Antitrust and Artificial Intelligence: How Breaking Up Big Tech Could Affect the Pentagon's Access to AI

CSET Issue Brief

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CENTER for SECURITY and
EMERGING TECHNOLOGY

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Executive Summary

Artificial intelligence stands to play an important role in America's defense posture in the coming decades. The Pentagon has identified AI as a critical technology for national security and is working to acquire and deploy AI tools across its operations.

Unlike with many prior defense technologies, the private sector currently drives the development of AI. Therefore, to use AI to America's national security advantage, the Pentagon will rely in large part on the domestic private-sector AI ecosystem. At the same time, antitrust policymakers are contemplating significant changes to this ecosystem, and are even considering breaking up its largest companies. How would such an action affect the Pentagon's AI capabilities?

In this paper, we offer an initial framework for understanding this question. We explore three ways in which breaking up Big Tech could affect the Pentagon's access to cutting-edge AI technology, outlining potential risks and benefits in each case and proposing questions for further research. Our goal is not to answer these questions, but instead to frame specific topics for policymakers and researchers to explore.

Our first and most central consideration is innovation. Large tech companies control many of the key inputs fueling domestic AI innovation, including data, compute (computing power), and talent. The Pentagon stands to benefit from this innovation both directly—by buying products from large, consumer-oriented companies like Google and Microsoft—and indirectly, as traditional defense contractors, military-focused startups, and Department of Defense (DOD) researchers develop AI tools derived from the consumer market. If antitrust action creates a less concentrated AI ecosystem composed of smaller companies, would the U.S. AI sector become more or less innovative on the whole? And would its innovation be more or less oriented toward the Pentagon's specific needs? Key considerations around these questions include the diversity and quantity of data held by big companies; the relationship between firm size, R&D, and innovation; and the effect of scale on talent acquisition, collaboration, anti-competitive practices, and compute.

Second, we consider the Pentagon's acquisition process. While direct contracting with leading tech companies—as exemplified by Project Maven (Google) and Project JEDI (Microsoft)—is not the only mechanism for private sector/DOD AI collaboration, we expect it will play a significant and increasing role. If tech giants are fractured through antitrust action, how might this mechanism evolve? Will smaller AI companies be in a better or worse position to partner with the Pentagon? Key factors to consider here include barriers to entry for Pentagon work and the draw of international markets.

Third, we consider containment. Even if the private sector produces innovative, strategically important AI tools and the Pentagon manages to acquire them, it will need to keep those same tools out of the hands of U.S. adversaries in order to maintain a strategic advantage. Will this process be harder or easier if America's largest AI companies are broken up? Will the Pentagon have those tools to itself? Our framework focuses on cybersecurity as one key factor to consider.

Introduction

In the early 1980s, Steve Jobs assumed leadership of the group of engineers and designers tasked with developing the Apple Macintosh computer. Despite Apple's rapid growth at the time, Jobs refused to expand the size of his team. Jobs had a rule: there could never be more than 100 people working on the Mac.[1] He believed large organizations were "bureaucratic and ineffective,"[2] hindering innovation. In fact, he once proposed breaking the different divisions of Apple into separate corporations so as to retain the features of smaller companies.[3]

Today, lawmakers and policymakers, rather than corporate leaders, contemplate breaking up Apple and other tech giants. Rising concerns about the concentration of economic and political power, anticompetitive behavior, and consumer protection have elevated antitrust enforcement in the national discourse. As of early 2020, Apple, Amazon, Google, Microsoft, and Facebook had a combined value of $5.5 trillion[4]—an amount equivalent to the combined value of the S&P 500's bottom 282 companies[5]—and dominated sectors including cloud computing, digital advertising, and internet search.

Some politicians and users argue that the scale and market power of these companies lets them collect and exploit massive quantities of personal data with minimal oversight. In turn, tech giants insist a break-up will make the United States less secure and competitive.[6] As Alphabet CEO Sundar Pichai has stated, "There are many countries around the world which aspire to be the next Silicon Valley. And they are supporting their companies, too. So we have to balance both. This doesn't mean you don't scrutinize large companies. But you have to balance it with the fact that you want big, successful companies as well."[7] Some policymakers agree. Senator Mark Warner (D-VA) recently stated that he was not ready to support a break-up, as companies like Facebook and Google might be "replaced by an Alibaba, Baidu or Tencent model, where there is no ability to have...controls."[8] Others disagree, noting vigorous federal enforcement of antitrust laws against tech giants such as IBM, AT&T, and Xerox in the 1970s and 1980s. These companies remained successful in spite of regulation; some even argue federal enforcement helped establish the modem market, online networking, and new, innovative companies like CompuServe and AOL.[9]

Antitrust and National Security in Historical Context

Antitrust enforcement and national security concerns have long competed. Thurman Arnold's antitrust crusade of the late 1930s, for example, was an early casualty of World War II. During the war, the Department of Justice dismissed or postponed antitrust actions against industrial powers including Standard Oil, DuPont, GE, Union Railways, and Alcoa.[10] A decade later, Iranian oil shut-offs during the Suez Crisis threatened European oil supplies, leading the Eisenhower administration to cease its antitrust investigations of Western oil companies. The National Security Council determined that antitrust enforcement was "secondary to the national security interest,"[11] and President Eisenhower promised to pardon any oil executive prosecuted.[12]

More recently, U.S. national security concerns have played a role in some of the most notable modern antitrust cases. In United States v. AT&T (1982), Secretary of Defense Caspar Weinberger unsuccessfully lobbied Attorney General William Smith to drop the antitrust case against AT&T,[13] arguing that the company's network was "essential to service national defense communications."[14] National security concerns similarly came into play in United States v. Microsoft (2001). After the September 11 attacks, the possibility of war made renewed relations between the federal government and the country's leading tech firm more important. U.S. District Judge Kollar-Kotelly ordered Microsoft and the federal government to reach a settlement two weeks after the attacks, stating, "in light of the recent tragic events affecting our Nation, this Court regards the benefit which will be derived from a quick resolution of these cases as increasingly significant."[15] The parties settled shortly thereafter.[16]

Understanding AI Innovation

The debate over breaking up Big Tech has profound national security implications. The Pentagon maintains that the innovation and acquisition of AI technologies is critical to America's national security.[17] Defense Secretary Mark Esper recently called AI the most significant emerging technology for warfare, predicting that "whoever masters it first will dominate on the battlefield for many, many, many years."[18] Although others within and beyond the Pentagon stress the limits of AI,[19] its potential is widely acknowledged.[20] In order to develop and deploy new, strategically decisive AI tools, the Pentagon must rely on an AI innovation ecosystem in which large private-sector companies play a critical role. At the same time, the Department of Justice, the Federal Trade Commission, Congress, and state attorneys general have targeted many of the private sector's largest and most innovative AI companies in ongoing antitrust probes.[21]

To be sure, AI innovations take many forms, not all of which hinge on Big Tech. For example, researchers across academia, government, and the private sector continue to push the conceptual bounds of AI, developing new theories and mathematical frameworks that could yield significant technical and commercial benefits down the road. In other cases, AI advances through smaller, practical steps that indirectly support its development—for example, as companies develop more efficient ways to clean and sort data for use in machine learning models.

While important, these theoretical efforts and incremental AI innovations are beyond our scope. We instead focus on AI tools and methods resulting from the integration of basic research with systems of production and deployment, and those with practical, foreseeable implications for AI end users. We assume innovations of this sort would most directly and significantly affect national security and strategic competition.

> **Defining AI**
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> Artificial intelligence has many definitions, and none is universally accepted. Throughout this paper, we use the term in a more colloquial sense than a technical one, but we recognize the importance of providing a working definition. We define AI as the capability of a non-human system to perform functions typically thought of as requiring human intelligence, such as pattern recognition or natural language processing. As used in this paper, "AI tools," "AI methods," and similar terms refer to technologies capable of performing such functions.

Today, the private sector dominates this domain of AI innovation. Other actors, including government funders and academic researchers, play an important role—especially in basic research—but at the application stage, the private sector generally consolidates critical inputs of data, computing power, and human capital, then applies them to real-world needs. In some cases, such as with Project Maven—where Google built AI-enabled image recognition programs for the Pentagon—the Pentagon is the customer; more often, AI products and conceptual breakthroughs developed by the private sector, from autonomous vehicles to image and speech recognition platforms, are (or could be) adapted for national security use.

