Is AI Truly Disruptive?

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Introduction

The AI acceleration is unprecedented and, undeniably, the increased capability of AI systems poses a threat to the traditional world order.

For a time, incumbent technology providers seemed to have no ready response: 30 months after the release of GPT 3, Google still didn't have a commercially available AI system, and in its 2023 developer conference Apple did not mention AI once. Now, after sitting on the sidelines, large technology enterprises have begun to respond.

Their responses sound a familiar refrain when incumbents face competition from potentially disruptive technologies. Will image generation threaten Adobe? Of course not. They'll make it a menu item in [Photoshop](). Will AI answers threaten search? No. Google will add language model outputs to its search results.[1] Will prompt-based interfaces be the next way to interact with computers? Not at all. Apple will use AI to turbocharge Siri across all its devices.[2]

Will mega-tech's delay in responding to the AI threat prove optimum as a strategy? Now that startups have demonstrated proof-of-concept, will large tech enterprises simply co-opt artificial intelligence to strengthen their formidable global franchises?

In other words, will AI be disruptive at all?

A first pass at the answer might be no: with their data, distribution, talent, and resources, how could the incumbents lose? Yet, such an analysis ignores the "disruptive" in disruptive technology.

With a focus on AI innovation today, this paper not only shares ARK's framework for identifying disruptive technologies, but also explores how incumbent technology providers are likely to harness AI to sustain their existing industry dominance, and why that strategic stance might falter.

What Are Disruptive Technologies?

Axiomatically, disruptive technologies are characterized by their *effects*: they allow poorly resourced firms to upend well-established and deep-pocketed incumbents, even when those incumbents recognize the importance of the technology and attempt to harness it to maximize their own business prospects.[3]

Disruptive technology platforms also can be characterized by three *intrinsic* properties:

They exhibit steep cost declines, which can improve performance dramatically at no additional cost. Technologies undergoing steep cost declines often wrongfoot incumbents with lower-cost offerings that attack their cashflow models and incentive systems, both of which reward short-term shareholder results at the expense of long-term strategy.

They cut across sectors, penetrating new markets that incumbents have neglected or underserved. Cross sector technologies frequently improve along metrics foreign to incumbents. Mega-tech companies may not consider them important or relevant because they do not understand the performance advantage that the new technology will offer their customers.

They serve as innovation platforms or launching pads for new technologies. Innovation platforms tend to address surprisingly large markets that at first seem too small to matter. They also tend to reward a business model that defers monetization and seems financially unattractive, while surreptitiously attracting developers and applications that are difficult to attract and duplicate once incumbents finally address the opportunity.

Based on those criteria, is artificial intelligence disruptive? Absolutely.

Artificial intelligence has had the steepest cost decline curve of any technology in history. Every sector in the global economy is harnessing AI, and the number of businesses spinning up on this disruptive platform is likely to be unprecedented.

AI And Cost Declines

AI is declining in cost faster than any disruptive technology we have measured. The cost to operate artificial intelligence models of equivalent performance has been halving *every four months*—a trend that we expect to persist throughout this decade. In contrast, Moore's Law[4] in the semiconductor space cut costs in half every 18-24 months, suggesting that the AI revolution is moving 4-6 times faster. In other words, the performance improvement that would have taken place over a decade in traditional technology is likely to take fewer than two years with AI. While available currently only in the cloud, world-beating AI models are likely to run on smartphones in a couple of years, as shown below.

Cost Of A Computer That Can Generate GPT-4 Class Output At 50 Words Per Second

(Dotted Line= Forecast)
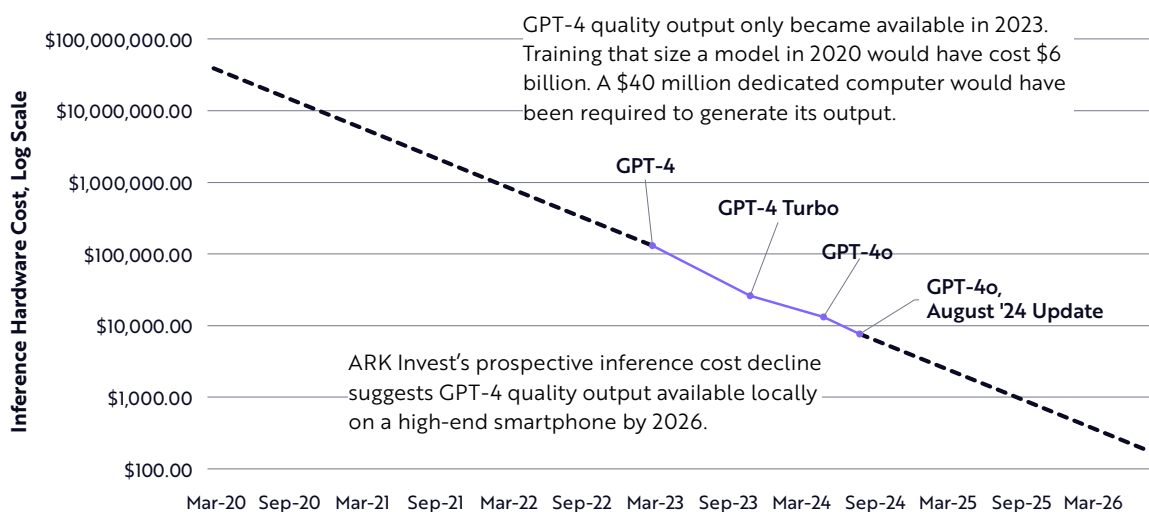
Note: The analysis above assumed that OpenAI price changes accurately reflect underlying cost to infer and that 80% of cost to infer is capital depreciation. ARK's cost decline is based on derived learning rate and future AI investment expectations consistent with Wright's Law.[5] Cost to train a GPT-4 model in 2020 is based upon ARK Invest's training cost decline and estimates that GPT-4's cost to train was approximately $100 million. Source: ARK Investment Management LLC, 2024, based on data from Semianalysis and OpenAI as of September 17, 2024. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security. Forecasts are inherently limited and cannot be relied upon.

