIONS AND FUTURE AGENDAS

1. Data and Methodology Limitations

Regarding methodology and data, there are areas that, if improved, would bolster the veracity of claims and analysis. First, the access to primary source data from the services, DARPA, and the private companies proved more difficult to come by than anticipated. Considering that many of those documents are classified, this issue is somewhat alleviated, and the research design remains overall intact since only acknowledged and open-sourced systems were considered in the study. Second, the types and numbers of interviews could be expanded, particularly from industry and within the Navy cases. It would have been helpful to access and interview personnel more closely associated with the programs in all their facets, from requirements building, acquisitions, testing, and warfighter employment. Additionally, the Navy interviews represent some bias due to the convenience sampling of officers and academics at the Naval Postgraduate School. The few interviews that went beyond these more readily available resources proved highly insightful as well, and with more time, a more robust interview schedule and sample could be developed.

Another limitation, related to the first area of concern, is the scope of causal mechanisms and factors considered throughout the study. While the number of episodes studied for each UAV case type is tightly focused, the ability to do analytical justice for each innovation perspective (rational, institutional, cultural) became challenging—an acknowledged design concern from the start. Combining UAV episodes such as the RQ-3 and X-45 into one high-end category, especially when separated by time and shifting contextual circumstances adds variety, but also partially muddles the perspective analysis since the episodes do not neatly overlap concurrent time periods or actors. Nonetheless, the number of variables considered across perspectives within and across case types/episodes supported the second research objective of heuristic building. Parsimony is partly sacrificed in favor of robust explanation. The number of factors considered enabled a richness of analysis that generated a more detailed and complete view of military innovation studies and the quality of arguments across the field. The most enduring empirical challenge of the study was the measurement of factor influence upon outcomes.

The author relied on a degree of judgement, bias awareness, and a wide-angle perspective that unfolded during the broad research process and historical analysis within in each episode and across cases.

Fourth, the dissertation only considers two of the three major U.S. services; therefore, in order to fully address the variance and trends in adoption patterns asked in the second major research question, future research should explore Army cases in more depth. Without any Army high-end systems emerging during the third UAV epoch—either experimental or adopted—the extant research provides some answers to the first research question without the Army cases. Of course, should the Army resurrect a high-end project like its 1980s Aquila venture, then a better sampling of cases could be studied across high-end episodes. To conduct cross-case, cross-service analysis in the future, researchers should consider Army systems such as the MQ-1C Grey Eagle, RQ-5 Hunter, RQ-7 Shadow, and MQ-8 Fire Scout. Without Army cases and episodes, it becomes problematic to fully satisfy one of the earlier critiques within the literature review—that military innovation research is biased towards ground-centric cases, and so less generalizable to all military organizations. Without a more in-depth analysis across all services through comparable UAV case studies, it is difficult to make any definitive observations for or against that accusation of bias. That said, the Air Force and Navy cases in this paper provide valuable insight to those institutions' innovative approaches, the mechanisms and their relationships that influence outcomes, and the cultural underpinnings within those organizations.

Finally, Chapter I highlighted an early concern in the methodology related to muddled levels of analysis, since each innovation perspective focuses on different actors and their agency along the hierarchical institutional spectrum. Rationalism lies across the national and service levels of analysis. Institutional perspectives inhabit primarily the service level, and the organizational culture perspective transverses the service level and its sub-groups within the organization (e.g., pilots, non-pilots, etc.). Lastly, the sociological perspective crosses everything from the national strategic culture to individual identities. The intended approach to deal with this methodological concern was to remain focused on the service level throughout each of the rational, institutional and organizational culture perspectives in order to maintain some common perspectives throughout. While there are definitely shortcomings, the study met its intended design for the most part, while staying perceptive to the structural and actor subtleties happening above and below the service level.

