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How to become a first mover? Mechanisms of military innovation and the development of drones

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Abstract
States generate the hardware of military power by either developing new technologies as first mover or adopting demonstrated technology as second mover. Given that military drones have arguably demonstrated effectiveness and thus proliferate, scholars have produced profound insights into today's second mover dynamics. Yet, the preceding political process of developing this military technology remains poorly understood. The article's objective is to explain how states become first movers of military hardware. To this end, it applies four causal mechanisms of military innovation studies to the historical trajectory of the development of drones. I argue that security threats initially formed state interests in drones. Yet, capacity was necessary for success. Politically induced transfers and cross-sector diffusion supplied technological progress. At the same time, distributional implications and legacy systems constrained the development process, but could ultimately be overcome. This mechanismic pathway results from the process-tracing analysis of two separate, but related trajectories in Israel and the United States since the 1970s. Given within-case variation, a sequencing and domain-of-application perspective allows the formulation of scope conditions of the mechanisms behind military innovation. This contributes to a historically contingent, yet generalisable, understanding of the political process of how states generate military power.

Keywords
Military Innovation; Material Power; Drones; Israel; United States

Introduction

Generating military power is among the key priorities of states in an anarchic environment. As drones, or unmanned aerial vehicles (UAVs), have strongly affected the projection of military force since 9/11, they have evolved as one of the most widely-debated issues in International Relations and security studies.[1] Approximately seventy to ninety states operate unarmed – often

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[1] John Kaag and Sarah E. Kreps, *Drone Warfare* (Cambridge: Polity Press, 2014); Peter L. Bergen and Daniel Rothenberg (eds), *Drone Wars: Transforming Conflict, Law, and Policy* (Cambridge: Cambridge University Press, 2015); Andrea Gilli and Mauro Gilli, 'The diffusion of drone warfare? Industrial, organizational, and infrastructural constraints', *Security Studies*, 25:1 (2016), pp. 50–84; Michael C. Horowitz, Sarah E. Kreps, and Matthew Fuhrmann, 'Separating fact from fiction in the debate over drone proliferation', *International Security*, 41:2 (2016), pp. 7–42; Denise Garcia, 'Future arms, technologies, and international law: Preventive security governance', *European Journal of International Security*, 1:1 (2016), pp. 91–111.

small tactical – UAVs, and almost thirty of them pursue armed UAV programmes.[2] To the extent that drones allow waging war without risking own casualties, scholars have even argued that they represent 'the most important weapons development since the atomic bomb' and the 'silver bullet of democratic warfare'.[3] However, it is widely acknowledged that the technological origin of drones goes back, at least, to the Cold War, namely to two interrelated periods in Israel and the United States (US) from the 1970s onwards.[4] Therefore, the question arises as to why it took more than thirty years to turn this nascent technical device into an instance of military technology effectively employed in operations. In theoretical terms, this article asks what the causal mechanisms were that triggered the technological development up to its breakthrough after 9/11; and to what extent we may generalise from this case study with respect to the political processes of generating military power. In short, how does a state become a first mover of military technology?

These are both empirically and theoretically relevant questions. First, historians of complex sociotechnical systems have always stressed the importance to focus on the political foundations of new technologies rather than exclusively on their implications.[5] Not only how to adopt demonstrated military power,[6] but also how to generate it in the first place is vital for international relations. Second, this political process of developing military devices is under-theorised. By tracing the historical trajectory of drones as an outcome, the article will advance a mechanismic pathway,[7] which will ultimately enable theory-building beyond the single case of how states develop and produce material power.

The article argues that constantly severe security threats shape state interest in transformative military hardware, which needs to combine with state capacity to supply technical progress. In turn, this combination is indispensable for new military technologies to overcome political resistance from vested interests and legacy systems. More specifically, Soviet-built Arab air defences challenged Israel's air supremacy in the 1970s and created an interest in the development of drones as a potential response. Yet, technical progress depended on capacity and thus on politically induced technology transfers supplied by the US. The preliminary product was a moderately capable drone

[2] Peter L. Bergen and Jennifer Rowland, 'World of drones: the global proliferation of drone technology', in Bergen and Rothenberg (eds), *Drone Wars*, pp. 300–44.

[3] Peter W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-First Century* (New York, NY: Penguin Books, 2010), p. 10; Frank Sauer and Niklas Schörnig, 'Killer drones: the "silver bullet" of democratic warfare?', *Security Dialogue*, 43:4 (2012), p. 363. See, in contrast, Lawrence D. Freedman, 'The drone revolution: Less than meets the eye', *Foreign Affairs*, 95:6 (2016), pp. 153–8.

[4] Konstantin Kakaes, 'From Orville Wright to September 11: What the history of drone technology says about its future', in Bergen and Rothenberg (eds), *Drone Wars*, pp. 359–87; Abigail R. Hall and Christopher J. Coyne, 'The political economy of drones', *Defence and Peace Economics*, 25:5 (2014), pp. 447–50; Bill Yenne, *Birds of Prey: Predators, Reapers and America's Newest UAVs in Combat* (Forest Lake, MN: Specialty Press, 2010), p. 14. See also Katharine H. Kindervater, 'The emergence of lethal surveillance: Watching and killing in the history of drone technology', *Security Dialogue*, 47:3 (2016), pp. 223–38; Linda de France, 'Weaponized predator has 40 years of UCAV predecessors', *Aerospace Daily* (26 February 2001).

[5] Robert L. Heilbroner, 'Do machines make history?', *Technology and Culture*, 8:3 (1967), pp. 335–45; Donald A. MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge, MA: MIT Press, 1990); John Krige, 'The peaceful atom as political weapon: Euratom and American foreign policy in the late 1950s', *Historical Studies in the Natural Sciences*, 38:1 (2008), pp. 5–44.

[6] Michael C. Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton: Princeton University Press, 2010).

[7] Derek Beach and Rasmus B. Pedersen, *Process-Tracing Methods: Foundations and Guidelines* (Ann Arbor, MN: University of Michigan Press, 2013).

employed in Israel's operations in 1982. Subsequently, the US irrevocably pushed the development of UAVs forward up to the so-called drone revolution after 9/11. While a tactical reconnaissance gap had evolved as a security threat to US interests in the beginning of the 1990s, technical progress depended on the supply by neighbouring sectors. However, 'theory-building process-tracing'[8] also showed that the very same threats might countervail the development process and, instead, privilege legacy systems, which had a stronger domestic constituency in place. In contrast to a widespread argument,[9] democratic governance played a less prominent role for developing drones. While casualty-shyness as a causal mechanism constantly loomed in the background of political decision-making, it was hardly a verifiable trigger for the development process.

The article contributes – theoretically and empirically – to a better understanding of how states create the technical prerequisites for generating power; or how to become a first mover of military hardware. Within-case variation across time and space enables the formulation of scope and temporal conditions beyond this single case study.[10] The resulting theoretical contribution stresses that security threats serve not only as the initial trigger, but need to remain constantly salient for military technology development to succeed. The supply of technical progress depends on the state's existing capacity. Strong states require cross-sector diffusion, while weaker ones may also benefit from foreign technology transfers. Moreover, future studies need to expand beyond the mechanisms of military technology development and explicitly theorise constraints, such as distributional implications, legacy systems, and vested interests. While the article's theoretical explanation thus remains historically contingent, it contributes to theory-building of the generation of military power in world politics.[11]

Empirically, the historical analysis does not only close a gap of the contemporary drone debate, but adds novel insights into the interaction of technology and politics and, thus, military innovation. While most scholars of security studies focus on the political implications of new technology, the article does not strictly separate the two domains, but examines their interrelationship. For instance, new politico-military challenges create a demand for technological responses. Yet the potential supply depends on the state's pre-existing technical capacity, which is itself the product of distributional politics over the availability of financial resources for research. In turn, progress of developing the technological response is critical to silence political opposition; and so on and so forth. Only if we understand this complex interaction between technology and politics will we be able to better disentangle the political prerequisites of military innovation.

The article is structured as follows: First, I introduce the scholarly debate on how states generate military power, in general; and drones, in particular. Second, the identified gap, namely a theoretical and historical understanding of developing drones is conceptualised. Third, I derive four theoretical mechanisms from security and military innovation studies to structure the article's theory-building process-tracing, which is itself explicated in section four. Fifth, the empirical analysis proceeds in two related steps in order to explain military drones as an instance of technology development in Israel

[8] Ibid., pp. 16–18.

[9] See, for example, Sauer and Schörnig, 'Killer drones'; Kaag and Kreps, *Drone Warfare*.

[10] Joseph Jupille, James A. Caporaso, and Jeffrey T. Checkel, 'Integrating institutions: Rationalism, constructivism, and the study of the European Union', *Comparative Political Studies*, 36:1–2 (2003), p. 19.

[11] Alexander L. George and Andrew Bennett, *Case Studies and Theory Development in the Social Sciences* (Cambridge, MA: MIT Press, 2005), pp. 111–15; Marc Trachtenberg, *The Craft of International History: A Guide to Method* (Princeton and Oxford: Princeton University Press, 2006), pp. 39–50; Beach and Pedersen, *Process-Tracing Methods*.

and the US since the 1970s. The sixth section engages in theory-building by discussing the theoretical implications beyond the single case. Finally, I conclude by stressing the article's theoretical and empirical contribution.

How to generate military power in world politics?