Because most U.S. AI innovation currently occurs in the private sector, and at least some of this innovation pertains to the Pentagon, the Pentagon needs the private sector.[22] Large tech companies, from Google, Apple and Amazon to slightly lower-profile giants such as IBM, Intel and Qualcomm, form the foundation of the private-sector AI innovation ecosystem.[i] For example, Google, Facebook, Microsoft, Apple, and Amazon[ii] generate the most AI patents with a "significant competitive impact" worldwide, according to analysis by economic consultancy EconSight.[23] The McKinsey Global Institute reports that large, digitally oriented tech companies worldwide spent $20-

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[i] This is not an exhaustive list of leading players in AI. The AI sector is broad and innovation stems from multiple sources. Companies that are not primarily considered tech companies (e.g. GE, Ford, Sony) are also significant contributors, as are niche start-ups and public-private research labs.

[ii] While we frequently cite Google, Facebook, Microsoft, Apple, and Amazon, the arguments in this paper should apply equally to all large-scale tech companies working on AI (regardless of the antitrust scrutiny they face at present), including firms such as Intel, IBM, and Qualcomm.

$30 billion on AI in 2016, 90 percent of which went toward R&D and deployment; for comparison, the Pentagon plans to spend $4 billion on AI and machine learning R&D in FY2020.[24] Private-sector AI companies are especially dominant in applied research and experimental development.[25]

AI innovation would presumably continue in some form without Big Tech, but the data indicates that breaking up the largest tech companies would fundamentally change the broader AI innovation ecosystem. Such action would create unpredictable, but likely significant, trickle-down effects on AI applications in specific domains, including national security.

Shifting Incentives

In order to use AI for America's strategic advantage, the Pentagon requires more than an innovative private sector. It must induce private companies to build defense-relevant AI products, acquire those AI innovations through procurement, and prevent those same products from diffusing to U.S. adversaries. In other technological domains, such as aerospace, the Pentagon has long relied on the private sector for procurement and holds significant leverage over industry. Its sheer scale and budget make it the defense industry's primary consumer. In 2017, for example, 70 percent of Lockheed Martin's sales went to the U.S. federal government.[26] Historically, this financial leverage has incentivized companies to meet the Pentagon's demands and build to its requirements.[27]

> ## Concerns Beyond DOD
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> Our analysis focuses on the Pentagon, but the intersection of antitrust and national security goes beyond the Department of Defense. Other actors, from the private sector to the Intelligence Community, merit consideration when evaluating the effects of antitrust action on national security. An AI ecosystem that favors the Pentagon may or may not serve other national security-relevant entities. For example, if today's tech giants are replaced by an array of smaller companies, including niche defense firms catering to the Pentagon's AI needs, intelligence and law enforcement agencies may lose the ability to access (when so authorized) large sets of diverse, well-organized, and highly concentrated data. An AI ecosystem that benefits the Pentagon on some fronts may harm it on others. The marketplace best suited to the Pentagon could be less favorable for national or international economic growth at large, adversely affecting the tax base and overall defense spending.
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> We focus on the Pentagon, but we do not advocate for a Pentagon-centric approach to the question of antitrust and national security. Rather, a more holistic understanding is appropriate. This understanding should account for and weigh the security trade-offs associated with antitrust enforcement for individual actors and the ecosystem at large.

But these incentives do not exist with AI: while AI is a priority for the Pentagon, the Pentagon is not a priority for AI companies. In general, the largest U.S. tech companies do not rely on government contracts and have relatively little need for Pentagon funding.[28] As a result, their research and products do not reflect defense priorities, and they have relatively little incentive to engage deeply in the government procurement process. Even in a future, AI-centric world, we expect large-scale, commercially oriented tech companies to play a critical role in AI innovation, and the Pentagon to remain a minor customer. As such, the Pentagon may rely on other firms —from defense-focused start-ups to traditional defense contractors—to translate general AI advances into defense-relevant products.

The Pentagon's access to these cutting-edge, national security-relevant AI products hinges on private sector cooperation. This willingness will drive whether it sells to the Pentagon, shapes its technologies in accordance with DOD priorities, and complies with DOD terms of acquisition—including, potentially, by safeguarding the same products from U.S. competitors and

adversaries.[29] We need to understand how antitrust enforcement might affect these dynamics, as well as private-sector innovation more broadly.

Research Questions

In this paper, we focus on how breaking up large companies might affect the Pentagon's access to leading technology. We divide this question into three parts: innovation, acquisition, and containment.

1. Innovation: If forced to become smaller, will tech companies become more or less innovative?
2. Acquisition: Will they be more or less likely to contract with the federal government? Will they be more or less able to contract with the federal government?
3. Containment: Will their innovations be more or less likely to leak or otherwise proliferate?

Our paper is intended solely as a framework for understanding AI and company scale. We propose questions and frame further research, but do not offer comprehensive answers or solutions.

Assumptions and Simplifications

Our analysis includes several assumptions and simplifications. First, by focusing solely on defense procurement, we omit many important dimensions of national security. Economic prosperity, for example, is a cornerstone of national security, enabling states to engage globally, project military power, and remain technologically competitive.[30] Antitrust enforcement could spur or disrupt economic growth. It could also affect the U.S. intelligence community's ability to collect data. Large tech firms store diverse, highly concentrated data, making them a valuable resource for U.S. intelligence collection efforts.[31] However, these concentrated stores also provide a one-stop shop for foreign intelligence agencies—a unique vulnerability.

Second, we equate antitrust enforcement with breaking up large companies. In practice, antitrust enforcers target not only overly large companies, but also companies engaged in a wide variety of anticompetitive practices, from bid-rigging to predatory pricing. Enforcers have an array of compliance tools, such as monetary fines. While these alternate enforcement mechanisms are important, we do not address them in detail in this paper.

Third, we assume antitrust enforcement decreases both absolute company scale (e.g., as measured by number of employees or revenue) and relative company scale (that is, it makes industry less concentrated). In other words, antitrust enforcement would create a less concentrated field of smaller companies, giving firms strong incentives to innovate to capture market share.

In reality, the effect of antitrust action on concentration and competition is unclear—and unlikely to be the same for all industries and economies. For example, scholars continue to debate whether the break-up of AT&T nearly forty years ago led to greater competition in the telecom sector.[32] On the other hand, those in favor of antitrust action frequently cite the experiences of IBM and Microsoft. Proponents argue that government antitrust action against these companies enhanced competition, creating a vacuum for a new generation of companies—including Google, Amazon, and Facebook.[33]

Fourth, we assume national security-relevant AI technologies will result, to some extent, from breakthroughs in general, commercially oriented AI innovation. Most private AI research is not defense-oriented, given the Pentagon's relatively minor role as a customer.[34] Nonetheless, many private sector AI advances are or will be convertible to military ends.[35] Some of this innovation will be transferred directly from the commercial or lab setting to defense applications by the original innovators—that is, commercially oriented tech companies. One recent example is Project Maven. In other cases, defense-focused intermediaries will convert other companies' AI advances into military applications.[36] We assume future AI breakthroughs, whether originating in the private sector or at universities, could be converted into defense applications.

Innovate: Would smaller AI companies be less innovative?

In this section, we evaluate the relationship between scale and innovation. Given a greater number of smaller companies in the AI market, would they and the overall market be more or less innovative? We consider the relationship between firm size and access to data, a critical input for AI innovation. We also examine the relationships between company scale, R&D expenditures, and innovation. If innovation tracks R&D spending, a post-breakup AI sector could be less innovative. Anti-competitive tactics are another concern. Finally, we consider other inputs and factors affecting AI innovation, including business strategy, human capital, and access to computing power.

We estimate that antitrust action will likely reduce the net amount and diversity of data held by firms that are broken up and could also reduce firms' R&D budgets. However, the effect these losses will have on innovation remains unclear. Similarly, we expect firms' computing resources to diminish with yet undetermined consequences; shared compute resources could perhaps more than compensate for any loss.

Data Quantity

Data is a core ingredient in AI development, especially for AI algorithms using machine learning approaches (such as neural networks). Currently, in order to build machine learning models that successfully identify patterns, AI researchers need large volumes of data.[37] Models trained on larger datasets are more accurate,[38] advantaging big firms with more data and users.[39] Breaking up these companies would diffuse large datasets, potentially slowing or preventing AI advances that could benefit the Pentagon. Even though datasets amassed by commercial companies may not always have immediate use for the Defense Department, we expect that most of Big Tech's data can directly or indirectly support innovation relevant to the Pentagon.[40]

However, policy mechanisms, such as a federal data pool or mandated data-sharing, could increase smaller firms' access to data and mitigate this concern. Similarly, firms could contract with one another to increase data access. Such actions could equalize the data playing field or even give small firms an advantage. In addition, standardized data pools might be better for building or training models than the current system of disorganized or siloed data at large firms. At the same time, these mitigating mechanisms could

discourage investments to secure additional data, reducing overall data quantities.[41] For example, a company might rely on a publicly supported database instead of building an innovative application to collect data by other means.

