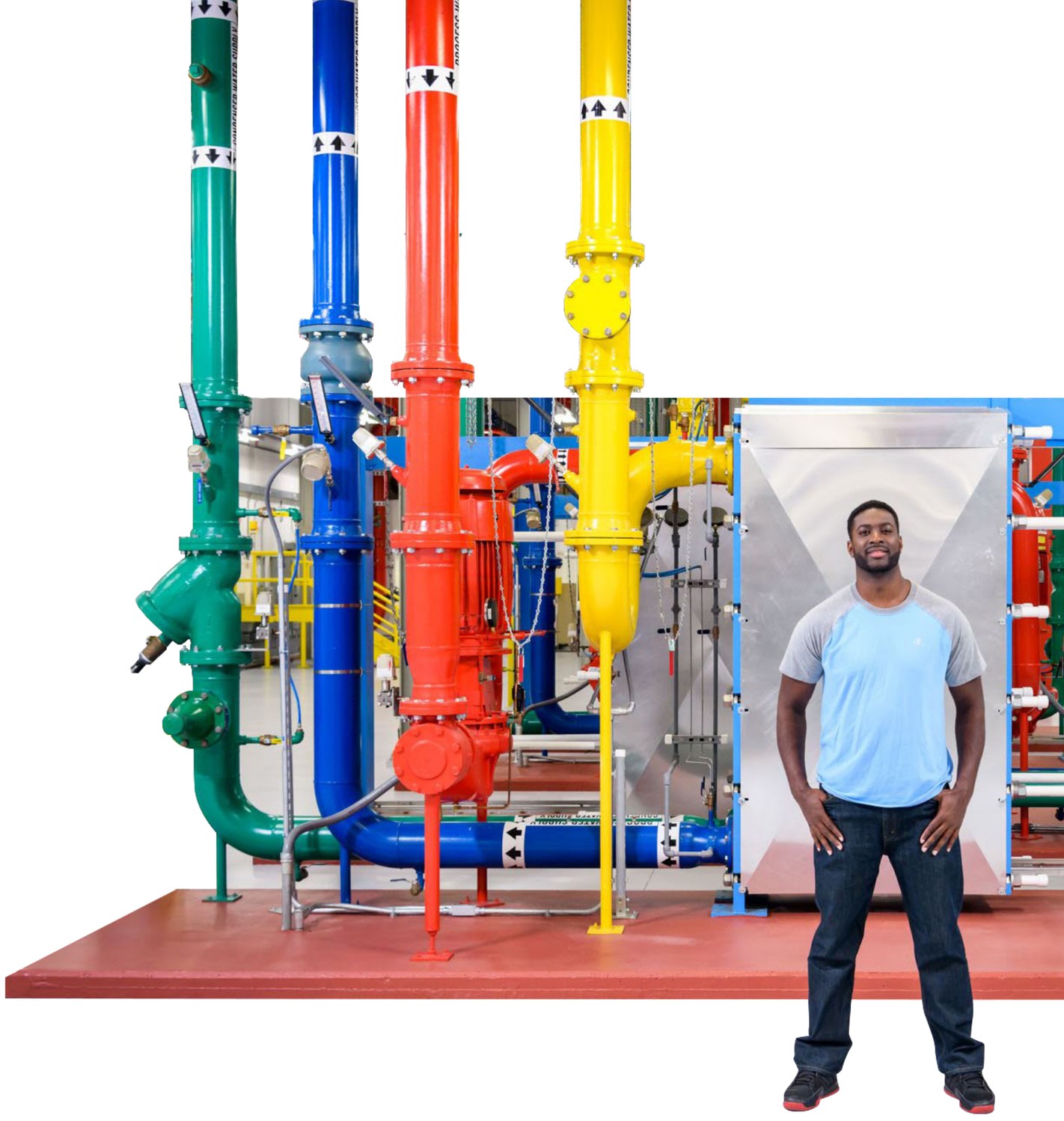
Future of cloud computing

A view of the future of cloud computing, through the eyes of the luminaries who helped build it.



Google Cloud

Google Cloud

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A stake in the future

Here at Google, we spend a lot of time looking at data and anticipating what will happen next. When it comes to the future of business, we get some of our best ideas by looking at new information technologies and thinking about their effects. Cloud computing has long powered Google and is increasingly an integral part of most organizations' technology stacks.

But the cloud is much more than a new generation of machines and software. We're already seeing that transformation happen to the billions of users and millions of companies that rely on our technology.

What makes us think that cloud computing will change things beyond IT itself? History argues for it. Mainframe computers made operations research possible. The PC revolution made anyone a potential entrepreneur. Client-server enabled corporate reengineering, and smartphones created the app economy and computing from almost anywhere.

Urs Hölzle

SVP Technical Infrastructure,
Google Cloud

The cloud, we believe, draws on more diverse data sources, breaks down more silos, utilizes faster network speeds, and enables more powerful analyses, all at a lower cost than anything tech has seen before. It is not a technology that belongs to any one provider, or even a bunch of big tech companies. It is a new generation of computing, a new way of using resources, like mainframes, PCs, and servers were in their time.

It is a way of thinking about and doing computing that creates something new: a future with new kinds of product creation, new partnerships, and new ways of working. This doesn't mean everything has to change – but organizations get more from their data, their competitive advantage, and their existing relationships.

As with any momentous change, business leaders must navigate the here and now – whether on-prem, hybrid, or multi-cloud – with an eye toward the future. Leading companies must strive for an even more elevated view as they embark on their business transformation journey, bringing with them the experience, history, and strengths of their established systems.

Google's mission is to organize the world's information and make it universally accessible and useful. The company was founded back in 1998, before anyone could have predicted how fundamental the changes would be in how humans access and consume information. Along the way, we've helped

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shape the evolution of how cloud computing works with customers. Our advances in areas like analytics and machine learning power data collection and productivity, and our security innovations protect billions of users' data. It's been 20 years now, but these changes are far from over. In fact, for many companies, they're just beginning.

This is why we assembled this report – to help business and IT leaders navigate the changing business world with cloud computing. We gathered insights from users, conversations with businesses of all sizes, surveys, polls, and knowledge from within Google itself to offer you a holistic view of the current landscape and where it's already going in terms of value, innovation, and competition.