As military innovation affects the global distribution of power, scholars from security studies have produced profound knowledge of how states combine the mastery of technologies with organisational practices to exploit this hardware on the battlefield.[12] Two pathways of the political process of generating military power need to be distinguished: either a first mover develops a new military technology to increase its power; or second movers adopt a powerful technology demonstrated by another state. Given that 'inventing technologies or even being the first to use them does not guarantee advantages in international politics',[13] scholars of International Relations have predominantly focused on how to become second – rather than first – movers of military hardware and how this affects the global spread of power. As a corollary, they left the field of studying the development of military hardware to sociologists of technology and military historians, which have developed powerful accounts of practices and technologies, albeit largely without generalising beyond the single case.[14]

The diffusion of military power, in general, and variation among early adopters, in particular, has developed into a vibrant field of International Relations and security studies.[15] Most prominently, Michael C. Horowitz has pushed forward adoption-capacity theory to explain the conditions under which second movers evolve rapidly, or not. He stresses a combination of financial intensity and organisational capital to explain this variation and its impact on the spread of military power across the international system.[16] In contrast to this supply-side perspective, other scholars stress state interests over state capacity. For instance, security competition and threats shape a demand for emulating demonstrated military power.[17] Moreover, scholars differentiate external from domestic drivers of innovation.[18] While operational challenges and foreign standards of behaviour (or norms) create an interest to innovate, domestic – often-times bureaucratic – politics may also affect military innovation.[19] Despite this diversity of approaches, the vast majority of accounts starts from the same

[12] Theo Farrell, 'The dynamics of British military transformation', *International Affairs*, 84:4 (2008), pp. 777–807; Dima Adamsky, *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US, and Israel* (Stanford, CA: Stanford University Press, 2010); Horowitz, *Diffusion of Military Power*.

[13] Horowitz, *Diffusion of Military Power*, p. 2.

[14] MacKenzie, *Inventing Accuracy*; Martin van Creveld, *Technology and War: From 2000 B.C. to the Present* (New York: Simon and Schuster, 1991).

[15] For helpful reviews, see Adam Grissom, 'The future of military innovation studies', *Journal of Strategic Studies*, 29:5 (2006), pp. 905–34; Stuart Griffin, 'Military innovation studies: Multidisciplinary or lacking discipline?', *Journal of Strategic Studies*, 40:1/2 (2016), pp. 196–224.

[16] Horowitz, *Diffusion of Military Power*, pp. 30–9.

[17] João Resende-Santos, *Neorealism, States, and the Modern Mass Army* (New York: Cambridge University Press, 2007).

[18] Matthew Evangelista, *Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies* (Ithaca, NY: Cornell University Press, 1988), pp. 6–14; see also Farrell, 'British military transformation', pp. 779–83.

[19] Stephen P. Rosen, *Innovation and the Modern Military: Winning the Next War* (Ithaca, NY: Cornell University Press, 1991); David E. Johnson, *Fast Tanks and Heavy Bombers: Innovation in the US Army, 1917–1945* (Ithaca, NY: Cornell University Press, 1998).

premise. Rather than investigating how states develop military hardware, the attention of scholars focuses on the 'employment of [given] technologies by organizations'.[20]

This predominant focus on second – rather than first – movers is also reflected in the scholarly debate on drone *warfare*. As UAVs have become 'emblematic of twenty-first century military technologies',[21] 'experts in international law, political science, and moral theory have each made a run at catching up with this potentially transformational military technology'.[22] Apart from addressing the effectiveness and legitimacy of drone warfare,[23] the primary question was, again, to what extent drones globally proliferate and what the drivers of these second mover dynamics are.[24] One group of scholars investigated the scale of proliferation and proposed various schemes of categorising drones.[25] This research stresses the increasing proliferation of drones, albeit with an American-Israeli centre. Other researchers moved beyond describing diffusion patterns and tested both constraints and drivers for the spread of drones. For instance, scholars proposed specific obstacles to proliferation (for example, platform and adoption challenges)[26] or stressed democracies' eagerness to acquire and employ drones.[27] Furthermore, Matthew Fuhrmann and Horowitz created a new dataset and examined the global diffusion of UAVs and the national variation among drone adopters, whereby the explanandum was theoretically linked to military innovation approaches. They argued that security benefits and regime-type shaped interests in drones, whereas the quality of an advanced economy – rather than alliance patterns – affected the capacity to adopt drones.[28]

In sum, states may follow two distinct pathways in their search for generating military power. They may either evolve as first mover by developing new military hardware or rapidly adopt demonstrated power and thus become second movers. While the latter process has been addressed by a vibrant theoretical debate of scholars of military innovation studies, the former has been ceded to neighbouring disciplines with less ambition into generalising beyond the single case study. Once more, this pattern of the scholarly literature applies to the recent debate on drones, which has not only revealed macro-patterns of drone proliferation, but also accounted for micro-variation among drone adopters. Therefore, it has to date created a profound understanding of second mover dynamics of drone warfare. However, *how to become the first mover* has remained a lacuna. The development of drones was occasionally described; yet not theoretically explained. The remainder of this article will build on theoretical approaches to second mover dynamics to address this blind spot.

Conceptualising the political process of developing military hardware

To capture first movers' efforts to build drones theoretically, their ultimate success is defined as an instance of technological development of military hardware. First, this explanandum may be present or absent as the outcome of a successful or failed development process. Second, the threshold for a

20 Horowitz, *Diffusion of Military Power*, p. 2.
21 Matthew Fuhrmann and Michael C. Horowitz, 'Droning on: Explaining the proliferation of unmanned aerial vehicles', *International Organization*, 71:2 (2017), p. 397.
22 Kaag and Kreps, *Drone Warfare*, p. 9.
23 Michael J. Boyle, 'The costs and consequences of drone warfare', *International Affairs*, 89:1 (2013), pp. 1–21; Kaag and Kreps, *Drone Warfare*; Bergen and Rothenberg (eds), *Drone Wars*.
24 Horowitz, Kreps, and Fuhrmann, 'Separating fact from fiction'.
25 Bergen and Rowland, 'World of drones'; Fuhrmann and Horowitz, 'Droning on'.
26 Gilli and Gilli, 'Diffusion of drone warfare'.
27 Sauer and Schörnig, 'Killer drones'.
28 Fuhrmann and Horowitz, 'Droning on'.

new technical device to count as an instance is when its employment has evolved as a political option. This normally depends on whether its actual deployment enables either new military practices or standard activities with improved efficiency.[29] Third, it is the product of a political process as both the initial Research & Development (R&D) funding and its purpose are ultimately political.[30]

Yet, in contrast to investigating military innovation as the combination of technological mastery and their organisational employment, the article's exclusive focus is on the first process. While the advancement of military hardware is always connected to the second process, I distinguish technological from diverse types of organisational development. Doctrinal transformation,[31] military adaptation,[32] and organisational transformation[33] are related, but distinct political processes. Although the empirical analysis cannot fully exclude these interconnected issues, the first mover's development of military technology will be at the centre of analysis. If its operational employment evolved as a political option, the military innovation literature would speak of the end of an incubation period or a demonstration point.[34] While this is the point of departure for studying second mover dynamics, it serves as the sequential end of this analysis. Given the fundamental importance of military power to world politics, not only early adoption of innovations shapes political outcomes, but also the initial development of military hardware.

To explicate the observable manifestations of the political process towards the technological development of transformative military hardware, I build on Matthew Evangelista's five consecutive stages of weapon developments in democratic countries. Each stage is defined by distinct challenges and different actors involved. First, scientists advocate military applications of new technological devices (that is, technocratic initiative). Second, in cooperation with military officials, the scientists need to generate interest in the new technology and gradually build a consensus. Third, entrepreneurial stakeholders promote the potential military technology among decision-makers. Fourth, windows of opportunity, such as external challenges, empower promoters to push a technology demonstrator into the production stage. Finally, an alliance of key executives with the legislative branch supports mass production of a new military device (that is, high-level endorsement).[35] According to the article's conceptualisation, the employment of a new military technology evolves as an option at the end of stage four and the beginning of stage five.

In contrast to the dichotomous outcome, the starting point of the historical trajectory is contested. Studies of sociology of technology have stressed that a clear origin of new technologies can rarely be demarcated.[36] The reason is that 'an innovative change is unfamiliar and sometimes inexpensive, it normally begins not in a decision at the higher levels of policymaking and budget-making but in

[29] Mark Z. Taylor, 'Toward an International Relations theory of national innovation rates', *Security Studies*, 21:1 (2012), p. 118; Evangelista, *Innovation and Arms Race*, pp. 51–2.
[30] Marc R. DeVore and Moritz Weiss, 'Who's in the cockpit? The political economy of collaborative aircraft decisions', *Review of International Political Economy*, 21:2 (2014).
[31] Elizabeth Kier, *Imagining War: French and British Military Doctrine Between the Wars* (Princeton: Princeton University Press, 1997).
[32] Theo Farrell, 'Improving in war: Military adaptation and the British in Helmand Province, Afghanistan, 2006–2009', *Journal of Strategic Studies*, 33:4 (2010).
[33] Anthony King, *The Transformation of Europe's Armed Forces: From the Rhine to Afghanistan* (Cambridge: Cambridge University Press, 2014).
[34] Horowitz, *Diffusion of Military Power*, pp. 8, 23–4.
[35] Evangelista, *Innovation and Arms Race*, pp. 53–68.
[36] MacKenzie, *Inventing Accuracy*; Krige, 'Peaceful atom'.

technical and organizational procedures for research and development'.[37] Hence, defining the starting point is ultimately an empirical question – to be answered below.

