October 11, 2019

CLOUD AND COMMUNICATIONS

Cloud Set to Drive a New "Roaring 20s" Defined by Big Productivity Improvements

A Once-in-a-Century General-Purpose Technology. Real Disruption Coming.

SUMMARY

The cloud is the most important technology in our lifetimes, we believe. It is enabling IoT to collect data, blockchain to secure it, and AI, AV, Robotics and Genomics to create powerful new services. Every industry and segment of society are set to be radically altered from a combination of one or more of these technologies and dozens of smaller ones. We highlight the impacts to financial services and the transportation industry in this report. The cloud itself is evolving to meet the needs of these new technologies by becoming globally meshed to the edge, or "fog." This suite of technologies greatly improves predictive capabilities in almost every industry/service for the first time ever and likely will drive $10 trillion plus in global market value in the next decade.

KEY POINTS

- **Only the Third Major General-Purpose Technology in 300 Years.** We believe the public cloud (sharing of compute/storage/networking infrastructure) is a general-purpose technology (GPT). The first two GPTs centered on power (steam engines and electricity), peak impact occurring 100 and 200 years ago, as is cloud now. General-purpose technologies drive major standard-of-living improvements, but ample disruption.
- **Entering Peak Impact from Cloud:** We estimate that it typically takes ~30 years for GPTs to reach peak impact occurring for the next ~10 years. Infrastructure, worker training, company organizations, and public policy need to catch up. In this regard, we think we are still in the early innings of cloud-based disruption and economic impact. Today, the infrastructure is in place; now it is time for entrepreneurs/developers to build on top of the cloud.
- **Aggressive Infrastructure Investments Will Continue:** Hundreds of billions of dollars of capital are flowing into cloud and communications networks at this point annually to support this innovation. Hyperscale capex has doubled in the last three years to an estimated $100B+ in 2019. We expect wireless, satellite, and fiber capacity to increase by 10x-1,000x in the next decade, with similar increases in compute capacity. Legacy wireless/cable companies can benefit from these trends also.
- **Limited Number of Cloud Longs, But Lots of Cloud-Driven Shorts:** MSFT, AMZN, EQIX, AMT, and a handful of other technology companies. There are some incumbent industries that will benefit, like insurance. But there are quite a few industries to avoid—autos, oil, financial services, legacy IT in every form, etc. The world improved because of the last two GPTs, but there were periods of turmoil that likely contributed to major social/political/economic conflicts.
- **We are hosting a Disruptive Innovation Summit in San Francisco on November 12th that will build on the themes and issues discussed in this report.** *Please contact us or your Oppenheimer salesperson for further details.*

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For analyst certification and important disclosures, see the Disclosure Appendix.

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Executive Summary: The Cloud Enables Six Revolutionary Technologies

The cloud is a once-in-a-century general-purpose technology that, as we see it, will completely transform our economy and society. We are at about the same point in adoption that electricity was in 1920 and steam engines were in 1820, and both of them led to the "Roaring 20s" of their centuries as we expect the cloud will do for ours. We envision a ubiquitous cloud with intelligent edge devices collecting data and transmitting data back to the centralized cloud in a meshed fabric, allowing edge devices to act on the data. Microsoft calls this the "intelligent edge," and we call it "fog computing." We view this global mesh compute/network fabric as a core general-purpose technology that is the cradle of much of incremental innovation going forward. We outlined six new primary technologies (out of a few dozen) that require cloud computing to progress:

1) **Artificial intelligence.** We use this term to include machine learning and deep learning and we believe this is the killer cloud application.
2) **Blockchain.** Protects data, automates trust, and with AI enables digital wallets, payments, and crypto currencies, among other innovations.
3) **Robotics.** Revolutionizes manufacturing and automates supply chains for step-function increases in productivity.
4) **Autonomous vehicles.** A once-in-a-century transportation transition allowing transportation as a service or autonomous pooled taxi networks. This will extend to every mode of transportation (planes, trains, and logistics).
5) **Genomics**. Includes CRISPR, and other healthcare technologies. And hopefully slash costs and improve quality on a $4 trillion industry.
6) **IoT**. Enables every electrical device to be become a sensor with access to unlimited compute/data, will rely heavily on next-generation wireless/satellite networks.

After investing hundreds of billions of dollars, the cloud providers (MSFT, AMZN, GOOG, etc.) all have extensive infrastructure, and a history of monetizing the data from cloud, required to enable and leverage these six technologies. We are already seeing this as the cloud providers embed AI and/or blockchain into almost every service they offer. The revolution comes from making accurate predictions—car crashes, heart attacks, diabetic problems, customer care problems, transportation bottlenecks, and thousands of other use cases—and proactively solving them before they occur. This dramatically improves productivity, but is difficult to measure.

Enterprise and consumer data, the necessary inputs, are usually collected at the network edge, then transported to the core of the cloud, stored and analyzed in "data lakes" using "data bricks" with outputs distributed back to the edge, the quintessential fog/cloud use case. These data lakes will grow to become oceans, we expect, with gravitational pull of data and applications, locking customers into the cloud provider with the best AI. Being able to act on your data in real time with AI will enable robotics, smart factories/cities, remote healthcare, autonomous vehicles, and dozens of other use-cases that have yet to be imagined.

Exhibit 1: Estimated Global Business Value Creation of These Six Core Technologies, AI Dominates

Worldwide Value Forecasts ($ in billions)	2018	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Artificial Intelligence	692.0	1,175.0	1,901.0	2,649.0	3,346.0	3,923.0	4,538.0	4,725.0
Y/Y Growth %		*69.8%*	*61.8%*	*39.3%*	*26.3%*	*17.2%*	*15.7%*	*4.1%*
Blockchain	5.0	9.0	21.0	37.0	50.0	64.0	96.0	176.0
Y/Y Growth %		80.0%	133.3%	76.2%	35.1%	28.0%	50.0%	83.3%
Robotics (Commercial)	25.4	30.0	36.3	44.3	53.8	65.1	78.1	93.3
Y/Y Growth %		18.4%	20.9%	22.1%	21.3%	21.0%	20.0%	19.5%
Genome Sequencing/Healthcare	1.1	1.2	1.4	1.6	1.8	2.0	2.3	2.6
Y/Y Growth %		13.37%	13.37%	13.37%	13.37%	13.37%	13.37%	13.37%
Autonomous Vehicles	0.5	2.0	8.0	13.8	17.1	21.8	27.5	32.5
Y/Y Growth %		304.0%	295.0%	72.9%	23.8%	27.9%	25.9%	18.2%
Internet of Things	726.5	832.4	923.2	1,027.0	1,124.6	1225.8	1336.1	1456.4
Y/Y Growth %		14.6%	10.9%	11.2%	9.5%	9.0%	9.0%	9.0%
Total	1,450.5	2,049.7	2,890.9	3,772.7	4,593.3	5,301.8	6,078.0	6,485.8
Y/Y Growth %		41.3%	41.0%	30.5%	21.7%	15.4%	14.6%	6.7%

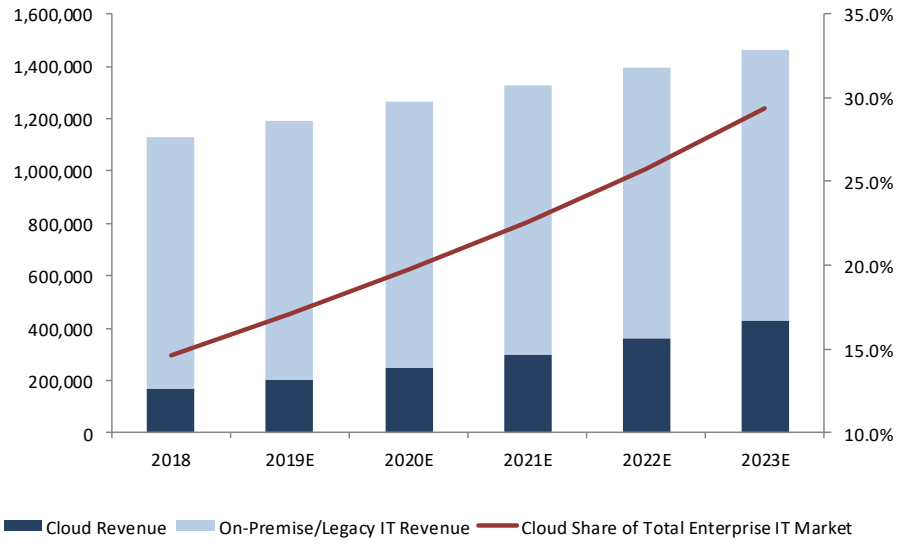
Source: IDC, Gartner, Microsoft, Globenewswire.com, OPCO est.

The cloud enables digital feedback loops in real time for enterprises, where the entire business is connected with data. This data is monitored and analyzed to improve every single function of the organization—from customer relationship management, enterprise resource planning, human resources, sales & marketing, finance & operations, and more. We view the cloud as the only platform that has the ability to break down the data silos between organizations/departments/groups/teams/etc. that can enable this digital transformation. However, enterprises need to flatten their organizational structures and enable employees to work more collaboratively.

The consumer cloud providers have been using AI for a decade now, acting on their own internal data. AI is embedded in almost every service the cloud providers offer customers (security, database, analytics, dashboard management, etc.). AI applications include Google Translate/Search, AWS's prediction engines/Alexa, Netflix's recommendation engines, and hundreds of other services. AI operating on the Cloud has become utility-like, running in the background of our day-to-day lives, very much like electricity. Other companies leverage these and their own AI including Salesforce, Telsa, and hundreds of other companies. Nonetheless, we have just begun to discover use-cases and applications, and having two-way edge devices with massive cloud data storage is set to accelerate this.

Today, only about 20% of enterprise workloads have moved to the public cloud; we think this gets to 80% or so in a decade. We believe the benefits of cloud cannot be understated (less capital-intensive, instantaneous updates, outsource back-office IT functions, better security, predictive as opposed to reactive and much more). We believe the cloud benefits from a "flywheel effect": the more customers/partners/vendors on a single platform, the more they can positively impact each other. Plus, the more data, the better AI will get at predictive analysis, which we think will be required for every company to compete in the digital age.

Exhibit 2: Cloud Early Innings of Adoption of a Large $1T+ Technology Market

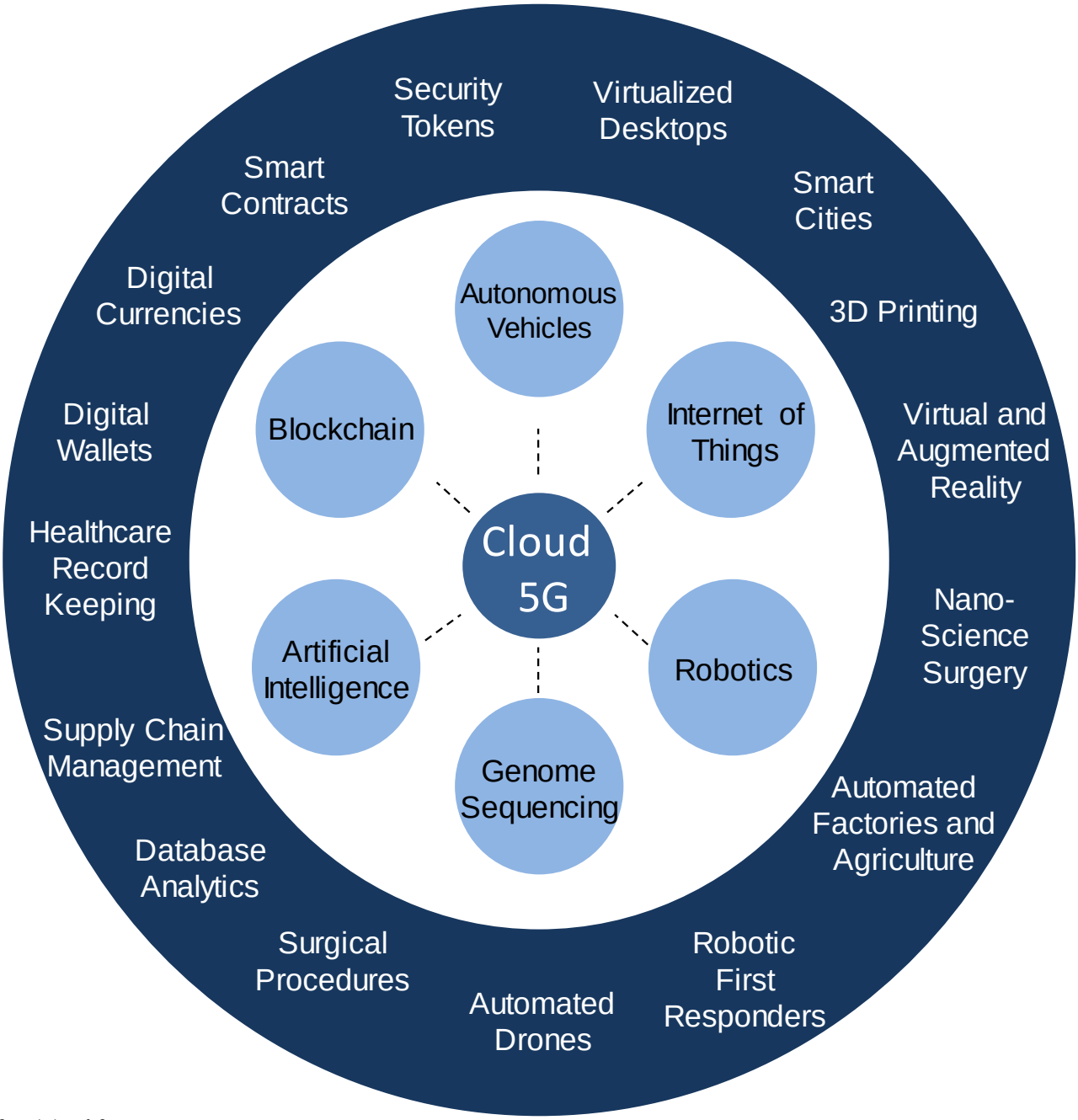


Source: Oppenheimer & Co.

The cloud provides the compute and processing necessary to power these technologies. 5G enables large sums of data to be transmitted at breakneck speeds (10x+ enhancement over 4G LTE), which is critical for IoT and robotic use-cases. The fog, where cloud architecture evolves and become more decentralized, will further enable new use-cases, primarily around very low-latency workloads such as autonomous vehicles (AVs), augmented and virtual reality (AR/VR), health care monitoring, and robotics. This will enable new organic and difficult-to-predict services/use-cases. Who foresaw Facebook, Twitter, and cryptocurrencies in the 1990s? Other surprising business models include those of Amazon, Etsy, Farfetch, Spotify, Redfin, and Netflix that are cloud-based and lightly intertwined with our physical world.

We believe that ~5% of jobs will be completely eliminated with the above technologies, and that approximately half of all jobs can see a 40% improvement in productivity over the next decade. In other words, we believe developed economies can improve labor productivity by ~25%, mostly by automating mundane or repetitive tasks. We guesstimate that a quarter of this will be offset from higher capex/opex of cloud/robotics, etc., translating into ~2% per year in productivity improvements. This can be seen in labor compensation trending down from 65% five decades ago to about 58% of business expenses today on average, a trend that likely will continue. In the next decade, all things being equal, companies should see approximately a 12% reduction in expenses, by our analysis. Competition will force the vast majority of this to be passed through to customers, but we still believe that profit margins can increase by 10% or so, which equates to $10 trillion in global enterprise value. Another $10 trillion in market capitalization could come from the 2% of the global economy that will come from a combination of new unpredictable services and a shift to spending on the above technologies, or approximately $2 trillion in revenue.

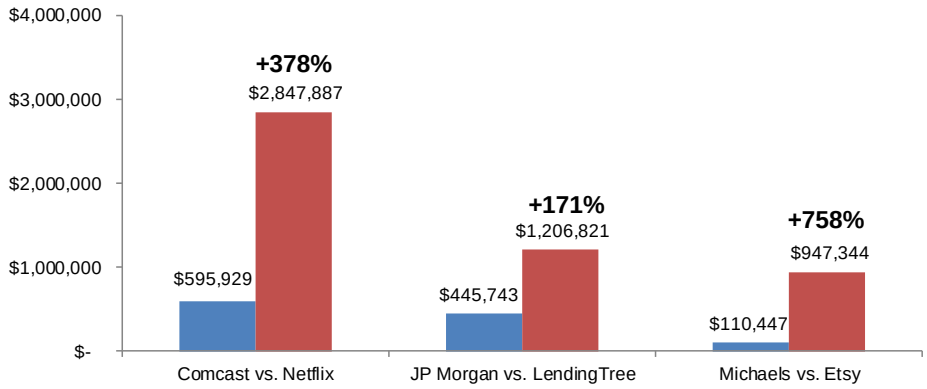
Exhibit 3: Cloud and 5G Driving Innovation, New Use-Cases



Source: Oppenheimer & Co.