The goal is to give you the insights you need to craft winning strategies by building on your existing environment and moving toward a future that unlocks the benefits of cloud computing. We hope that you can put these examples from real companies, current market trends, and learnings from Google executives to good use, and as always, we look forward to partnering with you on whatever comes next.

– Urs Hölzle, SVP Technical Infrastructure, Google Cloud

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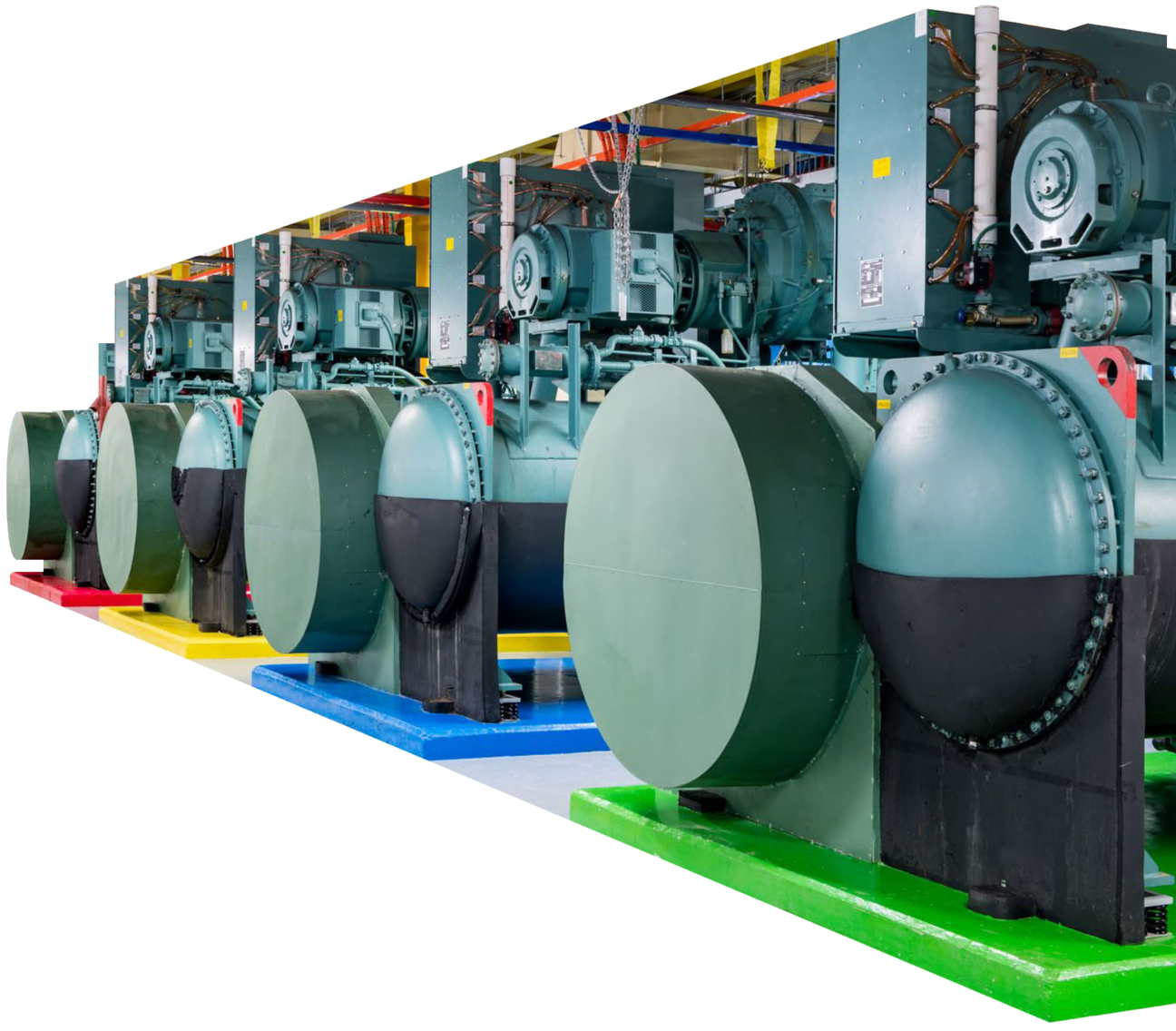
PART 1

The enterprise of the future



What makes new computing technologies great? It's not just networking speeds, compute power, or storage capacity. Those are critical minimums, and cloud computing can deliver them far more effectively than previous methods. There is more, however. The real value of technology is not what it's made of, but what it does.

Great IT enables a company to do the things it's best at, by getting low-value work out of the way. That means more time to focus on delighting customers, the core of any successful business. Innovation fuses hard-won knowledge about customers, products, and markets with new capabilities, enabled by transformative IT.

This is why so much of the economy runs on and was shaped by evolving technologies. For a reasonable investment, technology has provided benefits like empowerment, improved teamwork, and services on demand. In fact, some technologies – like cloud computing – offer all of this at a lower overall cost than their traditional alternatives.

A decade since businesses first started to run on public clouds, many have discovered that cost savings were just the beginning. Our customers are creating businesses that are continuous and nearly frictionless, maximizing their organizations' missions and leveraging current resources with

[Our customers] are gaining something new in cloud computing: speed, efficiency, reliability, and security in service of a new wave of business-driven innovation.

faster times to insight and action. They are gaining something new in cloud computing: speed, efficiency, reliability, and security in service of a new wave of business-driven innovation.

If the value of a technology is the net experience it delivers to the enterprise – on cost, on performance, and on time to innovation – it's clear why so many believe that cloud computing's interconnected, continuous streaming will be an important part of our future economy. In other words, the future of business will depend on realizing the promise of cloud computing.

In the following pages, we'll explore:

1. What the enterprise of the future will look like
2. What fundamentals shape the cloud enterprise
3. How cloud computing will impact businesses
4. How business and IT leaders and decision makers can prepare

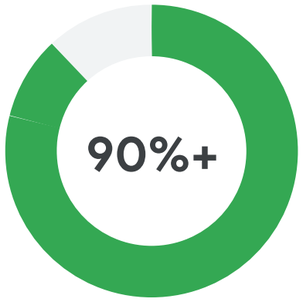
From the data center, to the cloud, to the edge

Cloud computing is already an integral part of most organizations. According to a survey by RightScale,[1] 81 percent of companies with 1,000 employees or more have a multi-platform strategy. By 2024, that number is expected to climb to more than 90 percent.[2] Between 2018 and 2021, worldwide spending on public cloud services is expected to grow 73 percent from $160 billion to $277 billion.[3]

Companies are moving to the cloud because it offers the agility they need to compete in a fast-moving, rapidly changing customer environment. Cloud saves companies the cost of maintaining their own internal systems; it drives innovation by making it easier to develop and change applications on the fly; and it helps standardize and simplify security management.