What does that steep cost decline mean for incumbent tech companies? Even small time-to-market delays are likely to cause severe performance gaps, as the speed of cost declines renders the fast-follower strategy less effective over time.

Incumbent technology providers tend to let startups *de-risk new technologies for them*—demonstrating the product market fit for new business models and technological innovations—before deploying them at scale themselves. Google and Apple have taken that approach to AI. Google didn't release a large language model publicly, for example, until OpenAI had been in the market for more than three years. Even then, despite marketing demos that seemed to indicate otherwise, Google's performance lagged. Indeed, since early 2023, using the most advanced Google model instead of the most performant OpenAI model would have cost customers 40%+ more in per-unit performance on average, as shown below.

Google vs OpenAI Price/Performance Difference
(Price Per Token Performance Adjusted By Log Of Error)
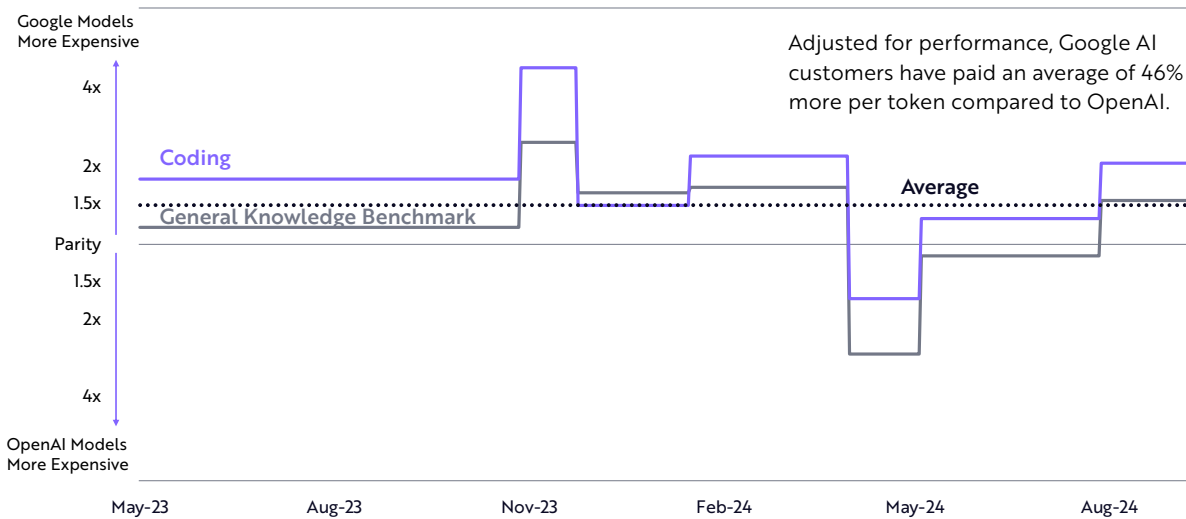
Note: MMLU (Massive Multi-task Language Understanding) 5-shot is used as a general knowledge benchmark; HumanEval for coding. Price per token assumes 75% input tokens to 25% output tokens. Price is denominated by absolute value of log error on benchmark. Source: ARK Investment Management LLC, 2024, based on data from OpenAI, HuggingFace, and Helm Stanford as of September 16, 2024. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security. Past performance is not indicative of future results.

While Google has operated a node behind Open AI, Apple has yet to launch a large language model at all. Apple will debut its first modern AI-driven products this fall, more than four years later than Open AI's initial release of GPT-3. Apple has conceded that its models will be less performant than not only the leading models from OpenAI and Anthropic but also the open-source model released by Meta, Llama 3.[6]

To be fair, slow does not mean necessarily that a competitor will lose the race. Mega-tech companies have giant strategy teams, nearly unlimited budgets, and monumental manpower. Surely, they will not be left behind.

Or, will they?

Google and Apple have good reason for delaying the introduction of AI features. AI technologies are unpredictable and have not been vetted thoroughly. They can "hallucinate." Both companies have reputations and massive cash flows to protect, with more to lose than startups or challenger firms. Unlike the software that Google and Apple have developed, debugged, and launched, AI systems are not shipping with known and constrained feature-sets.

Shipping a product that performs in unpredictable ways can be terrifying for the stewards of a carefully developed reputation. As an example, on its front page the *New York Times* detailed how Microsoft's ChatGPT chatbot tried to break up the author's marriage, as shown on the left below. For Microsoft, Google, Apple, and other mega-tech companies with established brands built upon the predictable and consistent performance of their software and services, this example starkly demonstrated the downsides of AI. Even good-faith efforts can result in bad PR. By guiding its AI systems away from ethnically homogenous images, for example, Google's Gemini produced a model with multi racial images of WWII nazi shock troops as historically accurate, as shown on the right below.

Source: Grant 2024.[7] For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security.

Incumbents must find ways to control the unpredictable performance of AI systems before deploying them safely. The time and engineering necessary to do so, however, are likely to disable the characteristics that make AI systems unique. Apple's approach to image generation with Apple Intelligence is a good illustration. In generating avatars, users will be limited to a menu of three different styles: animated, illustrated, or sketched, as shown below.