Theorising mechanisms of developing military hardware

What accounts for states' efforts to generate military power by developing hardware up to the demonstration point? While the sociology of technology provides fascinating insights into the contingent – oftentimes even accidental – trajectories,[38] these historical case studies have not sufficiently found their way into International Relations theory. Consequently, there are few comparable, or even, generalisable insights into the political processes of generating military power. As these processes remain under-theorised, the article builds on the two established distinctions of the military innovation literature to derive four potential mechanisms. First, demand and supply can trigger the development of military hardware. In military innovation terms, these two perspectives translate into interests and capacity: a government might be willing and/or might have the capacity to develop military hardware.[39] Second, political drivers of technology development may originate from the domestic setting and/or from the external environment.[40] Again, two different pathways open up so that we may ultimately distinguish between four mechanisms of military technology development. Each of them is specified below.

First, liberal approaches stress the importance of domestic interests in general, and the relevance of specific governance processes in particular.[41] While there is a rich literature on how different types of political regimes promote distinct military technologies,[42] the article departs from democratic peace theory to derive a mechanism of how governments generate military power. The premise is a systematic link between democratic governance structures and the development of military technologies for the use of force.[43] Casualty-shyness is the causal mechanism that connects the macro-level

[37] James Kurth, 'A widening gyre: the logic of American weapons procurement', *Public Policy*, 19:3 (1971), p. 396.

[38] Heilbroner, 'Machines and history'; MacKenzie, *Inventing Accuracy*; Krige, 'Peaceful atom'. See also van Creveld, *Technology and War*.

[39] Horowitz, *Diffusion of Military Power*; Matthew Fuhrmann, *Atomic Assistance: How 'Atoms for Peace' Programs Cause Nuclear Insecurity* (Ithaca, NY: Cornell University Press, 2012); Fuhrmann and Horowitz, 'Droning on'.

[40] Evangelista, *Innovation and Arms Race*, pp. 6–14; see also Farrell, 'British military transformation', pp. 779–83.

[41] Culturalist mechanisms, such as socialisation, could domestically trigger a government's interest in military technology development, too. Yet, I deliberately decided to exclude this line of reasoning from the article's analysis, such as, Kier, *Imagining War*; Farrell, 'British military transformation'; and, Adamsky, *Culture of Military Innovation*. While culturalist explanations are certainly relevant for technological development of military hardware, two main reasons informed this choice. First, the article's objective is to provide a better understanding of the mechanisms triggering development rather than explaining variation across countries or organisations. Yet, the latter has been the home turf of culturalist theorising. Second, culturalist theories have been particularly applied to the organisational practices of innovation, whereby the armed forces adapt to a new technological environment. Yet, the article focuses on technological mastery in a much narrower sense. Therefore, my decision is based on selecting those theoretical underpinnings, which are most apt to answer the way that the article's research question is raised.

[42] Erik Gartzke, 'Democracy and the preparation for war: Does regime type affect states' anticipation of casualties?', *International Studies Quarterly*, 45:3 (2001), pp. 467–84; Todd S. Sechser and Elizabeth N. Saunders, 'The army you have: the determinants of military mechanization, 1979–2001', *International Studies Quarterly*, 54:2 (2010), pp. 481–511; Jonathan D. Caverley, *Democratic Militarism: Voting, Wealth, and War* (Cambridge: Cambridge University Press, 2014).

[43] Gartzke, 'Democracy and preparation for war'; Sauer and Schörnig, 'Killer drones'.

of political institutions to the micro-level of policy decisions. Given that democratically accountable politicians are risk-averse and fear costly military operations, the development of safe technologies becomes imperative.[44] For instance, democracies have increasingly moved from labour-intensive towards capital-intensive militaries.[45]

The observable manifestation of this causal mechanism is that democratic governance shapes government incentives to invest in casualty-avoiding technological devices. Hence, this mechanism is substantiated when democratic governments particularly promote those military technologies that provide a solution for the tension between its willingness to use force and the otherwise pacifying impact of democratic political structures.[46] More specifically, we should observe that the unmanned nature of UAVs predominantly motivated initial R&D investments in military drones. In contrast, political decision-makers clearly subordinated the operational battlefield advantages in surveillance to the purpose of avoiding casualties or captures of soldiers.

Second, realist thought stresses the predominance of security competition in the international system, which drives state interests in survival and national security.[47] For instance, the nuclear proliferation literature often emphasises the importance of widespread security competition for 'why nations forgo nuclear weapons'.[48] The corollary is that the more a country is disposed to competitive forces, the more resources it will devote to armed build-up and the development of military hardware.[49] Threat to national security is the causal mechanism that connects the macro-level of the security environment to the micro-level of policy decisions. For instance, interstate rivalry over territory is particularly war-prone and easily escalates into war.[50] This threat shapes a government's interest in the development of military hardware.

The observable manifestation is that governments respond to security threats, such as territorial disputes, by increasing their military funding and by promoting new technological devices. Given that arming drones had been the second rather than the first step in the development of unmanned aerial vehicles, their primary military potential was initially seen in advanced reconnaissance.[51] Thus, improved surveillance provides an operational advantage as the monitoring of troop movements and weapons deployments is of critical importance in armed conflicts over disputed territory. In short, this causal mechanism is corroborated, if the government pushes for increased efforts in research and development of military drones as a direct response to territorial disputes or other security threats.

[44] Niklas Schörnig and Alexander Lembcke, 'The vision of war without casualties: On the use of casualty aversion in armament advertisements', *Journal of Conflict Resolution*, 50:2 (2006), pp. 204–27; Kaag and Kreps, *Drone Warfare*, pp. 53–77.

[45] Gartzke, 'Democracy and preparation for war'; Michael C. Horowitz, Erin M. Simpson, and Allan C. Stam, 'Domestic institutions and wartime casualties', *International Studies Quarterly*, 55:4 (2011), pp. 909–36; Caverley, *Democratic Militarism*.

[46] Sauer and Schörnig, 'Killer drones'.

[47] Barry R. Posen, *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars* (Ithaca, NY: Cornell University Press, 1984); Moritz Weiss, 'Power and signals: Explaining the German approach to European security', *Journal of International Relations and Development*, 12:3 (2009), pp. 317–48.

[48] T. V. Paul, *Power versus Prudence: Why Nations Forgo Nuclear Weapons* (Montreal and Ithaca, NY: McGill-Queen's University Press, 2000); Fuhrmann, *Atomic Assistance*.

[49] van Creveld, *Technology and War*; Rosen, *Innovation and the Modern Military*; Resende-Santos, *Neorealism*.

[50] Thomas C. Walker and Paul K. Huth, 'Standing your ground: Territorial disputes and international conflict', *The American Political Science Review*, 91:3 (1997), p. 381.

[51] Hall and Coyne, 'Political economy of drones'.

In conclusion, both casualty-aversion and security threats are firmly established mechanisms to explain state interests in the generation of military power. In contrast to this demand perspective, scholars of military innovation studies emphasise the supply side.[52] The underlying premise is that industrially advanced states have sufficiently strong technological capacity at their disposal to develop cutting-edge armaments. As a consequence, technical progress itself drives the development of new military hardware.[53] Two supply-side mechanisms need to be distinguished as they suggest different pathways towards new military technologies.

First, foreign allies may supply technological input and thus help to provide the capacity for the development of military hardware. For instance, sensitive nuclear assistance contributed to some states' nuclear power. There is a 'strong statistical and causal link between the number of nuclear cooperation agreements (NACs) and the likelihood that a country will initiate a nuclear weapons program and eventually acquire the bomb'.[54] These exchange relationships are first and foremost politically induced as militarily relevant technologies are often not available on global markets.[55] The causal mechanism connecting alliance politics with the development of military hardware is bilateral technology transfer. Given that the development of military hardware is often an incremental and highly contingent process, access to technical support may help to overcome setback and failure at various stages and strengthen the domestic capacity to develop military power.

The observable manifestation is that a state's development capacity of military hardware is supplied by foreign (political) sources. In contrast to arms imports, technology transfers do not necessarily imply the delivery of full military platforms, but of important subsystems, individual technical solutions or demonstrators. This causal mechanism is validated when important stages of the development process of military drones depend on foreign and politically induced input of technical solutions, which represent indispensable prerequisites for military technologies to reach the demonstration point.

Second, advances in neighbouring technologies as well as domestic exchanges across sectors may supply solutions and thus capacity for developing military hardware.[56] For example, commercial exchanges contributed to the spread of dual-use and commercial off-the-shelf technologies. This availability of civilian and military technologies has enabled numerous historical instances of arms development.[57] The causal mechanism that connects a state's technological infrastructure with the development of military hardware is diffusion or, more precisely, learning and emulation.[58] This technological imperative of scientific progress may evolve across technologies and across sectors.