The overall research and conclusion provide limited generalized inferences to wider populations, primarily due to the fact that the relationship among mechanisms were not linear.[714] Yet, limited inferences to other cases remains possible and need exploration given the latest combinations of causal mechanisms and contextual considerations generated by the study. Overall, I guard against overgeneralization and limit "contingent generalizations" until the inferences can be tested in new cases, some of which are suggested below.[715]

2. Future Work in Military Innovation Studies

Future work can take four veins: improving the research deficiencies through more evidentiary depth; exploring the Army cases as suggested, along with other institution's such as the Joint Special Operations Command, the Coast Guard, and the Department of Homeland Security; adding new theory-testing research agendas for the field of military innovation studies to include social shaping of technology and the impact of narratives on adoption outcomes; and testing the newly modeled heuristics against other military innovation cases. The first two suggestions were covered above. As for the last suggestion, researchers should apply this study's theoretical findings and heuristics against a widening variety of cases to weigh the validity of the emerging models. In addition to these four veins, the field should reconsider using the term revolutions in military affairs associated primarily with technological phenomenon and ask more how questions, expressly how to innovate best.

The services and industry partners should temper ideations of revolutions in military affairs, certainly associated with technology. Attempts by civilian or military

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[714] George and Bennett, *Case Studies and Theory Development*, 75.

[715] George and Bennett, 84.

leaders to skip generations of technology in warfare applications has a dismal record in all but the most nationalized of efforts such as with atomic weapons.[716] Additionally, categorizing technology within the military sphere as evolutionary or revolutionary has had little sway on actual outcomes and has lost its meaning as the react-adapt cycles have shortened and access to technology as spread globally. As Paul Scharre recently commented, debates over whether a certain technology is evolutionary or revolutionary, have become tiresome and uninteresting given the shift in broader contexts.[717]

The culture of the two services exhibited a track record of innovative success when adopting late but adapting fast, spurring further questions of "how" to best innovate. According to VADM Rondeau. For instance, the MQ-1 for the Air Force; the carrier for the Navy. A significant part of the challenge in developing UAVs and UCAVs like the X-47/UCLASS is that the services are actively learning amid the adoption decision space. The Navy and Air Force are challenged on three fronts: engineering, integration, and ethical frames. Put another way, these challenges echo this study's approach: the rational-technical (engineering), institutional-cultural (integration), and sociological (ethical) perspectives. One of the organizational culture factors considered in this study is the quality of an organizational learning ethos, and Admiral Rondeau's insight about learning while developing supports the notion that the more open an organization is to creative learning processes, the more effective the organization will be in innovating with technology. For the Air Force, the macro-cultural norm outstripped the micro-cultural biases, which the data revealed as secondary steps to the process. Field experimentation with warfighter input as to the viability of the technology in combat environments is what lends credibility to a program once broad, institutional requirements and strategic planning sets the general direction of a technology invention program. A timely article on innovation adoption by three Air Force officers summarized this idea arguing, a good field test can temper

[716] Peter Hickman, "The Future of Warfare Will Continue to Be Human," War on the Rocks, last modified May 12, 2020, https://warontherocks.com/2020/05/the-future-of-warfare-will-continue-to-be-human/.

[717] Paul Scharre (@paul_scharre), "Great Thread on AI+War," Twitter, May 13, 2020, 7:53 a.m., https://twitter.com/paul_scharre/status/1260583999321358339.

technologist and bureaucratic impulses before programs harden institutionally.[718] Again, what is often mistaken as principal cultural bias was really rationalist, utilitarian resistance to poorly thought out design and futurist overreach for those having to employ the systems to achieve military tasks.

With these aspects of future work open to researchers, this dissertation also recommends several questions for the field:

- *How have the civil-military relationships changed regarding their influence and ability to guide or direct innovation?* The changing character of relationships between the military institutions and their civilian leaders indicate a more impervious and resilient institution against civilian inputs, expressly in the long-term.

- *How does funding and budgets affect and sway innovation outcomes?* At first, this question appears overly simplistic and obvious; however, the findings in this study suggest that funding is a key driver of innovation adoption. This finding is in contradiction to Rosen's early work, and most of the innovation study literature either ignores this important factor or takes it as an assumption as always there when and if prioritized. The data from the last twenty-five years covered by this study suggests otherwise.

- *What drives stakeholder consensus in the emerging ecosystem of 21st century acquisitions?* Is the Iron Triangle still a valid lens or model through which to view cross-institutional consensus? What about consensus within the institution, and what is the interplay between top-down and bottom up mechanisms?