Source: Apple Intelligence 2024. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security.

Perhaps *Apple Intelligence* is the right approach for its ecosystem but, by sticking to that strategy, Apple will operate well behind the cutting edge in AI. Its image generation will look much like the Adobe Photoshop's artistic filters that have been available since 1994. In contrast, unconstrained AI image generation will not limit the number of options, making it interesting and unique.

Compare Apple's cookie cutter approach to Midjourney, a best-in-class image-generation AI model. Midjourney can produce not only photographic images—a "no-no" in Apple's system—but also photographs that mimic the style of the four most influential portrait photographers of the 20th century, as illustrated below.

Exploring AI Model Latent Space:
In The Style Of The Four Most Influential Portrait Photographers Of The 20th Century

Note: All images above were created by ARK Investment Management LLC 2024, elicited from Midjourney v6.1 using the same prompt: "An award winning portrait shot by [PHOTOGRAPHER]. Portrait photography. Fine art photography. Large format photography." For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security.

As Apple and Google use AI to curate interesting images, their choices are likely to grow stale quickly based on how steeply costs are declining and how quickly AI is evolving. Offering users a palette of pre-set image styles might seem practical and conservative now, but those judgment calls are likely to look misplaced as image-generation algorithms beyond Apple's ecosystem become more manipulable, more responsive, more precise, and more realistic.

From their own strategic perspectives—and wholly consistent with disruption theory— incumbents like Apple and Alphabet can afford to let users, at least those seeking cutting edge AI capability, find it elsewhere. Because *their* core customers are not early adopters, and they don't want disruption. They don't like change. They want products to work the way they always have.

Cross Sector Technology

If AI were not to cut across sectors and become a platform for more innovation, incumbents might be safe over the medium-to-long term. The catch, of course, is that AI systems do cut across sectors, and they are platforms that spawn more innovation. From that perspective, adopting disruptive technology as "sustained" innovation is likely to leave incumbents deeply vulnerable.

Many businesses hope to harness AI, as illustrated by the breadth of AI discussions during quarterly earnings calls, as shown below. The most valuable AI services could emerge from a sector other than technology, potentially a grave threat to traditional technology incumbents.
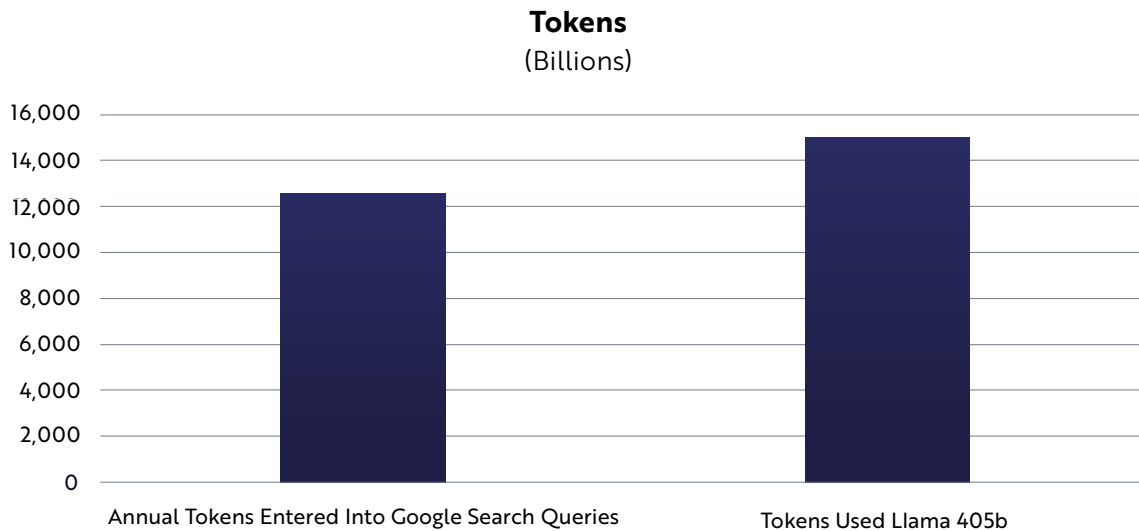
Share Of Earnings Calls Where AI Is Mentioned
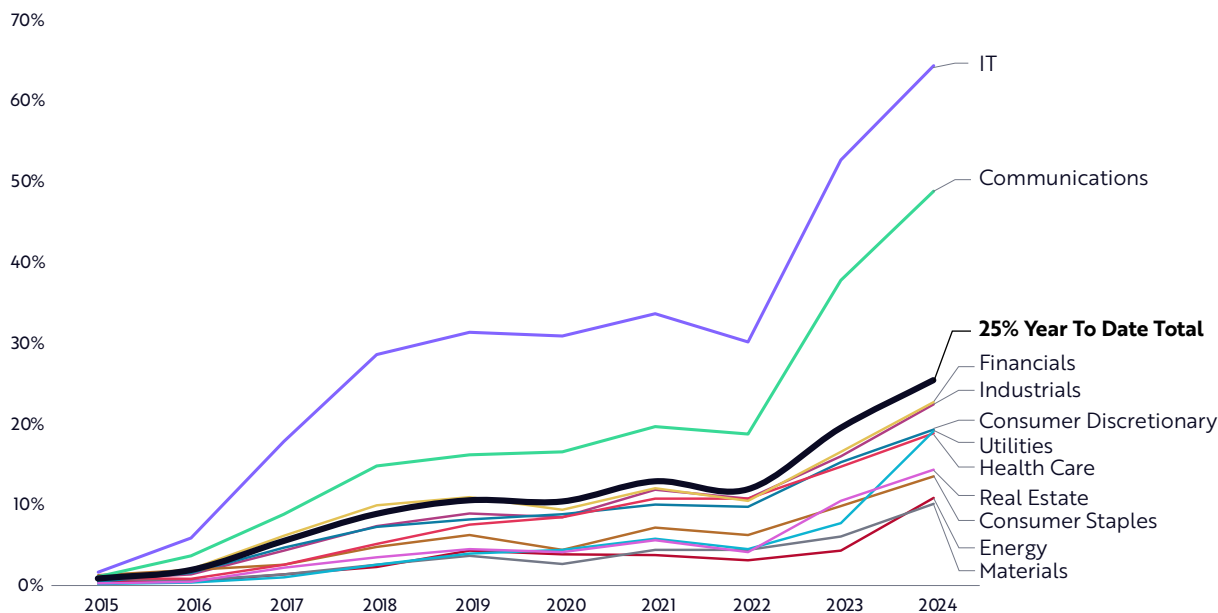
Source: ARK Investment Management LLC, 2024. This ARK analysis draws on a range of external data sources, including CapitalIQ, as of August 20, 2024, which may be provided upon request. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security.