This will require all large corporations to restructure into much more of a flat organizational hierarchy, away from the command-and-control management hierarchies in place since World War II. Organizations are already data-conscious, and the organizations that move away from the limitations of centralized and siloed structures will be able to take advantage of AI/blockchain/IoT. Organizations can accomplish this by breaking down walls between departments so data can be shared and aggregated throughout an organization. This is more of a DevOps type of organizational structure.

Exhibit 4: Cloud-based 2019E Revenue/Employee vs. Legacy Organizations



	Content and Distribution		Consumer Finance		Retail	
Company	Comcast	Netflix	JP Morgan	LendingTree	Michaels Companies	Etsy
2019E Revenue ($ in millions)	1,096,510	202,200	1,141,570	10,970	51,910	8,024
Number of Employees	184,000	7,100	256,105	909	47,000	847
2019E Revenue/Employee	$ 595,929	$ 2,847,887	$ 445,743	$ 1,206,821	$ 110,447	$ 947,344
Delta		**378%**		**171%**		**758%**

Source: Oppenehiemer & Co.

We think the cloud providers are well-positioned to capture an outsized chunk of this value creation—Amazon AWS is already worth half a trillion dollars in our estimation, and Microsoft Azure is a close second. Google and Alibaba are major competitors too, and we see a world where multi-cloud strategies are likely preferred by enterprises to avoid lock in to a single vendor (this is difficult to prevent because of the gravity of data).

Most of our coverage universe though is fairly well positioned. Our horizontally segmented infrastructure names do have higher and more stable ROICs because of limited supply and strong demand, and the need for wireless/cloud infrastructure to enable these six technologies. AMT, EQIX, and AKAM are our top picks as infrastructure providers focused on core competencies. The wireless carriers have valuable fiber/spectrum that will see increased utilization as do the cable companies with their fiber/coax lines. Wireless has made much of the transition away from relying on OTT (over the top) voice traffic, and should be a relatively stable industry. Cable will be a bit more volatile, given that TV is just now moving to OTT and there is a risk that wireless will compete with cable's broadband offering over time.

The US is a leader in cloud, and most of the companies that leverage the cloud are relatively nimble versus our global competitors. For this reason, we believe the US can gain share back in manufacturing and continue to gain in technology and many other industries as a result, but will also export these technologies globally. In this report, we go into the transportation and financial services impact from these technologies in more detail, but touch on other industries. We are not healthcare or manufacturing experts, but we think both will be revolutionized by these technologies. The Internet did help many industries, but nowhere near as much as new AI/blockchain-based software can, particularly when combined with robots and IoT. Incumbent companies will need to adopt these technologies or die. Positively, companies with lots of data can now monetize this in ways that were not possible before (insurance, health care etc.) and companies with defensible revenue streams should be able to lower their expenses substantially, by automating back-office tasks. A study from consultants at McKinsey estimated that a half of all activities carried out by workers could be automated by AI/robotics. Companies in competitive industries will face a huge amount of stress. This will obviously also provide a lot of social stress.

Entire segments of the tech sector will evaporate. Cloud is an order of magnitude cheaper, and you can do things with its technology that you can't do anywhere else. What investors need to understand is that cloud totally changes how IT is consumed and who buys IT. It is now provisioned as a service, the buyers are people who use the service, and sales are now to department heads. IT departments in enterprises will shrink dramatically, we expect. The buyers of IT are now largely just six global companies, not hundreds of small ones. Additionally, these companies are buying nearly 80% of available global servers. They are massively pressuring prices for all components in IT. The cost advantage of using the cloud will be an order of magnitude more than legacy. This will be exacerbated with Moore's law breaking down AMZN.

Entire components of the Dow will evaporate, we believe (technology, oil, healthcare, financial services, etc.), although this is nothing new. Only two companies from the 1898 Dow were in the 1928 Dow, or 15%; and only 11 currently from 1987, or 36%, still are part of the Dow. If we are correct, we expect many of the existing technology, financial services, retail, drug, oil companies to not be in the market in 30 years. Our vote for the companies to be out of the Dow in 30 years include—American Express, Apple, Chevron, Cisco, Dow, Exxon, General Electric, Home Depot, Intel, IBM, J&J, 3M, Merck, Pfizer, Procter & Gamble, UnitedHealth, Visa, and Walmart, or likely half the existing Dow companies. *See Appendix.*

Cloud Is the Third General-Purpose Technology

The last two major general-purpose technologies (GPTs) were high pressure steam-powered engines and electricity. Each hit peak adoption rates approximately 100 and 200 years ago, and drove accelerated productivity/economic growth over the subsequent decade. This is what we expect for the next decade. Both of these core "platform" technologies became pervasive, spawned massive innovation and applications that leveraged these core technologies, and saw continuous productivity improvement. While the first two GPTs enabled improvements in power, we believe the cloud improves intelligence (compute/processing power, and AI is intelligence on steroids), and more important, predictive capabilities, which is revolutionary.

Exhibit 5: General Purpose Technology Adoption

Accelerating Widespread Adoption of Major Innovations			
Innovation	**Invention to Peak Adoption**	**Peak Adoptive Period**	**Description**
Steam Power (Savery Engine)	1698 - 1850 (152 years)	1760-1830 (70 years)	The industrial use of steam power began in the 1700's after Thomas Savery constructed and patented the first engine in London, which was intended to pump water from mines. The new invention helped workers drain mines, serviced towns without water, and helped mills operate that did not have benefit from water access or constant winds.
Electricity (Light Bulb)	1878 -1940 (62 years)	1895-1930 (35 years)	Thomas Edison was able to produce a reliable, long-lasting electric light bulb, creating small electric stations located in various U.S. cities. Light had wide social implications, allowing people to extend their activities throughout the day and provided the infrastructure to provide electricity to every home and business.
Cloud Computing (www)	1989 - 2030 (41 years)	2005-2030 (25 years)	Cloud Computing is on-demand delivery of compute power, storage, applications, database, and other IT services. The cloud services platform provides flexible and low cost IT resources that help users operate more efficiently with lower upfront IT costs. With cloud compute, users can easily deploy applications across multiple physical locations that reduces latency.

Source: Oppenheimer & Co.

The cloud/fog like other GPTs will spawn dozens of new industries, in our scenario. AI is the most important application/service on the cloud and will enable self-perpetuating improvements on the cloud, as data is collected and used in learning models to improve every single business process across the economy. Data will now become an asset and maybe the most important asset of a company. This could even be used to raise financing much as real estate or accounts receivables are. This could create a global "flywheel effect" never before witnessed in history. It has been 25 years since the start of the cloud, and we can see the tangible productivity improvements that cloud is achieving. Generally, it takes approximately 35 years for peak impact, so we see a long runway of growth going forward

For example, the first high-powered steam engine patent was issued in 1802 and deployed in steam ships starting in 1815. New York City deployed its first electrified subway on a purpose-built subway car in 1915, and almost all new factories built at that point were designed around electric motors. This was about 35 years after the first lightbulbs and electric power plants had been launched. Manufacturing and transportation infrastructure needed to be rebuilt and regulations/standards established. At those two points, economic activity accelerated to some of the fastest ever recorded for the subsequent 15 years. At the end of that cycle, though, technology-driven deflationary forces and probably high debt leverage caused economic depressions. Steam power and electricity were clearly not the only important technologies at the time, but we rate them the most important. Telephones and automobiles would not have been practical without electricity.

For the process to continue, we believe that a GPT requires a continued 30% improvement in cloud/broadband productivity. This will be driven by compute architectures more so than semiconductors, improved energy storage and fiber optical technology. In the case of semiconductors, future productivity will be driven by more specialized chips in the cloud (serverless architectures) and ultimately quantum compute as opposed to Moore's Law. Broadband technology is also a key enabler of cloud and in turn is set to see major improvements in speed/coverage/latency with a combination of LTE-Advanced, 5G, low earth orbiting satellites, DOCSIS 3.1 and improved fiber optics.

Organizations Need to Restructure To Achieve Digital Transformations

Enterprises shifting to digital architectures will require revolutionary restructuring by business, not just technical (all legacy IT will be replaced, we project) but also managerial, which are only now getting started. Old on-premise hardware is designed for software and applications from the client-server era which in turn supported business processes developed in the 1950s. Business organizations will be much flatter, as opposed to the command-and-control structure of the last 100 years. Access to real-time data and leveraging AI will make possible flatter organizations that are nimble. We think employee headcounts could be trimmed by 20% in most organizations. Sales forces can become more targeted with better AI-assisted lead generation, and organization charts in every business unit can become flatter as AI software replaces middle management. This is really only possible in the cloud, where almost all innovation is happening today.

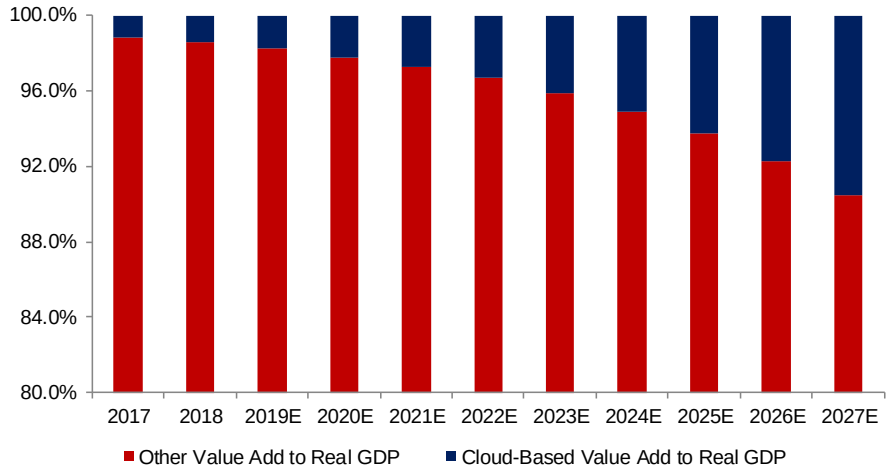
New compute will be bought as a service not provisioned by in-house IT (this is a similar transition that electricity went through a hundred years ago). The new compute architecture is agile and customer focused, thanks to the integration (CRM software integrated with ERP/UCaaS/databases) that cloud enables. At the end of the day, it's a race to get the best answers quickest. With cloud and AI, we can process data extremely fast and break down silos between applications and aggregate data in data lakes on the cloud. Companies can become much more efficient by allowing departments to work more fluidly with each other.

For example, a customer may call into a call center representative with a highly technical question. The underlying AI-based routing capabilities can transfer the customer to the right engineer in the organization to answer the question. By breaking down walls between departments and using AI/cloud-based services, organizations can streamline process much like DevOps aims to accomplish in software development. According to enterprise software maker Atlassian, the concept of DevOps is founded on building a culture of collaboration between teams that historically functioned in relative siloes, so processes can be much more streamlined, information can be shared, and problems can be remediated quickly.

Cloud Set to Create $10 Trillion in Market Capitalization in the Next Decade

We think the Internet has created $10 trillion or so in increased global stock market capitalization in the past fifteen years, but we see cloud doubling this in the next decade. New productivity cycles are driven by new technology and major technology improvements occurring approximately every hundred years. In that sense, if we are correct on cloud driving a new productivity cycle, it will be a game-changer for every industry. As we highlighted above, the public cloud and infrastructure providers are extremely well-positioned. Any technology/software company not aligned with cloud will face a much harder time. We've seen this before. In fact, a huge percentage of the Dow stocks turn over, and these companies are typically market leaders with enormous balance sheets and reach. (We look at historical Dow turnover in the Appendix.) However, it is never easy for entrenched companies to restructure and align to new technologies (take a look at Harvard professor Clayton Christensen's *Innovators Dilemma* book, and you realize how hard it will be for many of these companies to restructure).

Exhibit 6: Cloud-Based Value Add to Real GDP



Source: Internet Association, Opco Estimates

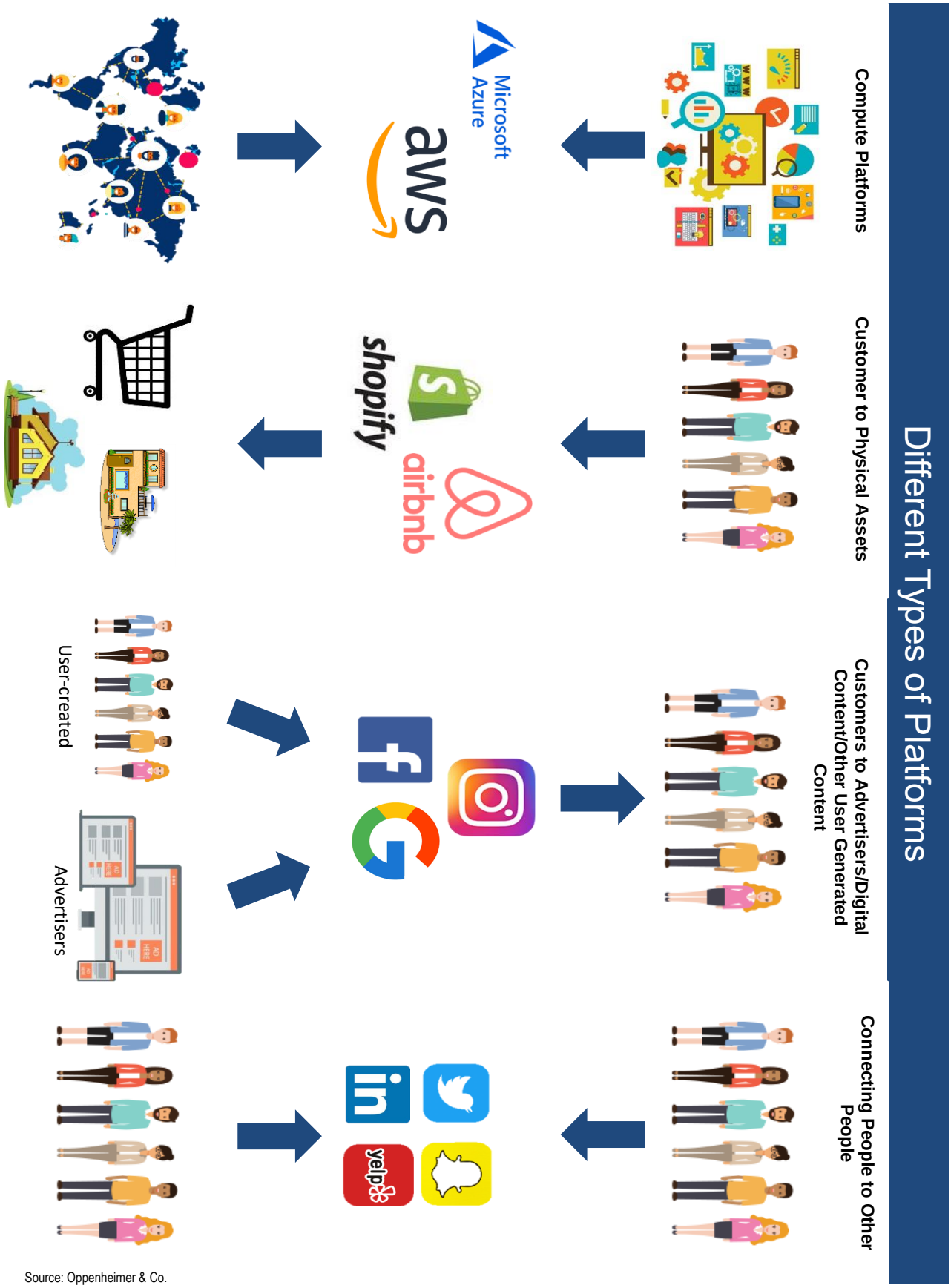
We believe that the cloud and these six technologies can drive GDP people growth and superior value for consumers. For example, we think the cloud and these six technologies have kept costs of many goods and services down. Most of Google's and Facebook's services are free to consumers and are not counted in GDP in any logical way. Thus, inflation has been able to stay in the 1.5% range for the last decade, below the Fed's 2% target which has allowed the Fed to keep its dovish policies. This, in turn, has allowed money to stay cheap for a decade which has greatly increased the amount of money being invested in these new innovations. We expect cloud value-add as a portion of real GDP to grow from 1% in 2017 to nearly 10% by 2027, assuming real GDP grows at a 2.5% CAGR from 2017 to 2027. Additionally, we expect cloud-related value to grow at a 26% CAGR during the same time, reaching $2.2 trillion-plus by 2027.