1. How much data do firms really need to innovate?

All else being equal, smaller AI firms have less data. While the relationship between the quantity of data inputs and the quality of algorithmic outcomes is not linear, a correlation is usually evident. For example, recent experiments by researchers at Google found a logarithmic relationship between the amount of data fed into an image recognition model and the model's performance.[42] If more data means more innovation, a post-breakup AI sector could be less innovative overall.

Antitrust action would likely reduce the amount of data held by large companies. This might hurt innovation, especially in application areas requiring exceptionally high amounts of data for acceptable performance.[43] In short, the impact of antitrust action on data-driven innovation may hinge on the size of broken-up companies and their data holdings. Google Search or Amazon Web Services, for example, would be large corporations in their own right.[44] AWS, one of Amazon's larger divisions, achieved revenues similar to Raytheon's company-wide revenues in 2018,[45] demonstrating the possible size of spin-offs.[46]

Although data currently plays a central role in machine learning approaches to AI, some question its future significance in innovation.[47] Less data-intensive machine learning approaches, such as few-shot learning and training on synthetic data, raise questions about the long-term relevance of data to AI.[48] In the longer term, data may be less important to innovation than presently thought, in which case a lower threshold (smaller quantities of data) might not significantly undermine innovation. Similarly, reduced access to traditional data inputs may incentivize companies to invest in alternative data collection and training approaches, which could spur new innovation.

2. How well are larger firms able to use the large quantities of data they have?

Data only matters for innovation insofar as it can be accessed and used. Large companies may struggle to fully utilize their large data holdings, potentially limiting harm to innovation in the case of antitrust enforcement.

Larger companies can't necessarily consolidate and access all of their data. Siloing and scattering occur when data is isolated within certain departments, inhibiting broader collaboration or cross-company use. Data curation—the management and integration of data—also affects its functionality. AI models are only as strong as their training data, and without adequate curation, training data usability diminishes.[49] Training AI models also requires flexible data easily adjusted or re-configured to fit various training approaches. 90 percent of manufacturing lacks this flexible format.[50]

Siloing and scattering disproportionately affect larger companies.[51] At Chinese AI giant Tencent, for example, executives report that siloed data prevents the company from using its WeChat app data to improve other products.[52] A third of executives at large U.S. companies[53] report that data siloing impedes data utilization efforts.[54] While antitrust action would likely limit the quantity of data within companies, it might not limit the amount of accessible, useful data as sharply if much of that data was inaccessible to begin with.

On the other hand, if large companies currently leverage their diverse data well, collaboration between companies or between government and industry could mitigate the winnowing effect of antitrust enforcement. In 1987, DARPA funded SEMATECH, a consortium bringing together leading U.S. semiconductor companies, in an attempt to improve domestic semiconductor competitiveness.[55] SEMATECH significantly reduced the amount of R&D funding needed to produce "each new generation of chip miniaturization" and lowered miniaturization cycles from three years to two.[56] Today, other consortiums like the National Alliance for Advanced Transportation Battery Cell Manufacture and the Department of Energy's solar initiative, SunShot, are modeled on SEMATECH.[57] AI may call for a similar approach; short of breaking up leading tech companies, antitrust policymakers may even consider mandated data sharing (whether through consortia or other means) as an effective antitrust remedy.

Data Diversity

Diverse data can also enhance innovation. Given the option, Fortune 1000 companies are more likely to diversify data sources than expand the quantity of data from existing sources.[58] Of Fortune 1000 executives, 69 percent reported that data variety was the most important factor in their data success.[59] Companies with more diverse data receive "faster intelligence" about products and market trends, which may enable them to better anticipate next-generation technologies.[60] Consistent with this broader dynamic, we assume companies with greater data variety would be better positioned to build new technologies for the Pentagon and other government customers. However, not all corporate data will be a relevant input for Pentagon applications. Mission-specific applications, in particular, will likely rely to some degree on classified or otherwise unique data already held by the DOD.

1. Do larger firms have more diverse data?

The sheer scale of large tech companies makes their data quite diverse; all else equal, smaller AI firms have less diverse data. Alphabet, for example, collects data from Google Search, Maps, YouTube, and Gmail. Antitrust action could reduce the diversity of data held by large tech companies as they fracture and focus on narrower markets. Even if the broken-up companies and their data stores remained large, this data would lose appreciable diversity. If more diverse data means more innovation, a post-breakup AI sector could be less innovative overall.

However, if companies' data did become more homogenous, adverse effects could be mitigated. Companies created in the wake of antitrust enforcement would *collectively* hold diverse data. Creating a centralized data pool might yield an even more diverse stockpile of data than what's currently held by the likes of Google or Amazon. The NIH's Data Commons offers one such example, with proposals circulating to create a similar global data commons for AI.[61] Data sharing through contracts or centralized pools would, however, present an additional set of challenges, including privacy concerns and data security.

2. How well do larger firms leverage their diverse datasets?

Large companies may struggle to fully utilize their diverse datasets, limiting both the innovation upside of diverse data and the innovation downside should antitrust enforcement result in more homogenous datasets. Siloing concerns apply equally to diverse datasets. Antitrust enforcement becomes far less of a threat to innovation if companies cannot currently leverage their diverse data.

R&D Spending

1. What is the relationship between scale and R&D expenditure?

If R&D spending drives innovation, firms that can spend more on R&D— presumably large ones—will generally hold an edge in innovation. A post-breakup AI sector could be less innovative as a result. Large tech companies do in fact spend more on R&D both in absolute and relative terms. According to PricewaterhouseCoopers, in absolute terms, Amazon and Alphabet were the world's top two corporate R&D spenders in 2018, with Samsung, Intel, Microsoft and Apple in the top ten.[62]

In terms of relative R&D spending—the percentage of total firm expenses spent on R&D—large tech companies remained among the highest spenders, led by Facebook (33 percent) in fifth place globally.[63] Alphabet and Microsoft, which each spent 20 percent, and Amazon (13 percent) ranked among the top thirty. The smallest firm (based on total operating expenses) of the top 100 global relative R&D spenders was NXP Semiconductors, a Dutch firm with $6.8 billion in operating expenses.[64]

Because larger firms tend to spend more on R&D, breaking them up would likely reduce their R&D spending. Increases in spending at smaller firms could counter this decline, but the amount and efficacy of that spending are uncertain—both at the individual firm level and in the aggregate across the post-breakup AI ecosystem.[65] That said, broken-up firms would remain very large, with sizable R&D budgets to match. Imagine a break-up of Alphabet, whose operating expenses amounted to $110 billion last year; a spin-off company with one-fourth of Alphabet's current R&D budget would still be larger than 77 of the 100 leading global relative R&D spenders.

2. What is the relationship between R&D expenditure and innovation?

AI innovation is expensive.[66] If R&D spending fuels innovation, larger, wealthier companies with more to spend on R&D will likely lead. However, the research is contradictory: some studies indicate larger R&D expenditures yield greater innovation, while others find the opposite.

Existing research on R&D may not translate neatly to AI innovation; for example, little research considers differences between massive companies like today's tech giants and very large corporations. Analysis of "small" firms' R&D patterns may not apply to potential post-breakup tech companies, which would probably remain quite large. In addition, much of the existing literature is years or decades old, and may not pertain to the fast-evolving AI economy. Nevertheless, existing research can at least guide further work, consistent with the questions and research priorities we frame in this paper.

Since the writings of economist Joseph Schumpeter in the mid-20th century, researchers have debated the relationship between innovation and R&D resources. Schumpeter argued that a strong correlation exists, noting that large firms have the resources to support risk-taking, more experienced and specialized staff, and cheaper access to capital.[67] He believed these characteristics made larger firms optimal for economic growth and innovation.[68]

Significant research now contradicts Schumpeter's work. Some studies show R&D productivity decreases with firm size,[69] and smaller firms are "more profit/cost efficient in innovation,"[70] generating more patents and more citations per dollar spent on R&D.[71] Smaller firms are also "disproportionately responsible for significant innovations,"[72] compared to larger firms that produce fewer innovations per dollar spent.[73] Even among larger firms, innovation doesn't neatly track with R&D budgets. For example, Apple ranked as the 2018 Global Innovation 1000 Study's most innovative company, but spent a relatively modest 5.1 percent of overall sales on R&D— far from the highest percentage among companies in the index.[74]

However, other researchers back Schumpeter. Their work finds large firms are more R&D "intensive"[75] and responsible for "higher quality" innovations.[76] Some posit that "R&D spending and R&D productivity increase with scale," as does "basic research, process innovation, and incremental innovation."[77] Large firms conduct almost six times more R&D, in aggregate, than small firms,

and do so more productively.[78] Collectively, large firms make up 87 percent of the "economic contribution of industrial R&D," making them the disproportionate engines of innovation.[79]

Clearly, no consensus exists around how R&D spending influences innovation. Predicting how antitrust action on R&D resources might affect AI company innovation is therefore difficult. However, some researchers argue more specifically that large firms are more ideally suited for research that utilizes "economies of scale and scope, or requires large teams of specialists such as fundamental, science-based innovations and large-scale applications."[80] AI research, with its high degree of specialization, may fall into this category.[81] If so, scale-reducing antitrust actions could prove damaging.