- *What caused the shift in strategy, law, and politics to enable the weaponization of UAVs once again, following the hiatus for over twenty-*

718 Paul Birch, Ray Reeves, and Brad Dewees, "Build ABMS From the Bottom Up, for the Joint Force," Breaking Defense, last modified May 13, 2020, https://breakingdefense.com/2020/05/build-abms-from-bottom-up-for-the-joint-force/?_ga=2.179949924.1315595859.1589420727-91389967.1589420727.

five years? What are the implications, if any for changing norms in warfare, to include the weaponization of space and other realms traditionally considered socially off-limits to state-sanctioned warfare? Also, treaties are political instruments that are conditional; furthermore, states can thwart treaties either through secretive measures or when changes occur between and among the parties involved.

- *What are the implications for small UAVs, which are gaining strong advocacy within the U.S. military?* Are these UAV types the real future of unmanned weapons, autonomy, and robotics within the arena of international conflict? There is evidentiary evidence to suggest this is the pattern, and several interview participants pointed to this growing trend.

- *Though early for study, what trends, factors, and causal mechanisms characterize the emerging fourth UAV epoch and why?* This is asked especially given recent DOD and service announcements indicating acquisition process changes and as services shed legacy UAVs (e.g., USAF RQ-4s are now drawing down, another indication of its weaker adoption outcome). Besides the small UAVs highlighted in the above question, manned-unmanned teaming concepts are taking root in the USAF, with engineering, manufacturing, and demonstration occurring for the XQ-58 Valkyrie.[719] The Navy is also increasing its procurement of the MQ-4 Triton and is aggressively pursuing adoption of the MQ-25 Stingray for carrier-based operations.

C. CONCLUSION

The field of innovations studies has a tradition of arguing for a single factor or perspective as having exclusive and predominant explanatory power over other perspectives and factors. This study rejected that premise as a place to start and sought instead to consider each perspective and its factors throughout the process tracing and

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[719] Axe, "The Air Force's Mysterious XQ-58 Valkyrie Drone is Almost Ready."

research efforts using unexplored cases in the recent modern era. The results of the study underline the hazards associated with examining innovation episodes from reductionist perspectives instead of systemically across all lenses. It also considered innovation programs over a considerable time period and in the context of peace time, heightened war, and perpetual conflict, resulting in new mechanism relationships for the innovative phenomena in military organizations.

Overall, the study arrived at the puzzle without any preference for a given perspective. Given the results of the hypothesis testing across perspectives, cross-case analysis, and evaluation of the mechanisms within and across UAV types and episodes from two very different military organizations, key drivers emerged that go against the grain of extant theory and instead chart fresh paths and ideas, elucidating why adoption of major technology is difficult in the military, even when the stakes for state security remain high. In the end, innovation remains more than technology itself, as evidenced by the application of the four perspectives as well as the questions being asked by senior leaders when reflecting on why high-end UAVs remain outside the inventory despite having broad, general support and maturing capabilities.

APPENDIX A. PREPARED INTERVIEW QUESTIONS

Context

- What was the prevailing strategic context, from a DIME and PMESII perspective?[720]
- What was the budget for DOD, service, programs, and research and development?
- What international treaties affected potential legal or normative constraints on technological development?
- What, if any, was the grand strategy shaping the types of technologies that would be pursued?
- What other executive or congressional policies guided DOD technological developments?

Rationalism

- Who and what were the prevailing threats as assessed by national and service level leaders and organizations? How did this assessment inform the organization’s work and decisions?
- Were there wargames or real-world missions that exposed significant challenges? If so, how and in what ways?
- Was there a prevailing doctrine or strategic approach favored by national civilian leaders? By service military leaders? How did this doctrine or strategic approach inform the service’s/organization’s work?

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[720] Traditionally recognized instruments of power are Diplomatic, Information, Military, and Economics (DIME). An intelligence community tool for assessing an adversary is through Political, Military Economic, Social, Information, Infrastructure (PMESII).

- How did leaders and services assess their capabilities against current and future adversaries?

- What programs and technology did civilian leaders support and why? Do we know? How did this affect the program/work?

- How did civilian leadership intervene, incentivize—if at all—the promotion processes and standards within the service?

- What key underlying technologies were required to make the invention more operationally significant compared to existing weapons technology? When did those underlying technologies become available and viable?