The next few years, according to data from analyst firms, will see cloud computing continue to evolve as part of a stack that includes the Internet of Things (IoT) and edge computing, or processing at the source of data ingestion. Gartner predicts that by 2025, 75 percent of enterprise-generated data is created and processed outside a traditional centralized data center or cloud.[4] In addition, more than 40 percent of organizations' cloud deployment will include edge computing, and 25 percent of endpoint devices will execute AI algorithms by 2022, according to IDC.[5]

The growing cloud



By 2024, most enterprises will have intensively **multi-cloud** environments, with on-prem, off-prem, public, and private cloud.[6]

Global spending for public cloud services is on track to reach **$277 billion** in 2020.[7]

How cloud computing will change the way we work

At its most optimal, cloud computing enables businesses to focus on performance as directly as possible, with minimal hassle or interruption. New advantages built upon the foundation of cloud computing – agility, mobility, flexibility, and security – emerge when highly scalable and flexible computing technology fuses with existing technology and processes (whether on-premises or in the cloud). The aim is to get the computation you want and need, the way you want it, and move on.

Let's begin with some examples from enterprise technology.

In software development, these include the continuous creativity of agile programming and the "launch and learn" characteristics of continuous integration and continuous delivery (CI/CD), along with the explosion of open-source software (a faster and more responsive version of the standards bodies and years-apart release cycles that used to be industry norms).

In technology security, elements like BeyondCorp, Google's zero-trust enterprise security model, envision work happening from anywhere, from any kind of approved device, replacing the previous standard of firewalls and other boundary-oriented practices. Devices stream their states to a managing host, and are thus permitted access. Access is managed on the user and device level, rather than the network level.

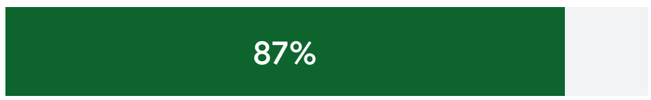
Businesses are quickly adopting cloud computing

of decision makers* say they will use cloud for a majority of their needs by 2029.[8]

A cloud for everyone

of decision makers* believe everyone will have access to computing by 2029, including remote regions.[9]

Cloud: the new growth lever



of decision makers* expect cloud computing to become an important driver of revenue growth by 2029.[10]

**IT and business decision makers at global mid-market and large companies*

In data collection and analysis, streaming data now feeds into existing machine learning systems for continuous learning and adjustment (see sidebar, "Streaming insights to feed the world").

Moving into this new world means transitioning to a new way of working that assumes continuous flow. Products are never "finished"; there is constant updating and iteration. Security is not a linear process based on static events, but rather an ongoing practice. Data analysis isn't just faster; it's continuous and iterative. The promise of cloud computing represents more than just a faster, more efficient version of everything we did before – it's an entirely new way of thinking and working across any IT environment.

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It stands to reason, then, that this creates a social impact, both internally and with customers, enabled by technology.

1. Collaborative technologies like document sharing end the stop/start practice of versions, in favor of a continual process of creating, editing, and commenting. Cheap and easy video at the click of a button strengthens communication, speeding actions.

2. Prototyping and personalization are faster and easier, thanks to rich data streams in both directions.

3. In product lifecycles, customer relevance is increased by cloud-connected objects subject to frequent software adjustments. This might be new versions of subscription-based software, or even alterations in the performance of hardware itself (like in 2018 when Tesla improved the braking capability of its cars with an over-the-air download). As awareness of customer behaviors increases, customers consciously and unconsciously raise the bar, effectively demanding that they be understood and their next need anticipated.

4. Even slow-changing aspects of business, like supply chain and logistics, are moving toward streaming capabilities. Blockchains enable real-time spec changes and payments. Virtual warehousing and Uber-type delivery services speed up slower processes by making them continuous. Cloud-based companies like Shippabo optimize route management and automate compliance for faster action.

There are many more examples. To fully understand how to prepare for the future, however, it's helpful to first examine how these attributes emerge within the enterprise.

A father of the Internet looks to the future

It's no exaggeration to call Vint Cerf a father of the Internet. Together with Bob Kahn, he developed the TCP/IP protocols that are the basis of the Internet. Now, as Google's Chief Internet Evangelist, Cerf travels the world talking and writing about what comes next.

"When we were designing the Internet, one of the things that we didn't care about was the details of each network, because we imagined hundreds of thousands of networks all interconnected to each other," Cerf recalls. "That's where cloud computing came from: The whole idea was that the computers you were using were somewhere in the cloud, connected to the Internet somewhere. You didn't care where." The division between public clouds is a temporary one, in Cerf's view. "There's now a recognition that the interaction between the clouds and the movement of data back and forth between the clouds makes sense," he says.

Cerf believes we're entering the next golden age of computing, where artificial intelligence and edge technology will bring computing to every corner of our lives until it's pervasive enough to go unnoticed.

"More and more computing and software are closer and closer to us, to the point where we're wearing it or it's embedded in us," he explains. "The distinction between the online world and the offline world starts to evaporate because the online world has penetrated so deeply into physical spaces everywhere. At some point, it could be that this kind of communication and computation will be as ubiquitous as we hope electricity is."

Vinton G. Cerf

VP and Chief Internet Evangelist, Google

This, of course, brings risk. “We are building yet another dependency into our social and economic fabric, and we should be giving that serious thought,” Cerf says. “I want to urge people to think more deeply about the kinds of infrastructure that we are dependent upon and ask: How do we make it resilient?”

He’s encouraged by conversations about the ethical implications of software development – not just about building it ethically, but also being aware of potential vulnerabilities. “I think finally, questions are being asked. I think that software producers, individuals, and corporations should feel an increased sense of ethical responsibility for assuring that whatever their products are, they don’t turn out to be harmful, even by accident.”