Built on the cloud, many platform companies have also been able to capture value. When a company creates a critical, lynchpin, neutral platform in the food chain ecosystem, growth becomes viral with essentially flat costs. In the physical space, wireless towers and interconnectivity-focused datacenters are similar to these platform companies. We consider the cloud a platform as well, connecting suppliers of specific applications to other customers/suppliers/partners, and then connecting that to hardware. These six

technologies—AI, blockchain, robotics, AVs, genome/healthcare, IoT —are likely to make platforms in all industries much more valuable—blockchain can track origin of data, secure it, and make it anonymous so users can share it with counterparties, important for the healthcare industry. Evidence of the value of these platforms is Applico's Platform ETF which includes publicly listed mid-to-large-cap platform business that are listed on US exchanges. From 2010 to 2018, the index is up 4x, while the S&P 500 only doubled over the same period. (These results cannot and should not be viewed as an indicator of future performance.)

There is an ecosystem of niche platform companies that have been built on top of AWS/Azure that are allowing businesses to abstract away code/hardware provisioning and focus on business logic. These companies focus on specific verticals and enable digital transformation, whether it's Salesforce.com offering complete CRM management tools or Stripe that offers payment processing code for eCommerce. They are all cloud-native and leverage cloud infrastructure to build agile and leading services/platforms which improve productivity (no longer do organizations need to hire a person and allocate resources to embed chat features into their application; use Twilio instead). When these platforms become essential hub spots for interconnectivity, they become extremely valuable and also monopolistic/duopolistic businesses.

Exhibit 7: Platforms Companies' Common Meeting Place



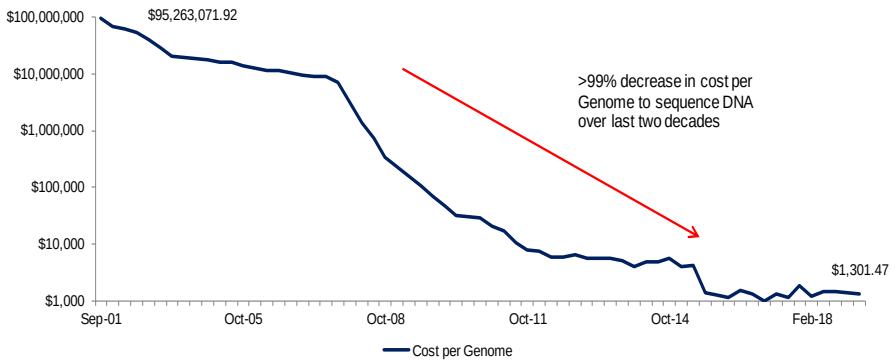
Source: Oppenheimer & Co.

Why Will Cloud Impact Accelerate Now?

It takes considerable time to harness the power of new technologies. In fact, the more core and dramatic the technology (GPTs), the longer time lag between invention and the full impact on the economy. The AWS platform was built in 2002 and was first made available to the public in 2004, leveraging the worldwide web built about 15 years before that. Historically, GPT adoption and impact occur 30 years after first deployment. Like the other general purpose technologies that we talked about above (power steam engine and electricity), killer use-cases typically don't come about until a decade or two after then technology is introduced. For steam engines and electricity, it took dozens of years to lay railroad track and build electrical infrastructure. For cloud, it took a decade to build enough datacenters and network to support IT transition, and now we are just beginning to expand to the fog.

In this regard, 30 years after electricity started to be deployed to manufacturing locations starting in 1890, only half of them had connections 30 years later. Existing owners of factories wanted to get as much out of their capital investments as possible. But at that point, the new factories that were redesigned from the bottom up to take advantage of the massive improvements that electrical power provided were substantially more efficient. Electric motors over centrally powered steam drives were much cheaper, cleaner, safer, and more flexible. They made the assembly lines possible and drove a boom in manufacturing in the US in the 1920s. Just taking a look at the cost for genome sequencing gives one example.

Exhibit 8: Cost to Sequence Genome Has Fallen Dramatically, Helped By Cloud



Source: National Human Genome Research Institute, Opco

A wave of "unicorns" that will drive the innovative services on Cloud have recently gone public. Many are built on top of or leverage the niche platform companies that we highlighted above. Almost every single "unicorn IPO" over the past year is cloud-native. We see this as a testament of the disruption that the cloud enables and expect this to be the norm. Uber, Airbnb, Slack, Zoom, and Pinterest are good examples, but over the next two decades, we expect every single industry to be impacted. We have detailed the benefits of building on top of the cloud before and which are now widely apparent, but they include:

1) The cloud reduces capital outlays by outsourcing compute/networking on-premise hardware to the cloud, allowing users to focus on core business logic while at the same time reducing cash burn.

2) Shared infrastructure results in higher asset utilization which spreads fixed costs over a wider number of users. This results in better returns, and the cost savings can be

passed on to customers in form of cheaper compute/storage/networking costs but also in embedded value-added services.

3) Cloud is almost infinitely scalable and with serverless architectures, it is easy to spin up new instances (or down) as infrastructure provisioning is automated. Equally important, it is much easier to and cheaper to use outsourced applications.

4) The cloud gives users access to better global software at scale. Earlier this year, we highlighted the AI capabilities that cloud users can gain from the public cloud providers. Basically, the cloud providers are investing $100 billion per year in CAPX and an equal amount in R&D, making innovative services available to customers.

5) The cloud is also a stronger environment for security (developers no longer have to patch many disparate systems together with on-premise systems).

6) The cloud platforms cultivate an ecosystem of shared collaboration and interconnectivity of traffic, essential for developer standards and advancing new technologies (AI/ML, IoT, and blockchain).

7) With cloud volumes just about doubling every year, there is a natural 15% improvement in costs per year and an additional benefit from Moore's Law of 20%, albeit slowing.

Exhibit 9: Cloud/Internet-Based Marketplaces vs. Brick & Mortar 2019 Estimates

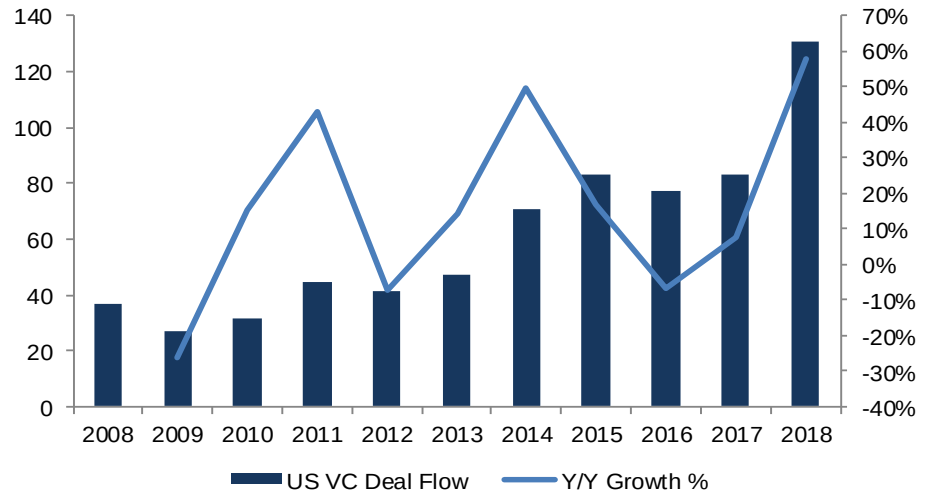
	Online Marketplaces				Physical Brick and Mortar			
Company	Etsy	Ebay	Angie's List	Chegg	Michaels	Macy's	Lowes	Nordstrom
Revenue ($ in millions)	$802	$10,827	$1,336	$402	$5,191	$24,871	$72,441	$15,597
2019E Y/Y Revenue Growth	32.9%	0.8%	18.0%	25.1%	-1.7%	-0.4%	1.9%	-1.5%
Gross Margins	68.9%	77.3%	96.8%	76.3%	38.6%	39.2%	31.7%	35.4%
EBITDA Margin	23.8%	34.0%	15.9%	30.1%	15.0%	9.4%	10.8%	9.6%
Net Income Profit Margin	12.4%	21.8%	3.3%	23.8%	7.2%	3.7%	6.1%	3.3%

Source: Factset concensus measurements

These new start-ups/technologies are enabled by inexpensive and pervasive compute, power and software. This allows developers, start-ups, and businesspeople to focus on creating unique and innovative new applications/industries. Cloud costs are also cheap enough that elasticity is kicking in. Cloud providers are also providing major productivity improvements in software by creating much of the basic software infrastructure that can be easily integrated with customized applications (payments for instance; Shopify offers the building blocks to an e-commerce website that can then be customized), and bundled in for free or highly discounted.

The cloud also required broadband connections and broadband mobility which are only a decade old. Broadband enabled the start of basic cloud infrastructure with Google and ultimately FB and AWS about 15 years ago. 5G is key here to enable even faster connections and handle much greater capacity. One of the key unknowns to fog development will be energy storage; how does it improve and can costs come down to fuel even more innovation? We believe the creation and the combination of very low-cost natural gas and battery technologies will soon make electric vehicles much cheaper, safer, more fun to drive, and more environmentally friendly than combustion engines.

Exhibits 10: Venture Capital Activity at All-Time Highs

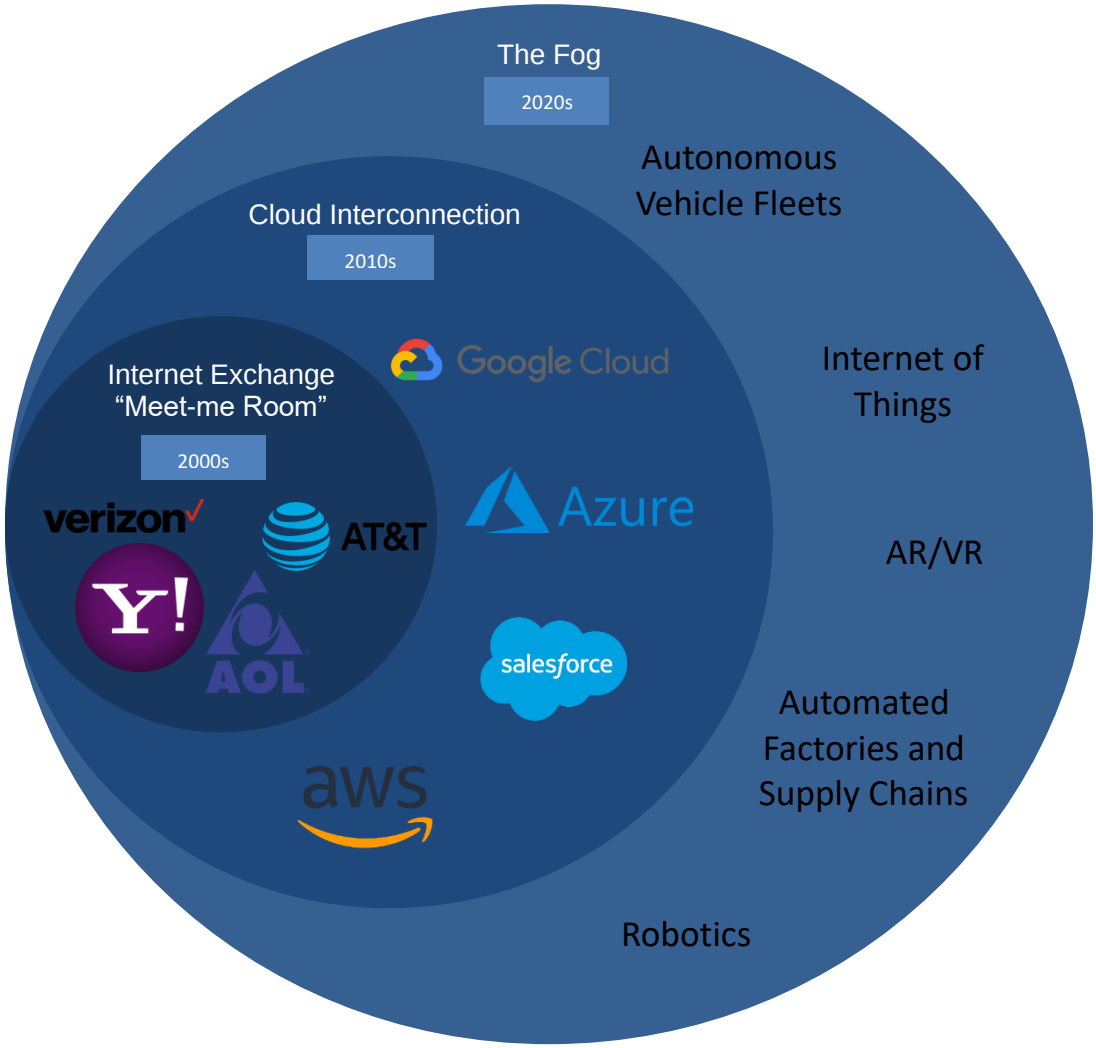


Source: Oppenheimer & Co., Pitchbook.com

Infrastructure is critical for the intelligent edge—we have been long been believers in shared infrastructure that benefits from high return on invested capital. In that sense, datacenters and towers are really well positioned for the growth in data traffic. We expect mobile data traffic to continue to grow 30-40%, likely accelerating with more video traffic and 5G. Cisco believes that Internet video surveillance traffic will increase sevenfold between 2017 to 2022, with much of this growth happening in mobile. Gaming video is also growing at a similar clip, which increases demand for infrastructure that can enable very low latency. In this sense, we believe content delivery networks (CDNs), including AKAM and FSLY, are very well-positioned. If we are correct and we are entering a period of extremely rapid technological/economic change, then the benefits are still in the future. The cloud and AI require massive amounts of infrastructure—fiber, wireless, datacenters, servers—which has been built out over the last 25 years and will take another 20 years to be taken advantage of.

EQIX and INXN are critically important as lynchpins in cloud/fog infrastructure, as we see it. EQIX has transformed to the critical switching point of cloud. The company had initially dominated internet traffic, then cloud traffic, and now we see it as well positioned for fog traffic. The latter is more last mile-facing versus the long-haul of the former two products. In this regard, EQIX likely will become the neutral interconnectivity point for local traffic generated from IoT to be used for AI, robotics, self-driven cars etc. We think other interconnectivity focused datacenters, like INXN, are well positioned as well.

Exhibit 11: Interconnection-Focused Datacenters Enabling the Fog



Source: Oppenheimer & Co.

General-purpose technologies are typically capital-intensive and need access to cheap capital. This is partly why peak innovation typically happens in parallel with economic cycles, when access to capital is relaxed. With that being said, we are in the middle of a ten-year bull market, with very low interest rates, and private equity/venture capital is investing record amounts of capital in 2019 to date. This fosters an environment of rapid innovation—AI start-ups benefited from a record $7.4B invested in 2Q19 according to market researchers CB Insights and the number of AI unicorn start-ups (those with more than $1B in valuation)has increased from 2 in 2016 to 18 in 2018. In total, over 3.6K AI start-ups in 70-plus countries have raised $66B since 2013 (according to CB Insights). Digital banking is helping expand access to capital in emerging markets, enabling innovation to be a global phenomenon.

We have seen the impacts of technology cycles on many industries, including automobiles. This improvement is not always captured in standard economic measurements. For example, the cost of transportation has fallen precipitously over the last 150 years, while at the same time greatly improving. We went from horse-drawn buggies that topped out at ~10-15 miles per hour to automobiles that enabled 65 MPH speed limits. Over the last 50 years, the automobile has gotten remarkably safer and more luxurious (seatbelts, backup mirrors, lane and parking sensors, entertainment systems, climate control, and more).