Institutionalism

- How did congressional laws, inquiries, or hearings impact R&D, budgetary processes, and existing programs of record as related to innovation efforts?

- What laws, regulations, or mandates guided and shaped the efforts? How so?

- Did the service or its subgroups exhibit key learning traps, particularly Methodism and Groupthink?

- What synergies and gaps did prevailing service doctrine exhibit with relation to national strategies and policies?

- Was there evidence that the service felt institutionally threatened by other services, and how did that compare to assessed international threats?

- What was the relationship between civilian leaders and the service, did it engender consensus, and how did that impact civilian receptivity for service preferences? Was the service receptive to civilian preferences?

- Describe the R&D and budgetary processes for the program / UAV.

- What other programs and projects competed for the organization's attention? Why?
- What objective expectations (time, effects, data) drove the organization internally? Externally?
- List or describe the documents and concepts guiding program efforts.
- Did the service significantly alter its human resources and policies with regard to an innovation episode? If so, how and to what extent? What were the lessons learned after these policies were either implemented (or not)?
- What was the policy preferences of key leaders toward UAV innovation? What were the policy preferences of key organizations toward UAV innovation?
- How did the program/effort receive support or resistance from external organizations and services?

Cultural (Organization Culture and Preferences)

- Does the service exhibit a learning culture and at what level of the organization?
- How did service culture impact the policy preference of the service during the time period of interest?
- What conflicts or hindrances arose throughout the program, and how were they resolved?
- Did the project/effort break ground or introduce new ways to think of the problem/solution? How about new processes?
- What was the preferred solution to the problems?
- What ideas, processes, concepts challenged the prevailing efforts? How so?

- What efforts characterized the service's focus on improvement? Was there a sense of need for improvement and in what areas?

- How did aviation-oriented subgroup cultures differ toward innovation efforts? What about non-aviation-oriented subgroups?

- What subjective expectations (values, norms, identity) drove the organization internally? Externally?

- What constraints such as time, technology, or resources affected decisions and if so, how? Can you describe anything that was sacrificed in that process?

Sociological

- What was the military problem or question driving the development and fielding of the program/system?

- What concerns, spoken or unspoken, shaped and or limited the adoption of a particular program/system?

- How did the service or sub-service group view the 'high-tech' image of war? How did members describe or view issues of human agency (or responsibility) versus the automation and/or mechanization of war?

- How can or would the adoption of UAVs start to remove humans from war in a beneficial or detrimental way?

- How would automation and unmanned systems affect conflict and aggression in society?

- In what ways do UAVs induce or reduce friction in warfare (consider operationally, socially, culturally, and institutionally)?

- What is the operational and societal role of UAVs in warfare? Are UAVs important? If so, how?

- How does an unmanned system affect the identity of the individual operator? The service? A Nation?
- Describe the allure or revulsion of UAVs and UAV warfare?
- What should be given up in order to make the transition to UAVs (and automation) smoother/faster (if at all)?
- What taboos or sacred cows, if any, do UAVs and like systems challenge the organization? the service? the nation?

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APPENDIX B. INTERVIEW LIST

U.S. AIR FORCE

- Michael A. Donley, Secretary of the Air Force, 2008–2013
  - DOD Director of Administration and Management, 2005–2008
  - Asst. Secretary of the Air Force for Financial Management, 1989–1993
- General Ronald Fogleman, Chief of Staff of the Air Force, 1994–1997
- General Timothy Ray, Commander, U.S. Global Strike Command
- Colonel Houston Cantwell, Vice Superintendent, United States Air Force Academy
  - F-16 and MQ-9 pilot
  - Commander, 49th Wing (Remotely Piloted Aircraft), 2016–2018
- Colonel Scott Campbell, former Vice Commandant of the United States Air Force Academy, 2018–2019
  - A-10 and MQ-9 pilot
  - Commander, 355th Fighter Wing (A-10s), 2016–2018
  - Commander, 451st Air Expeditionary Group (F-16s, MQ-9, others)

U.S. AIR NAVY

- Vice Admiral Ann E. Rondeau (Ret.), President, Naval Postgraduate School
- Captain Edward McCabe, Air Warfare Chair, Naval Postgraduate School
  - Commodore, StratCommWing ONE, 2016–2018
  - P-3 and E-6 pilot