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– Vinton G. Cerf, VP and Chief Internet Evangelist, Google

In Cerf’s view, better products stem from a clearer understanding of how those products work. This could mean including software or security engineers in product development meetings from the beginning so that the product strategy incorporates technical infrastructure, data management, and security considerations. “It’s really a new model of the role of technology inside the business,” Cerf says, “where the developer is part and parcel of the product offering.”

But Cerf is also a big thinker, and he doesn’t hesitate to explore the topic of an interplanetary version of the Internet, designed to connect humans and machines as we venture beyond our galaxy. “Certainly by the end of the century, and maybe before that, we will have a stable interplanetary backbone to support our exploration into the solar system,” he says, an explorer’s twinkle in his eye. “The universe is full of problems, and I’m an engineer. I like solving problems.”

Looking to the cloud for ERP Solutions

When it comes to investing in enterprise software, most companies are not dazzled by gee-whiz technology. Instead, they have a singular demand: a platform that can provide the data and analysis necessary to gauge what the marketplace demands and deliver value. “It’s what every enterprise has been after for the last 20 to 30 years,” says Pavan Srivastava, a principal at Deloitte Consulting LLP, who leads the SAP on cloud practice. “But the technology just wasn’t there yet at a cost attractive for mass adoption.”

This is hardly the case going forward, and Pavan is discovering signals of this change every day. When SAP companies describe what they want from their ERP, he almost always finds a way to deliver in the cloud. That’s partly because the cloud platform centralizes mass amounts of decision-making data from sources with speed and performance previously unimaginable. Retailers, for instance, can now install sensors in their shelves that gather and analyze data to help them understand what products consumers want most, and when to replenish those popular items to bolster sales and reduce waste.

Better yet, cloud-based tools can deliver real-time analysis in a steady stream, transforming otherwise useless bits of data into actionable items. Pavan points to a dairy manufacturer who measures the temperature and weight of cheese and butter flowing through their production line with sensors.

By sending this data to the cloud where machine learning tools study its patterns, manufacturers can determine what portion of their products have already spoiled before shipping and devise a strategy to reduce the number of bad cartons arriving in stores.

Cloud computing also removes the burden from companies to process data themselves. Semiconductor manufacturers typically run simulation tests on their microchips once or twice a month – a task that requires quickly spinning up hundreds of virtual machines for a short period of time and costs millions of dollars in hardware to deploy. By conducting these tests in the cloud, businesses can reduce their expenditure to a pay-as-you-go subscription model rather than wasting money on limited-use technology that lays dormant most of the year. With these newfound savings, they can run tests more frequently, keeping regular tabs on their chips' performance and making improvements more quickly.

The cloud can fuse these solutions together. As Pavan says, "The innovation of the cloud comes from pooling and sharing these kinds of capabilities so that companies can consume tools like machine learning as a service rather than by building it themselves." For enterprises, that translates into more time spent on innovating and delivering value to customers, a boon to everyone involved.

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– Pavan Srivastava, Principal, Deloitte Consulting

Google Cloud

PART 2

Fundamentals of the cloud enterprise

The qualities of cloud computing – speed, flexibility, and continuity – manifest in different ways within different companies, and even vary within cloud stacks. Large-scale clouds, of course, play a key role in the organization, analysis, and management of much of this. Equally important is the vast increase in the number of edge devices built to send and receive new information, whether in the form of connected computers, IoT sensors, or purpose-built appliances.

An increasingly important dimension is the advent of cloud-type technologies *inside* and *alongside* existing technology. Kubernetes, the highly popular container management platform, and Istio, a microservice management layer, were both initially open-sourced by Google to extend the benefits of cloud computing to the rest of the IT stack. As with any open-source solution, adopting tools like these can spur new levels of information-sharing and interoperability with existing public and even private clouds, further strengthening the trend toward streaming.

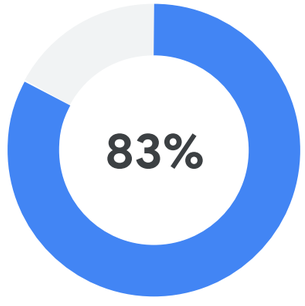
In this section, we've taken a technology-driven approach to analyzing how the enterprise of the future takes shape – from the specific **tools** a company adopts, to the internal **systems** these tools create, to the company's evolving **culture** and **leadership**. Although rooted in technology, each of the examples we explore holds broader implications for the rest of the business.

Edge computing goes mainstream[11]

1 in 3 companies* use edge computing for a majority of their cloud operations.

↑ 66%

more companies* will use edge computing for a majority of their cloud operations by 2029.



of companies* believe that by 2029, edge computing or IoT will impact every industry.

**Global mid-market and large companies were surveyed.*

Tools

For many companies, cloud adoption starts with a simple objective: handling core computing tasks like storage, networking, and application management more cheaply and efficiently. And of course, everyone's universe of data is growing. According to IDC, the total volume of global data will reach 175 zettabytes by 2025.[12] To stay relevant, companies need to manage and make use of that. The cost of storing data on-premises starts with the investment in physical storage devices, but new costs appear in the form of storing, updating, and maintaining these machines.

It's not just a volume problem. The variety of data formats and sources (IoT devices, online customer interactions, legacy business systems, and so on), as well as the velocity with which data is created, processed, and analyzed, create additional complexity. Getting all of these to play well together requires a network that is secure, reliable, and fast enough to process them all in real time, even in areas with low accessibility and high latency.

To meet these challenges, companies are turning to the cloud. By moving data out of physical servers, businesses can take advantage of virtually unlimited storage while saving money on upkeep. These companies also unlock cloud computing's other networking and computing benefits, such as high reliability, minimal downtime, and complementary tools to facilitate data processing and analysis.

With storage that expands to need, and the networking and computing power that can bring the Internet places where it has never been before, it's no wonder so many companies are moving their data to the cloud.

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In fact, according to research by Cisco, public cloud workloads and compute instances are going to grow by 28 percent from 2016 to 2021.[13]

Once the data is secured in the cloud, it can easily be processed and managed to power a diverse set of advanced tools to provide greater speed, flexibility, and functionality to application development, IT operations, data analysis, and more. According to Urs Hölzle, one of the company's original employees and the SVP of Technical Infrastructure for Google Cloud, "Google initially built a high-velocity information environment – a platform where massive amounts of data can be transmitted and analyzed at a rapid pace — to support its search engine. Now that the cloud can expand storage of its data delivery, the demand for high-velocity is universal – and the pace and scale will only increase."