[52] van Creveld, *Technology and War*; Peter J. Dombrowski and Eugene Gholz, *Buying Military Transformation: Technological Innovation and the Defense Industry* (New York: Columbia University Press, 2006).
[53] Judith Reppy, 'The technological imperative in strategic thought', *Journal of Peace Research*, 27:1 (1990), pp. 101–6.
[54] Scott D. Sagan, 'The causes of nuclear weapons proliferation', *Annual Review of Political Science*, 14:1 (2011), p. 232; see, in contrast, Krige, 'Peaceful atom'.
[55] David Rodman, *Arms Transfer to Israel: The Strategic Logic Behind American Military Assistance* (Brighton, UK: Sussex University Press, 2007); Fuhrmann, *Atomic Assistance*.
[56] MacKenzie, *Inventing Accuracy*; James M. Hasik, *Arms and Innovation: Entrepreneurship and Alliances in the Twenty-First-Century Defense Industry* (Chicago: University of Chicago Press, 2008).
[57] Hasik, *Arms and Innovation*; Marc R. DeVore, 'Arms production in the global village: Options for adapting to defense-industrial globalization', *Security Studies*, 22:3 (2013), pp. 532–72.
[58] Resende-Santos, *Neorealism*; Horowitz, *Diffusion of Military Power*.

For instance, Israel's advance in the military information technology sector is attributed to diffusion processes between neighbouring firms of battlefield sensors, on the one hand, and data-fusion techniques on the other.[59]

The observable manifestation of this mechanism is that state capacity enables diffusion across sectors, which, in turn, triggers the development of new military hardware. This diffusion process materialises in technological progress or even breakthroughs in neighbouring sectors, which may 'travel' to new military applications so that successful practices are emulated. When we observe recent technical solutions from neighbouring sectors to overcome technological obstacles of UAV development, this causal mechanism is substantiated.

In sum, the avoidance of casualties, security threats as well as technology transfers and cross-sector diffusion may all have triggered – or not – drones as an instance of developing military hardware. These four mechanisms are sufficiently concise to suggest observable manifestations for historical analysis; yet, sufficiently broad to relate them to standard models of security and innovation studies. The article's underlying premise is that the four mechanisms are *individually insufficient* to explain the outcome.[60] Hence, I assume that they apply only to certain domains of drone developments or only to specific temporal sequences of their historical trajectory. This requires applying a method capable of investigating this kind of within-case variation. Therefore, I chose process-tracing to provide a historically contingent, yet, generalisable understanding of how states generate military innovation and material power.

Process-tracing, theory-building, and the development of military drones

Given the article's research design as a case study, which seeks to know 'more about less' rather than 'less about more',[61] the challenge is how 'can we make inferences from the explanation of individual historical cases to the general explanatory power and scope conditions of the underlying theories that explanations of cases draw upon'?[62] The answer is within-case analysis, in general, and process-tracing, in particular. Therefore, the article applies this method to advance theory development of how to generate military power. Yet, it confines itself in two respects. First, the exclusive focus is on the development of military hardware rather than organisational innovation. Second, it investigates the pathway to become a first and not a second mover.

The method of process-tracing allows to study the drivers of this form of military innovation with a focus on causal mechanisms, 'understood as relatively simple, parsimonious pathways whereby X contributes to producing Y'.[63] The strength or weakness of these mechanisms will result from the empirical analysis. In this sense, the article is eclectic by engaging with theory, developing explanatory mechanisms and applying them to the empirical evidence.[64] The objective is to make

[59] DeVore, 'Arms production'.
[60] Beach and Pedersen, *Process-Tracing Methods*, p. 12.
[61] John Gerring, 'What is a case study and what is it good for?', *American Political Science Review*, 98:2 (2004), p. 348.
[62] Andrew Bennett, 'Process-tracing: a Bayesian perspective', in Janet M. Box-Steffensmeier et al. (eds), *The Oxford Handbook of Political Methodology* (Oxford: Oxford University Press, 2008), p. 702.
[63] Beach and Pedersen, *Process-Tracing Methods*, p. 12.
[64] Rudra Sil and Peter J. Katzenstein, *Beyond Paradigms: Analytical Eclecticism in the Study of World Politics* (Basingstoke: Palgrave Macmillan, 2010); see also Trachtenberg, *International History*.

within-case inferences about the operation of these mechanisms, which can be generalised – under certain scope conditions – to further instances of developing military hardware.[65]

Against this backdrop, the rationale for selecting the development of drones was twofold. First, it was necessary to find a 'typical case … as one that is a member of the set of X and Y'.[66] In other words, all four causal mechanisms need to be realistically present and effective in the ultimately successful development process of military drones. Yet, the question is when, where, and to what extent do the mechanisms influence the development process. Second, in order to draw inferences about the impact of each mechanism, within-case variation across time and space is required. The article applies a domain-of-application approach assuming that the four mechanisms' impact may depend on certain scope conditions. For instance, technology development as unit of analysis facilitates variation across the spatial domain of two states. As a corollary, size and capacity of a state may serve as scope conditions. In turn, the sequential perspective stresses a temporal view, by which different mechanisms account for individual observations within the case, all of which are successively combined to a comprehensive explanation of the outcome.[67] For example, temporal sequencing allows investigating almost-failures of military innovation at certain points of time in order to provide insights into the constraints of technology development. This case selection facilitates midrange theorising of how states generate military power as it allows for: (i) statements on the explanatory leverage of theoretical mechanisms; (ii) contingent generalisations; and (iii) the potential identification of new explanations.[68]

Finally, the development of drones as an instance of developing military hardware needs to be specified. While distinct types of contemporary UAVs are based on distinct technologies and have therefore followed distinct historical trajectories,[69] a better understanding of contemporary drones needs to focus on intelligence gathering: '[by] the 1950s, drones had been adapted to conduct aerial *reconnaissance*, which would become *their principal mission for the next half century*'.[70] Two countries were outstanding for their initial development, both of which have to date evolved as prime actors on global UAV markets. Whereas the United States undoubtedly dominate drone production and military applications,[71] Israel has evolved as the largest exporter, which accounts for the majority of global sales since 1985.[72] This specification provides extensive within-case variation of time (that is, more than two decades of technological progress and setbacks) and space (Israel and the US), which will, in turn, enable theory-building beyond the single case.

A mechanismic pathway of developing military drones

This section examines the historical trajectory of military drones as one instance of military technology development; yet, proceeds in two separate, but related steps. First, the origin is traced back to development efforts in Israel since the 1970s and ends with the creation of an intermediate

[65] Beach and Pedersen, *Process-Tracing Methods*, p. 3.
[66] Ibid., p. 154.
[67] Jupille, Caporaso, and Checkel, 'Integrating institutions', pp. 19–23.
[68] George and Bennett, *Case Studies*, pp. 76–9, 111–15; Beach and Pedersen, *Process-Tracing Methods*, p. 11.
[69] Gilli and Gilli, 'Diffusion of drone warfare'.
[70] Steve Zaloga and Ian Palmer, *Unmanned Aerial Vehicles: Robotic Air Warfare, 1917–2007* (Oxford and New York: Osprey, 2008), p. 4, emphasis added. See also Kindervater, 'Emergence of lethal surveillance'.
[71] Stimson Center, *UAV Export Controls and Regulatory Challenges Working Group Report* (Washington, DC, 2015).
[72] Tia Goldberg, 'Israel leads global drone exports as demand grows', *Associated Press* (5 June 2013); George Arnett, 'The numbers behind the worldwide trade in drones', *The Guardian* (16 March 2015).

demonstration point in 1982.[73] Second, the analysis shifts to the United States, which pushed – despite several setbacks – the development of drones forward to ultimately become the first mover of this military hardware.

The starting point of the process-tracing analysis is Israeli initiatives in the mid-1970s, as – from today's point of view – one may link this period directly with the contemporary drone revolution.[74] First, '[a]lthough the US Air Force had extensive UAV experience in Vietnam, by the 1980s, this experience had largely been forgotten'.[75] Second, in 2000, today's Special Assistant to the Chief of Staff of the US Air Force, Tom Ehrhard, argued that 'Israel is the only nation whose military has achieved *enduring* weapon system innovation with the UAV'.[76] Third, Abe Karem, an aeronautical engineer who later became the *Predator*'s 'dronefather',[77] started to engage with UAV technologies in Israel in the 1970s.

Israel and regaining air supremacy after the Yom Kippur War

First, Israel's historical trajectory suggests that threats to national security were the predominant mechanism for the technological development of drones. Although casualty-shyness constantly loomed in the background, overcoming Arab air defences was the predominant state interest. Second, process-tracing also indicates that Israel's capacity was a necessary prerequisite for technical progress. Since UAVs were not a completely new technology of the 1970s, but drew upon predecessor models by US firms and had been moderately used by Israel's military, the politico-technological environment was generally supportive. Beyond commercial exchanges, the US-Israeli alliance provided access to politically induced technology transfers as a foundation to develop indigenous military drones.[78] Third, given the severe nature of security threats that Israel was facing, political constraints – stemming, in particular, from legacy systems and vested interests – were modest. After the development of military hardware had overcome distributional obstacles at the corporate level, the decision-making process was no longer politicised. In short, Israel generated military power to regain air supremacy *vis-à-vis* its neighbours.

Technocratic initiative. Already since the end of the 1960s, Israel's military planners have increasingly become concerned over the deployment of modernised Soviet surface-to-air-missiles (SAMs) in Arab neighbour countries, as this threatened their reconnaissance missions and air supremacy. As long as these security concerns had not materialised, Israel predominantly imported UAV

[73] An intermediate demonstration point is meant to imply the successful employment of military technology on the battlefield, which raises, at least, some attention among military decision-makers. Yet, both its operational and strategic implications are too modest as to count as a demonstration point of major military innovations. See Horowitz, *Diffusion of Military Power*, p. 24.