- Captain Markus Gudmundsson, Dean of Students, Naval Postgraduate School
  - A-6, EA-6, and F-18 pilot
- Captain Michael Wallace (Ret.), Commander, Carrier Air Wing 3, 2011–2013
  - F-14 and F-18 pilot
- Commander Kathleen Giles, Permanent Military Professor, Naval Postgraduate School
  - Test Pilot; P-3, P-8, S-3B, RQ-21
- Dr. Oleg Yakimenko. Professor, Naval Postgraduate School, Graduate School of Engineering and Applied Science
- Lieutenant Andrew Scherer, MQ-4C pilot; P-3 pilot

APPENDIX C. SCIENCE AND TECHNOLOGY MANAGEMENT

The DOD established a Defense Technology Objectives, Advanced Technology Demonstrations, and Advanced Concept Technology Demonstrations. Subtle, but key, differences have programmatic impacts toward potential adoption outcomes. Understand what sets them apart is important background information for S&T and acquisition processes in the period of interest. A Government Accountability Office document provides insightful definitions and descriptions, which are provided verbatim.

Defense Technology Objectives

> Defense technology objectives (DTO) are used to bring more discipline to S&T projects and to link them more closely with weapon system development programs. A DTO typically involves a particular technology advance, such as high temperature materials for turbine engines and high fidelity infrared sensors. It can also group several technologies into a larger demonstration. Each DTO identifies a specific technology advancement that will be developed or demonstrated, the anticipated date of the technology availability, the ultimate customer, and the specific benefits resulting from the technology. It places a corporate attention and commitment on the technology project by having the technologists, product developer, and customer involved in the project.[721]
>
> According to DOD, the focus of its S&T investment is enhanced and guided through DTOs. Each DTO must go through a formal review and approval process within DOD and must be directly related to advancing the operational concepts depicted in DOD's "Joint Vision 2010" planning document. According to DOD officials, those requirements have helped to eliminate instances in which technologists work on projects of particular interest to them, but with no military application, because the projects should be linked to a specific warfighter need. For fiscal year 1999, DOD established approximately 350 DTOs, which accounted for $3 billion, or less than 50 percent, of the funds DOD had allocated to S&T projects. The remaining funds were allocated to projects under the jurisdiction of each military service or other defense agencies and did not go through the same review and approval process.[722]

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[721] Government Accounting Office, *BEST PRACTICES: Better Management of Technology*, 54.

[722] Government Accounting Office, 54–55.

Advanced Technology Demonstrations

Advanced technology demonstrations (ATD) are intended to more rapidly evolve and demonstrate new technologies so they can be incorporated into a product, if warranted. An ATD has four characteristics that distinguish it from a conventional S&T project. They (1) require large-scale resources; (2) involve the user; (3) use specific cost, schedule, and performance metrics; and (4) identify a target product for inclusion. An ATD is managed by an S&T organization and should conclude with an operational demonstration of the potential capabilities of the technology, equating to a TRL 5 or 6. The original approach to the ABL was essentially an ATD approach. Most ATDs use laboratory hardware to demonstrate the potential capability of nonproduct specific technologies and not prototype hardware. If the technology is determined to be feasible and provides some military use, then it may proceed to the program definition and risk reduction phase of an acquisition program. From that point, the product developer completes the technology development for a specific product.[723]

Advanced Concept Technology Demonstrations

In 1994, DOD initiated Advanced Concept Technology Demonstrations (ACTD) to help expedite the transition of mature technologies from the developers to the warfighters. ACTDs are intended to help the DOD acquisition process adapt to budget constraints while developing technology more rapidly. The purpose of an ACTD is to assess the military use of a capability, such as a weapon, comprised of mature technologies. Typically, ACTDs last 2 to 4 years and consist of building and demonstrating a prototype to provide a warfighter the opportunity to assess a prototype's capability in realistic operational scenarios. From this demonstration, the warfighter can refine operational requirements, develop an initial concept of operation, and determine the military use of the technology before it proceeds to the product development process. According to DOD, ACTDs, which are managed by S&T organizations, will be a key mechanism to ensure technology development is separated from product development.[724]

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[723] Government Accounting Office, 55.

[724] Government Accounting Office, 55–56.

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