A reason to believe that incumbents *should* win—even if late to the race—is their massive distribution and data advantages relative to startups. Google has dominated search in part because user clicks provide valuable information about the results best matched to queries. If language model results prove important to search, then Google should be able to layer them easily into its queries and continue to dominate search with data. Even if that approach were to hurt its commercialization engine in the short term—a cost-per-click ad model does not readily match with natural language AI answers—Google probably would maintain its lead in query and traffic volumes.

Alternatively, if the most valuable set of AI interactions occurs in a different digital context, Google's distribution muscle might not be exposed to the generation of new data streams. Currently fielding an estimated 8.5 billion queries per day, Google has a data monopoly in search. Though the average search is quite short, this works out to more than 10 trillion language tokens annually. In a year, Google collects roughly the same volume of text in search queries as is used to train the most powerful AI language models in the world, as shown below.[8]

Tokens
(Billions)

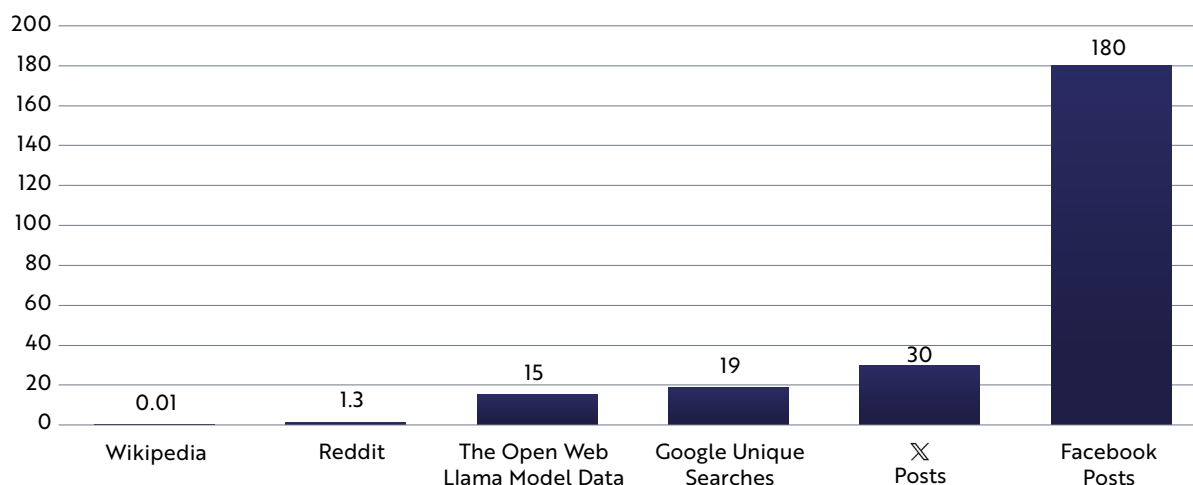| | Annual Tokens Entered Into Google Search Queries | Tokens Used Llama 405b |

Source: ARK Investment Management LLC, 2024. This ARK analysis draws on a range of external data sources, as of August 20, 2024, which may be provided upon request. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security. Past performance is not indicative of future results.

Does Google's search and data collection give it an unimpeachable data advantage in the race for AI dominance? In a word: no. Search queries are short—averaging 3 to 4 words—and lack variety—85% of queries are repetitions.[9] That isn't very rich material for training a natural language system. Moreover, Google's existing cost-per-click advertising ecosystem has evolved to maximize revenue generation from these short clipped fragmentary entries. Put simply, Google's existing pool of data is not well-optimized to training language models, and a shift to natural language questions and answers would undermine Google's highly tuned revenue model.

Meanwhile, much larger and less exploited pools of proprietary language data exist away from Google's core search functionality. Indirectly, those data pools could prove disruptive to Google search.

In consumer entertainment, for example, Meta can tap massive data pools spanning across WhatsApp, Facebook, and Instagram. Even X—formerly Twitter—has volumes of language data larger than most publicly or commercially available elsewhere, as shown below. Both Meta and X are developing AI models aggressively—X at arms-length via xAI.