[74] Yenne, 'Birds of prey'. In contrast, Kindervater, 'Emergence of lethal surveillance' starts out in the World Wars and stresses the US's *Lightning Bugs* in the 1960s and 1970s. Yet, tracing the mechanisms behind today's most salient drones suggests departing from Israeli developments in the 1970s.

[75] Zaloga and Palmer, *Unmanned Aerial Vehicles*, p. 28. After the Vietnam War, in the US, 'no large constituency for drones ever developed within the military.' Richard Whittle, *Predator: The Secret Origins of the Drone Revolution* (New York, NY: Henry Holt, 2014), p. 22.

[76] Thomas P. Ehrhard, 'Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation' (PhD thesis, The Johns Hopkins University, Washington, DC, 2000), p. 182, emphasis added.

[77] 'The dronefather', *The Economist*, Technology Quarterly (1 December 2012).

[78] Ralph Sanders, 'UAVs – an Israeli military innovation', *Joint Force Quarterly* (2002/2003).

technologies from the US. From the mid-1970s onwards, these bilateral exchanges provided Israel the required capacity needed for the development of indigenous drones.[79]

It was the Yom Kippur War in 1973 that proved to become a watershed.[80] While Israel's Air Force (IAF) had dominated the skies in the Six-Day War (1967), it meanwhile faced Soviet-built Arab air defences. Surface-to-air missiles were supplemented by thousands of advanced anti-aircraft guns, which had prompted Israel's loss of more than 100 of its 340 combat aircraft and, in particular, prevented any Air Force support for Israeli ground forces. In turn, this had not only caused restrictions on the operational room of manoeuvre, but also numerous casualties among both pilots and infantry.[81] The failure to anticipate the battle developments and the heavy losses it had to absorb in the early phase of the fighting dramatically undermined the formerly strong belief in the country's war-preparedness.[82] The near-defeat led to a reevaluation of military hardware. The analysis of the causes for initially poor performance by the Israel Defense Forces (IDF) suggested that Israel lagged behind the developments on the ground due to insufficient reconnaissance means.[83] In short, a severe security threat had materialised and the question was how to generate new military power as a response.

The technocratic initiative began to form during the ceasefire in autumn 1973. Two military functions were considered: (i) drones as decoy for the SAMs; and (ii) drones to improve intelligence. Responding to an informal request by the IAF, Abe Karem, the director of preliminary design of state-run Israel Aircraft Industries (IAI), proposed to develop an unmanned decoy, which could potentially fool SAMs radars. The idea was that the 'enemy's radar' would identify the decoy 'as a manned aircraft and signal a short-range SAM battery to attack it. When the SAM battery turned its radar on …, Israeli planes with antiradar missiles would detect the SAM radar and fire at the enemy missile battery while the SAM battery pointlessly fired on the decoy.'[84] When the ceasefire between Israel and the Arabs stabilised, Abe Karem attempted to advance his potential invention of a UAV decoy, but did not succeed against IAI's establishment. Ultimately frustrated about the distributional struggles within a large defence contractor, he left the company to build an own enterprise and eventually emigrated to the US.

Yet, other scientists came up with a similar initiative, but with a stronger focus on intelligence gathering. Alvin Ellis, a US-Israeli engineer who moved to Israel in 1967 to engage in IAI's fighter projects, had worked as an autopilot engineer in two different UAV companies in the US.[85] In his response to the new threat, he argued that 'a mini-RPV [remotely piloted vehicle; or a drone], slow, capable of good maneuvering, equipped with a TV camera, transmitting pictures in real-time back to the launch point, would change everything and establish the mini-RPV as a first class intelligence tool'.[86] Given that Ellis

[79] Laurence R. Newcome, *Unmanned Aviation: A Brief History of Unmanned Aerial Vehicles* (Reston, VA: American Institute of Aeronautics and Astronautics, 2004).
[80] Michael Raska, *Military Innovation in Small States: Creating a Reverse Asymmetry* (Abingdon, New York: Routledge, 2016), pp. 71–3.
[81] Martin van Creveld, *The Sword and the Olive: A Critical History of the Israeli Defense Force* (New York: Public Affairs, 2002), p. 277.
[82] Ibid., pp. 218–38.
[83] Anthony H. Cordesman and Abraham R. Wagner, *The Lessons of Modern War, Volume I: The Arab-Israeli Conflicts, 1973–1989* (Boulder, CO: Westview Press, 1990), pp. 109–14.
[84] Whittle, *Predator*, p. 11.
[85] Sanders, 'UAVs'.
[86] Ehrhard, 'Unmanned Aerial Vehicles', p. 191.

was also defeated in IAI's distributional struggles, he followed Karem to the corporate world and subsequently promoted his ideas at a private military electronics firm called Tadiran. These failed initiatives indicate that distributional implications unfolded not only at the level of the political system, but also at the corporate level. Large-scale prime contractors like IAI were anxious about the potential impact of small unmanned systems on their business models and thus resisted these innovative ideas.[87] Despite the first-glance failures, scientists had formulated an innovative idea of how to generate military power for Israel.

Consensus-building. Aerospace engineers and the military were able to respond to the new air defence threat by drawing on a given capacity of established technological expertise. While the external threat promoted an interest in ideas of military technologists and entrepreneurial military scientists alike, this was an effort that 'was not directed, rather it emerged organically, the product of an intrepid band of radio-controlled airplane enthusiasts'.[88] Yet, the first attempts to supply a technological solution had met resistance.

Thus, Ellis and his group had taken their drone project to Tadiran. In a quite entrepreneurial and improvised manner, they managed to build a first prototype by drawing substantially on Tadiran's capacity and on commercially imported key parts from the US. These efforts ultimately supplied the *Mastiff* programme. Despite initial opposition, IAI followed suit with the development of the *Scout* drone, after having received politically induced US technology transfers from the mid-1970s onwards.[89] While Ellis and his team favoured a cheap and slim vehicle, manually operated by remote control, IAI scientists worked on a more costly and sophisticated tool that would allow for a wider range of functions.[90] This parallel – and competitive – research track suggested an emerging consensus on the general potential of UAV technologies as battlefield reconnaissance assets. Yet, there were distinct supply options and still little agreement on the specific technological requirements that these vehicles had to fulfill.[91] Ultimately, both politically induced technology transfers and commercial exchanges within and across sectors supplied technological advance of military hardware.

Promotion. Against this backdrop, both firms increasingly promoted their new technical solutions among decision-makers. In parallel, the widely shared crisis perception from the near-defeat in the Yom Kippur War encouraged several far-reaching reforms within the IDF.[92] Responsiveness towards new technical solutions was – all else being equal – higher than in the past. In particular, relevant decision-makers in the military command chain showed increased interest.[93] From 1975 onwards, Tadiran had developed some technological solutions for the Intelligence Corps, whereas IAI could ultimately lever sophisticated technologies developed and transferred by the US for the IAF.[94] Despite this technological progress, no breakthrough had been achieved. Again, a deteriorating security situation enabled further promotion of the new devices.[95]

[87] Whittle, *Predator*, pp. 12–18; see also Hasik, *Arms and Innovation*.
[88] Ehrhard, 'Unmanned Aerial Vehicles', p. 190.
[89] Sanders, 'UAVs', pp. 115–16.
[90] Compared to US projects, both programmes were tiny. Regarding both capabilities and costs, the scope of UAV development in the US clearly went beyond all Israeli efforts combined.
[91] Newcome, *Unmanned Aviation*, p. 94; Zaloga and Palmer, *Unmanned Aerial Vehicles*, p. 21.
[92] Raska, *Military Innovation*, pp. 73–6.
[93] Cordesman and Wagner, *Lessons of Modern War*, pp. 109–14.
[94] Rodman, *Arms Transfer to Israel*, pp. 27–75; see also Ehrhard, 'Unmanned Aerial Vehicles', pp. 193, 196.
[95] Charles D. Freilich, *Zion's Dilemmas* (Ithaca, NY: Cornell University Press, 2012), pp. 122–6.

When the situation in Lebanon began to escalate in late 1980, the IDF's chief of intelligence invited all field commanders to his drones' ground control station to show them hostile activities in real-time. In addition, he established a ground link to military headquarters in Tel Aviv, and senior officials could watch real-time images of armed tensions in the Bekaa Valley. Decision-makers perceived this new military hardware as an adequate instrument to respond to threats; while the prevention of casualties was a secondary consideration.[96] These promotion efforts boosted acceptance of the new technology – a strategy similarly applied during difficult phases of the US's *Predator* development in the 1990s. Ultimately, both the *Mastiff* and the *Scout* were cautiously incorporated into the IDF's military doctrine in 1980.

Open windows and high-level endorsement. The security threats induced by recurring territorial disputes between Israel and its neighbours triggered the breakthrough to employ the new technology and to capitalise on its battlefield achievements. When Syria deployed SAMs to Southern Lebanon in April 1981, it 'not only posed a challenge to Israel's freedom of aerial maneuver over Lebanon, essential to the battle against PLO terrorism from that country, but was in effect extending its control to the south'.[97] The 1982 invasion in Lebanon became the pivot for the full integration of both the *Mastiff* and the *Scout* into Israel's military operations. After the devastating experiences in 1973, the greatest military challenge at the time was Syria's air defences deployed in Lebanon's Bekaa Valley, which essentially prevented any Israeli ground offence towards the Beirut-Damascus motorway. Given drones' extensive loitering capabilities, the IDF acquired precise knowledge and real-time imagery of the enemy's air defence forces that was far more detailed than that obtained by prior means of reconnaissance.