Other Inputs and Considerations

In this subsection, we explore other variables that could influence innovation in the AI context. While the previously discussed relationship between innovation and firm size may capture some of these variables, we give them individual attention here, as they may have different or stronger effects for tech firms or AI-focused companies.

1. Will breaking up large AI companies lead to a larger AI innovation ecosystem overall?

We assume that antitrust action would produce an AI ecosystem with smaller companies, leading to changes in per-firm innovation capacity. At the same time, aggregate shifts in the AI innovation ecosystem must be considered. If post-breakup companies collectively have less data and compute than contained in the pre-breakup ecosystem, for example, innovation in the aggregate could suffer. On the other hand, if antitrust enforcement leads to a proliferation of new, smaller companies, the sector as a whole could grow larger, potentially accelerating innovation. A new wave of upstart companies could also fuel novel innovation just as the emergence of Google, Facebook, Apple, and Amazon did.

Although the exact composition of a post break-up AI ecosystem is unknown, consumer patterns will serve as a key determinant. If consumers flock to new firms while remaining engaged with existing platforms, the aggregate quantity and diversity of data in the market may increase.[82] Conversely, the break-up

of tech giants could reduce network effects for user-centric companies like Facebook, thus reducing consumer platform activity and participation.

The distribution of new companies will also be a critical factor. These companies could create new markets, products, and platforms distinct from existing firms, yielding previously untapped sources of data and new forms of innovation. Facebook and Amazon have successfully engaged in these practices. On the other hand, a more even playing field might prompt emerging companies to compete directly with broken-up giants. Incumbent firms could challenge Google's internet search monopoly, YouTube's video dominance, and Apple's smartphone market share. Although this competition may spur innovation and shake up the marketplace—just as today's large tech companies did when they arrived—it could also de-concentrate data sources without increasing aggregate data quantities.

2. Can smaller AI firms efficiently collaborate?

Breaking up large tech firms would scatter the inputs to AI innovation, such as datasets, computing power, and human talent, across more companies. However, these same inputs could be reconsolidated through joint ventures, data sharing agreements, industry consortia, and other forms of collaboration between smaller post-breakup companies. If reasonably easy to implement and sustain, interfirm cooperation could drive innovation as effectively as intrafirm coordination pre-breakup, or even more so. In fact, this sort of cooperation is already emerging in the market. Microsoft and Graphcore, for example, just announced the development of Graphcore Intelligence Processing Units, designed to support machine learning.[83] Recent DARPA challenges, like the Spectrum Collaboration Challenge, also indicate that the Pentagon values a collaborative approach to AI.[84]

In practice, though, cooperation is not always easy.[85] When different parties supply set components for larger products, the end product can suffer because no entity has high-level, comprehensive control over it. [86] Similarly, existing research suggests that cooperation driven by vague or short contracts often falls short for "projects involving advanced innovation."[87] Greater reliance on contractual relationships and collaboration for critical inputs like data and compute could also make AI firms more vulnerable to supply shocks.

Finally, a more collaborative environment also raises questions of integration. Instead of drawing on central, intrafirm sources, companies will have to leverage diverse inputs from multiple vendors, which could complicate coding, cleaning, and sorting data. Although contracts could serve as substitutes for intrafirm resources, negotiating and enforcing contractual relationships entails potentially significant transaction costs; large firms can avoid this inefficiency and accelerate innovation by bringing inputs together under one roof, making contracts unnecessary.[88]

3. Are smaller vendors more likely to produce innovative products that meet the Pentagon's needs?

Tech industry leaders have relatively little incentive to work with the Pentagon. Their companies already enjoy broad customer bases and financial independence from U.S. government contracts—including those at the Pentagon.[89] DOD contracts involve applying AI technology in varied, complex, and operationally demanding environments with low tolerance for error. Similarly, industry has little motivation to take on unique DOD data management and privacy requirements, such as data compartmentalization, protection against deceptive or compromised data inputs, and strict data accountability provisions complicating algorithm training.[90] Finally, some commercial AI advances will easily convert into Pentagon applications. Others will require significant, difficult adaption and productization.

Antitrust action could create smaller AI firms targeting DOD business as their "niche." With the Pentagon as their sole customer, these firms could focus on its unique needs, tailoring broader AI innovations for the Pentagon through productization and organizational adaptation. They could follow the example of Palantir, which makes 50 percent of its revenue from government contracts,[91] or Kratos (60 percent).[92] In the last five years, a number of companies have emerged in this mold, including Anduril Labs (2017), Shield AI (2015), Descartes Labs (2014), and Uptake (2014). As smaller firms' primary, high-value customer, the Pentagon can dictate their innovation objectives, ultimately yielding AI applications better suited to defense needs.

U.S. Tech Companies' Sales Derived from Defense Department Contracts in 2016[93]

Company[94]	Sales ($ Billions)	Percentage of Sales Derived from DOD Contracts[95]
Apple	216	<1%
Amazon	136	<1%
General Electric	111	<2%
3M	30	<1%

U.S. Tech Companies' Revenues Derived from Defense Department Contracts in 2016[96]

Company	Revenue ($ Billions)	Percent of Revenue Derived from DOD Contracts
Google	90	0%[97]
Microsoft	85	<1%
IBM	80	<1%
Hewlett Packard	48	<2%
Facebook	28	0%
Tesla	7	<1%

4. Does scale influence the speed with which firms can iterate?

Innovation requires iteration, so if smaller, post-breakup firms iterate faster or slower than the larger firms they replace, the pace of AI innovation could change. Unsurprisingly, firms completing production cycles faster tend to produce more innovations over time,[98] but whether larger or smaller firms have an advantage here remains unclear.[99]

The speed with which a company iterates can depend on the flexibility of its resources.[100] At small firms with more limited resources, an "influential

champion" might steer resources or support toward a project, changing its timeline.[101] Small firms may also deploy and redirect resources more quickly than large firms, although the evidence is far from conclusive.[102] These advantages could activate as companies become smaller in the wake of antitrust enforcement.

5. Are larger AI companies more diverse?

Scale might position bigger companies to be better innovators in other ways. For example, racial, ethnic, and gender diversity in the workforce makes firms more innovative.[103] One study found companies with diverse management teams generated 19 percent higher revenues due to innovation.[104] Diverse companies may therefore advance AI faster than smaller, post-breakup companies, though little data exists on whether smaller or larger firms have more diverse workforces. Most existing literature on corporate diversity measures diversity across a range of large firms; very little compares diversity between large and small firms.

As smaller firms proliferate, workforces may become more homogenous, lessening innovation.[105] While large tech firms' diversity problems (especially among engineers) are well documented,[106] more research is needed to understand how changing tech firms' scale might affect their diversity, and any related effects on innovation.

6. How important is internal crossover to innovation?

According to research by the Boston Consulting Group, the most innovative firms have "multiple divisions."[107] These divisions encourage collaboration, employee mobility, and multifaceted projects, leading to more knowledge- and resource-sharing with the end result of greater innovation.[108] Smaller AI companies may have less internal cross-over, which could slow innovation.

All else equal, we would expect more opportunities for internal crossover in larger tech firms.[109] Breaking them up could diminish this input to innovation. It is unclear whether offsetting factors could increase mobility within start-ups or smaller firms if larger firms were broken up. Employees at smaller, newer firms may wear multiple hats at once, for example, creating a sort of intrapersonal crossover.

Again, however, the offshoots of Big Tech could remain relatively large. A standalone version of YouTube or AWS would retain the structure of a large company and the intra-firm mobility opportunities to match. Large companies with numerous divisions can also become paralyzed by bureaucracy, turf wars, siloing, and other anti-innovative dynamics. These dynamics could undermine the innovative benefits of internal crossover both in existing large tech companies and their potential broken-up (but still large) successors.

7. Does scale encourage business tactics that undermine overall innovation?

As companies grow, so does their leverage over the market. Large tech companies have long touted themselves as key enablers of small businesses through their advertising, communication, and sales platforms.[110] Earlier this year, Mark Zuckerberg argued that Facebook provided small companies with "the same technology that previously only big companies have had."[111] While this argument has some merit,[112] the presence of large-scale companies can also suppress innovation and stifle competition within a marketplace.