At Google, streaming analytics – the ability to process, analyze, and act upon data in real time – is "actually the fastest-growing analytics sub-case that we have" and will continue to grow, Hölzle says.

When applied in the right use case, the business impact of streaming analytics can be significant: Google itself has used streaming analytics to cool its data storage centers, generating up to 40 percent in savings (see sidebar, "How Google reduced data-center cooling costs"). Businesses don't need to be fully on the cloud to benefit from streaming analytic services, Hölzle notes. For example, data analysts can send a copy of on-premises data to the cloud and receive real-time analysis within seconds.

To further extend the value of their data, many companies are beginning to rely on machine learning (see sidebar, "Cloud computing unlocks the AI potential"). After decades of stop-start progress, ML is now a reality due to the recent convergence of three factors: advanced algorithms, access to huge volumes of digital training data, and cheap, abundant computing power – available, of course, through the cloud. ML tools can help businesses identify patterns within huge, streaming datasets; automate repetitive tasks; and free humans to spend more time on creative, non-automatable work (like writing new applications or crafting great user experiences).

How Google reduced data-center cooling costs by up to 40% using AI

Reducing energy consumption has long been a priority for Google. We have built our own super-efficient servers, invented better ways to cool our data centers, and invested heavily in green energy sources, with the goal of being powered 100 percent by renewable energy. One achievement we're particularly proud of is using machine learning to reduce the amount of energy we use for cooling by up to 40 percent. This not only helps us reach our energy efficiency goals, but also passes energy savings on to our customers.

Using the historical data collected by thousands of sensors within the data center – including temperatures, power, pump speeds, setpoints, and more – we trained an ensemble of deep neural networks on the average future PUE (power usage effectiveness), defined as the ratio of the total building energy usage to the IT energy usage. We then trained two additional ensembles of deep neural networks to predict the future temperature and pressure of the data center over the next hour. The purpose of these predictions is to simulate the recommended actions from the PUE model, to ensure that we do not go beyond any operating constraints. We then tested the model by deploying on a live data center.

The result? Our machine learning system was able to consistently achieve a 40 percent reduction in the amount of energy used for cooling, which equates to a 15 percent reduction in overall PUE overhead after accounting for electrical losses and other non-cooling inefficiencies. It also produced the lowest PUE the site had ever seen. Because the algorithm is a general-purpose framework to understand complex dynamics, these results can be applied in a range of other scenarios.

Learn more about our data center approach at google.com/about/datacenters

Source: DeepMind blog

Cloud computing unlocks AI's potential

Thanks to the cloud's ability to deliver an unprecedented level of computing power at relatively low cost, artificial intelligence – broadly defined as the ability of machines to exhibit intelligent behaviors such as learning, complex problem-solving, and natural language recognition – and its subset of machine learning are becoming mainstream. A survey by MIT Technology Review shows that, in the business world, AI and machine learning are happening now.[14] The majority of respondents (60 percent) have already implemented machine learning strategies, and nearly one-third considered themselves to be at a mature stage with their initiatives.

"Machine learning is a natural outgrowth of cloud computing," says Hölzle, Google Cloud's SVP of Technical Infrastructure. "If there are massive amounts of data stored on the cloud, then the obvious next step is to use built-in tools to make sense of the data and predict future outcomes."

AI and ML have broad implications for business – from helping farmers sort cucumbers in Japan, to improving the accuracy of medical diagnoses, to helping law enforcement officers apprehend child abusers. They can help analysts spot patterns in unstructured data such as images and videos, automate data analysis for faster insights, and merge historical data with real-time inputs to anticipate security vulnerabilities or product failures. But for many companies, bridging the gap between possibility and reality is the tricky part.

"For customers to realize AI's full potential, cloud-based ML tools must be accessible enough for non-experts to use without any IT assistance," Hölzle explains. "While this is the case in some areas of cloud computing, we are not there yet." But cloud providers are hard at work on solutions, and tools like Google Cloud AutoML and machine-learning APIs offer a starting point to an exciting future.

"The beauty of ML is that it allows analysts to look at data in several different iterations, and ask new questions with each one – thus developing a much deeper understanding of their data," Hölzle says. "That quality will expand as ML tools on the cloud become more accessible."

"Machine learning is a natural outgrowth of cloud computing."

– Urs Hölzle, SVP Technical Infrastructure, Google Cloud

Systems

Cloud-based tools often represent the first step in a company's digital transformation, and frequently lead to more systemic changes. When applied systemically, cloud computing can usher in a new IT model centered on standardization, interoperability, and openness. This shift can have powerful business implications, such as reducing operating costs, increasing efficiency, and even making customers and employees happier. Let's take a look at how these systems evolve.

Standardization

Over the past 20 years, enterprise IT has spent considerable energy integrating disparate off-the-shelf solutions to create a system that works for its unique needs, says Google Cloud CTO Brian Stevens, an industry veteran who spent nearly 13 years as CTO of Red Hat before joining Google in 2014. "They all build off common sets of products, but they each knit it together in their own special way, because there's been no notion of 'IT as a service' for the last 10 years." Cloud platforms are helping to standardize a company's approach to IT infrastructure and management, which in turn can eliminate some of the "mundane work" of creating and re-creating custom integrations. And the less time a company's IT team spends on mundane, undifferentiated work, the more time and energy it can devote to creating differentiated value that supports the company's mission.

Standardizing on cloud platforms also creates new opportunities for automation at scale, which can help companies more effectively manage compliance and security.

In a few years, Urs Hölzle envisions, the cloud will make compliance much easier. "For example, it should be possible for you to get a HIPAA audit for a few hundred dollars because most of the audit is automated and the stack is already audited," he says. By contrast, every proprietary on-premises environment is unique, so automation isn't always possible (or scalable). "There are too many cases, and the test matrix is too big."

Cloud computing holds similar promise for security. "Imagine you have a million machines, and they're all reporting on their security status," says Heather Adkins, Director of Information Security and Privacy at Google. "You could look across the baseline of all these machines at the same time and pick out the anomalies. That's the power of operating in a centralized model. The old IT way of thinking was to buy a bunch of machines and plug them all into a network. But that means you also can't measure whether your security is good."