Large Language Repositories
(Trillions Of Tokens)

Bar chart values:
- Wikipedia: 0.01
- Reddit: 1.3
- The Open Web Llama Model Data: 15
- Google Unique Searches: 19
- X Posts: 30
- Facebook Posts: 180

Source: ARK Investment Management LLC, 2024. This ARK analysis draws on a range of external data sources, as of August 20, 2024, which may be provided upon request. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security. Past performance is not indicative of future results.
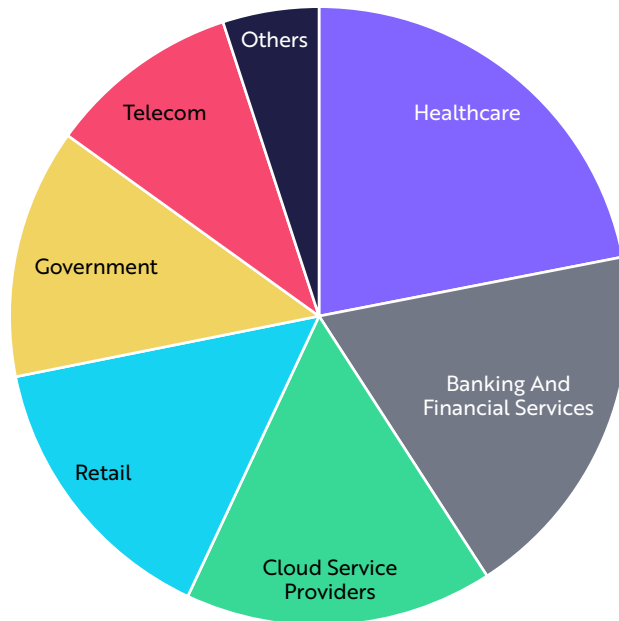
Social media companies' strategic positioning extends beyond their language data advantage; they also operate consumer-facing applications where AI-powered-search could operate more seamlessly. People already prefer information from friends; more so in an age where the fiction of expertise has largely evaporated. If a personable chatbot, such as Grok on X, has all the answers already, why would a consumer bother leaving X to find information via traditional search?

AI answers on social media distribution platforms should also prove monetizable. The move toward social commerce is well underway; that AI fashionistas could supercharge the experience. Social media companies have the data, motivation, and positioning to pose a threat to incumbent search and commerce, not by launching a competing search or commerce engine but by giving customers precise answers, with products and services to match, obviating the need for them to search elsewhere. In a world populated by personalized, knowledgeable AI companions, why would users rely on anything else for information? [10]

Indeed, AI applications in specific verticals could perform so well that they disintermediate and dislodge generalized search volume. Highly valued search terms in sectors with heavily regulated data access, like healthcare and finance, could be at particular risk.

By sector, healthcare is the largest purchaser of data storage, followed by finance, as shown below. Healthcare comprises 30% of stored data globally but, given the sector's notorious inefficiency, is not yet putting that data to good use. In our view, healthcare providers underexploit the data they collect and still do not collect as much data as they should.

Next Generation Storage Market Share
(By End-Use, 2023)

Pie chart segments:
- Healthcare
- Others
- Telecom
- Government
- Retail
- Cloud Service Providers
- Banking And Financial Services

Source: ARK Investment Management LLC, 2024, based on data from Grand View Research as of August 20, 2024. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security.

An estimated 7% of Google searches, 1 out of 14, is health related.[11] Now that LLMs (Large Language Models) are passing medical licensing exams, why wouldn't an AI model—prompted by a patient's medical history—provide better answers to health queries than Dr. Google? With its recently announced *olivia* model, Tempus Health now offers one such solution. Disruptive AI systems should see impressive growth not only in healthcare but also in financial services if integrated into consumer-facing digital wallets.

Away from the mega-tech incumbents, companies with meaningful proprietary data in both healthcare and finance could build broader services on top of that strategic foundation. AI agents to whom consumers entrust their health or wealth are likely to act on their behalf in many other contexts as well. Will consumers still turn to Google search when they have a fiduciary agent that can search, personalize, and select goods and services on their behalf?

Another threat to the incumbents could emerge not from the world of bits but from the world of atoms. While most contemporary AI systems have been trained primarily on language data, humans learn much more from moving around in the world. By tripping, falling, and scraping their knees, toddlers learn cause and effect early in life. They learn language much later in the development process.

State-of-the-art language models today infer cause and effect from physics textbooks. Systems that capture physical cause-and-effect data from the real world ultimately could prove much more meaningful for developing the most performant AI systems. Here again, we encounter competitors outside of the traditional tech sector. As a case in point, our work suggests that Tesla's robotaxi launch could cause the most profound business transformation in history. Tesla's ability to develop that service depends upon the real world cause-and-effect data that its fleet of vehicles can collect.