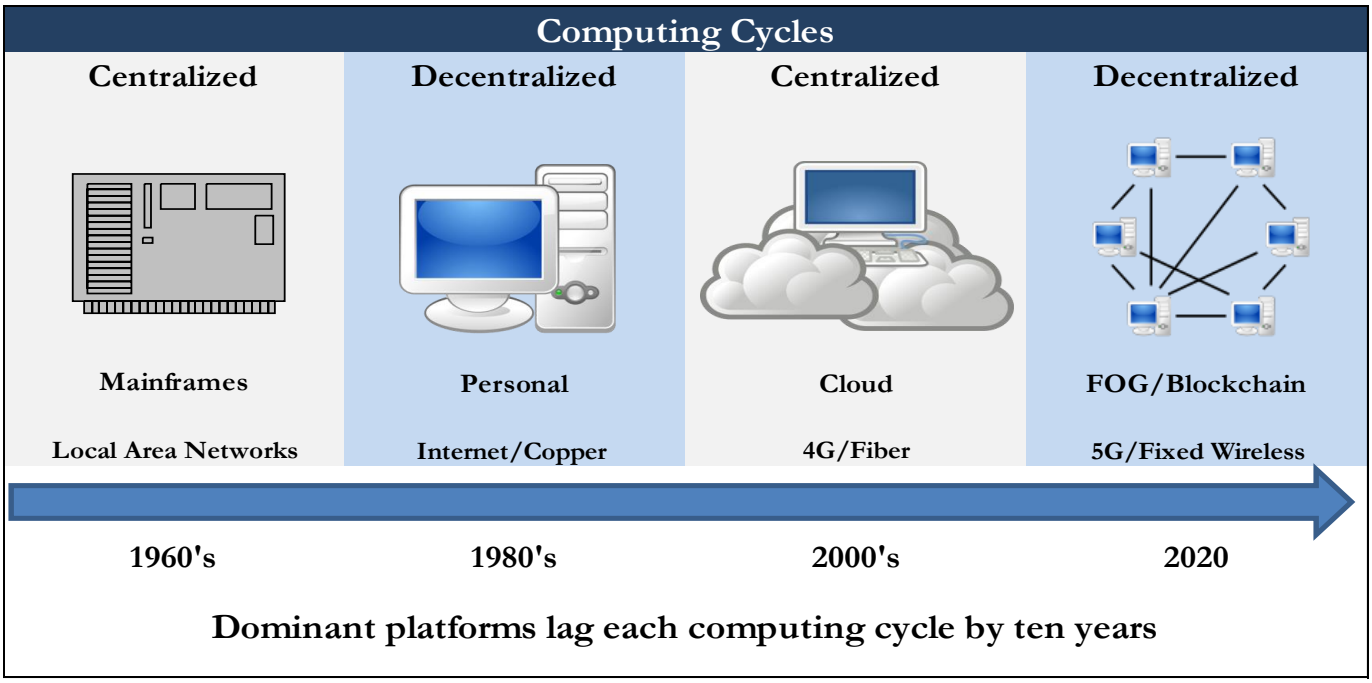
Cloud Architecture Evolving To Fog

The cloud is virtualized compute, such that software controls the hardware enabling applications to be built on more flexible “container built software” in micro-service architectures. This structure is dramatically more capital-efficient for everyone involved, and aligns with our long-held horizontal segmentation thesis. This structure in turn enables more and lower cost innovation. Maintenance of software/applications, also called technology debt, is also dramatically improved, as is the agility and malleability of applications.

The cloud/fog becomes more powerful with 5G wireless networks. We believe that businesses and organizations can dramatically improve their productivity by the combination of outsourced IT (compute/storage/networking and more), and leveraging as many of the six new disruptive technologies as possible. This will usher in a new era of hyper-productivity for global economies, in our worldview. The challenge is to balance the deflationary forces and disruption to legacy services/product with new growth. This historically has not been achieved well in short-term periods, but has been in the long term. Positively, capital going into every facet of cloud has been growing rapidly from just $30 billion five years ago by the big six US cloud providers to an over $100 billion run rate currently to enable this evolution. The networking companies have been consistently spending in the $60 billion per year range in the US.

Over the last half-century, we have seen compute and processing power cycle between stages of centralized and decentralized infrastructure. Mainframes dominated the 1960s and 1970s, and are largely centralized machines. The advent of personal computers in the 1980s and 1990s democratized and distributed compute to every desktop device in America. The public cloud ushered in a new era of centralized compute, an era in which superior networking capabilities (4G, fiber) allowed compute to move from edge devices back to large, hyperscale datacenters. However, this is quickly evolving to a more decentralized, edge compute infrastructure that we call the “fog.” Basically, new and future use-cases are extremely latency-sensitive, and new networking technology (l5G) is required to have compute abstracted away from the edge devices that need extremely quick decision making power (autonomous vehicles, augmented and virtual reality, robotics).

Exhibit 12: Computing Cycles—From Centralized to Decentralized



Source: Oppenheimer & Co.

It's important to note that we view fog as complementary to the cloud, and the cloud providers today (AWS, Azure and GCP) are well-positioned to help enable fog architectures. AWS has a suite of core IoT services that offers analytics, security, networking, and more for connected devices at the edge. AWS IoT Greengrass is the flagship product in AWS's IoT suite, and supports our thoughts that the edge and centralized cloud can complement each other. According to AWS, Greengrass seamlessly extends AWS to edge devices so they can act locally on the data they generate, while still using the cloud for management, analytics, and durable storage. We think this makes sense, in that most of the time-sensitive processing will be conducted on the edge (therefore, we need logic to extend to the edge) while more complex datasets could be up-streamed to the cloud for more in-depth analysis.

MSFT refers to the combination of connected devices with powerful sensors that leverage AI to interact with surroundings and people as the "intelligent edge." The concept is still the same as fog; cheap, connected devices that transmit data back and forth from the edge are enabling the physical and digital worlds to intertwine. We think MSFT's cloud services are leading at the edge. HoloLens is already creating augmented reality, such as providing a technician with a digital overlay of analytics, diagnostics and documentation for a piece of equipment that they are working on.

Serverless Revolutionizes Cloud

For cloud customers, this shows up in the total cost of developing and managing new applications and then monetizing the data that those applications develop. In this regard, we view serverless compute as the most important development in cloud, because it completely outsources the provisioning of cloud infrastructure away from the customer. AWS Lambda and Microsoft Functions have seen stellar growth, but are only three years old. With serverless compute, the infrastructure acts like software, and is perfectly scalable to the end user. Also, those users pay only for what they use. The software developed for serverless is radically different than legacy software. The primary difference is that its serverless functions outsource the management and procurement of the underlying hardware (and some of the code), so businesses can focus on writing the business functions into their application. These services are bundled in by the cloud providers at a fraction of what it would cost a company to build and more importantly maintain on its own. It is essentially a way to not just offload all your infrastructure needs but probably half your software development/maintenance.

Exhibit 13: Cloud AI Services—Azure vs. AWS

Machine Learning Layer	Description	Services	
		AWS	Azure
Application Services	Application layer services typically include pre-built models that are easily configured and provisioned by users without the need for AI/ML expertise. Typically 'plug-and-play' functionality.	Comprehend, Forecast, Lex, Personalize, Poll, Rekognition, Transcribe, Translate, etc.	Azure Cognitive Services - Vision, Speech, Language, Knowledge, Azure Bot Service, and Web Search (Bing Search APIs).
Platform Services	Cloud platforms can be used by developers to build, train, and deploy their ML models in a consistent environment.	Amazon Sagemaker, Amazon Machine Learning, AWS DeepLens, Amazon Mechanical Turk	Machine Learning Studio, Azure Machine Learning, Azure Databricks
Frameworks & Infrastructure	Powerful compute and infrastructure tools, including specially designed hardware, that are purpose-built to run AI/ML workloads and support the training, building, and deployment of ML models.	TensorFlow, Apache MXNet, PyTorch, GPU (P3 instances), Amazon Inertia, Greengrass (for IoT), AWS Deep Learning AMI	Data Science Virtual Machines, ONNX, Azure Kinect DK, and open source frameworks such as Pytorch, TensorFlow, and Scikit-learn

Source: aws.amazon.com, azure.microsoft.com

With serverless, customers can focus on value-add activities. They can also run much leaner IT staffs (because a lot of the heavy lifting is outsourced to the cloud). This is how Uber disrupted the taxi market, Square might disrupt the banking industry, Carvana in the used car market, Expedia in the travel industry, and so on. The service provided and the cost structures of these new cloud-based startups are much thinner than many incumbents, with much better capabilities due to the cloud.

Artificial Intelligence and Blockchain Key New Embedded Cloud Offerings

Cloud companies are bundling these two critical technologies into their cloud infrastructure offerings. We think AI will be the most important and will enable self-perpetuating improvements on the cloud as data is collected and used in learning models to improve every single business process. AI is particularly useful when there are predictions needed; where will demand for wireless networks be, cooling in datacenters, self-driving cars, machine maintenance, healthcare diagnosis, and more. All these devices will have massive amounts of sensors which will generate data sent back to the cloud to be stored in data lakes. AI improves over time; as more data is collected, and more data is applied to learning models in a self-perpetuating virtuous cycle. These learnings can also be applied globally almost instantly. Google's search engine is the largest AI application in the world and is the best evidence of this global scale, but AWS and Azure now have the ability to spread AI capabilities globally and virtually instantly at very low cost.

Cloud supports data storage capacity, scalable compute power, and embedded GPUs to handle large amounts of data and algorithms AI systems need to work on. Hyperscale internet companies offer superior AI capabilities by leveraging their built-out cloud infrastructure and cloud platforms for both enterprises and consumers. The cloud is optimal to run AI as applications can be integrated seamlessly. Significant R&D spending, CAPX in expanding data storage capacity, and easier/cheaper network transport have accelerated AI technological capabilities. We expect the large cloud providers (AMZN, MSFT, and GOOG) will spend $100B plus in R&D and $100B in cloud-related CAPX over the next five years, representing 2x their current run rate. Given their scale, cloud/AI/API offerings, and up-front massive R&D/CAPX spend, we believe the large cloud providers will continue to offer the best solutions for customers seeking to integrate AI capabilities. As AI adoption accelerates, we expect AMZN, MSFT, and GOOG will increase their public cloud infrastructure share from 70% to 85% by FY22.

Companies are increasing their focus on monetizing data at faster rates, which not only improves their businesses but also makes their data more valuable. AI enables a feedback loop whereby data stored in the cloud can be monetized, which improves applications provided by major cloud providers. As AI capabilities progress, we expect cloud adoption will accelerate in the form of services and platforms, reaching 25% of global GDP growth in the next decade.

The Cloud Providers' AI Strategies:

- AMZN's key cloud platform strategy involves storing/capturing customer data and providing services which monetize customers' data. Cloud-native enterprises (Lyft, Peloton, Pinterest, and Slack) run on top of AWS because of the suite of tools that fosters a vibrant developer ecosystem. Many new start-ups and developers chose AWS early on because the company gave away cloud resources to lock in developers. Additionally, customers choose to use AWS's AI stack for its platform/infrastructure and application solutions. AMZN's infrastructure service, SageMaker, allows customers to use the entire ML workflow (label, preparing data, and running the AI algorithm). In terms of applications, AWS offers leading services for computer vision, speech, and natural language processing.

- Microsoft's cloud platform provides both turnkey solutions and infrastructure elements using Azure's databases to enable AI. Azure Data Lake Storage ingests data from the Azure data directory, letting users apply AI and analytics to large sums of data. The company has massive amounts of valuable data for its Azure cloud, which includes content from Office, LinkedIn, Team, Bing, and Skype. MSFT's competitive advantage is its large enterprise installed base, which provides upsell opportunities for AI solutions. Nearly 1.2B customers use

MSFT Office. Many enterprises deploy Windows and other MSFT software because Azure is tightly integrated with the company's other applications.

- Google's Google Cloud Platform (GCP) has considerable scale by specializing in offerings like big data, analytics, and machine learning, but has less market share than AMZN and MSFT. GOOG has limited enterprise reach relative to MSFT and AMZN. However, we believe Google's cloud AI services will extend the company's cloud market share. GCP's AI solutions can be broken into three areas: AI solutions, AI Building Blocks, and AI Platform. Similar to MSFT, AI Building Blocks allows developers to leverage AI in applications with limited experience. Building Blocks allows developers to choose from a set of 10 different APIs to add. Google's AI Platform is a serverless compute environment. Open source has become a core tenet for Google's AI/cloud strategy, attracting developers to new compute platforms has been critical to almost every large technology company in the last decade.

Examples of Major AI Productivity Improvements

- MSFT's AI vision technology can leverage existing security cameras on site to identify construction workers on site. The AI vision can alert managers when an un-identified person walks onto a construction site, or if an unauthorized person is using a tool that they are not properly trained for.

- Blue River Technology claims that its "See and Spray" technology can reduce agrochemical use 90% by using computer vision targeting. The technology precisely sprays herbicides only where needed, and with exactly what's required. Globally, farmers spend $25B each year on pesticides, and Blue River's technology can potentially reduce global herbicide use by 2.5B pounds, according to the company, a unit of Deere.

- Amazon's recommendation system leverages analytics with AI/ML, enabling customers to discover value in their data sets. Inawisdom partnered with AWS ML competency to accelerate initial recommendation system implementations faster than before. This resulted in more personalized communications and recommendations, leading to a 300% increase in recommendation system engagements across the company's Retail and Finance Sector customers.

Blockchain is a critical component, allowing data and transactions to be more secure. We see blockchain technology being used by retailers and grocery stores to track goods throughout the supply chain, recording data such as arrival times to facilities, any impairment to the goods or food, and in some cases providing more insight to the consumer about the food they are about to purchase. In this application, companies will be able to more effectively practice quality control and determine where there are inefficiencies or contaminations in the supply chain. Walmart has been working with IBM for years testing and implementing a blockchain comprised of nodes at each point of handling of food that has been effective at improving the traceability of contaminations in the supply chain. In the future, companies should be able to forgo recalls on foods and prevent widespread breakouts such as those attributable to *E.coli*. Using IBM's Food Trust blockchain solution, Walmart was able to reduce the amount of time it took to trace the source of food from 7 days to 2.2 seconds.

Exhibit 14: Cloud Providers' Blockchain Offerings

Blockchain as a Service Offering	
Company	BaaS Offering
Microsoft	**Azure Blockchain Workbench Tools** End-to-end blockchain applications can be easily built and implemented on a ready-to-use infrastructure. Workbench automates deployment of distributed ledgers and network construction.
Amazon	**Blockchain on AWS** AWS provides a fully managed, scalable blockchain service. AWS provides a ledger database, which eliminates the need to build complex audit tables or building blockchain networks.
IBM	**Enterprise Blockchain Solutions & Services** Provides all needed tools to create, test, govern, and manage a working blockchain network - which accelerates creation of blockchain applications

Source: Investopedia.com, aws.amazon.com, ibm.com, Oppenheimer & Co.

We also believe that eventually most consumer data will be stored on the blockchain. Retailers who save customer data, such as credit card information, phone numbers, email addresses, and even more sensitive information, have been targets for hackers, leading to widespread consumer data compromise and increasingly costing firms millions in fines. Keeping consumer data on a private blockchain would keep the data safe via the innate encryption feature of blockchains and could also improve the quality and usability of the data. All of these forthcoming applications of blockchain likely will result in vast increases in demand for services rendered by cloud providers, AMZN, MSFT, and IBM. It will also facilitate robust IoT deployment, as blockchains require nodes at point of contact in supply chains and at point of sale for recording customer data. While data could be manually entered by factory workers and cashiers, we believe that we are close to having these tasks automated by smart factories and other IoT-enabled tools. Widespread deployment of blockchains will require higher throughput from hyperscalers at the edge to process and record all of the new data being used.

Exhibit 15: Blockchain Use-Cases

Selected Enterprise Blockchain Use Cases	
Industry	**Potential Use Cases**
Financial	Redesign legacy workflows, reduce infrastructure costs, increase transparency, reduce fraud and improve execution and settlement times.
Retail/Manufacturing	More efficient logistics and supply chain management, smart contract platforms, digital currencies and tighter cyber security.
Healthcare	Remove 3rd party verifiers such as health informatione exchanges by directly linking patient records to clinical and financial stakeholders. Also provides sage and secure access to personal medical records across healthcare organizations and geographies.
Government	Increase transparency and traceability of how money is spent. Track assets such as vehicles and reduce fraud.
All	Increase quality and control. IoT is an excellent use case for blockchain across all industries for tracking, monitoring quality and vertification across all asset types.

Source: Microsoft

Examples of Cloud-Enabled Disruption

Transportation Impact—EV/AV Adoption

Electric vehicles (EVs), which will ultimately become autonomous vehicles (AVs), will be greatly influenced by the cloud. The last two major transportation shifts were also impacted by general purpose technologies, and like them we are facing the third major transportation revolution. The proliferation of AVs/EVs will result from the culmination of AI/5G/IoT, enabled by cloud and improved battery storage. The sector will undergo transformational changes similar to how we transitioned from using horses and buggies to internal combustion engines (ICE) and 100 years before that to steam-powered boats and trains. This has the potential to make driving: (1) safer—AI based vehicles can detect defects up to 90% more accurate than humans, (2) environmentally friendlier—AVs will likely be EVs; it makes sense that the electricity that powers computers in EVs will also fuel the engine, (3) more efficient—More vehicles per road and coordination with lights for faster traffic flow, and (4) less costly—the UAW estimates the shift to EV will reduce factory headcount by 35,000 based on fewer moving parts in factories and use of robotics. We expect the shift from ICE motor vehicles to AV/EV is natural because of the significantly lower total cost of ownership (30-40% cheaper than ICE vehicles). We are more bullish on EV in the next five to ten years, and use-cases for AV may take longer to transition.