Interoperability & openness

Open-source software plays a key role in standardization across tools, systems, and clouds (see sidebar, "Bridging multi-cloud and on-premises environments"). By definition, vendor-neutral, open-source software is designed to work with any platform (and any functionality that doesn't exist from the start can be built and shared by an active community of third-party developers). This protects companies from betting too heavily on a single vendor and then having to replace the entire platform if or when it becomes obsolete. Adoption trends bear out the value of open-source solutions. According to a 2018 survey by The New Stack, more than half of companies are likely to run open-source software, and when zooming in on enterprises with more than 1,000 employees, the adoption rate of open-source software jumps to 63 percent.[15]

In addition to incorporating open-source solutions into their IT strategies, streaming enterprises also prioritize interoperability. Choosing from a mix of proprietary, open-source, and even home-grown tools and platforms gives companies maximum flexibility, while ensuring these tools and systems work together allows them to maintain speed and scale throughout the stack. As more companies adopt hybrid and multi-cloud strategies (more than 90 percent will by 2024, according to IDC[16]), open source will only grow in importance.

Openness and interoperability do not mean more complexity or a loss of control. On the contrary, companies can leverage the benefits of the cloud while continuing to meet business needs. They get central management, a more seamless transition to the cloud, clear choice, and protection from vendor lock-in. Open-source solutions, like containers, are foundational tools that bridge multiple cloud and on-premises environments to allow for consistent management across any environment. With a hybrid cloud environment, businesses can "modernize in place" or "move and improve" applications to the cloud to reap benefits with less effort. Open architectures give IT leaders the flexibility to tap the best solutions that meet their unique business needs.

Bridging multi-cloud and on-premises environments

For most organizations, moving to the cloud is a gradual process. The longer a company has been in business, the more it's likely to have invested in legacy data and IT systems, along with the skill, talent, and institutional knowledge to manage those systems. Transitioning to a cloud platform can be difficult and costly for businesses that have to manage this change while also keeping old systems and teams intact. In heavily regulated industries such as financial services and healthcare, certain workloads may need to remain on-premises indefinitely, making hybrid IT a long-term – rather than temporary – strategy.

As Google Cloud CTO Brian Stevens puts it, IT teams "are living in this world of pain, of legacy systems and architectures that, to be honest, is going to be there for the next number of years – and meanwhile they are using public cloud technologies for many of their newer workloads and data analytics projects."

So what's a leader to do?

Start by leveraging your existing resources. Whether you're in an on-premises, hybrid, or multi-cloud environment, you can start by modernizing your applications in place to keep your existing systems while incorporating innovative cloud services on your own terms.

In Stevens' view, stay focused on standardization, openness, and interoperability. Tools like the open-source container orchestration platform Kubernetes exist to help IT teams build, deploy, and manage applications consistently across multiple cloud and on-prem environments.

But there's also the challenge of keeping existing talent engaged while reallocating certain resources to new projects and hybrid integrations. Stevens recommends starting with small teams and small projects that can yield quick wins in a matter of weeks, then scaling gradually as more workloads are deployed on cloud platforms, in hybrid-friendly formats.

Containers to future-proof businesses[17]

1 in 3 workloads are containerized across on-prem and cloud in the enterprise segment.

↑ 46%

Containerized workloads are expected to grow by **46%** in the public cloud by 2021.

Leadership & culture

Even with the right tools and systems in place, success in the cloud can't happen without the leadership to guide it and the culture to achieve it. And, as a company transitions to its streaming future, new tools and systems in turn affect company culture.

"[Migration to the cloud] doesn't necessarily start by changing the whole organization at once," Stevens says. "It just starts by getting a small group of people really subscribed to the mission, and then they bring everybody else along."

For example, a company might choose to containerize applications so they work across multiple cloud and on-premises environments. It might choose an open-source container management layer like Kubernetes to further support its multi-cloud strategy and need for interoperability among different environments. The integration of an open-source solution into its IT stack might increase enterprise developer participation in the Kubernetes community, which might lead to a cultural shift to prioritize openness and transparency. This, in turn, might lead to the adoption of workflows that support these values, like a development and operations (DevOps) model in which both software developers and operators are jointly responsible for outcomes and openly share feedback in blameless postmortems. Ultimately, the cultural shifts in this example can yield significant improvements in productivity, agility, product quality, reliability, and security. In the next section, we'll delve into specific examples of what these improvements look like in the real world.

The future of news

About a decade ago, the news industry was in the midst of a major transition as readers were opting for smartphones over paper. While some publications struggled with the digital migration, U.K.-based Telegraph Media Group saw it as an opportunity to connect with readers on new platforms, launching its most radical transformation since The Daily Telegraph's inception in 1855 – all while using resources constricted by the 2008 recession.

Chief Technology Officer Toby Wright had a bold new digital vision. Properly delivering that vision required talent – technology professionals capable of creating apps and websites to resonate with the new generation. And, while Telegraph Media had plenty of smart people in their IT department, the day-to-day maintenance of the existing legacy infrastructure required much of their attention.

That's when Wright and his team discovered that the resources his team required were in the cloud. They started small by boosting collaboration with G Suite. This eliminated the need for infrastructure maintenance, freeing Telegraph Media's IT people to focus on product innovation. In one move, the technology team captured IT services and a new revenue-generating engine with the same budget and staff.

In one move, cloud became the default position for most major technology purchases and implementations. "We have discovered ways to use the [cloud] as an agent for change," says Wright.

From there, Telegraph Media migrated to a public cloud and then on to a multi-cloud platform. The IT team adapted application programming interfaces (APIs) to distribute news to all mediums via the cloud. (Last year, the media company made around 460 automated release-updates to its content API.) Journalists started using popular productivity tools that seamlessly integrate with G Suite to collaborate on complicated stories written by contributors from all over the globe. And the technology department built specialized tools to speed up certain content creation processes. For example, compiling a photo gallery to accompany an online story used to take as long as 18 minutes, an eternity by today's publishing standards. A new custom-built, cloud-based authoring tool can do the job in just a few minutes. In addition, Telegraph Media could process up to 4 TB of analytical data in less than a minute, which drives the tools they use to provide more relevant content. To Wright, this "means as long as we have an idea, we can pretty much do it, and at low risk. Experimentation at scale is much easier."

This change has also allowed the existing technology team to build their own tools, enabling operations people and software developers to work seamlessly – the basic tenet of the DevOps model. “Culturally, that leads to a strong sense of accountability and responsibility,” explains Wright, “because engineers cannot, nor will they, just throw software over the wall to an operations team.”