In recent years, Facebook, Amazon, and Alphabet have purchased or copied features of possible rivals, most of which were start-ups.[113] In some instances, large firms replicate the start-up's service, then incorporate it into their own platforms, as happened with OfferUp and Houseparty—start-ups that inspired Facebook's marketplace and group video platforms. These practices undermine the original innovators and may thereby discourage innovation in the first place.

Over the past decade, AI start-ups have become hot acquisitions. In 2014, 42 AI start-ups were acquired; by 2019, this number rose to 231, led by Apple, Google, and Microsoft.[114] These acquisitions further consolidate specialist talent and decision-making within existing tech giants, enabling them to set future innovation objectives and approaches. The acquisition of potentially disruptive start-ups by incumbent firms, which sometimes resist products that might radically alter existing market dynamics, could hurt AI innovation overall.[115] In this case, breaking up large AI firms could increase innovation.

Scale can also shift the *nature* of innovation. Maintaining market position doesn't always require fundamental innovation when a company controls a market share majority in a given field, as leading U.S. tech companies do:

Google controls 90 percent of internet search,[116] Amazon over 50 percent of online commerce,[117] and Facebook 83 percent of social media ad spending.[118] One study found very large organizations are the *least* likely to introduce "radically new products."[119] Large tech companies have less incentive to continue innovating in domains they already dominate. In fact, as their market share expands, incentives progressively increase for larger companies to bury innovations threatening existing market power.

The innovation incentives for start-ups are changing, too. Increasingly "built for sale, not for scale," start-ups may fill obvious, existing niches rather than pursue industry-changing "moonshot" innovations.[120] The presence of large-scale firms even stops some innovative entrepreneurs from launching start-ups in the first place and prevents others from receiving the requisite seed funding to do so.[121] When these start-ups do successfully launch, their ability to scale has become compromised. One recent study found that the rate at which "high-quality startups" were founded in America remained steady between 1988 and 2014, while their ability to "scale in a meaningful and systematic way" markedly decreased.[122] Incumbents could be to blame.

8. What is the relationship between firm size and access to computing power?

Computing power, also referred to as compute, is one of four key ingredients for AI innovation, along with data, algorithms, and talent.[123] Smaller AI firms may have less access to compute, which could hinder innovation given the amount of compute needed for advanced AI training.[124] It takes four to 12 years for the cost per unit of compute to decrease by one order of magnitude.[125] The biggest AI experiments thus grow more costly, increasing by a factor of 10 every 1.1 to 1.4 years.[126] Since compute is expensive, firms with more money, which tend to be larger, enjoy a strong advantage.[127] Many AI start-ups also pay leading providers like Amazon, Microsoft, and Google for compute.[128] As a result, these start-ups both fund their rivals and risk being "priced out of the space" through monopoly rent practices, damaging their ability to innovate.[129] In lieu of mandated break-ups, antitrust policymakers could stipulate that leading cloud providers—like Amazon and Microsoft—sell compute at cost to companies under a certain size.

In the future, however, pooled compute could ease this imbalance. The resource barrier that small firms face could be offset by a central compute reserve, compute consortium, or by external contracting. Some states, like

Massachusetts, have established High Performance Computing (HPC) centers. State-level HPC facilities make compute more accessible and help smaller firms overcome the prohibitive costs associated with it. These firms could also continue to contract compute from large vendors like AWS, although doing so might cost more than outright ownership for companies with extensive compute needs, defeating the point of contracting for compute in the first place.[130]

9. Are larger firms better able to recruit top AI talent?

Talent is another critical input for AI innovation. To the extent large AI firms can better attract talent, including foreign-born researchers, they have a strong advantage over smaller firms with scarcer resources. Existing research indicates that small firms "more efficiently offer contracts that reward performance,"[131] such as contracts giving engineers and other key employees equity, enabling firms to "attract and retain engineers with higher ability and skill."[132] At the same time, after controlling for employee quality, large firms pay higher wages[133] and offer more benefits[134] than small firms, though this gap is shrinking.[135]

Overall, it remains unclear exactly how shrinking tech companies would affect talent recruitment in the AI sector. The standalone components of broken-up tech giants would remain large. Whether or not today's Alphabet might attract more talented researchers than a standalone Google Search is hard to determine and may hinge on other benefits of scale (e.g., more money for R&D or larger research staff). Talent flows must be monitored if antitrust action occurs.

In addition, talent in the U.S. AI sector is heavily foreign-born. Large companies may secure more top foreign-born AI researchers and scientists given their well-documented advantage in the U.S. visa process.[136] Large companies can afford the sunk time, fees, and personnel resources inherent in the process, providing better access to top AI talent. In fiscal year 2019, for example, one percent of company applicants accounted for half of all approved H-1B petitions.[137] Large companies also dominate the employer-sponsored green card process.[138]

Antitrust enforcement could result in fewer U.S. firms with the resources to navigate the immigration process, diminishing the entire U.S. AI sector's ability to sponsor critical foreign talent. The total number of foreign AI

researchers entering the U.S. AI ecosystem could decrease as a result, potentially hurting innovation. Conversely, as tech giants shrink through antitrust action, the same number of green cards and visas could be spread across more companies, diffusing talent to more firms and generating new sources of innovation.

However, some immigration pathways are not employer-sponsored.[139] In the future, U.S. immigration policy could shift away from an employer-centric system altogether.[140] With this change in immigration policy, breaking up large employers would have less of an effect on foreign talent. Other changes to U.S. immigration policy could help AI companies of all sizes remain competitive in the fight for top talent. Lifting numerical limits on employment-based green cards and H-1B visas, for example, could increase the U.S. pool of foreign-born AI researchers, as could an end to country-specific green card caps.[141] Congress could also give the AI industry preference in the visa process, establishing new visa or work authorizations specifically for the field.[142]

Acquire: Does the Pentagon's ability to access private-sector products change with firm size?

In this section, we consider whether the Pentagon's ability to access private-sector products changes with firm size. Today's tech giants are increasingly focused on and entangled with foreign markets, complicating their ability to contract with the U.S. government. Would smaller firms be less entangled? For their part, smaller AI firms may face bureaucratic challenges in the federal procurement process that their larger predecessors would have avoided. Would this hamper their ability to effectively contract with the Pentagon?

We believe antitrust action could spur the growth of more "niche" AI firms—smaller companies focusing almost exclusively on government contracting. The emergence of these firms could reconfigure existing incentive structures, which disempower the Pentagon. We also expect small firms to be less entangled internationally, making them more appealing contractors. While the Pentagon has a mixed record on small business contracting, post-breakup firms could be large and sophisticated enough to successfully navigate the government contracting process.

1. Are larger companies more likely to focus on international growth?

A post-breakup AI sector composed of smaller firms might have fewer foreign governments and technology linkages, reducing the risks of U.S. government contracting for both the Pentagon and companies themselves. International expansion and domestic government contracting sometimes stand at odds. Yet the leading U.S. tech firms all have an international presence and prioritize foreign expansion.[143]

As companies become more intertwined with and subject to pressure from foreign customers and governments, the Pentagon and other national security customers may view those companies and their products as too risky for defense purposes. The Pentagon has previously ended contracts on the basis of contractors' foreign entanglements. In 2017, it terminated its relationship with Kaspersky Lab, a Russian software and cyber firm, following concerns about Russian intelligence bugs in Kaspersky products.[144] In 2019, it cut ties with Huawei, the Chinese telecommunications giant,[145] going so far as to ban the sale of Huawei phones on U.S. military bases.[146] Huawei joined a growing list of Chinese companies the DOD monitors in an effort to protect American supply chains.[147]

At the same time, as U.S. firms become more entangled globally, they may choose foreign markets over U.S. government contracts. Foreign markets, particularly in China, have high sales volumes and potential for large profits. The allure of these markets could outweigh a few, large contracts with the U.S. government. Larger companies will more likely encounter this choice given their international opportunities of significant scale. Companies choosing to expand abroad would more probably accumulate foreign creditors, regulatory requirements, supply chain relationships, and other exposures reducing their appeal for the U.S. government. Smaller firms are less likely to face this tradeoff, and less inclined to choose foreign markets; for these firms, the value of international expansion often does not exceed that offered by domestic growth.

Moreover, just as the U.S. government has warned private and public entities from partnering with foreign companies like Huawei and Kaspersky, foreign governments may cut off American firms' access to their citizens if seen as too close to Washington.

2. **What obstacles prevent smaller companies from working with the Pentagon?**

Contracting with the Pentagon is difficult, expensive, and time-consuming. Smaller AI firms may be less able to navigate the federal procurement process, effectively preventing the Pentagon from accessing their technology. The few DOD programs that do partner with smaller firms are under scrutiny for their efficacy.

The high barriers of entry, coupled with an unstable budgetary environment and the high certification costs of federal contracting, favor larger companies.[148] Simply put, large firms have more resources and deeper institutional knowledge to bring to the federal contracting process.