The scale of data is enormous. While the largest language models in the world have been trained on 15 trillion tokens, and Instagram and YouTube each have generated cumulative uploads of videos and images totaling ~7 quadrillion tokens, Tesla's current fleet of camera-equipped vehicles have generated *at least 80 quadrillion tokens* in the last year alone. If those vehicles were to operate as robotaxis, as we believe they will, that number would soar nearly four-fold to more than 300 quadrillion tokens worth of data per year toward the end of this decade, as shown below.[12]
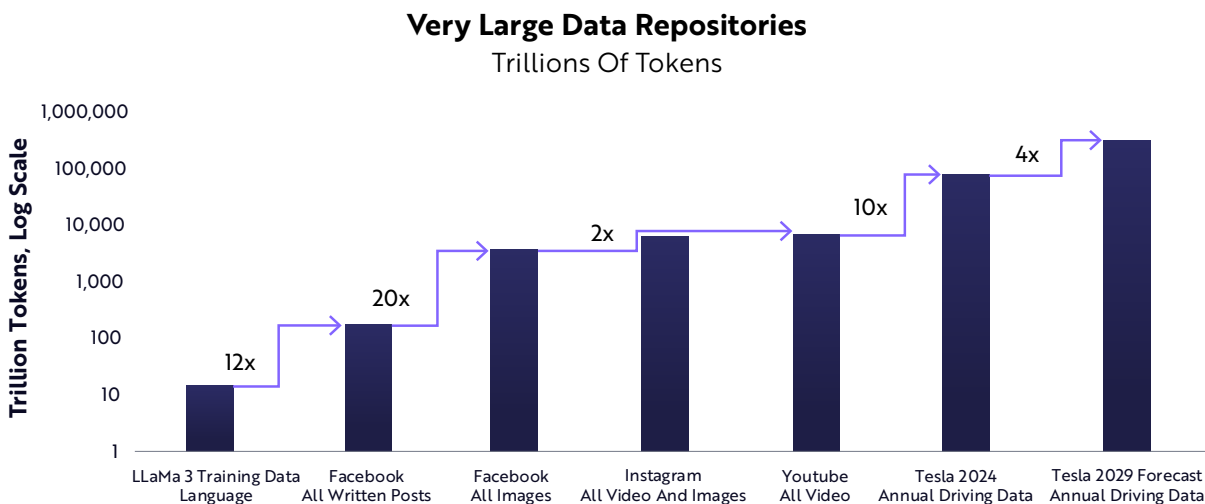
Very Large Data Repositories
Trillions Of Tokens

Source: ARK Investment Management LLC, 2024. This ARK analysis draws on a range of external data sources, as of August 20, 2024, which may be provided upon request. Tesla 2024 datapoint is an annualized estimate. Facebook, Instagram and YouTube datapoints are cumulative estimates across the life of the respective platforms as of 8/20/24. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security. Past performance is not indicative of future results. Forecasts are inherently limited and cannot be relied upon

In turn, Tesla intends to exploit that data and develop humanoid robots with generalized capabilities—robots that not only add to its data collection but also offer consumers both physical and digital services. Why bother pulling out a smartphone to ask AI a question when personal robots can provide the answer? If AI-enabled robots could operate in both physical and digital domains, then the consumer-facing platforms that have catapulted companies into mega-tech status, thanks to the network effect, during the last 20-30 years could lose their data advantages during the next five to ten years.

Incumbent technology companies could sidestep disruption if AI simply were to scale across sectors in response to lower costs and rapid performance gains but were not to serve as a platform for additional innovation. Their "sustained innovation" might miss new market opportunities, but still could harness AI to grow cash flow for shareholders.

AI, Platform Of Innovation

Indisputably, AI is a platform upon which more innovation can take place, potentially putting incumbent technology companies in harm's way. Of all the disruptive technologies that ARK's research studies and scores,[13] AI is the most important catalyst for more innovation, as shown below.
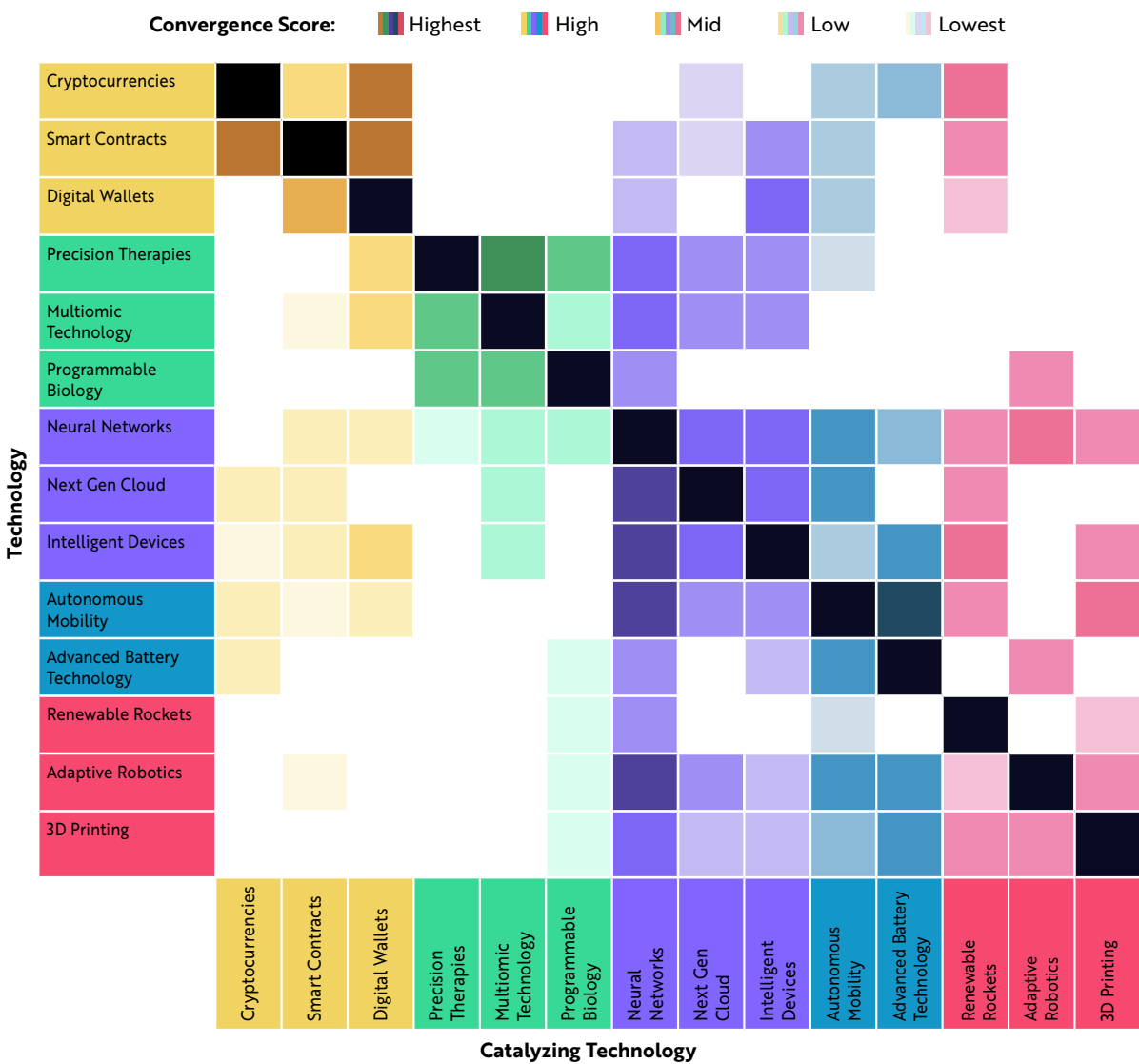