Today, leveraging the cloud is the norm for Telegraph Media employees. Here are Wright’s top three recommendations to help companies transition smoothly to the cloud:

1. **Choose your platform wisely:** Whether you’re thinking about using single- or multi-cloud services, make sure your structure fits your company’s needs. Telegraph Media recently announced plans to operate mostly on Google Cloud, but Wright sees advantages to both. Using one cloud guarantees fluidity and one-stop-shop service, while multi-cloud platforms can provide rapid access to a sea of best-in-class solutions that fuel continuous innovation. In addition, multi-cloud platforms can be a draw for talented IT and technology professionals looking to become fluent in different cloud universes. Multi-cloud also creates a great opportunity for vendors to compete on features and customer satisfaction instead of locking businesses into multi-year contractual agreements.

2. **Embrace open source:** Open source makes it easier for your team to learn how to build software while helping to give them a solid understanding of the technologies that underpin cloud. Being able to “see” into the black box is very useful.

3. **Trust your people.** Let employees experiment with cloud-based tools on their own. Engineers have access to the whole spectrum of Google Cloud technologies and don’t have the hurdle of needing permission to experiment. Journalists at The Telegraph uncovered new purposes for Google’s cloud-based collaboration tools that Wright had never even anticipated.

Google Cloud

PART 3

What are the impacts for business?

The enterprise of the future represents the realization of cloud computing's original promise: speed and agility at scale, real-time insights from a large volume and variety of data, and improved security and reliability. Each of these changes also affects the way people work – particularly the people writing and operating cloud services.

Melody Meckfessel, VP of Engineering at Google Cloud, leads Google's DevOps practice, and she's seen firsthand how culture plays into a company's transition to the cloud. "What we've learned within DevOps specifically is that the productivity, speed, and quality that comes with using the automation – and the culture within how you develop software – is powerful, and it leads to better business outcomes," Meckfessel says.

At companies like FTD, a premier floral and gifting company with operations in the U.S. and U.K., the impact of cloud technology is already clear (see sidebar, "How the cloud helped keep a 110-year-old company relevant"). Recognizing that it needed new tools and systems to compete in a streaming world, FTD migrated to Google Cloud Platform. This change enabled FTD to deploy services 10 times faster and helped foster a culture of continuous integration and delivery – which ultimately helped ensure that the company was better meeting the needs of a demanding digital customer base.

In this section, we'll explore how realizing the full potential of cloud computing can impact businesses across industries and geographies.

"The things that we cared about [20 years ago] are pretty much the things we care about today: flexibility, cost attractiveness, a stack that gets updated every day. What really has changed is the depth of how all of that has played out – through open source, through ML stacks, through content delivery networks. The offering today is much more complete than it was back then, but really, the principles are the same."

– Urs Hölzle, SVP Technical Infrastructure, Google Cloud

How the cloud helped keep a 110-year-old company relevant

FTD Companies, Inc. (FTD) has provided floral products and services to consumers for more than a century. Its iconic "Mercury Man" logo is displayed in approximately 35,000 floral shops in more than 125 countries, reflecting the widespread popularity of the company's FTD and Interflora brands. Today, FTD operates a diversified portfolio of brands, including ProFlowers, ProPlants, and Shari's Berries.

FTD understands that in order to be successful, it must focus its efforts on technology and develop innovative new software and services. To move into this new world, it needed to get out of its data centers and into the cloud. Based on flexibility, cost, and the variety of managed services available, FTD decided to build a cloud-native architecture on Google Cloud Platform to speed development for its new ecommerce sites.

"We couldn't afford to be held back as we reinvented the company, and we didn't want to put a Band-Aid on our existing infrastructure," explains Vamsi Muddada, Chief Technology Officer at FTD Companies. "Once we decided to move to Google Cloud Platform, we never looked back. Our lives became so much simpler."

FTD's business is seasonal, with peaks during the most popular floral and gift-giving holidays such as Valentine's Day and Mother's Day. FTD needed its new cloud infrastructure to be ready in time to take on a portion of the holiday load, so IT enlisted Google Cloud Professional Services for a four-week engagement.

"In just four weeks, Google helped us design an ecosystem of Google Cloud Platform services architected in the most optimal and cost-effective way," Muddada says. "Getting to that point on our own would have taken us a year or more."

FTD now runs a container-based architecture based on Google Kubernetes Engine (GKE), using Terraform by HashiCorp to automate cluster deployment and Stackdriver for monitoring. Data is stored either in Cloud Datastore, a fully managed NoSQL database service for web and mobile applications, or in Cloud SQL MySQL databases. With GKE, FTD can deploy services 10 times faster, accelerating time to market for new software and features. With automated deployment and scaling, developers were able to ramp up quickly and improve their productivity.

“GKE is a beautiful thing,” Muddada says. “Within a day we can write, build, and spin up a new service that would take us two weeks to deploy on-premises and a week to configure with any other cloud provider – and we don’t have to manage the clusters ourselves.”

FTD now follows a continuous integration/ continuous delivery (CI/CD) model, using Jenkins to automate portions of the development process to continuously deliver new features and accelerate app innovation. With its CI/CD pipeline on GCP, the company expects to be able to make the most of its seasonal sales peaks, with improved conversion rates and related revenue benefits.

“With Google Cloud Platform, we were able to drive a cultural shift toward continuous integration and DevOps that puts us in a much better position to compete,” Muddada says. “It’s such a developer-friendly platform that we were able to get buy-in very quickly. Everyone loves working on GCP because it’s so easy.”

Adapted from cloud.google.com/customers/ftd

With its CI/CD pipeline on GCP, the company expects to be able to make the most of its seasonal sales peaks, with improved conversion rates and related revenue benefits.

Speed & agility at scale

In the streaming enterprise, change is a constant, and operating at the speed of digital activity and data is crucial to delivering on customer expectations. This is true across industries – from personalization in retail to high-performance computing in finance to supply-chain optimization and reliability in manufacturing. The streaming enterprise must have the tools, systems, and culture in place to enable real-time action and constant agility at scale.