A number of programs encourage the Pentagon to partner with smaller firms, bypassing traditional obstacles. While the component pieces of large tech firms (Google Search, YouTube, AWS, and so on) would not qualify for these programs, niche AI firms focused on productization and Pentagon-specific AI applications could be eligible. The SBIR and STTR programs help fund new technologies developed by small businesses,[149] and OTAs (Other Transaction Authorities) incentivize work with smaller vendors. These newer approaches to federal contracting—with their faster timelines and increased flexibility—suit

technology products. Yet in spite of their promise and expansion,[150] these programs have yielded mixed results; they would not be feasible options for major AI contracts like JEDI. Five recent audits found the Pentagon does not prioritize small business contracting.[151] Other investigations concluded that these "small business" initiatives have disproportionately benefited large companies, channeling contracts to traditional vendors.[152] In the long term, the extent to which the Pentagon invests in small businesses and how well existing programs facilitate that relationship remains unclear.

While the Pentagon may have more leverage over small firms, these firms' difficulties working with the Department of Defense may continue. Smaller firms emerging in the wake of antitrust action will have to overcome these challenges. Yet the relative size of broken-up tech companies remains unknown. Though somewhat smaller than their present size (i.e., a standalone YouTube would be smaller than Alphabet), these companies would still dominate the market. If firms emerge from a break-up at this size, concerns about leverage or contracting capacity may lose relevance.[153]

Contain: Are significant breakthroughs more likely to proliferate from small firms?

Finally, we consider the "containability" of national-security relevant AI products. Technology matters in national security only when it creates asymmetries: if stolen or leaked, breakthrough technologies don't provide their owners with the same strategic advantage. Would defense-related AI innovations from smaller AI companies be more likely to leak or otherwise proliferate, offsetting any potential national security advantage for the United States?

We acknowledge that some intangible AI advances, such as open-source machine learning libraries, may not be easily containable. However, more task-specific AI applications embodied in physical systems, including security-relevant applications, are less likely to be shared openly. In addition, to the extent software and other AI intangibles develop clear and immediate implications for defense and strategic balance, we expect national security actors would increasingly look to limit their proliferation with tools such as export and investment controls or cybersecurity mandates.[154] While costly and imperfect, these tools could slow diffusion to some extent.

Less research exists on the proliferation of dual-use technologies such as AI than on tech innovation and acquisition, and relevant "facts on the ground" change rapidly. As a result, this section is more provisional than the others and our discussion illustrative, rather than comprehensive. We first focus on cyberespionage, a major means of technology transfer. We explore whether smaller firms invest less in cybersecurity, which could increase their vulnerability. Similarly, we consider targeting: Are smaller firms easier targets for cyberattacks? Or does their size help them fly under the radar? We then consider technology transfer by means other than cyberwarfare, such as traditional human collection. Although these non-cyber means are gaining attention, more research is needed to determine how firm size might affect them.

1. Does scale affect the resources a company invests in cybersecurity?

Smaller AI firms might invest less in cybersecurity, making them and their products more vulnerable. Cybersecurity is expensive, and trade secret theft occurs primarily through cyberattacks.[155] Although big companies have a larger attack surface and more points of vulnerability, they also have the

ability to invest in cybersecurity. By contrast, small firms often lack the cybersecurity resources to defeat sophisticated, state-sponsored hackers.

The top U.S. tech firms lead in domestic absolute spending on IT, which includes cybersecurity.[156] Facebook's Head of Global Affairs, Nick Clegg, claimed that "the resources that we will spend on security and safety this year alone [2019] will be more than our overall revenues at the time of our initial public offering in 2012. That would be pretty much impossible for a smaller company."[157]

Not coincidentally, smaller businesses run a greater risk of cyberattack,[158] and they are less likely than large companies to identify the source.[159] Because of their size and access to larger companies through the supply chain, smaller firms are lucrative cyberattack targets.[160] Moreover, if smaller, post-breakup companies increasingly work on defense-relevant products, they will become more salient targets for foreign actors. Cybersecurity breaches generally result from internal mistakes rather than foreign government activity,[161] yet "Defense Technology" and "Information and Communication Technology" are two of six industries identified by the National Counterintelligence and Security Center as the most likely targets for foreign intelligence collectors.[162]

Again, however, the companies created in the wake of antitrust action will not necessarily be "small" or even "middle tier." A company like YouTube, for example, would likely retain the cybersecurity resources and posture of a large company.[163] It is worth evaluating whether large companies (i.e. YouTube) would be more or less secure than massive companies (i.e. Alphabet). Both companies could devote significant resources to cybersecurity, but it is unclear whether massive companies' vulnerabilities from increased attack surface and organizational complexity might outweigh any additional investment they might make.[164]

Smaller firms can mitigate cybersecurity shortcomings. Pooled resources—sharing threats, intruder detection programs, and patches—like those afforded by Managed Security Services Networks could enhance security.[165] Small firms also benefit from industry-wide security programs like Information Sharing and Analysis Centers (ISACs), which serve as a central resource for cyber threats and information exchanges for small and large firms alike.[166] Finally, despite available data suggesting small firms lag behind on cybersecurity, those prioritizing and investing in cybersecurity may be able to

overcome handicaps and mount a viable cyber defense—perhaps as part of a deliberate business strategy to target government customers with high-security requirements.

2. Could critical innovations proliferate through other (non-cyber) means?

Cyber-theft is one of many avenues for innovations to proliferate. China's technological transfer programs for AI innovations, for example, mainly employ legal practices.[167] These practices include direct technology purchases, talent recruitment programs like the Thousand Talents Plan, and the direct enrollment of Chinese students in American universities.[168]

Many of these avenues are poorly understood, only recently attracting American policymakers' scrutiny. As a result, it remains unclear how firm size may affect AI companies' exposure to technology transfer through non-cyber means. Niche firms largely reliant on Pentagon contracts might be more willing to prioritize their relationship with the U.S. government over engagement with foreign actors, for example, while multinational giants might struggle to avoid certain markets. On the other hand, smaller companies may be less sophisticated and more easily compromised when it comes to vetting potential collaborators, investors or acquirers for technology transfer risk. Smaller firms may also be more likely to leak confidential data.[169] Further research should analyze these and other issues at the intersection of firm scale and technology transfer.

Further Resources

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Appendix I: Pentagon Positions on Mergers

After the Cold War, the Department of Defense pushed for rapid defense industry consolidation. In the face of declining defense budgets—the Pentagon's procurement budget fell 65 percent between 1986 and 1995—many worried that defense companies would go bankrupt, endangering the U.S. defense industrial base.[170] Consolidation offered a solution. Deputy Secretary of Defense William Perry hosted a dinner party in 1993, known as the "Last Supper," where he called for mass consolidation.[171] Spurred by concerns across government, from the Pentagon to Congress and the White House, America's defense industry transformed, as 12 major companies merged into four.[172] The five-year period from 1992 to 1997 saw a wave of military-industrial acquisitions worth at least $55 billion in the aggregate.[173]

In recent years, however, the Department has seemingly grown weary of mergers. In its 2016 annual Congressional report, the Office of Acquisition, Technology and Logistics wrote that "the Department has been concerned about mergers and acquisitions among the top tier of weapons suppliers for some time and does not view consolidation among our top weapon system primes as a favorable development."[174] In 2015, Frank Kendall, the former head of Acquisition, Technology and Logistics, called for increased Pentagon involvement in defense merger oversight.[175] He cited the dangers that consolidation poses to industrial innovation and the U.S. supply chain, including threats to the domestic supply base and higher barriers to entry for small and mid-size businesses.[176] The Defense Department subsequently drafted (but did not release) a legislative proposal that would have authorized the Pentagon to run its own merger review process parallel to that of the Department of Justice.[177]

Other recent events have stoked uncertainty about Pentagon competition policy. Ellen Lord, the current Under Secretary of Defense for Acquisition and Sustainment, stated in her Senate confirmation testimony that "it is difficult to foresee supporting further consolidation of our principal weapons-system prime contractors. It should continue to be the Department's policy to oppose business combinations (mergers, acquisitions, or joint ventures) that are not in its ultimate best interest and represent harm to our Nation's security."[178] However, Raytheon and United Technologies announced a merger in early June 2019, and the Pentagon did not file a formal objection.[179] Similarly, Lord signaled the Pentagon's support for Qualcomm's chip monopoly in July

2019, joining an amicus brief in FTC v. Qualcomm that defended Qualcomm's market position on national security grounds.[180]

Bidding over Project JEDI, the Defense Department's lucrative cloud computing contract has also contributed to uncertainty. The contract's scale and requirements eliminated[181] all but the largest cloud computing firms—Amazon and Microsoft—from contention.[182] A number of companies have criticized the Pentagon's approach to JEDI, arguing that it minimizes innovation and reduces competition.[183] In response, a Pentagon spokeswoman stated, a "single award is advantageous because, among other things, it improves security, improves data accessibility and simplifies the Department's ability to adopt and use cloud services."[184]

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[23] Microsoft and Alphabet are two leading companies in "world-class AI patents." See Kai Gramke, "Leading Companies and Research Institutions In Artificial Intelligence," *EconSight*, https://blogs-images.forbes.com/louiscolumbus/files/2019/01/Leading-AI-Companies.jpg; Louis Columbus, "Microsoft Leads The AI Patent Race Going Into 2019," *Forbes*, January 6, 2019, https://www.forbes.com/sites/louiscolumbus/2019/01/06/microsoft-leads-the-ai-patent-race-going-into-2019/#3b19f31b44de.