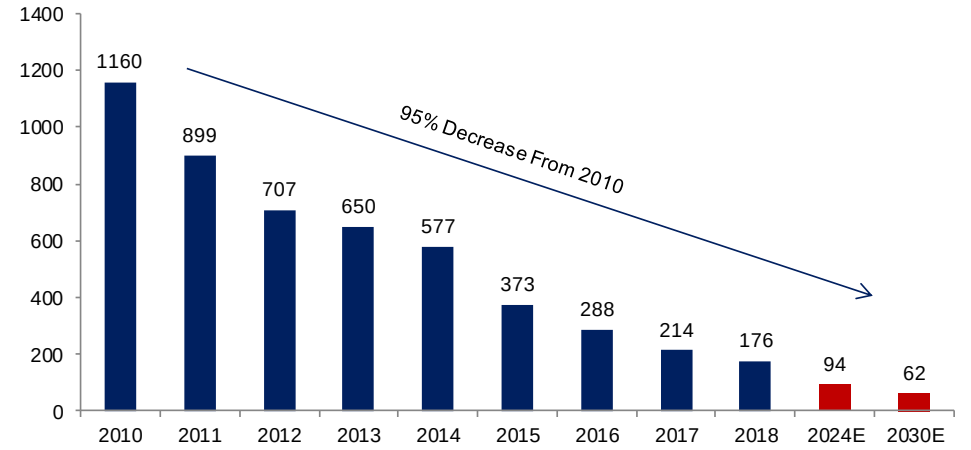
The total cost per mile to operate a vehicle should plummet from the current $0.70 to half this or less. We're seeing an entire connected-car ecosystem begin to unfold as current legacy auto suppliers roll-out mobility as a service with cloud capabilities: Uber, Google, Amazon, and Apple. The combination of the cloud with fog will enable AVs to quickly capture a majority of new vehicle sales and economics as convenience trumps anything else. This will drive a once-in-a-century revolution in mobility, we believe, likely displacing combustion engines in most urban areas 20-30 years from now. All existing auto industry plants and manufacturing processes will need to be completely redesigned for automation. We've seen this take shape as Tesla cars only have 8 moving parts compared to traditional automobiles with over 100. Additionally, truck drivers and pilots will become obsolete, driving major cost savings in the hundreds of billions per year range. We are starting to see some of the first investments deployed by enterprises for delivery truck automation, which has the capability to accelerate same-day deliveries (5% of all deliveries today; 15% by 2025E) and drive lower costs with faster traffic flow (total cost savings are expected to reach 55% with AV/EV by 2027).

We think autonomous vehicles will become required in urban areas as truck deliveries are required to make deliveries at night. AVs will be utilized up to 40%+ of the time vs. current 4% levels for privately owned cars. By utilizing the time spent driving ourselves around and time spent driving for free solely, we think GDP could see a one-time improvement in the 5% range. Vehicles will largely be peer-to-peer operated with 5G as the bridge connecting vehicles to smart infrastructure on the road. We expect fleet owners, municipalities, manufacturers, etc. will leverage AI on top, enabling vehicle communication with infrastructure (traffic lights, toll bridges, etc.). AI will act on collective data stored in the cloud in real time to dynamically fulfill riders' needs.

Aside from cloud as the general-purpose technology for AV/EV adoption, lower battery costs are the key driver. Battery costs are declining approximately 15% per year through scale production and make up approximately half the cost of an EV. If battery costs are cut in half in the next five years, in line with trends, we should see EVs selling for 25% lower price points and a total cost of ownership that will be half of an ICE. The cost per transport per person per mile could be even lower through a network of minibuses that are autonomous and are an upgrade to existing car-pooling, possibly a third the cost of a combustion engines.

The development of AV/EV reflects the innovation in general-purpose technologies that we have seen over the last transportation cycles. Until the 20th century, horses and buggies leveraged steam ships and steam driven railroad cars for the last mile transport and were the primary methods of transportation, which shortened travel time and allowed delivery of heavy/bulky goods across the country. Around 1820, the construction of macadam roads improved the infrastructure horses and buggies relied on, which increased averaged miles per hour traveled from 5 mph to 15 mph. However, society faced environmental and unintended consequences as manure accumulated on city streets, resulting in the Great Horse Manure Crisis of 1894. For instance, New York had a population of 100,000 horses producing nearly 2.5M pounds of manure per day.

Exhibit 16: Average Lithium Battery Prices Decreasing



Source: BloombergNEF, Opco

Developments from 1900 to 1920 were an inflection point in transportation, as the internal combustion engine could travel at faster spends, longer distances and carry more weight. However, automobiles were only affordable to the wealthiest consumers and saw adoption accelerate once prices became affordable for everyone. Henry Ford introduced Ford's assembly line and drove up production amounts to enable a lineup of motor vehicles at $500, which could be purchased by his own factory employees who were being paid $5 per hour. As a result, the number of automobiles had reached the same number of horses and buggies in some areas of the US by 1910. The number of registered motor vehicles accelerated from 4,000 in 1900 to ~9M in 1920. Local roads and highways were developed in the depression era to meet this demand, and the use of asphalt for roads instead of cobblestones furthered productivity improvements. Additionally, the food chain to support cars were created (i.e., gas stations, car washes, etc.), and regulation caught up (drivers licenses, traffic lights etc.). The sector is about 9% of GDP today both in the US and globally.

Similar to the inefficient methods of transportation with horses and buggies, today our society faces unintended consequences. Transportation can account for nearly 25% of carbon emissions in major cities and traffic congestion results in increased cost of doing business/lower economic productivity for consumers and enterprises. According to the World Economic Forum, traffic congestion cost the US economy nearly $87B in 2018. Electric vehicles will be able to reduce greenhouse gas commissions by 17-30% lower than emissions of petroleum and diesel cars and with autonomous, faster traffic flow.

Financial Services—New, Global Banking Start-ups

The cloud allows new start-up financial service companies to scale globally—such as payment applications like Venmo and cryptocurrencies. With Venmo, users can easily send cash to any other user. All that is needed is a smartphone connection. In this regard communications and compute networks have been critical to pass innovations in finance. Credit cards would not have been possible if AT&T did not establish data networks in the 1960s and IBM did not invent the mainframe. We have listed other historical examples below:

Exhibit 17: Currencies Have Been Communications/Technology Driven for a Long Time

Time	Communications Technology	Impact on Money
1200s	Compass and large-scale shipbuilding increase trade	Gold coins
1800s	Carrier pigeons	IOUs and British paper currency see massive adoption
1860s	Telegraph	Electronic fund transfers by Western Union are enabled
1950s	Telephone networks	Credit Cards
2000s	Wireless smartphones	Mobile banking and payment systems
2020s	5G and cloud compute	Digital wallets and virtual currencies

Source: Oppenheimer & Co.

The cloud is helping a number of start-ups that use AI and Blockchain to create disruptive new financial services. Legacy financial institutions are adopting these technologies themselves also. They are using AI services to increase customer engagement, reduce back-office inefficiency, and mitigate risk/fraud dynamically at a lower cost. London fintech start-up Ravelin uses Google cloud and AI technology to detect fraud in online payments and checkouts—in three years, Ravelin has prevented over £100M in fraudulent transactions by analyzing over 12 petabytes of data with AI. FINRA oversees up to 75 billion unique market events per day (equity and options trades), and the only way it can detect anomalies in this large of a population is by using AI that it built leveraging AWS machine learning services. Incumbents are reacting to digital start-ups by incorporating AI to make services better for customers. For example, Charles Schwab leverages Google's AI to automatically rebalance portfolios and analyze customer inquiries for concerns that need to be addressed. JPMorgan has been using AI to automate tedious back-office like Know-Your-Client (KYC) and document archival, which is helping the company cut costs.

Digital wallets are a killer use-case for financial services, we believe, which allow start-ups to provide banking, payment, insurance and wealth management services. Importantly, they offer these services to previously underserved and underbanked populations. By leveraging the cloud and AI, digital wallets make the economics more attractive to provide banking services to developing regions around the world. Digital wallets are key to unlocking new markets/customers because banking is the precursor to building wealth (having a savings account, budgeting, etc.). As wealth builds, consumer brands and products can target these new greenfield opportunities. Blockchain is key to tracking wealth and provenance.

The Narrow Bank USA Inc. (TNB) is a depository institution founded on the idea that non-bank large institutional cash investors (i.e. money market funds) should be able to deposit cash at the Federal Reserve, securing a low interest rate of return and assuming zero risk. Banks already benefit from this concept and are the only entities that have the privilege of this. We see blockchain as a possible method for institutional investors to secure their cash deposits.

Exhibit 18: Disruptive, Cloud-Based Fintech Companies

Company	TAM	Industries Disrupted	Description of Services
Lemonade	$1.2T	Home and Renters Insurance Providers	Lemonade disrupts the traditional home and rental insurance industry by charging customers a flat fee from monthly payments and the rest is allocated to paying claims to remove the insurance industries incentive to avoid paying out claims.
Chime	$650B	Retail Banking	Chime is a cloud-native digital bank that offers customers more than a traditional retail bank. Customers benefit from early direct deposits, no-fee overdraft, mobile banking services, and customizable security and account settings.
Robinhood	$160B	Brokerage	Robinhood was an early entrant in low-cost investing, offering a trading platform with zero trading fees. The company has also launched a cryptocurrency exchange.
Venmo	$23B+	Wire Transfers	Venmo, owned by PayPal, is a digital wallet for fiat currency that facilitates low cost peer-to-peer transactions and more recently began partnering with merchants, in tandem with PayPal POS Braintree, to process payments.
SoFi	$1T +	Brokerage Financial Services	SoFi provides financial solutions products such as student and personal loans, and also offers low cost investing (ETFs and fractional shares) solutions and a cryptocurrency exchange.
Coinbase	~$30B+	Wire Transfers	Coinbase operates the largest US-based cryptocurrency exchange; offering digital asset wallet hosting, fee-based and no-fee trading platforms, and also offers institutional custodial services for digital assets.
Zap Solutions	~$15B*	Wire Transfers Emerging Market Retail Banking	Zap is a bitcoin wallet that leverages a new development in Bitcoin's development, called Lightning Network, which is an additional layer of protocol on the core blockchain network that enables nearly instantaneous transactions for near-zero fees. The goal is to improive the UX of Lightning Network to increase adoption to bank the unbanked.

Source: iii.org, Deloitte, OPCO est.

*Zap does not currently charge retail users transaction fees for profit

Blockchain Is Helping Embed Trust and Security into New Financial Start-Ups

Blockchain is revolutionary because it automates trust between parties, democratizes control and governance, and enables peer-to-peer decentralization that fosters security, all in addition to making data immutable (for the most part). Public blockchain can also reduce bottlenecks and system dependencies that are common in centralized frameworks, but at the expense of slower transactions. Notably, decentralization prevents censorship and makes privacy and confidentiality more likely. We are seeing dozens of new platforms developing that are enabling these new applications. A vast majority of these platforms and applications will fail, much as happened with the Internet 20 years ago, but those that survive can revolutionize a number of industries, notably financial services.

AWS, Azure, and IBM have built blockchain-as-a-service platforms that allow enterprises to adopt the technology and shorten time-to-market. These platforms are easing deployment hurdles by making it easier for non-developers to launch networks through automated solutions and easy-to-use frameworks. The cloud also enables broader collaboration, between parties that can meet on a central platform to work on blockchain projects. This, along with lower cost cloud storage/processing costs, will make automation easier and more secure.

Exhibit 19: Interesting AI/Fintech/Blockchain Companies

Company	Industry	Description
Agorai	AI	Agorai makes using AI understandable, accessible, and affordable to allow any company take advantage of the technology.
BlockFi	FinTech	BlockFi provides interest bearing accounts and crypto-backed loans for cryptocurrency holders, driving the development of consumer financial services in cryptocurrencies.
Blockstack	Blockchain	Blockstack is building the new internet and app ecosystem powered by decentralized compute and storage.
Circle	Blockchain	Circle is a leading cryptocurrency based financial services company. They operate Poloniex crypto exchange, issue a USD-backed stable coin, enable early-stage equity crowdfunding, provides custodial solutions to institutions, and provides liquidity for cryptocurrency holders via OTC desk traders.
Dharma	Blockcahin	Dharma securitizes debt arrangements, such as municipal bonds and margin lending, onto blockchain-native tokens.
Digital Assets Data	Blockchain	Digital Assets Data builds software that provides asset managers with high quality data and tools to manage crypto investments and assist in due dilligence.
Harbor	Blockchain	Harbor is streamlining alternative investments for both issuers and investors, and creates liquidity for traditionally less liquid assets.
Inxeption	Blockchain	Inxeption is a B2B e-commerce platform that is built on blockchain.
Maker DAO	Blockchain	Maker DAO issues a price stable decentralized currency for the financial services industry to improve settlement times without volatility and offer fair access to capital to anyone.
Overstock	Blockchain	Overstock.com is a leading e-commerce platform that has shifted its focus to blockchain. Through Medici Ventures, Overstock operates many blockchain-based startups ranging from a trading platform for security tokens to blockchain solutions for land governance.
Pay Pal Holdings	FinTech	PayPal is a fintech company that facilitates P2P transactions through its PayPal and Venmo, as well as provides credit to consumers, and is making cryptocurrency viable currency by allowing SMBs using Braintree POS systems to accept Bitcoin payments.
Polymath	Blockchain	Polymath tokenizes securities to create more robust capital markets via programmable equity, 24/7 markets, removing intermediaries, and introducing access to wealth outside of Wall Street.
Securitize	Blockchain	Securitize is a digital securities platform that allows issuers to tokenize equity, funds, fixed income, and real estate to create better efficiency and liquidity.
Set Protocol	Blockchain	Set Protocol allows users to easily employ automated portfolio management and strategies.
Tagomi	FinTech	Tagomi is an institutional grade aggregation platform for trading crypto assets, executing trades across multiple exchanges to provide the best liquidity and execution price available.
TokenSoft	Blockchain	TokenSoft is a security token platform that focuses on enabling compliant and secure issuance of securities.

Source: Company reports; Oppenheimer & Co. Inc.

How to Invest in the Cloud

Within 100-year productivity cycles, we see smaller productivity cycles. In compute, we started with mainframes, moved to more decentralized client-server architectures, and back to centralized cloud. If you look at the transition from mainframe to PC, hardly any tech company survived (Unisys, Siemens, Fujitsu, etc.). The transition to the cloud has hurt most of the legacy PC companies also (Dell, HP, Compaq,, etc.) and likely will ultimately hurt Intel. We particularly see hardware companies as facing huge stress in the next decade. However, higher order applications that can be ported to the cloud are still well-positioned. Hardware is being commoditized, and open-sourced software (virtualization) is being enabled by the cloud with much more agile and flexible software/applications. The rigidness and archaic nature of legacy software is a technical debt that will become more burdensome for incumbents as new cloud-based start-ups advance.

On the infrastructure side, we are watching the creation of several new cloud-based duopolies which we see as safe for the next 20 years. In Infrastructure as a Service (IaaS), MSFT Azure and AWS (Amazon) are effectively duopolies. GCP (Google) and Alibaba are more niche players at the moment, but both can play important roles in multi-cloud strategies, we think. Particularly, Google has very intriguing artificial intelligence/machine learning capabilities that could drive adoption of its platform. Microsoft is also rapidly becoming a monopoly for enterprise IT with Office 360 becoming integrated with Linked-In and Teams. There is also a food chain duopoly that has been created—EQIX/INXN in neutral interconnectivity datacenters and AMT/CCI in towers. We think the fiber industry will consolidate as well down to a duopoly structure, but this will take some time.

The cloud will impact every industry; incumbents who do not undergo digital transformations will be upended by cloud-native disruptors.