> Before the strike, waves of IDF RPVs [that is, UAVs] moved into place to monitor each of the nineteen SA-6 sites and other tactical targets – they did so at low level to induce the Syrians to turn on their radars. The RPVs were followed by a wave of *Samson* and *Delilah* decoy drones (domestic replacements for US *Chukar* decoys), simulating a massive, manned fighter attack, which caused Syrian crews to expend missiles. When the radars came on, the RPVs beamed radar frequencies back to orbiting battle coordination crews in modified Boeing 707 battle management aircraft, who ordered F-4 *Wild Weasel*-type aircraft to volley-launch improved US *Shrike* and *Standard* anti-radiation missiles … . These missiles and RPVs either hit SA-6 radars or caused Syrian operators to turn them off, effectively blinding the sites. Knowing the condition of the sites due to UAV ELINT and photo links, Israeli air controllers in Grumman E-2C *Hawkeye* aircraft vectored in manned strike aircraft firing optically guided *Maverick* missiles and dropping general purpose bombs and cluster munitions. Seventeen of nineteen SA-6 sites were destroyed in less than one hour, making the air safe for operations against the enemy air force.[98]

This operation demonstrated the drones' combat potential to military experts and subsequently reinforced their integration into the IDF.[99] As a result, UAVs were now battlefield-proven to enhance military power and this operational breakthrough turned out as an intermediate demonstration point.[100]

[96] Ehrhard, 'Unmanned Aerial Vehicles', pp. 196–7.
[97] Freilich, *Zion's Dilemmas*, p. 123.
[98] Ehrhard, 'Unmanned Aerial Vehicles', p. 199; see for more details, Cordesman and Wagner, *Lessons of Modern War*, pp. 142, 186–93; Adamsky, *Culture of Military Innovation*, pp. 94–6; Raska, *Military Innovation*, pp. 75–6.
[99] Sanders, 'UAVs', p. 115.
[100] Newcome, *Unmanned Aviation*, p. 95.

The United States and the tactical reconnaissance gap in the 1990s

The second step of tracing the mechanisms behind military drones turns to the United States and asks how they generated military power by advancing technology development over the 1980s and 1990s. Already since the late 1950s, the US had consistently invested in drone technologies. While their *Lightning Bugs* were deployed to Asia in the course of the Vietnam War and flew over 3,000 sorties,[101] subsequent technological developments had been less successful until the mid-1990s. Given that the innumerable projects of the Army, the Navy, the Air Force, the Central Intelligence Agency (CIA), and other joint organisations created such a variety of technological knowledge, this process-tracing analysis will exclusively focus on the arguably most successful drone, the *Predator*.[102] Yet, it is important to keep in mind that the development of military drones strongly benefited from the US's multi-billion dollar aerospace research infrastructure and key advancements in computing technologies. Against the backdrop of this vast capacity, drones were also a 'free-rider technology'.[103]

First, the process-tracing analysis demonstrates that, again, Soviet-built conventional air defences were the initial catalyst for large-scale US investments in the beginning of the 1980s. Yet, most of these projects lost political support over the course of the 1980s, and were cut down. *Predator*'s predecessors almost failed for their distributional implications. However, a new security problem was shaping the government's interest in UAV technology in the beginning of the 1990s. The US's tactical reconnaissance was unable to track Serbian artillery in the Balkans and thus compromised effective military options. Second, this interest of the government combined with capacity when technological diffusion of dramatically enhanced microprocessors and the operational formation of GPS, supplied technical solutions for UAVs. Third, distributional implications and legacy systems repeatedly exacerbated the successful development of drones, which consistently lacked a strong public constituency. Only when the US Air Force clearly committed to its development could the process of technological development be sustained up until the demonstration point after 9/11. Again, considerations over casualties became only prominent towards the end of this political process.

Technocratic initiative, consensus-building, and preliminary failure. Israel's operational success in the Bekaa Valley served as the background condition of re-enhanced US efforts in developing drones. Though not comparable to the devastating Yom Kippur War, the US experienced a watershed event in Lebanon in the winter of 1983. US Navy fighter pilots conducted an alpha strike against Syrian air defence positions in Bekaa, after the latter had launched surface-to-air missiles against US flight missions. A large number of aircraft should have overwhelmed the Syrians, yet the 'final toll amounted to three US aircraft destroyed, one pilot killed, and a bombardier-navigator taken prisoner'.[104] The Soviet-built SAMs had in practice evolved as a severe threat to US air power. The failure of its operation stood in stark contrast with Israel's success a year ago and US interests formed.

Then-Secretary of the Navy, John Lehman, immediately contacted Israel's authorities to learn about their operational tactics of how they had succeeded against Syria's air defence. Bypassing traditional acquisition channels, the US Navy imported the *Mastiff*. The idea was to learn from the Israelis about

[101] Kindervater, 'Emergence of lethal surveillance', pp. 227–8.
[102] Michael R. Thirtle, Roben V. Johnson, and Joun L. Birkler, *The Predator ACTD* (RAND: Santa Monica, 1997); Whittle, *Predator*.
[103] Ehrhard, 'Unmanned Aerial Vehicles', p. 572.
[104] Ibid., p. 347.

how to overcome Soviet-built air defences, which represented one of the key conventional challenges for the hotspot of US security interests, namely a large-scale confrontation with the main competitor in the European theater.[105] In other words, Israel's use of drones was evolving as an intermediate demonstration point of how to employ military power against a severe conventional threat. In the US, the initial 'impetus for UAV development clearly came from a desire to counter the rise of Soviet air defenses'.[106] As a result, senior Pentagon officials increasingly showed their interest in reconnaissance drones beyond importing the *Mastiff* and turning it into the more advanced *Pioneer* drone.[107]

The technocratic initiative for developing the *Predator* went back to Abe Karem, the former chief of preliminary design of IAI, who had emigrated to the US and constantly worked on high endurance drones (for example, *Albatross*, *Amber*, *Gnat*).[108] He advocated endurance as key asset to the battlefield success of UAVs and attracted the attention of the Pentagon's Office of the Secretary in the form of the Defense Advanced Research Projects Agency (DARPA), whose task was to fund farsighted ideas on the cutting edge of technology. In November 1983, successful tests increased interest in the new technical device and consensus was gradually growing. DARPA aimed to turn Karem's *Albatross* technology demonstrator into a larger endurance UAV that would be able to carry enough weight for military missions. The new drone – a secret and black project – would be called *Amber*. Karem's company, Leading Systems, received a five-million-dollar contract to construct the prototype. Both the Navy and the Army and later the CIA joined in with multiple amounts of funding.[109] Yet, *Amber* did not survive the US's organisational reforms towards centralised drone development in the end of the 1980s as Congress ended the arguably inefficient proliferation of single-service drone projects.[110] What was now at stake were the distributional implications of the new technical device.[111]

First, drones lacked a constituency. Given that DARPA's projects were external to the four armed services, scientists were relatively free to seek non-standard technical solutions. Yet, this privileged position with regard to engineering, in turn, disadvantaged these projects in distributional struggles, as none of the services' vested interests had a stake in them.[112] Ultimately, the project failed to assemble sufficient support by powerful interests within the Pentagon. 'Amber is yet another example of how a weak, divided constituency combined with congressional scrutiny kept a promising system from reaching the field.'[113]

105 Jon J. Rosenwasser, 'Governance Structure and Weapon Innovation: The Case of Unmanned Aerial Vehicles' (PhD thesis, Tufts University, Medford, Massachussetts, 2004), pp. 124–8.
106 Ehrhard, 'Unmanned Aerial Vehicles', p. 50.
107 Whittle, *Predator*, p. 51.
108 Thirtle, Johnson, and Birkler, *Predator ACTD*.
109 Whittle, *Predator*, pp. 53–4.
110 Robert C. Duncan, Director of Defense Research and Engineering, *Memorandum for Secretaries of the Military Departments, Chairman, Joint Chiefs of Staff, Specified Commanders and Directors, Defense Agencies. Subject: Charter of the Unmanned Aerial Vehicles Joint Project Office (UAV JPG)* (Washington, DC, 16 October 1989).
111 General Accounting Office, GAO/NSIAD-89-41BR, 'Assessment of DOD's Unmanned Aerial Vehicle Master Plan', Briefing Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, US Senate (Washington, DC, December 1988).
112 Ehrhard, 'Unmanned Aerial Vehicles', p. 179; see also Rosenwasser, 'Governance Structure', pp. 289, 390.
113 Ehrhard, 'Unmanned Aerial Vehicles', p. 172.