[24] "Artificial Intelligence—The Next Digital Frontier?" (McKinsey Global Institute, June 2017), Page 4, https://www.mckinsey.com/~/media/McKinsey/Industries/Advanced%20Electronics/Our%20Insights/How%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/MGI-Artificial-Intelligence-Discussion-paper.ashx; Chris Cornillie,

"Finding Artificial Intelligence Money in the Fiscal 2020 Budget," *Bloomberg Government*, March 28, 2019, https://about.bgov.com/news/finding-artificial-intelligence-money-fiscal-2020-budget/.

[25] The White House*, FY 2019 U.S. Research and Development (R&D) Spending* (Washington, DC: 2018), Page 233. https://www.whitehouse.gov/wp-content/uploads/2018/02/ap_18_research-fy2019.pdf; John Wu, "Why U.S. Business R&D Is Not as Strong as It Appears," *Information Technology and Innovation Foundation*, June 2018, http://www2.itif.org/2018-us-business-rd.pdf. Over the past forty years, overall U.S. R&D, particularly in the private sector, has increasingly favored developmental research. In 1980, basic and applied research constituted 30 percent of private-sector R&D budgets; by 2010, this figure was down to 22 percent. Over the same timeframe, overall basic and applied research spending increased nationwide by 244 percent, while developmental research increased 325 percent, making private sector priorities evident. See John Wu, "Why U.S. Business R&D."

[26] Christian Davenport and Aaron Gregg, "Lockheed Martin Got $35.2 Billion From Taxpayers Last Year. That's More Than Many Federal Agencies," *Washington Post*, February 16, 2018, https://www.washingtonpost.com/business/economy/in-trumps-budget-lockheed-looms-almost-as-large-as-the-state-department/2018/02/15/e7eb3aa8-11c1-11e8-9570-29c9830535e5_story.html.

[27] To be sure, the relationship between the Pentagon and its traditional suppliers is not one-sided. The Pentagon has a unique set of needs—it requires products that meet high security standards, operate in non-traditional environments, and perform battlefield tasks. Defense firms like Raytheon and Lockheed Martin have to be willing and able to build these products and meet these standards in the first place. Many firms would unable to do so and, as Project Maven demonstrated, some may lack the political will to in the first place.

[28] Even though large tech companies do not *need* large government contracts, they still compete for them and recognize that government contracts constitute a sizeable market. Some companies, like Amazon and Microsoft, have recently moved to expand their share in this market. Despite these moves, Pentagon contracts remain relatively insignificant for large tech companies, which distinguishes them from traditional Defense Department vendors. See Brett Bachman, "The U.S. Government Is The World's Largest Purchaser Of Consumer Goods. Amazon Wants A Piece," *Vox*, May 1, 2019, https://www.vox.com/the-goods/2019/5/1/18524111/amazon-business-government-purchasing-state-city-local; Cat Zakrzewski, "The Technology 202: Satya Nadella Wants Microsoft To Be The Tech Company The Government Trusts--And Buys From," *Washington Post*, October 8, 2019, https://www.washingtonpost.com/news/powerpost/paloma/the-technology-202/2019/10/08/the-technology-202-satya-nadella-wants-microsoft-to-be-the-tech-company-the-government-trusts-and-buys-from/5d9b661e88e0fa747e6d5168/; Jon Banister, "Facebook, Silicon Valley Quietly Growing D.C. Office Footprint Amid Federal Scrutiny," *Bisnow*, April 11, 2018, https://www.bisnow.com/washington-dc/news/office/facebook-silicon-valley-quietly-growing-dc-office-footprint-amid-federal-scrutiny-87210.

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Jared Serbu, "Pentagon Issues Long-awaited Cyber Framework For Defense Industry," *Federal News Network*, January 31, 2020, https://federalnewsnetwork.com/defense-main/2020/01/pentagon-issues-long-awaited-cyber-framework-for-defense-industry/; "Addition of Software Specially Designed To Automate the Analysis of Geospatial Imagery to the Export Control Classification Number 0Y521 Series, *Federal Register/National Archives*, January 6, 2020, https://www.federalregister.gov/documents/2020/01/06/2019-27649/addition-of-software-specially-designed-to-automate-the-analysis-of-geospatial-imagery-to-the-export.

[30] See: Paul Kennedy, *The Rise and Fall of the Great Powers* (Random House, 1987); Richard Neu and Charles Wolf, Jr., "The Economic Dimensions of National Security" (RAND Corporation, 1994), https://www.rand.org/pubs/monograph_reports/MR466.html; Michèle Flournoy and Richard Fontaine, "Economic Growth Is a National Security Issue," *Harvard Belfer Center*, May 26, 2015, https://www.belfercenter.org/publication/economic-growth-national-security-issue.

[31] See, e.g.: Barton Gellman, Ashkan Soltani, and Andrea Peterson, "How We Know The NSA Had Access To Internal Google And Yahoo Data," *Washington Post*, November 4, 2013, https://www.washingtonpost.com/news/the-switch/wp/2013/11/04/how-we-know-the-nsa-had-access-to-internal-google-and-yahoo-cloud-data/?utm_term=.62d536830ce9.

[32] Many have argued that the break-up of Bell Labs did not spur telecommunications competition. See Christopher Yoo, "The Enduring Lessons of the Breakup of AT&T: A Twenty-Five Year Retrospective," *Federal Communications Law Journal*, Vol. 61, no. 1 (2008), http://www.repository.law.indiana.edu/fclj/vol61/iss1/2https://www.repository.law.indiana.edu/cgi/viewcontent.cgi?article=1514&context=fclj; Keach Hagey, Amol Sharma, Dana Cimilluca and Thomas Gryta, "AT&T Is in Advanced Talks to Acquire Time Warner," *Wall Street Journal*, October 21, 2016, https://www.wsj.com/articles/at-t-is-in-advanced-talks-to-acquire-time-warner-1477061850. However, antitrust action is not necessarily to blame. Poor policies could be at fault. See Robert Crandall, "The AT&T Divestiture: Was it Necessary? Was It a Success?" Presentation to the U.S. Justice Department on March 28, 2007, https://www.justice.gov/atr/att-divestiture-was-it-necessary-was-it-success.

[33] Tim Wu, "Where New Industries Get Their Start: Rebooting the Startup Economy," Testimony To The Committee on the Judiciary, Subcommittee on Antitrust, Commercial, and Administrative Law U.S. House of Representatives, July 16, 2019, https://docs.house.gov/meetings/JU/JU05/20190716/109793/HHRG-116-JU05-Wstate-WuT-20190716.pdf; Richard Blumenthal and Tim Wu, "What The Microsoft Antitrust Case Taught Us," *The New York Times*, May 18, 2018, https://www.nytimes.com/2018/05/18/opinion/microsoft-antitrust-case.html; Larry Downes, "How More Regulation For U.S. Tech Could Backfire," *Harvard Business Review*, February 9, 2018, https://hbr.org/2018/02/how-more-regulation-for-u-s-tech-could-backfire.

[34] Tom Simonite, "The Pentagon Doubles Down on AI—and Wants Help from Big Tech," *Wired*, February 12, 2019, https://www.wired.com/story/pentagon-doubles-down-ai-wants-help-big-tech/.

[35] Many such applications already have clear utility for national security—for example, self-driving convoys could improve supply-chain efficiency, and behavior prediction software could forecast the enemy's future actions based on past decisions. See Benjamin Jensen and Ryan Kendall, "Waze For War: How The Army Can Integrate Artificial Intelligence," *War on the Rocks*, September 2, 2016, https://warontherocks.com/2016/09/waze-for-war-how-the-army-can-integrate-artificial-intelligence/.