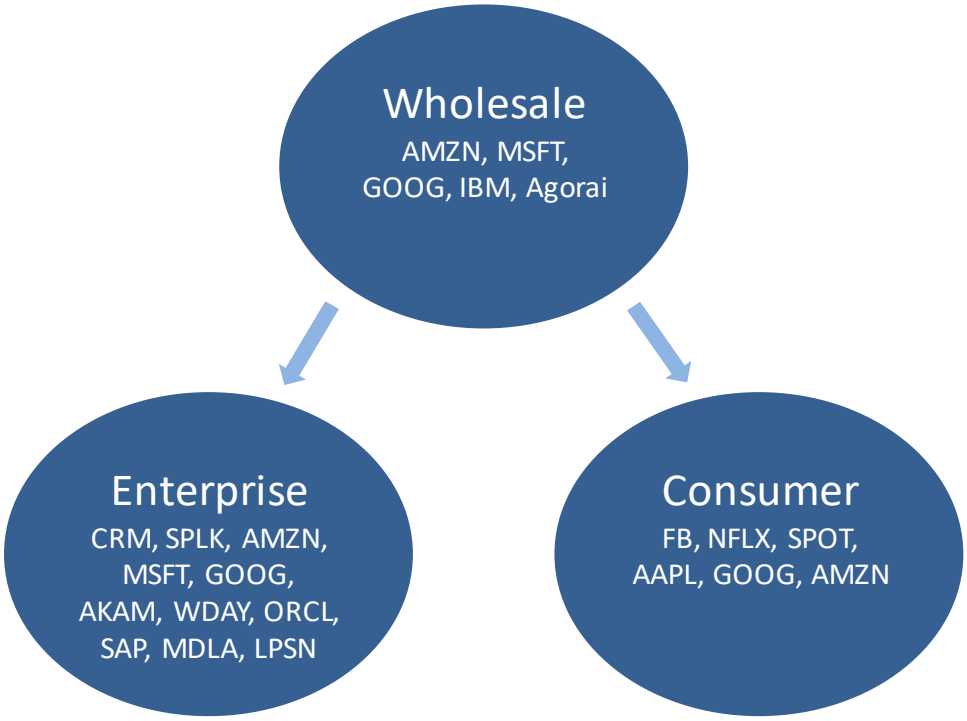
Ways to Invest

1. Critical Infrastructure becomes more important—datacenters, fiber, towers
2. Public cloud providers—AMZN, MSFT, GOOG
3. SaaS companies—RNG, CRM, NOW, WDAY
4. Companies in all industries that embrace digital transformations

Our UCaaS names (RNG, EGHT and VG) are completely changing how employees within organizations communicate with each other. Embedding cloud AI into contact center services produces much more favorable outcomes. Many UCaaS and cloud contact center providers are leveraging Google's Contact Center AI, which can help automate simple calls, utilizes speech recognition, and search technology to find answers in real time. Additionally, business communications are all digital and hosted on the cloud, allowing data to follow the customer call as they are transferred to new representatives. This eliminates annoying identification questions (name, social security number, DOB, etc.) every time the call is transferred.

Our horizontal thesis on investing in cloud/communications is accelerating, owing to this process. The level of abstraction is increasing with networking, software, and other services being outsourced to cloud-based providers. We also have whole new industries being created in SaaS (business communications, outsourced HR, etc.). SaaS companies, as an application companies, are major beneficiaries of both the cloud and the coming restructuring by businesses.

Exhibit 20: Horizontal Segmentation



Source: Oppenheimer & Co.

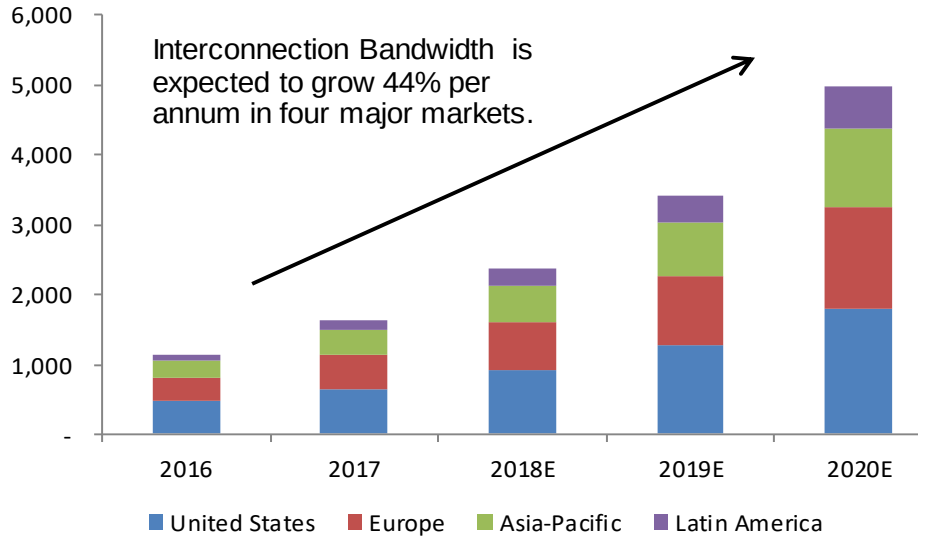
The shift to fog will have a direct impact on infrastructure; we view this as positive for datacenters, CDNs, fiber, and towers. The move to fog computing has a large impact on datacenters, which we describe as two-fold: 1) Datacenter capacity at the edge will need to increase (in tier 2 and tier 3 markets) to enable low latency for IoT applications such as autonomous driving, robotic surgery and AR/VR, much of which will be peer–to peer and switch or store directly in the local datacenters. 2) Billions of connected devices will generate vast pools of data that will need to be processed in the cloud, and enterprises will need storage and compute in highly interconnected datacenters to maximize the value of this IoT data. Even if only ~1% of data generated from connected devices is up-streamed to the cloud, we believe investors are underestimating the need for colocation capacity.

The communication networks are critical for cloud. Unfortunately, the legacy carriers have fought the cloud trend for 20 years by trying to have proprietary value added services integrated with proprietary networks, instead of standardized open networks. Wireless is moving in the right direction with open sourced, IP-based networks, particularly with 5G. Regardless, wireless is shaping up to be an oligopoly with strong demand and volume growth. We think VZ/AT&T are best positioned in the short term, as they should be first to nationwide 5G coverage and will likely take share as TMUS/S work through a complex integration. Wirelessestimator.com reported in late August that TMUS is already delaying purchase orders for new equipment and installations a few months and that orders could be pushed back to next year. We expect Sprint's network experience to deteriorate through the integration and for churn to pick up for the company.

We also need CDNs to deliver traffic with extremely low latency to end users, positive for AKAM, LLNW and FSLY. Much of the growth in data has been from applications that require low latency, and we expect this trend to continue (OTT video/game streaming, AR/VR, SaaS applications, autonomous vehicles, etc.). The largest difference will be the rise of two-way traffic, as devices begin transmitting more data back to the cloud. To

handle two-way traffic, we are going to need better solutions that deliver data from the edge to the cloud—what we would call a reverse CDN.

Exhibit 21: Interconnection Bandwidth Needed For Hybrid Cloud



Source Equinix Interconnection Index report

Fastly defines the edge as the point of the network just before users lose control of the data. Network architecture is essential to support instant data availability for today's data intensive applications. The company's network consists of ~100 locations built with servers with 100% SSDs and large RAM capacity. Compared to AKAM, Fastly relies on its edge computing language, Varnish, an open source software that performs intelligent caching. Fastly focuses on a premium edge experience and provides a host of APIs for developers. The company uses its APIs and its open source software to provide data and analytics for users based on their data traffic. We think the future for CDNs will move beyond caching users' data. Fastly expects that edge will enable CDNs to move a large portion of a customers' data from its origin nodes where it's fast and secure. This allows data to be more efficiently sent to the right location while increasing speed. Fastly views the rise of the edge compute as requiring more logic instantly available at the edge for managing data-like content validation and gaining insights from real-time monitoring. Real-time analytics can help enterprises resolve threats before they become too costly. Inside the cloud, architecture is changing how IT environments are built from the ground up.

Exhibit 22: Data Consumption by Use-Case

Application	Data Usage per Month	Comments
Listening to Spotify	1 GB - 5 GB	Listening to 1 hour of Spotify/day for a month (not connected to WiFi) will make a 1GB impact to your cell-phone plan based on Spotify's normal quality audio. On extreme audio quality, this can rise to 5.0 GB per month.
Global Average Smartphone Usage	6 GB	Average world smartphone usage in 2018 was nearly 6 GB and is expected to increase to 21 GB per month by FY24. Roughly 60% of mobile data comes from video consumption.
Global Internet Traffic per Capita	16GB	Monthly IP traffic is expected to reach 50 GB per capita by FY22, representing a CAGR of 26% from FY17. In 2007, per capita internet traffic was well below 1 GB per month and was 10 MB per month in 2000.
Unlimited Phone Data Plans (Includes Wi-Fi and Cellular)	31 GB	Cellular data use among consumers with unlimited plans is 67% higher than those with limited plans, mainly because limited-plan users rely more on Wi-Fi.
AR/VR App Usage	150 GB	As mobile data usage surges with 5G, Ericsson expects 10 minutes of AR app usage each day translates into 50GB per month for each user. Assuming users spend only 30 minutes per day, this translates into 150 GB of data per month.
Broadband-Only Home TV	400 GB	Charter Communications stated median residential data usage is around 200 GB. However, customers who don't also bundle video service with their broadband average 400 GB of data usage per month. Additionally, the percentage of U.S. wireline broadband users consuming more than 1TB per month of data doubled to 4% in FY18.
Autonomous Vehicles	25,000 GB	Level 2 or partial automation cars today generate around 25 GB of data per hour. As self-driving features become more complex, various sensors will need to be embedded in vehicles to achieve additional autonomy layers.

Source: Oppenheimer & Co., Inc. Ericsson, Cisco, Charter Communications, Tuxera, WhistleOute, NPDs Connected Intelligence

Appendices

Appendix 1: Many Legacy Company/Industries Will Be Disrupted

One of the first verticals that we see blockchain disruption in will likely be financial services. Financial services are all about trust. Blockchain essentially automates trust for the first time ever. Blockchain has become popularized by bitcoin, which was conceived as an alternative financial system that is completely decentralized. We believe this has altered and will dramatically alter the financial services industry and will improve the store of value and ultimately lower transaction costs.

Which industries will see the most impact? Virtually everyone, but we believe financial services is set to be disrupted next. Digital mobile banking will make buying and selling much easier and cheaper. It is the dominant payments system in China now. Venmo and Square cash apps are examples of new services that take advantage of the cloud. Facebook's Libra could make crypto mainstream. Most new bank accounts will be digital, eliminating the need for physical bank branches over time. Customer acquisition and service costs for these cloud based digital banks will be a fraction of that for traditional banking. But there are dozens of new cloud-based companies targeting wealth management, insurance, cryptoassets etc. These companies will also leverage AI/blockchain to improve security, privacy etc.

Only two companies from the 1898 Dow were in the 1928 Dow, or 15%; 16 of the 1928 Dow were in the 1959 Dow, or 53%; 19 of the 1959 Dow were in the 1987 index, or 63%, and only 11 currently from 1987, or 36%, still are part of the Dow. If we are correct, we expect many of the existing, technology, financial services, retail, drug, oil companies to not be in the Dow in 30 years. Our vote for the companies to be out of the Dow in 30 years include—American Express, Apple, Chevron, Cisco, Dow, Exxon, General Electric, Home Depot, Intel, IBM, J&J, 3M, Merck, Pfizer, Procter & Gamble, UnitedHealth, Visa, and Walmart, or likely around 60% of existing companies. *See exhibit on next page.*

Exhibit 23: History of Legacy Companies Being Disrupted

1928	1959	1987	2019
Allied Chemical and Dye	Allied Chemical	Allied-Signal	3M
General Railway Signal Co.	GE	Eastman Kodak	Goldman Sachs
Sears Roebuck & Co	Sears Roebuck & Co	Navistar Intl	Pfizer
American Can	Aluminum Company of America	Aluminum Company of America	American Express
B.F. Goodrich	General Foods	Exxon	Home Depot
Standard Oil Co. of NJ	Standard Oil Co. of California	Phillip Morris	P&G
American Smelting & Refining	American Can	American Can	Apple
International Harvester	GM	GE	Intel
The Texas Company	Standard Oil Co. of NJ	P&G	The Travelers Companies
American Sugar Refining	American Telephone and Telegraph	American Express	Boeing
International Nickel Co.	Goodyear	GM	IBM
Texas Gulph Sulpher	Swift & Co.	Sears Roebuck & Co	UnitedHealth
American Tobacco	American Tobacco	American Telephone and Telegraph	Caterpillar
Mack Trucks	International Harvester	Goodyear	Johnson & Johnson
Union Carbide Corp	Texaco Inc.	Texaco Inc.	United Technologies
Altantic Refining Co.	Anaconda Copper Mining	Bethlehem Steel	Chevron
Nash Motors	International Nickel Co.	IBM	JP Morgan Chase
US Steel Corp	Union Carbide Corp	Union Carbide Corp	Verizon
Bethlehem Steel	Bethlehem Steel	Boeing	Cisco
North American Company	International Paper Company	International Paper Company	McDonald's
Victor Talking Machine Co.	United Aircraft	United Technologies	Visa
Chrysler	Chrysler	Chevron	Coca-Cola
Paramount Publix	Johns-Manville Corp	McDonald's	Merck
Westinghouse Electric	US Steel Corp	USX Corp	Walgreen's
GE	E.I. du Pont de Nemours & Co	Coca-Cola	DowDuPont
Postum Inc	Owens-Illinois	Merck	Microsoft
F.W. Woolworth	Westinghouse Electric	Westinghouse Electric	Walmart
GM	Eastman Kodak	E.I. du Pont de Nemours & Co	Exxon
Radio Corporation of America	P&G	Minnesota Mining & Manufacturing	Nike
Wright Aeronautical	F.W. Woolworth	F.W. Woolworth	Disney

Turnover Each Cycle	83.3%	46.7%	36.7%	63.3%
Dow to GDP Ratio	2.9	1.2	0.4	1.2
Sector Weighting				
Technology/Telecommunications	3.3%	3.3%	6.7%	20.0%
Consumer Discretionary/Staples	43.3%	50.0%	36.7%	33.3%
Energy/Utilities	20.0%	13.3%	13.3%	10.0%
Healthcare	-	-	3.3%	13.3%
Industrials/Aerospace & Defense	13.3%	13.3%	20.0%	10.0%
Chemicals/Materials	20.0%	20.0%	16.7%	-
Financials/Real Estate	-	-	3.3%	13.3%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Note: Blue highlighted companies are new to the index
Source: Oppenheimer & Co. and Bloomberg

Appendix 2: Notable Artificial Intelligence Use Cases

AI is also likely to show productivity improvements in surprising places. Datacenters are using AI to massively improve power consumption, and wireless engineers are using AI to design and optimize networks. AI is being used to forecast product demand, maintenance needs of equipment, and dozens of other applications. In fact, many experts think that a third of the labor force in the US could be automated with existing levels of AI, and levels in ten years could drive two-thirds of the labor force. This data will be extremely valuable and is one of the reasons every software and services company is looking to migrate customers from on-premise IT to the cloud to collect this data and apply AI to it.

- MSFT's AI vision technology can leverage existing security cameras on site to identify construction workers on site. The AI vision can alert managers when an un-identified person walks onto a construction site, or if an unauthorized person is using a tool that they are not properly trained for. Additionally, cameras can be used to locate tools and the nearest construction worker authorized to use it for upcoming projects. This saves time and quickly authorizes users on construction sites that can span multiple building or floors. MSFT's AI vision technology makes workflow efficient and safer compared to prior methods.
- AMZN's SageMaker, a fully managed infrastructure service that covers the entire ML workflow, enables oil and gas companies to create AI platforms for problems like well spacing and predictive maintenance. SageMaker enables customers to unify their datasets and create proprietary analyses using unlimited compute. Typically, oil fields are delineated into 1-2 square-mile drilling units, which each cost nearly $100M to develop. Until recently, oil and gas companies relied heavily on trial and error to improve well spacing, which was sustainable in higher commodity price environments. In today's lower price commodity environment, capital allocation efficiency is imperative.
- Google's servers and open-source AI framework, TensorFlow, assists film studios with audience discovery, helping filmmakers and studios better understand their customers with data-driven insights. Film studios leverage analysis on YouTube 8M, a dataset of YouTube videos that Google provides, to parse out predefined characteristics that determine which elements of videos are most predictive of moviegoers' preferences. The data generated takes into account how long specific features appear on-screen and when they show up in a video. As a result, film studios can better predict the success of a film by using data captured from GOOG's AI offerings.

We have seen firsthand the impact that AI and machine learning is having in our coverage universe. A number of our companies are using AI to improve processes and reduce costs. Enterprise communications are particularly well-positioned to leverage AI. Approximately 10% of global businesses have moved to cloud-based communications, and most of these will start to use some form of AI, whether the CIO knows it or not. Slack is a collaboration tool that is using AI to enable chatbots to moderate chat-room discussions and/or comments, teach online education courses, connect people to the Internet of Things, and conduct more thorough searches of past chat history. Active.AI is a conversational AI start-up that incorporates conversational agents into messaging platforms (Siri, Google, and Amazon) for financial services. Of course, Alexa, Siri and Cortana leverage AI to make conversations more fluid and human-like, and also to find answers and recommend suggestions to users.

Many AI services today revolve around language—natural language processing, translation, transcription, etc. Contact centers are low-hanging, but very expensive, fruit that can be made more efficient with AI. UCaaS is enabling communications to be more deeply integrated with contact center, collaboration, and workstream apps. Flock, an AI start-up, is using AI in its collaboration service to dynamically create and assign tasks for team members. AI can free up time by flagging important conversations and by more

effectively searching chat history. Cloud-based UCaaS enables enterprises to seamlessly tie into their corporate IT systems (CRM/ERP/supply chain applications) to create automated/AI-based interactions with customers, employees and suppliers. AI will play an important role by giving businesses better insights into the data they are collecting every day from their own staff and end-customer communications.