Note: A more detailed version of this graphic, including detailed scoring information and justification available here.[14]
Sources: ARK Investment Management LLC, 2024. This ARK analysis is based on a range of underlying data from external sources, which may be provided upon request. Forecasts are inherently limited and cannot be relied upon. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security. Past performance is not indicative of future results.

Capital is flowing to fund these potential platforms. As can be seen below, a third of global venture funding—more than $90 billion—has been devoted to AI companies this year. The skew is even higher in the US startup ecosystem, where AI has attracted more than 40% of venture dollars year-to-date and more than half over the last three months. With so many hungry competitors, funded by so much venture capital, aiming to disrupt the traditional world order from so many angles, the threat could prove profound.

Share Of Venture Funding To AI
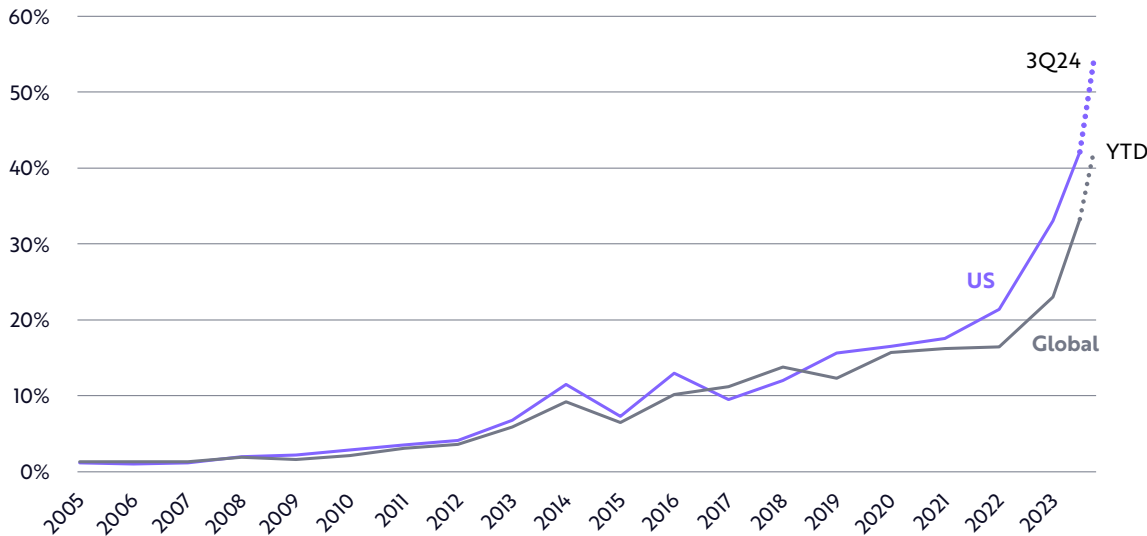
Source: ARK Investment Management LLC, 2024. This ARK analysis draws on a range of external data sources, including Pitchbook, as of August 20, 2024, which may be provided upon request. 2024 value is year-to-date through 9/17/24. For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security.

Both OpenAI and Perplexity, for example, are challenging Google search directly, while Rabbit, Friend, and Humane are trying to disintermediate Apple and Android's operating system duopoly. Could Meta glasses become more useful than an iPhone? Would a form factor designed natively to exploit the benefits of AI—without making concessions to its weaknesses—attract developers? Given enough users, absolutely.

And yet, even if new hardware does not take hold and Apple protects its ecosystem with fast-follow strategies, the AI platform itself is likely to develop separate and apart from the devices through which it is distributed. As AI systems and agents become increasingly performant, users will expect to access them on any device anywhere.

Such arrangements run counter to the closed ecosystem that Apple seeks to cultivate, much like AOL's experience in the internet age. Moreover, in their respective fights for developer time and attention, neither Google nor Apple currently enjoys a spotless reputation, as suggested by the newsclip below. Both companies face heavy shareholder pressure to continue delivering profitable growth—an impediment that incumbents typically face when trying to invest and insinuate themselves into a new ecosystem.

Developers Are in Open Revolt Over Apple's New App Store Rules

European app makers are seething, comparing Apple to "the Mafia" and piling pressure on lawmakers to act.

Source: Meaker 2024.[15] For informational purposes only and should not be considered investment advice or a recommendation to buy, sell, or hold any particular security.