Second, beyond distributional politics, drones faced powerful competitors. They were not the only platform to meet the conventional threat of Soviet air defences. As drones were still lacking essential technical capabilities, highly effective systems, such as the $6 billion stealth fighter, represented a more promising investment for funding military technologies at the end of the 1980s.[114] Consequently, Karem could not prevent bankruptcy despite a few export activities with a militarily less capable version, the *Gnat*. He had to sell his company with all material, patents, and development efforts to General Atomics.[115]

A politico-military window opens. When the leftovers of Karem's drone developments were gradually starving, an unexpected window of opportunity created new demand in 1993. The CIA was facing an imminent tactical reconnaissance gap in Bosnia. The Clinton administration's interest was to break the Serbian blockade of Sarajevo, but the US was lacking any reliable ground information on tracking mobile Serbian artillery.[116] Furthermore, the parallel development of precision-guided munitions as weapons of choice required improved reconnaissance. Hence, US theatre commanders requested better intelligence information than legacy systems like satellites or U-2 reconnaissance jets provided and, thus, became interested in investing in long-endurance drones like the *Gnat* or the nascent *Predator*.[117] By this, 'the Air Force felt its doctrinal autonomy credibly threatened and responded by aggressively claiming Predator for itself'.[118] While distributional consequences had almost drowned the *Amber-Predator* project years ago, the pressing politico-military demand imposed competition to push forward technological developments.[119]

Promotion. The drones' development from the *Gnat* to the *Predator* was accompanied by strategic promotion efforts in order to augment the initially weak constituency among influential decision-makers. A private firm was hired to turn raw tapes of *Predator* video into packaged presentations set to music and deliver them every few weeks, beginning in September 1994, to military leaders, civilian Pentagon officials, members of Congress, and congressional aides.[120] Even a live video link was established to attract the attention among Pentagon leaders: 'Just as the Israelis found when they installed UAV television links in the offices of senior military and government officials, the real-time optical feed can have a transformational effect on skeptics.'[121]

Decision-makers' increasing interest allowed *Predator* participation in the US military's largest annual air and missile defence exercise, *Roving Sands '95*, producing a satisfactory performance.[122] In the summer of 1995, two *Gnats* were deployed to the Bosnian theater as Advanced Concept Technology Demonstrations, the Pentagon's new acquisition category to circumvent the usual legal hurdles of public procurement.[123] Whereas the CIA was in charge of the deployment, the US Army operated them.

[114] Dombrowski and Gholz, *Buying Military Transformation*, pp. 50–1; see also General Accounting Office, 'Assessment'.
[115] Whittle, *Predator*, pp. 59–67.
[116] Rosenwasser, 'Governance Structure', p. 363.
[117] United States Department of Defense, *Unmanned Aerial Vehicle Master Plan* (Washington, DC, 1994); see also Ehrhard, 'Unmanned Aerial Vehicles', p. 47; Whittle, *Predator*, pp. 69–71.
[118] Rosenwasser, 'Governance Structure', p. 400.
[119] Thirtle, Johnson, and Birkler, *Predator ACTD*.
[120] Whittle, *Predator*, p. 95.
[121] Ehrhard, 'Unmanned Aerial Vehicles', p. 356.
[122] Rosenwasser, 'Governance Structure', pp. 236–7.
[123] Thirtle, Johnson, and Birkler, *Predator ACTD*.

A technological window opens. While the escalating security situation in Bosnia shaped US interest in new reconnaissance devices, technological advancements in related – yet, independent – fields supplied new opportunities, which helped to promote the progress of long-range endurance drones. Based on satellites, the GPS provided the long-awaited means for addressing the key challenges of navigation and surveillance.[124] This neighbouring technological innovation delivered drones enhanced capability at essentially no cost.

First, the new system supplied an off-board, omnipresent, and highly accurate location signal and made it significantly more reliable.[125] Second, the frequency-hopping technology of GPS created jam resistance, which in turn improved the UAV's performance even in more hostile environments. However, the operational establishment of GPS was merely one important part of the more encompassing microprocessor revolution, which improved computing power and miniaturisation by leaps. Third, this enabled developing UAVs with more capable payloads and sensors necessary to compete effectively with legacy systems of reconnaissance.[126] In short, technological diffusion supplied solutions to some of the main operational weaknesses of military drones, which was in turn essential to win political support.

High-level endorsement. The operationally moderate – yet politically salient – success over Bosnia evolved as a new model of how to conduct reconnaissance missions, for example, some years later over Kosovo. While the Army had been in charge of the *Predator* in those missions, high-level endorsement was particularly provided by the Air Force – also to prevent the CIA from taking it over.[127] In contrast to his predecessor, the new Air Force chief of staff, General Ronald R. Fogleman, committed his service to the further development of long-endurance drones.[128] Crystallising Congressional support for the drone and an Air-Force-Congress-alliance had indirectly contributed to this choice.[129]

When some Pentagon officials argued to close the reconnaissance gap by legacy systems (that is, satellites), Fogleman did not follow, but instead supported drones like the *Predator* or the emerging *Global Hawk* as a more adequate solution.[130] In August 1995, he formed a UAV squadron near Nellis Air Force Base, Nevada, to prove his commitment. Ultimately, the secretary of defence selected the US Air Force, rather than the Army, as lead service in 1996.[131] '[T]he Air Force's dedication to the program can be measured by the millions of dollars they spent turning the contractor [that is, General Atomics] into a mature aerospace company that can provide technical data and supportability products meeting Air Force standards'.[132] Ultimately, the drone had arrived in Congress,

[124] Zaloga and Palmer, *Unmanned Aerial Vehicles*, pp. 30, 32.
[125] Ehrhard, 'Unmanned Aerial Vehicles', p. 51.
[126] Ibid., p. 499; Zaloga and Palmer, *Unmanned Aerial Vehicles*, p. 29.
[127] United States Department of Defense, *UAV Master Plan*; see also Rosenwasser, 'Governance Structure', pp. 279–86, 383, 396.
[128] 'U.S. Air Force Chief of Staff Ronald Fogleman is turning out to be a big supporter of unmanned aerial vehicles', *Aerospace Daily* (19 June 1995); see also David A. Fulghum, 'Star unmanned aircraft faces bureaucratic fight', *Aviation Week & Space* (12 March 2001).
[129] Darlene Druyun, Assistant Secretary of the Air Force (Acquisition), *Memorandum for USD(A&T), PDUSD (A&T), Subject: Transition for the Predator UAV* (Washington, DC, 9 November 1995).
[130] Whittle, *Predator*, pp. 109–10.
[131] William Perry, Secretary of Defense, *Memorandum for Secretaries of the Military Departments, Chairman of the Joint Chiefs of Staff and Under Secretaries of Defense. SUBJECT: Assignment of Service Lead for Operation of the Predator Unmanned Aerial Vehicle (UAV)* (Washington, DC, 9 April 1996).
[132] Ehrhard, 'Unmanned Aerial Vehicles', p. 543; see also Dombrowski and Gholz, *Buying Military Transformation*, p. 83.

where many influential members were now promoting it for its innovativeness and, in particular, for its potential to avoid casualties.[133] At this stage of the development process, the employment of drones had evolved into a political option, which increasingly provided the opportunity for new or more efficient military practices.

In sum, this historical trajectory draws a picture of a cumbersome pathway towards ultimate success. No state has spent more on UAVs; no state has such a history of failures; and no state predominates drone technologies to such an extent today. In the end of the 1980s, threat-induced interest formation was insufficient, as the technological supply lagged behind. Ultimately, organisational reforms of UAV management stimulated distributional struggles and almost made long-endurance drones obsolete given their weak constituency among the four armed services. However, the tactical reconnaissance gap, which had emerged in-between satellites and manned U-2 spy planes, prevented an employment of precision-guided munitions and thus decreased US military power in the Balkans. In contrast to Israel, where direct and indirect technology transfers from the US were pivotal, the breakthrough of related cross-sector technologies supplied the preconditions for successful development. Advancements in microprocessors in the 1990s and the operational establishment of GPS, in particular, diffused and added so much capability to drones that – from that watershed onwards – they could realistically compete against other reconnaissance options. This combination silenced distributional struggles and resistance from legacy systems to ultimately pave the US's way towards becoming the first mover of drone technologies. Whereas casualty-aversion always played a role in the background, it hardly appeared as an initial trigger of UAV development.

Implications for theory-building: Interests, capacity, and the politics of military innovation

The article's process-tracing analysis has explained how UAV technology could reach the demonstration point after 9/11. Now, the question arises as to what extent the theoretical results can be generalised to the population of instances of military technology developments. What are the implications of within-case variation, sequencing, and domain-of-application for theory-building?

First, state interests in developing military hardware turned out to be prior to the capacity to develop. A severe threat to national security initially formed the interest to consider new technical devices as a response in Israel as well as in the United States. From a sequencing perspective, threats initiated state efforts to generate military power. As long as threats remained constantly salient (that is, Israel), they helped to overcome distributional struggles by making decision-makers more responsive. In contrast, when threats lost salience (that is, US in the beginning of the 1990s), the distributional implications of military innovation endangered further investments. Numerous observations within the process-tracing of the *Predator* indicate that a failure would have been more than likely, if cross-sector diffusion (esp. GPS) had not combined with a new threat (that is, tactical reconnaissance in the Balkans) to reinforce US interests in new technical devices.

The tracing of threats and casualty-shyness indicated the simultaneous presence of the hypothesised mechanisms in the political efforts to find new technical solutions. Yet, the sequential perspective of the instance of drones clearly suggested that threats were temporally preceding and more effective. It is true that decision-makers always prefer fewer rather than more casualties. However, the disentanglement of the sequential process demonstrated that the benefits of certain military missions

133 Rosenwasser, 'Governance Structure', pp. 276–7.

initially outweighed the potential costs. The problem of manned reconnaissance missions was not only the potential death of pilots, but that they would have never gathered the required intelligence (even if they died for it). Casualty-aversion seemed to be an important consideration in the final decision of turning a technology demonstrator into mass production and a much stronger driver of subsequent proliferation.[134] Yet, it was much less a trigger to initiate development efforts in the first place. In short, casualty-aversion only gains in significance over time as the demonstration point approaches and even more as it has passed.