AI is also important in cybersecurity. Akamai is adding AI features to its security portfolio in order to automate tasks and reduce human touch points (prone to error). Akamai is also using AI to help customers identify malicious bots and other security threats. By studying how a visitor interacts with a webpage (cursor movements, typing, etc.), Akamai's Bot Manager can identify a human from a bot. Okta, Inc., a leading independent provider of identity solutions for the enterprise, is using machine learning to bring awareness to its security applications. For example, Okta is exploring machine learning to provide its customers with adaptive authentication—which monitors authentication patterns to improve logins. According to Okta, login signals such as device, time, location, and frequency can feed into machine-learning algorithms to build risk scores or drive adaptive policies. Low-risk scores can result in experiences such as reduced-friction logins, etc., while high-risk logins can result in deployment of smart multi-factor authentication (MFA) policies.

Exhibit 24: Notable AI Use-Cases

Artificial Intelligence Use Case Examples by Company/Industry

Company	Industry	Using AI to…
Facebook	Internet/ Social Media	Facebook leverages AI across its 2B+ user base for targeted advertising campaigns by enabling "FB Learner Platform," an internal AI/ML tool that runs decision tree simulations. Facebook takes personal data from its user base and packages them into a group of people expected to behave similarly. These packages are sold to corporations seeking to target individuals with advertisements. FB Learner Platform is used by more than 25% of FB's engineering teams and can make more than 6M predictions per second.
General Motors	Technology	Autonomous vehicles will likely be made as automakers shift to electric vehicle production, which will rely on AI/5G/IoT/Cloud capabilities. GM's Cruise division, which is expected to garner $7B in investment in 2020, has built AVs that continue to be tested in San Francisco, Phoenix, and Milford. The number of factory workers required for EV/AV development is expected to reduce factory headcount by 35K according to the UAW.
Netflix	Video Streaming	Netflix leverages AI and data capabilities for its recommendation engine on its OTT platform. As a result of the data accumulated over time from viewers, nearly 75% of users select what to watch based on the company's recommendations. Additionally, the recommendation has fostered the creation of original hit shows like Bird Box, which garnered 26M viewers in the opening week. As a result, Netflix now accumulates for 10% of TV viewing time.
Aetna	Insurance	The health insurance industry is enabling AI and partnering with healthcare companies by venturing into wellnes. Aetna in partnerhsip with CVS created a "health hub" where consumers are assessed by a set of sensors, health information from personal devices, and algorithims to help insurance get in front of treating the consumer/avoid unnecessary claims. Nearly 50% of consumers undergone by Aetna's digital primary care don't need to go on further for physical primary care visits and over two years of Aetna's merger with CVS, there has been a 23% reduction of unnecessary medical claims.
J.P. Morgan	Finance	JPMorgan Chase claimed that Persado, an AI message machine, wrote advertisements that generated 2x-5x the responses it received from traditional human copywriters, attracting new business from retail consumers for credit loans and debt/credit cards. The technology rewrote and copied headlines that a marketer, using subjective judgement, likely wouldn't have. The Persado message machine builds copies from a database of more than one million words and phrases.
Pinterest	E-Commerce	Pinterest leverages AI to accurately identify more than 2.5B objects in photos of fashion and home designs on a 300M global monthly active user base. The company's AI algorithims gradually improved because of more than 200B photos or pins consumers and enterprises upload to site. Built on AWS, Pinterest spends more time on scaling the platform as data generated from consumers provides an improved feedback loop to target market consumers. This has allowed Pinterest to become one of the largest IPOs this year.
Chevron	Energy	Every day Chevron receives dozens of reports generated from various oil wells and each report ranges between 75 to 300 pages. After receiving reports, employees review them page by page to extract the critical data that may be impacting oil wells. The company is starting to use AI and robotic process automation to streamline the process by automating the sourcing of the data from reports using Microsoft's Azure Cognitive Services, Form Recognizer. This service learns a company's particular forms and discovers key values and patterns, saving substantial time for value-add functions.
Revelin	Cybersecurity	London FinTech has prevented over £100M in fraudulent transactions by analyzing over 12 Petabytes of data with AI. Identifying fraudulent transactions has become even more difficult as the number of online transactions worldwide has doubled since 2011 and the number of fraudulent transactions has grown 25% faster.
Spotify	Music Streaming	Spotify logs over 100B data points per day based on the activities of 207M active users around the world. More than half of the company's user base have free, ad-supported users who receive advertisements in the form of audio, video, and display banners. The company leverages its scale with AI to enable ad delivery as a user experience to its heavily ad-supported customer base.

Source: Opco Research, Company Reports, WSJ

Appendix 3: Industry Models

Exhibit 25: IaaS/PaaS Cloud Market Share (Big 4)

	2018	1Q19	2Q19	3Q19E	4Q19E	2019E	2020E	2021E	2022E
AWS Revenue	**25,656**	**7,696**	**8,381**	**9,150**	**10,031**	**35,258**	**46,540**	**59,106**	**71,518**
Y/Y Growth	47%					37%	32%	27%	21%
Q/Q Growth									
MSFT Azure Revenue	**9,633**	**3,289**	**3,720**	**4,280**	**4,323**	**15,612**	**23,651**	**33,111**	**43,045**
Y/Y Growth	92%	73%	64%	60%	55%	62%	51%	40%	30%
Q/Q Growth		18%	13%	15%	1%				
% of AWS revenue	37.5%	42.7%	44.4%	46.8%	43.1%	44.3%	50.8%	56.0%	60.2%
Google Cloud Services Revenue	**5,742**	**1,924**	**2,116**	**2,328**	**2,561**	**8,929**	**12,500**	**16,626**	**20,782**
Y/Y Growth	81%	67%	60%	53%	46%	55%	40%	33%	25%
Q/Q Growth		10%	10%	10%	10%				
Alibaba Cloud Services Revenue	**3,213**	**1,137**	**1,219**	**1,410**	**1,615**	**5,381**	**8,610**	**12,914**	**18,080**
Y/Y Growth	92%	63%	71%	68%	68%	67%	60%	50%	40%
Q/Q Growth		18%	7%	16%	15%				
Total Cloud Revenue	**44,244**	**14,046**	**15,436**	**17,168**	**18,529**	**65,180**	**91,301**	**121,757**	**153,425**
Y/Y Growth	62%	53%	48%	47%	43%	47%	40%	33%	26%
Q/Q Growth		9%	10%	11%	8%				
Market share									
AWS Share	58%	55%	54%	53%	54%	54%	51%	49%	47%
MSFT Share	22%	23%	24%	25%	23%	24%	26%	27%	28%
Google Share	13%	14%	14%	14%	14%	14%	14%	14%	14%
Alibaba Share	7%	8%	8%	8%	9%	8%	9%	11%	12%

Source: Oppenheimer & Co., Company reports

Exhibit 26: Cloud Revenue and Capex Model

Last Updated: 8/13/2019

	2016	2017	2018	2019E	2020E	2021E
Revenue:						
Apple	219,214	238,399	263,756	260,780	272,608	283,796
Amazon	135,987	177,866	232,917	278,696	326,732	378,647
Alphabet	73,479	89,183	136,819	162,142	186,356	220,528
Microsoft	92,683	102,273	118,459	132,918	147,496	160,771
Facebook	27,638	40,653	55,838	70,175	85,299	102,742
Total	**549,001**	**648,374**	**807,789**	**904,711**	**1,018,491**	**1,146,484**
Growth YoY %	*(6.6%)*	*18.1%*	*24.6%*	*12.0%*	*12.6%*	*12.6%*
Capital Expenditures:						
Apple	12,671	12,668	12,757	11,557	12,991	13,199
Amazon	13,650	23,716	25,219	29,734	37,099	43,711
Alphabet	10,183	13,164	25,139	25,627	28,566	30,565
Microsoft	9,114	11,138	15,800	17,688	19,175	20,900
Facebook	4,491	6,733	13,915	16,967	19,202	20,599
Total	**50,109**	**67,419**	**92,830**	**101,573**	**117,033**	**128,974**
Growth YoY %	*13.9%*	*34.5%*	*37.7%*	*9.4%*	*15.2%*	*10.2%*
% of Revenue	*9.1%*	*10.4%*	*11.5%*	*11.2%*	*11.5%*	*11.2%*
Estimated Cloud-Based CAPX:						
Apple	6,336	8,868	9,313	9,246	11,042	11,219
Amazon	5,193	9,190	9,783	11,282	14,427	15,959
Alphabet	7,128	9,215	15,083	17,939	21,425	22,924
Microsoft	5,468	7,240	10,744	14,150	17,258	18,810
Facebook	3,144	5,050	10,854	14,422	17,282	18,539
Total	**27,269**	**39,562**	**55,777**	**67,039**	**81,433**	**87,451**
Growth YoY %	*33.1%*	*45.1%*	*41.0%*	*20.2%*	*21.5%*	*7.4%*
% of Revenue	*5.0%*	*6.1%*	*6.9%*	*7.4%*	*8.0%*	*7.6%*
% of Total CAPX	*54.4%*	*58.7%*	*60.1%*	*66.0%*	*69.6%*	*67.8%*

All estimates are consensus, except AMZN, MSFT

Source: OPCO, FactSet, Company Reports

Exhibit 27: Global Server Shipments & Utilization Analysis

Server Analysis	2018	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Worldwide Server Install Base Units	**36,519,000**	**37,550,000**	**38,300,000**	**39,171,000**	**40,139,000**	**40,941,780**	**41,760,616**	**42,595,828**
yoy growth	*3.1%*	*2.8%*	*2.0%*	*2.3%*	*2.5%*	*2.0%*	*2.0%*	*2.0%*
Total Servers Shipped	**11,762,500**	**12,130,300**	**12,638,700**	**13,178,200**	**13,925,500**	**14,621,775**	**15,206,646**	**15,662,845**
yoy growth	*15.7%*	*3.1%*	*4.2%*	*4.3%*	*5.7%*	*5.0%*	*4.0%*	*3.0%*
Windows Server Installed Base	**22,669,000**	**21,937,000**	**20,926,000**	**20,024,000**	**19,169,000**	**18,480,780**	**17,802,810**	**17,138,481**
yoy growth	*-1.9%*	*-3.2%*	*-4.6%*	*-4.3%*	*-4.3%*	*-3.6%*	*-3.7%*	*-3.7%*
Market Share	*62.1%*	*58.4%*	*54.6%*	*51.1%*	*47.8%*	*45.1%*	*42.6%*	*40.2%*
Windows OS Servers Shipped	**4,219,000**	**4,093,000**	**3,960,000**	**3,821,000**	**3,676,000**	**3,528,960**	**3,387,802**	**3,252,290**
yoy growth	*-2.7%*	*-3.0%*	*-3.2%*	*-3.5%*	*-3.8%*	*-4.0%*	*-4.0%*	*-4.0%*
Market Share of Shipments	*35.9%*	*33.7%*	*31.3%*	*29.0%*	*26.4%*	*24.1%*	*22.3%*	*20.8%*
Linux Server Installed Base	**13,514,000**	**15,327,000**	**17,122,000**	**18,917,000**	**20,753,000**	**22,961,720**	**25,355,289**	**27,961,917**
yoy growth	*13.5%*	*13.4%*	*11.7%*	*10.5%*	*9.7%*	*10.6%*	*10.4%*	*10.3%*
Market Share	*37.0%*	*40.8%*	*44.7%*	*48.3%*	*51.7%*	*56.1%*	*60.7%*	*65.6%*
Linux OS Servers Shipped	**4,882,000**	**5,435,000**	**6,013,000**	**6,580,000**	**7,167,000**	**7,812,030**	**8,593,233**	**9,452,556**
yoy growth	*11.9%*	*11.3%*	*10.6%*	*9.4%*	*8.9%*	*9.0%*	*10.0%*	*10.0%*
Market Share of Shipments	*41.5%*	*44.8%*	*47.6%*	*49.9%*	*51.5%*	*53.4%*	*56.5%*	*60.4%*
Worldwide Server Equipment Market Revenue (000s)	90,300,000	91,000,000	94,400,000	97,300,000	104,200,000	109,825,000	114,858,000	119,930,922
yoy growth	*27.9%*	*0.8%*	*3.7%*	*3.1%*	*7.1%*	*5.4%*	*4.6%*	*4.4%*
Average Selling Pricer Per Server	**7,677**	**7,502**	**7,469**	**7,383**	**7,483**	**7,511**	**7,553**	**7,657**
yoy growth	*10.6%*	*-2.3%*	*-0.4%*	*-1.1%*	*1.3%*	*0.4%*	*0.6%*	*1.4%*
On-premise vs Off-premise (colocation datacenter, cloud)								
Off-premise spending	45,300,000	47,700,000	50,800,000	53,100,000	58,300,000	64,130,000	70,543,000	79,008,160
Y/Y growth	*42.0%*	*5.3%*	*6.5%*	*4.5%*	*9.8%*	*10.0%*	*10.0%*	*12.0%*
Off-premise shipments	6,330,500	6,769,200	7,200,400	7,569,700	8,176,200	8,993,820	10,073,078	11,281,848
Y/Y growth	*25.0%*	*6.9%*	*6.4%*	*5.1%*	*8.0%*	*10.0%*	*12.0%*	*12.0%*
average value of off-premise server shipped	7,156	7,047	7,055	7,015	7,130	7,130	7,003	7,003
On-premise Spending	45,000,000	43,400,000	43,500,000	44,300,000	45,900,000	45,695,000	44,315,000	40,922,762
Y/Y growth	*16.3%*	*-3.6%*	*0.2%*	*1.8%*	*3.6%*	*-0.4%*	*-3.0%*	*-7.7%*
On-premise shipments	5,432,000	5,361,100	5,438,300	5,608,500	5,749,300	5,627,955	5,133,568	4,380,998
Y/Y growth	*6.4%*	*-1.3%*	*1.4%*	*3.1%*	*2.5%*	*-2.1%*	*-8.8%*	*-14.7%*
average value of on-premise server shipped	8,284	8,095	7,999	7,899	7,984	8,119	8,632	9,341

Utilization Analysis	2018	2019E	2020E	2021E	2022E	2023E	2024E	2025E
AWS CAPX (000s)	9,783,000	11,282,000	14,427,000	15,959,000	16,449,000	17,572,000	18,743,424	20,617,766
AWS Server Spend (000s)	**4,891,500**	**5,641,000**	**7,213,500**	**7,979,500**	**8,224,500**	**8,786,000**	**9,371,712**	**10,308,883**
% of Server Spend	*5.4%*	*6.2%*	*7.6%*	*8.2%*	*7.9%*	*8.0%*	*8.2%*	*8.6%*
AWS Cost per server	6,432	6,417	6,458	6,418	6,563	6,655	6,717	6,780
AWS New Servers Added	**760,547**	**879,084**	**1,117,027**	**1,243,266**	**1,253,111**	**1,320,241**	**1,395,215**	**1,520,526**
% of Total Servers Shipped	*6.5%*	*7.2%*	*8.8%*	*9.4%*	*9.0%*	*9.0%*	*9.2%*	*9.7%*
Net Servers Added	267,304	368,767	287,763	482,719	374,027	203,214	151,949	267,414
AWS Revenue (000s)	**25,656,000**	**35,258,000**	**46,540,000**	**59,106,000**	**71,518,000**	**83,676,000**	**93,717,120**	**103,088,832**
AWS Total Servers	**2,110,129**	**2,478,896**	**2,766,658**	**3,249,377**	**3,623,404**	**3,826,618**	**3,978,567**	**4,245,982**
% of Total Servers shipped Globally	*5.8%*	*6.6%*	*7.2%*	*8.3%*	*9.0%*	*9.3%*	*9.5%*	*10.0%*
% of Total Enterprise Servers	*6.9%*	*8.0%*	*9.0%*	*8.5%*	*9.4%*	*9.2%*	*10.7%*	*7.3%*

Source: Oppenheimer & Co., IDC, Gartner, Company Websites

Exhibit 28: Datacenter and Capex Analysis ($ in millions except where noted)