Conclusion

Is AI disruptive technology? Demonstrably yes! AI is undergoing steep cost declines, cuts across sectors, and serves as a platform of innovation. Given the scope and scale of their business operations, incumbent technology companies—some of the most profitable franchises in the world—cannot afford to incorporate AI disruptively. As a result, they are likely to deny their consumers most or all of what makes the technology so magical, creating room for other enterprises to grow beyond their competitive spheres of influence.

That said, another set of outcomes is possible. Perhaps Google can transform search links to answers, using an abundance of user data to create personalized agents that people trust. Perhaps Apple, with its protective stance on privacy, can do the same. Perhaps their agents will be slightly dim-witted relative to the competition, but better to have an assistant that is slightly dim and knows your appointments than a genius denied access to your email by Apple's privacy policy.

That the AI revolution will shove Apple or Google aside is not a foregone conclusion. Given the choice, each might opt to slow the pace of AI's progress: AI systems that do not grow wildly performant, AI systems that do not have compelling relevance to sectors beyond their current reach, AI systems that will not serve as new computational platforms or launching pads for more innovation—all that, they surely would prefer.

No surprise. They are incumbents. They would prefer technology that is not so disruptive.

To their detriment, it is.

The disruption is underway.

Endnotes

1   Swipe Insight. 2024. "Google Officially Rolls Out Generative AI in Search Results."

2   Apple Intelligence. See https://www.apple.com/apple-intelligence/

3   Clayton Christensen introduced the idea in his book, The Innovator's Dilemma, juxtaposing disruptive technology against sustaining innovations that incumbents can harness to prolong their dominance. Though we co-opt some of his framing—notably the tendency of incumbents to misunderstand the new metric of performance improvement that disruptive technologies exploit—we do not adopt his framework entirely. Famously, Christensen dismissed the iPhone as non-disruptive because it didn't enter the market at a low price point. Moreover, while Christensen analyzed technology disruption within the context of specific subindustries—hard drive manufacturers and mechanical excavators are examples— our lens identifies disruptive technologies that can cascade across industries and sectors.

4   Moore's Law is the observation made by Intel co-founder Gordon Moore in 1965 that the number of transistors on a microchip doubles approximately every two years, while the cost of computing power decreases correspondingly. This trend has driven exponential growth in computing power and efficiency over the decades. It is not a physical law but rather a historical trend in semiconductor technology, which has had significant implications for technological advancement, particularly in computing and electronics.

5   Wright's Law states that for every cumulative doubling of units produced, costs will fall by a constant percentage. See Winton, B. 2019. "Moore's Law Isn't Dead: It's Wrong—Long Live Wright's Law." ARK Investment Management LLC.

6   https://the-decoder.com/apple-intelligence-is-efficient-but-its-intelligence-is-average/

7   Grant, N. 2024. "Google Chatbot's A.I. Images Put People of Color in Nazi-Era Uniforms. The New York Times.

8   At 8.5 billion queries a day, Google would generate 3 trillion queries per year. Google queries tend to be short; studies suggest 3 to 4 words long. At 4 tokens per search, this suggests that Google takes in 12 trillion tokens per year. GPT 4 reputedly was trained on 13 trillion tokens.

9   Gomes, B. 2017. "Our latest quality improvements for Search." Google.

10   Kim, A. 2024. Is AI Companionship The Next Frontier In Digital Entertainment? (ark-invest.com))

11   Murphy, M. 2019. "Dr Google will see you now: Search giant wants to cash in on your medical queries." The Telegraph.

12   Assumes Tesla tokenizes image data at the same data per pixel rate of multimodal models sampling at 1 frame per second. This is consistent with the Gemini model video product. 1 frame per second clearly is too infrequent, but there are almost certainly tokenization efficiencies associated with moving from stills into video.

13   Winton, B. 2024. "Platforms Of Innovation: How Converging Technologies Should Propel A Step Change In Economic Growth." ARK Investment Management LLC.

14   ARK-Invest_BigIdeas_TechnologicalConvergenceMatrix (https://research.ark-invest.com/hubfs/ ARK-Invest_BigIdeas_TechnologicalConvergenceMatrix.pdf)

15   Meaker, M. 2024. "Developers Are in Open Revolt Over Apple's New App Store Rules." Wired.

About The Author
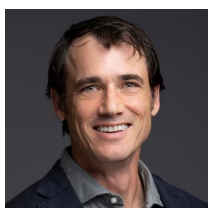
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Brett joined ARK in January 2014 and has worked alongside Cathie for almost 15 years since their time at AllianceBernstein. As Chief Futurist, Brett drives ARK's long-term forecasts across convergent technologies, economies, and asset classes, helping ARK dimension the impact of disruptive innovation as it transforms public equities, private equities, cryptoassets, fixed income, and the global economy. Brett also serves on the ARK Venture Investment Committee. Brett joined ARK as Director of Research, guiding and managing the proprietary research of ARK's investment team.

Prior to ARK, Brett served as a Vice President and Senior Analyst on the Research on Strategic Change team at AllianceBernstein. In that role, Brett conducted thematic research, served on the thematic portfolio's strategy committee under Cathie Wood's stewardship, and advised portfolio managers across asset classes. His research topics included Global Energy in the Face of Carbon Dioxide Regulation; Social Media and the Rise of Facebook; the Reformation of the Financial Services Landscape; and the Emergence of Electric Vehicles.

Brett earned his Bachelor of Science in Mechanical Engineering at the Massachusetts Institute of Technology (MIT).

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