[36] We recognize the challenges of converting civilian products for military use. See Maaike Verbruggen, "The Role of Civilian Innovation in the Development of Lethal Autonomous Weapon Systems," *Global Policy Journal*, Volume 10, no. 3 (September 2019): 338-342, https://onlinelibrary.wiley.com/doi/10.1111/1758-5899.12663. There are institutional barriers, trust issues, and technical obstacles. The Pentagon has unique needs and challenges. Military standards are different; products must last longer under harsher conditions and test at higher levels. See Verbruggen, "The Role of Civilian Innovation in the Development of Lethal Autonomous Weapon Systems." Explainability—understanding how and why an AI algorithm produces certain outputs—also takes on added significance in military contexts, as these technologies cannot be deployed in life and death situations without operators trust. See Luke Hartig and Kendall Vanhoose, "Solving One of the Hardest Problems of Military AI: Trust," *Defense One*, April 1, 2019, https://www.defenseone.com/ideas/2019/04/solving-one-hardest-problems-military-ai-trust/155959/.

[37] Randy Bean, "How Big Data Is Empowering AI and Machine Learning at Scale," *MIT Sloan Management Review*, May 8, 2017, https://sloanreview.mit.edu/article/how-big-data-is-empowering-ai-and-machine-learning-at-scale/.

[38] However, there are diminishing returns. See Chen Sun, Abhinav Shrivastava, Saurabh Singh, and Abhinav Gupta, "Revisiting Unreasonable Effectiveness of Data in Deep Learning Era," *Google Research and Carnegie Mellon University* (August 4, 2017), https://arxiv.org/abs/1707.02968.

[39] Juliane Begenau, Maryam Farboodi, Laura Veldkamp, "Big Data in Finance and the Growth of Large Firms," *National Bureau of Economic Research Working Paper,* no. 24550 (April 2018), https://www.nber.org/papers/w24550.

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[41] These investments could take the form of innovations designed to yield data.

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[43] Katrine Spirina, "Deep Learning in Image Recognition Opens Up New Business Avenues," *InData Labs*, July 26, 2019, https://indatalabs.com/blog/ai-image-recognition; Mark Brayan, "Building World-class AI For Autonomous Vehicles Requires A Single Source Of

Reliable Data," *TechCrunch*, https://techcrunch.com/sponsor/appen/building-world-class-ai-for-autonomous-vehicles-requires-a-single-source-of-reliable-data/.

[44] YouTube generated $15 billion in revenue in 2019. See Nick Statt, "YouTube Is A $15 Billion-a-year Business, Google Reveals For The First Time," *The Verge*, February 3, 2020, https://www.theverge.com/2020/2/3/21121207/youtube-google-alphabet-earnings-revenue-first-time-reveal-q4-2019.

[45] Alison Griswold, "Amazon Web Services Brought In More Money Than McDonald's In 2018," *Quartz*, February 1, 2019, https://qz.com/1539546/amazon-web-services-brought-in-more-money-than-mcdonalds-in-2018/; "Raytheon Reports Strong Fourth Quarter and Full-Year 2018 Results," *CISION*, https://www.prnewswire.com/news-releases/raytheon-reports-strong-fourth-quarter-and-full-year-2018-results-300787117.html.

[46] For context, in the third quarter of 2019, Amazon Web Services accounted for 13% of Amazon's overall revenue and 71% of Amazon's "overall operating profits." See "Amazon Quarterly Reports—Quarter Three 2019," Amazon, https://ir.aboutamazon.com/quarterly-results/default.aspx; Nat Levy, "Amazon Web Services Approaches $9b In Quarterly Revenue, But Growth Slows Again, Missing Analyst Expectations," *GeekWire*, October 24, 2019, https://www.geekwire.com/2019/amazon-web-services-growth-slows-missing-analyst-expectations/; "News Release Amazon.com Announces Third Quarter Sales up 24% to $70.0 Billion," *Amazon*, October 24, 2019, https://ir.aboutamazon.com/news-releases/news-release-details/amazoncom-announces-third-quarter-sales-24-700-billion.

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[48] Akisato Kimura, Zoubin Ghahramani, Koh Takeuchi, Tomoharu Iwata, Naonori Ueda, "Few-Shot Learning of Neural Networks From Scratch by Pseudo Example Optimization" (July 15, 2018), https://arxiv.org/abs/1802.03039.

[49] "Data Curation and Enrichment in Artificial Intelligence," *AITouch*, September 24, 2018, https://aitouch.in/our-blogs/data-curation-and-enrichment-in-artificial-intelligence/.

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[51] Cliff Saran, "AI Struggles With Data Silos and Executive Misconceptions," *Computer Weekly*, May 30, 2019, https://www.computerweekly.com/news/252464222/AI-struggles-with-data-silos-and-executive-misconceptions; "Emerging Business Opportunities in AI," *CompTia*, May 2019, https://comptiacdn.azureedge.net/webcontent/docs/default-source/research-reports/emerging-business-opportunities-in-ai.pdf?sfvrsn=5872e25_2.

[52] See: Jeffrey Ding, "ChinAI #48: Year 1 of ChinAI," *ChinAI Newsletter*, April 1, 2019, https://chinai.substack.com/; Celia Chen and Iris Deng, "Tencent Seeks to Kill Silo Culture That Gave it WeChat as it Expands Into AI, Big Data," *South China Morning Post*, November 14, 2018, https://www.scmp.com/tech/apps-social/article/2172967/tencent-seeks-kill-silo-culture-gave-it-wechat-it-expands-ai-big.

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[62] Barry Jaruzelski, Robert Chwalik, Brad Goehle, "The 2018 Global Innovation 1000 Study" (PricewaterhouseCoopers, October 2018), https://www.strategyand.pwc.com/gx/en/insights/innovation1000.html.

[63] Data based on CSET's analysis of the 500 global firms with the highest reported expenditures conditional on reporting non-zero R&D expenditures. The Celgene Corporation (biotech pharmaceuticals) ranked first at 56%.

[64] According to Refinitiv data as of October 24, 2019. For reference, Amazon spent $220 billion on operating expenses; Alphabet ($110 billion); Facebook ($30 billion); Apple ($195 billion).

[65] As discussed elsewhere, aggregate R&D spending across the entire AI ecosystem could also increase if breaking up big companies triggered a flood of new entrants.

[66] See, e.g., Nate Lanxon, "Alphabet's DeepMind Takes on Billion-Dollar Debt and Loses $572 Million," *Bloomberg*, August 7, 2019, https://www.bloomberg.com/news/articles/2019-08-07/alphabet-s-deepmind-takes-on-billion-dollar-debt-as-loss-spirals.

[67] Fisher and Temin, "Returns to Scale in Research and Development: What Does the Schumpeterian Hypothesis Imply?"

[68] Fisher and Temin, "Returns to Scale in Research and Development: What Does the Schumpeterian Hypothesis Imply?" 56.

[69] The relationship between firm size and R&D productivity is debated and may hinge on the metrics used to measure productivity. Knott and Vieregger (2016) find that R&D productivity actually increases with firm size, although this increase is not perfectly linear. Overall, the single most productive firms are small firms, but larger firms more productive on average. See Anne Marie Knott and Carl Vieregger, "Reconciling the Firm Size and Innovation Puzzle," The Center for Economic Studies Research Paper, March 2016, https://www2.census.gov/ces/wp/2016/CES-WP-16-20.pdf; Zoltán J. Ács and David B. Audretsch, "Innovation and Technological Change," *University of Michigan Press* (1991): pages 12-13.

[70] Robert Vossen, "Relative Strengths and Weaknesses of Small Firms in Innovation," *International Small Business Journal*, vol. 16, no. 3 (April 1998): 88–94, page 92, 10.1177/0266242698163005.

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[75] Zoltán J. Ács and David B. Audretsch, "Innovation and Technological Change," 12-13.

[76] Vossen, "Relative Strengths and Weaknesses of Small Firms in Innovation," 92.

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[82] This re-distribution of consumers relies, in part, on the assumption that new firms will provide unique services or products.

[83] Nigel Toom, "Microsoft And Graphcore Collaborate To Accelerate Artificial Intelligence," *Graphcore*, November 2019, https://www.graphcore.ai/posts/microsoft-and-graphcore-collaborate-to-accelerate-artificial-intelligence; Other forms of collaboration, like joint labs, are also growing such as IBM's joint AI lab with MIT and Google's joint AI lab with Atos. See Blair Frank, "IBM Pledges $240 Million For Joint AI Lab With MIT," *VentureBeat*, September 6, 2017, https://venturebeat.com/2017/09/06/ibm-pledges-240-million-for-joint-ai-lab-with-mit/; "Atos Unveils Its North American Artificial Intelligence Lab In Partnership With Google Cloud," *Atos*, October 4, 2019, https://atos.net/en/2019/press-release_2019_10_04/atos-unveils-north-american-google-cloud-artificial-intelligence-lab.

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