Datacenter Level Analysis	2018	2019E	2020E	2021E	2022E	2023E	2024E	2025E
AWS Availability Zones	65	73	78	83	87	91	94	96
Adds in Year	12	8	5	5	4	4	3	2
Revenue per AZ (000s) (average)	**434,847**	**510,986**	**616,424**	**734,236**	**841,388**	**940,180**	**1,013,158**	**1,085,146**
At Scale Power Capacity Per Average AZ (MWs)	60	60	60	60	60	60	60	60
Total	3,900	4,380	4,680	4,980	5,220	5,460	5,640	5,760
At Scale Servers Per AZ (assumes 500 watts per Server)	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Watts per Server	500	500	500	500	500	500	500	500
sq. ft. per server	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Assumed sq. ft. per MW	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Total Servers	2,110,129	2,478,896	2,766,658	3,249,377	3,623,404	3,826,618	3,978,567	4,245,982
Estimated Constructed Sq. Ft.	**6,330,386**	**7,436,687**	**8,299,975**	**9,748,132**	**10,870,213**	**11,479,855**	**11,935,702**	**12,737,945**
Revenue per sq. ft. (average)	**4,327**	**5,122**	**5,915**	**6,550**	**6,937**	**7,488**	**8,005**	**8,356**
Estimated KW per sq. ft. design	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Estimated Utilized Power (MW)	1,055	1,239	1,383	1,625	1,812	1,913	1,989	2,123
Revenue per MW (average)	**25,961,349**	**30,732,460**	**35,489,103**	**39,298,970**	**41,623,904**	**44,926,575**	**48,028,131**	**50,137,136**
Datacenter per AZ	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0
Total Estimated Datacenters	163	183	234	249	261	273	282	288
Estimated Servers per DC	12,985	13,583	11,823	13,050	13,883	14,017	14,108	14,743
Revenue per DC (000s)	**157,883**	**193,195**	**198,889**	**237,373**	**274,015**	**306,505**	**332,330**	**357,947**

CAPX and Return Analysis	2018	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Estimated Constructed Sq. Ft.	6,330,386	7,436,687	8,299,975	9,748,132	10,870,213	11,479,855	11,935,702	12,737,945
Added Sq. Feet	801,911	1,106,301	863,288	1,448,157	1,122,081	609,642	455,847	802,243
AWS Total CAPX (000s)	9,783,000	11,282,000	14,427,000	15,959,000	16,449,000	17,572,000	18,743,424	20,617,766
AWS Cumulative CAPX (000s)	30,747,803	38,755,146	47,826,950	58,904,626	69,583,964	79,722,322	90,114,681	102,236,584
AWS Server Replacement CAPX	3,172,321	3,274,657	5,355,196	4,881,324	5,769,662	7,433,642	8,351,065	8,495,863
AWS Expansion CAPX (000s)	6,610,679	8,007,343	9,071,804	11,077,676	10,679,338	10,138,358	10,392,359	12,121,904
CAPX per added sq. Ft.	**8,244**	**7,238**	**10,508**	**7,649**	**9,517**	**16,630**	**22,798**	**15,110**
Construction costs per sq. ft.	600	600	600	600	600	600	600	600
Cost of Servers per sq. ft.	2,144	2,139	2,153	2,139	2,188	2,218	2,239	2,260
Cost Per Server	6,432	6,417	6,458	6,418	6,563	6,655	6,717	6,780
Estimated avg. Servers per Rack	20	20	20	20	20	20	20	20
Estimated Sq. Ft. per Rack	60	60	60	60	60	60	60	60
Networking per sq. ft. (whiteboxes and fiber)	4,990	3,989	7,246	4,400	6,220	13,302	19,449	11,740
Software Development per sq. ft.	510	510	510	510	510	510	510	510
Estimated CAPX Per Added Sq. Ft.	**8,244**	**7,238**	**10,508**	**7,649**	**9,517**	**16,630**	**22,798**	**15,110**

Source: Oppenheimer & Co., IDC, Gartner, Company Websites

Appendix 4: Oppenheimer Disruptive Innovation Summit on November 12, 2019 in San Francisco

Oppenheimer's Disruptive Innovation Summit in San Francisco, CA—Over 30 participating companies will identify and address institutional investment opportunities in fintech, blockchain, and AI. We see this as the most transformative technology since the internet, as we discussed in our blockchain (January 16, 2019) and AI white papers (April 1, 2019).

This summit follows our first Blockchain conference which we hosted in February 2019 in New York City featuring a diverse set of panels, company presentations, and 1-on-1 meetings with companies, all addressing the new technology and exploring investment opportunities in the space. *Please contact your OPCO salesperson for more information.*

Oppenheimer Disruptive Summit Agenda:

7:15 AM	Breakfast and Conference Registration	
	Rose Ballroom	**Concert Ballroom**
8:00 AM - 8:40 AM	**Morning Keynote: Fidelity Investments** *Tom Jessop, President, Fidelity Digital Assets*	
8:45 AM - 9:20 AM	**PANEL: How Does Bitcoin Disrupt the Economy?** *Crescat Capital, Delphi Digital*	**OneChronos** *Kelly Littlepage, Founder*
9:25 AM - 10:00 AM	**Morgan Creek Digital** *Anthony Pompliano, Partner*	**PANEL: Fintech VCs** *Core Innovation Capital, GreenVisor Capital, Greycroft, Pivot Investment*
10:05 AM - 10:40 AM	**PANEL: Disrupting Financial Services Markets** *BlockFi, Dharma, MakerDAO, Set Protocol*	**Consumer WealthTech: Democratizing Retail Access to Structured Products** *Halo Investing*
10:45 AM - 11:20 AM	**Securitize** *Carlos Domingo, Co-Founder & CEO*	**PANEL: Generating Bottom Line Returns from AI and Data** *Agorai*
11:25 AM - 12:05 PM	**Lunch Keynote: S&P Global Market Intelligence** *Dan Seideman, Managing Director, Innovation & Strategic Development*	
12:10 PM - 12:45 PM	**Blockstack: Using the Cloud & Blockchain to Disrupt FANG** *Muneeb Ali, CEO*	**PANEL: Investing in Blockchain - The VC Perspective** *Blockchain Capital, CoVenture VC*
12:50 PM - 1:25 PM	**PANEL: Data Analytics & Blockchain** *Circle, Coinmetrics, Digital Assets Data*	**PANEL: New Apps Enabled by Blockchain** *Inxeption, TQ Tezos, Web3 Foundation*
1:30 PM - 2:05 PM	**PANEL: State of Security Tokens** *Harbor, Polymath, Tokensoft*	**NASDAQ** *Jeff Thomas, SVP Corporate Services*
2:10 PM - 2:45 PM	**PANEL: Navigating Public Crypto Markets** *Arca, Vision Hill Group, Tagomi*	**LendingClub (LC)** *Scott Sanborn, CEO*
2:50 PM - 3:25 PM	**The Public Blockchain for Enterprises** *Dan Heyman, PegaSys @ Consensys*	**Better.com**
3:30 PM - 4:05 PM	**TBD**	**Zebit**
4:10 PM - 4:50 PM	**Afternoon Keynote: Figure Technologies** *Mike Cagney, CEO*	
5:00 PM - 6:00 PM	Reception	

Stock prices of other companies mentioned (as of 10/10/2019):

3M (MMM-NYSE, $152.26, Not Covered)
Alcoa (AA-NYSE, $18.73, Not Covered)
Boeing (BA-NYSE, $372.88, Not Covered)
Chevron (CVX-NYSE, $114.30, Not Covered)
CVS Health (CVS-NYSE, $62.16, Not Covered)
Deere (DE-NYSE, $166.94, Not Covered)
Dell Technologies (DELL-NYSE, $49.42, Not Covered)
Disney (DIS-NYSE, $129.87, Not Covered)
Dow Chemical Company (DD-NYSE, $64.29, Not Covered)
Eastman Kodak (KODK-NYSE, $2.59, Not Covered)
Ericsson (ERIC-NASDAQ, $8.32, Not Covered)
ExxonMobil (XOM-NYSE, $68.03, Not Covered)
Fujitsu (FJTSY-OTC, $16.32, Not Covered)
General Motors (GM-NYSE, $34.70, Not Covered)
IBM (IBM-NYSE, $141.24, Not Covered)
International Business Machines (IBM-NYSE, $x, Not Covered)
International Paper Company (IP-NYSE, $40.27, Not Covered)
Johnson & Johnson (JNJ-NYSE, $129.53, Not Covered)
Merck & Co. (MRK-NYSE, $84.14, Not Covered)
Navistar International (NAV-NYSE, $26.28, Not Covered)
Overstock.com (OSTK-NASDAQ, $10.97, Not Covered)
Pfizer (PFE-NYSE, $35.87, Not Covered)
Philip Morris International (PM-NYSE, $78.06, Not Covered)
Pinterest (PINS-NYSE, $26.25, Not Covered)
Procter & Gamble (PG-NYSE, $121.55, Not Covered)
S&P Global (SPGI-NYSE, $251.37, Not Covered)
Siemens (SIEGY-OTC, $53.12, Not Covered)
The Coca-Cola Company (KO-NYSE, $53.70, Not Covered)
The Michaels Companies (MIK-NASDAQ, $9.47, Not Covered)
The Travelers Companies (TRV-NYSE, $141.69, Not Covered)
Unisys (UIS-NYSE, $6.95, Not Covered)
United Technologies (UTX-NYSE, $133.28, Not Covered)
US Steel (X-NYSE, $10.55, Not Covered)
Walgreens Boots Alliance (WBA-NASDAQ, $53.19, Not Covered)

Disclosure Appendix

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Important Disclosure Footnotes for Companies Mentioned in this Report that Are Covered by Oppenheimer & Co. Inc:

Stock Prices as of October 11, 2019

T-Mobile (TMUS - NASDAQ, $78.30, PERFORM)
Sprint (S - NYSE, $6.27, NOT RATED)
Comcast (CMCSA - NASDAQ, $44.50, OUTPERFORM)
Equinix Inc. (EQIX - NASDAQ, $572.20, OUTPERFORM)
Alphabet Inc. (GOOG - NASDAQ, $1,208.67, OUTPERFORM)
Zayo Group (ZAYO - NYSE, $34.00, NOT RATED)
CenturyLink (CTL - NYSE, $11.63, OUTPERFORM)
Pareteum (TEUM - NASDAQ, $1.22, OUTPERFORM)
Twilio, Inc. (TWLO - NYSE, $111.03, OUTPERFORM)
Boingo Wireless, Inc. (WIFI - NASDAQ, $9.28, OUTPERFORM)
Cogent Communications (CCOI - NASDAQ, $55.58, PERFORM)
Crown Castle International (CCI - NYSE, $138.22, PERFORM)
GTT Communications, Inc. (GTT - NYSE, $6.93, OUTPERFORM)
Microsoft Corporation (MSFT - NASDAQ, $139.10, OUTPERFORM)
Amazon.Com, Inc. (AMZN - NASDAQ, $1,720.26, OUTPERFORM)
Vonage Holdings Corp. (VG - NYSE, $10.58, OUTPERFORM)
InterXion Holding N.V. (INXN - NYSE, $83.40, PERFORM)
Netflix, Inc. (NFLX - NASDAQ, $280.48, OUTPERFORM)
Salesforce.com (CRM - NYSE, $146.41, OUTPERFORM)
Tesla, Inc. (TSLA - NASDAQ, $244.74, OUTPERFORM)
Facebook, Inc. (FB - NASDAQ, $180.03, OUTPERFORM)
Twitter, Inc. (TWTR - NYSE, $39.54, OUTPERFORM)
JPMorgan Chase & Co. (JPM - NYSE, $114.21, PERFORM)
Alibaba Group Holding Ltd. (BABA - NYSE, $166.07, OUTPERFORM)
Shopify Inc. (SHOP - NYSE, $324.47, PERFORM)
Zoom Video Communications (ZM - NASDAQ, $71.01, PERFORM)

Snap Inc. (SNAP - NYSE, $14.08, PERFORM)
AT&T, Inc. (T - NYSE, $37.42, OUTPERFORM)
Verizon (VZ - NYSE, $59.83, OUTPERFORM)
Charter Communications, Inc. (CHTR - NASDAQ, $426.93, PERFORM)
Apple Inc. (AAPL - NASDAQ, $230.09, PERFORM)
Oracle Corporation (ORCL - NASDAQ, $55.49, PERFORM)
American Tower Corp. (AMT - NYSE, $226.28, PERFORM)
Akamai Technologies (AKAM - NASDAQ, $89.36, OUTPERFORM)
Fastly, Inc. (FSLY - NYSE, $24.89, OUTPERFORM)
Limelight Networks (LLNW - NASDAQ, $3.09, OUTPERFORM)
ServiceNow Inc. (NOW - NYSE, $263.18, PERFORM)
Workday, Inc. (WDAY - NYSE, $174.32, OUTPERFORM)
RingCentral (RNG - NYSE, $174.45, OUTPERFORM)
8x8 Inc. (EGHT - NYSE, $19.57, OUTPERFORM)
SPLUNK Inc. (SPLK - NASDAQ, $118.15, OUTPERFORM)
Spotify Technology S.A. (SPOT - NYSE, $112.52, PERFORM)
LendingClub Corp. (LC - NYSE, $11.53, OUTPERFORM)
Okta, Inc. (OKTA - NASDAQ, $114.57, OUTPERFORM)
Slack Technologies, Inc. (WORK - NYSE, $23.82, PERFORM)
LendingTree, Inc. (TREE - NASDAQ, $308.54, OUTPERFORM)
Farfetch Limited (FTCH - NYSE, $7.95, OUTPERFORM)
Redfin Corporation (RDFN - NASDAQ, $15.57, OUTPERFORM)
Etsy, Inc. (ETSY - NASDAQ, $57.77, PERFORM)
Atlassian Corporation Plc (TEAM - NASDAQ, $125.87, OUTPERFORM)
Uber Technologies, Inc. (UBER - NYSE, $28.87, OUTPERFORM)
Expedia Group (EXPE - NASDAQ, $135.99, OUTPERFORM)
Home Depot Inc. (HD - NYSE, $231.61, OUTPERFORM)
Intel Corp. (INTC - NASDAQ, $51.11, PERFORM)
Yelp Inc. (YELP - NYSE, $32.22, PERFORM)
General Electric Co. (GE - NYSE, $8.45, PERFORM)
Hewlett Packard Enterprise (HPE - NYSE, $14.11, OUTPERFORM)
American Express Company (AXP - NYSE, $115.02, OUTPERFORM)
Visa Inc. (V - NYSE, $174.88, OUTPERFORM)
Walmart Inc. (WMT - NYSE, $119.61, PERFORM)
Nasdaq Inc. (NDAQ - NASDAQ, $98.56, OUTPERFORM)
Goldman Sachs Group (GS - NYSE, $199.87, OUTPERFORM)
UnitedHealth Group, Inc. (UNH - NYSE, $223.73, OUTPERFORM)
Caterpillar Inc. (CAT - NYSE, $122.69, PERFORM)
Cisco Systems (CSCO - NASDAQ, $46.15, OUTPERFORM)
McDonald's Corporation (MCD - NYSE, $211.76, PERFORM)
Nike, Inc. (NKE - NYSE, $93.00, OUTPERFORM)
LivePerson, Inc. (LPSN - NASDAQ, $37.67, OUTPERFORM)
Medallia, Inc. (MDLA - NYSE, $28.07, OUTPERFORM)
SAP SE (SAP - NYSE, $115.25, OUTPERFORM)
CVS Health Corp. (CVS - NYSE, $62.14, PERFORM)

All price targets displayed in the chart above are for a 12- to- 18-month period. Prior to March 30, 2004, Oppenheimer & Co. Inc. used 6-, 12-, 12- to 18-, and 12- to 24-month price targets and ranges. For more information about target price histories, please write to Oppenheimer & Co. Inc., 85 Broad Street, New York, NY 10004, Attention: Equity Research Department, Business Manager.

Oppenheimer & Co. Inc. Rating System as of January 14th, 2008:

Outperform(O) - Stock expected to outperform the S&P 500 within the next 12-18 months.

Perform (P) - Stock expected to perform in line with the S&P 500 within the next 12-18 months.

Underperform (U) - Stock expected to underperform the S&P 500 within the next 12-18 months.

Not Rated (NR) - Oppenheimer & Co. Inc. does not maintain coverage of the stock or is restricted from doing so due to a potential conflict of interest.

Oppenheimer & Co. Inc. Rating System prior to January 14th, 2008:

Buy - anticipates appreciation of 10% or more within the next 12 months, and/or a total return of 10% including dividend payments, and/or the ability of the shares to perform better than the leading stock market averages or stocks within its particular industry sector.

Neutral - anticipates that the shares will trade at or near their current price and generally in line with the leading market averages due to a perceived absence of strong dynamics that would cause volatility either to the upside or downside, and/or will perform less well than higher rated companies within its peer group. Our readers should be aware that when a rating change occurs to Neutral from Buy, aggressive trading accounts might decide to liquidate their positions to employ the funds elsewhere.

Sell - anticipates that the shares will depreciate 10% or more in price within the next 12 months, due to fundamental weakness perceived in the company or for valuation reasons, or are expected to perform significantly worse than equities within the peer group.

Distribution of Ratings/IB Services Firmwide

			IB Serv/Past 12 Mos.	
Rating	Count	Percent	Count	Percent
OUTPERFORM [O]	398	65.35	192	48.24
PERFORM [P]	210	34.48	66	31.43
UNDERPERFORM [U]	1	0.16	0	0.00

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Note: Stocks trading under $5 can be considered speculative and appropriate for risk tolerant investors.

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