Yet, one caveat remains. Although within-case variation allowed for observations of almost-failures, the article provides no evidence for a negative case of failed development of military hardware. In order to substantiate the suggested pathways, Germany's Cold War development efforts, for instance, could be examined as the scope conditions of interest formation are, at first glance, present: a virulent threat and democratic casualty-aversion.[135] The preliminary answer to this challenge would most likely focus on the combination of capacity and distributional politics. However, this is ultimately an empirical question to be addressed by future research.

Second, moving from an interest to develop towards ultimate success depends on capacity. The process-tracing shows that, whether intended or unintended, the supply of new technical solutions has been a prerequisite for progress and ultimate success. Within-case variation across space helps to specify this mechanism. While both Israel and the US benefited from the supply of technologies across states and across sectors, the former was clearly more important for the weaker actor, Israel. Technology transfers came close to a *sine qua non* for the IDF's initial developments. In turn, the US also profited from Israel's drone development efforts, albeit to a clearly lesser extent. Here, technological progress in neighbouring sectors, such as microprocessors or GPS, diffused and ultimately supplied the technical opportunities for drones to succeed. As a corollary, the technological supply options are contingent on national capacity and technological infrastructure: while stronger states need to rely more on technological diffusion from related fields, smaller states may also access technical solutions by politically induced technology transfers.[136]

Beyond sequencing and domain-of-application, the process-tracing analysis allowed advancing new explanations.[137] While the proposed causal mechanisms focused only on the *drivers* behind generating military power, they neglected the *constraints*. Indeed, the historical trajectory revealed several obstacles, two of which have been central to the political process: distributional implications of developing military hardware and the role of legacy systems. Given that these constraints *almost* led to failures, they also allow for suggestions with respect to non-successful instances of how to generate military power.

First, a new military technology necessarily creates winners and losers at both, the corporate and the political level. Yet, the distributional implications of drones varied and thus unfolded different effects. The process-tracing analysis demonstrated that the weaker the security threat was, the more important the distributional struggles and the more relevant the constituency of the new military

[134] Sauer and Schörnig, 'Killer drones'; Fuhrmann and Horowitz, 'Droning on'.
[135] I am indebted to one of the reviewers for this suggestion for a case study of Germany's development efforts would definitely provide the opportunity to confirm or refute the theory built on the basis of the ultimately successful development of drones in Israel and the US.
[136] See also Rodman, *Arms Transfer to Israel*, pp. 27–75.
[137] Beachand Pedersen, *Process-Tracing Methods*, pp. 19–20; George and Bennett, *Case Studies*, pp. 7, 109–12.

hardware became. While vested interests played a hampering role at IAI's corporate level in Israel, political decision-making was relatively unconstrained once the corporate obstacles had been overcome. In contrast, the US's uncertain security situation around 1990 intensified domestic distributional struggles and drones' weak constituency among the four services almost drowned the *Predator* project. Only when a clearly identifiable security problem re-emerged in Bosnia was the project boosted. The US Air Force emerged as a strong constituency for the project and brought the *Predator* to completion. However, the politics of military technology development went beyond these well-known bureaucratic turf-wars.

Second, legacy systems acted as another constraint for developing new military hardware. Defence planning links military functions via specific requirements with technical solutions in terms of platforms. This implies that new military technologies face a legacy system. The empirical record of the US *Predator* evidently demonstrated this. While drones were meant to confront Soviet air defences in the 1980s, they were not the only technology specified for this task. Most crucially, the immensely capital-intensive stealth fighter project represented an alternative technological solution. In a similar vein, endurance drones faced the legacy of tactical reconnaissance devices as they were squashed between satellites and spy planes, both of which had predefined constituencies in the Pentagon and in Congress. Although none of the systems could close the tactical reconnaissance gap at that point of time, one could have also invested in these technologies in accomplishing this task in the future. The *Predator* ultimately prevailed; yet other technical solutions seemed conceivable in the mid-1990s. These constraints clearly made the historical trajectory of military drones more cumbersome, vague and by no means inevitable. Future studies of technology development may conceptualise distributional implications and legacy systems either as political obstacles at equal footing with causal mechanisms, or as scope conditions for the mechanisms to unfold. Anyway, understanding new military technologies needs to consider existing hardware.

Finally, these constraints also suggest why the development of military technology frequently fails. Although the article's non-variation of outcomes prohibits definite statements beyond instances of successful development, the process-tracing analysis of drones indicates triggers of failures. Distributional implications at both the corporate and the political level showed that these forces have to be overcome by a powerful coalition. In particular, threats have to be salient to enable such a strategy, as the political process in the US has clearly shown. In a similar vein, the progress of the technical development helps to overcome political opposition, as the successful development becomes more realistic. Moreover, one needs to consider legacy systems and development efforts targeted at similar military functions, both of which might contribute to failure, albeit being completely independent from the project itself. This implies the necessity to expand the perspective beyond the respective development of military hardware, if we want to gain a better understanding of varying outcomes of how to generate military power. For this purpose, it seems worthwhile to integrate culturalist and organisational approaches, which have successfully addressed variation of military innovation.

Conclusion

This article addressed two gaps in the literature. Empirically, the drone debate has exclusively focused on effectiveness, legitimacy, and proliferation; yet drones' technological prerequisites and their historical trajectory remained poorly understood. Theoretically, scholars predominantly investigated 'the employment of technologies by organizations, rather than the technologies themselves'.[138] Despite important insights, this perspective has led to a bias towards organisational practices of adopting innovation. In contrast, the development of military technologies has insufficiently been theorised. Against this backdrop, the article asked how to become a first mover, or, more specifically, how to explain the development of drones as an instance of successful innovation.

The process-tracing analysis applied four causal mechanisms – casualty-aversion, threats, technology transfers, and cross-sector technical diffusion – to the historical trajectory of military drones in Israel and the US since the 1970s. It was demonstrated that security threats served as the predominant trigger of the development of drones. Evidence was not only provided by successful steps towards drones, but also by the almost-failure of the US drone programme in the 1990s, which was directly linked to less salient threats. Moreover, technical input – from either politically induced transfers or from neighbouring technologies – was critical for progress. The source itself depended on existing capacity: the weaker the capacity was, the more important were technology transfers. In contrast to the security threat, casualty-aversion was not an initial trigger, as it only gained prominence towards the end of the development process. Beyond the importance of theorised mechanisms, which shape an interest and exploit capacity, process-tracing revealed the importance of the politics of military technology development. Not only distributional implications of new technical devices, but legacy systems also constrained progress at various stages.

These results contribute to two debates in security and military innovation studies. First, they provide a systematic understanding of how to *generate* – rather than adopt– military power. The article does not approach second mover dynamics and thus does not explain system-wide diffusion of power. Instead, it reveals the mechanisms of Israel's and the United States' establishment as the first movers in the world of drones. There is no a priori reason why the article's mechanismic pathway could not be applied to further case studies of military technology development – be it historical instances like submarines or recent innovations, such as cyber weaponry (for example, Stuxnet). When we accept that military power is among the main currencies of world politics, the technological prerequisites of weapon platforms are a highly relevant field of study. While the ultimate employment of technologies is more important for operational success than the possession of these technologies, it is true that the existence of a technical device is the *sine qua non* to employ it. Thus, expanding the scope of military innovation studies towards the technological development process appears as a valuable and necessary enterprise.

Second, this refers, in turn, not only to the empirical focus, but clearly expands toward theorising. Scholars of security studies tend to stress either interests or capacity in their analyses of the dynamics of military power. Yet, the article's sequencing approach suggests that causal mechanisms from both perspectives interact. Neither interests nor capacities are necessarily constant over longer periods of time. This requires moving beyond a short-term perspective by investigating how the varying combination of these dimensions make military innovation succeed or fail. Thus, combining the pathways of these mechanisms across time and space provides a more comprehensive approach, as long as we understand the generation of military power as a long-term political process rather than a brief incubation period preceding the ultimate demonstration of major military innovations.

Finally, the question about the scope of the article's argument arises. The mechanismic pathway, originating from threats, progressing over technical supply towards developing military hardware

[138] Horowitz, *Diffusion of Military Power*, p. 2.

while balancing political constraints, applies to the mastery of technologies side of the story. Despite this limited scope, the theoretical argument seems fully applicable to military technology developments in other democratic states – small and large – and to further time periods. Given the article's close theoretical links to military innovation studies, the results also contribute to this broader debate, as both the development of military hardware and its operational employment in combat are two sides of the same coin: generating military power in an anarchic environment. A better theoretical grasping of the mechanisms behind one of these processes ultimately contributes to a better understanding of the phenomenon of generating military power as a whole. Both sequencing and the domain-of-application have each defined certain qualifications of when the specific causal mechanisms seem to prevail; and it might be rewarding to confront these claims with additional case studies. Ultimately, further contingent generalisations may gradually result from these research efforts to produce a more comprehensive picture of the generation of military power.[139]

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[139] George and Bennett, *Case Studies*, pp. 111–12.