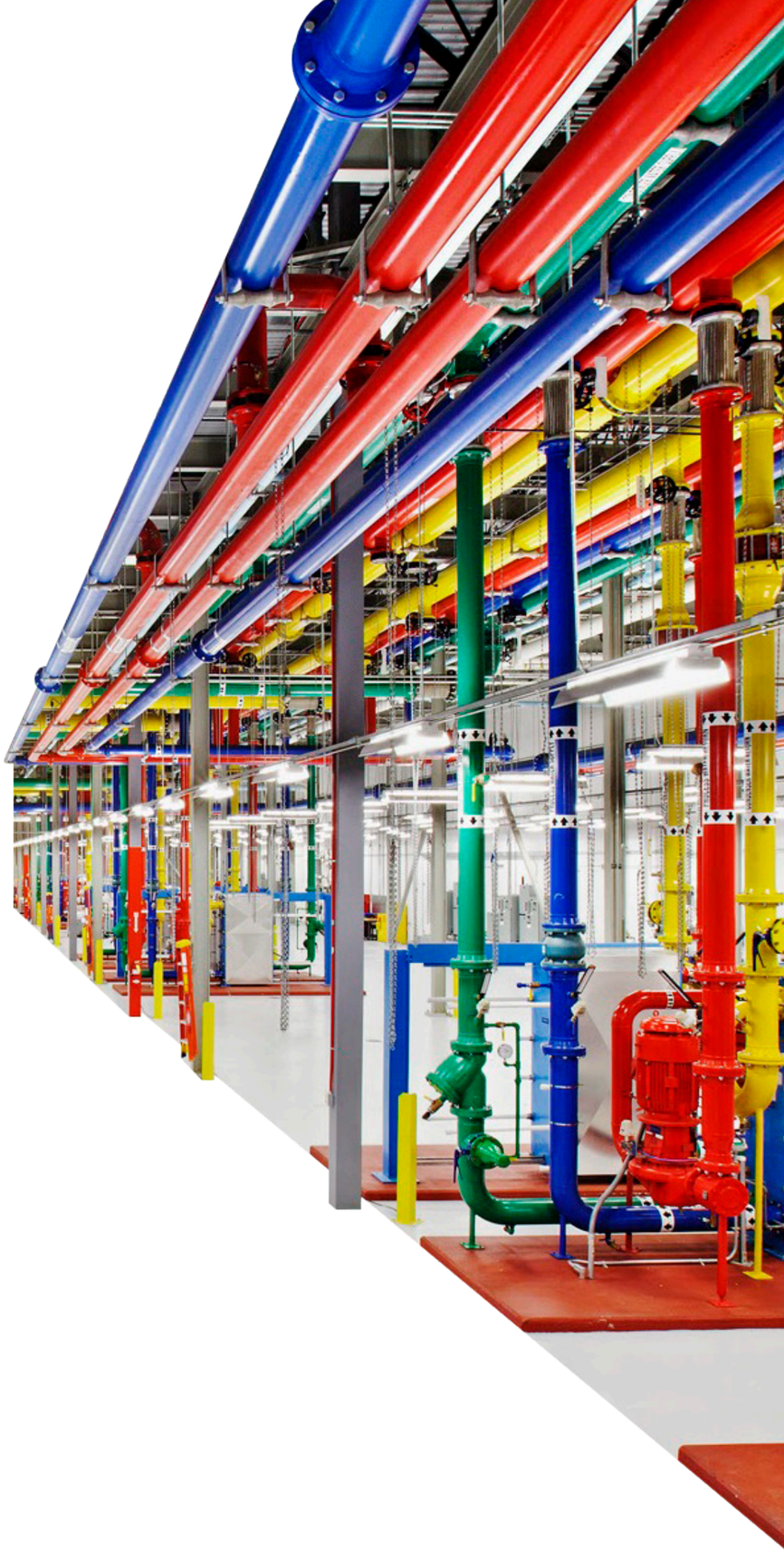
Take, for example, human genomics, the science of studying patterns within human DNA. It increasingly relies on high-performance compute and storage resources.

The Broad Institute of MIT and Harvard, a collaboration of MIT, Harvard University, and Harvard-affiliated hospitals, studies the human genome to reveal the secrets behind the origins of diseases and to help find new cures and therapies. The Broad Institute builds on the success of the Human Genome Project, the international research effort to sequence and map the genetic instructions inside each of us.

A single human genome contains more than 3 billion base pairs of genetic material. For accuracy, researchers typically examine each base pair approximately 30 times for sequencing, meaning they gather almost 100 billion base pairs worth of raw data – nearly 100 gigabytes – per person.

In 2018, the Broad Institute generated one human genome equivalent every eight minutes – roughly 16 terabytes of data every day.

That's where Genomes in the Cloud and Google Cloud Platform come in. Together, they let Broad Institute researchers continually analyze data from thousands of samples each year without having to worry about delays or interruptions to their potentially life-saving work.



Moving to Google Cloud meant the Broad Institute could analyze human genomes 400 percent faster, supporting researchers in their efforts to find new cures and therapies.

“We can do important research faster than ever,” says Geraldine Van der Auwera, associate director of outreach and communications for the data sciences platform at the Broad Institute. “That will lead to a greater understanding of the human genome and the links between genetics and human disease.”

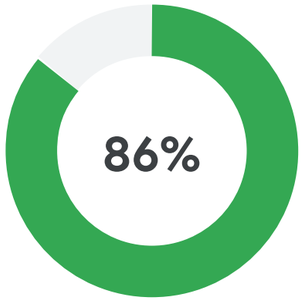
For many companies, the way applications are created, updated, and managed is a natural starting point. The rise of DevOps – a software development model that combines software development (dev) with IT operations (ops), now in use at 60 percent of companies globally, according to Harvard Business Review Analytic Services[18] – and growing popularity of CI/CD indicate that more and more IT organizations are embracing a streaming approach to application development and IT management (see sidebar, “The state of DevOps”).

Often, increased speed and agility result from improvements (even minor ones) in developer and IT operator productivity. “If you go in and look over the shoulder of a developer or an IT person, it can be eye-opening how much complexity they have to deal with,” says Stevens, Google Cloud’s CTO. “There’s so much inefficiency that they have to go through just to do the impactful part of their job.” In one company after another, Stevens has seen how cloud technology can reduce or eliminate those inefficiencies to yield “massive impact.” By standardizing on cloud platforms, Stevens says, “you can dramatically change how they spend their day...and if organizations can redeploy their staff and move away from the cost center that IT is today into a value center, that’s exciting.”

Faster feedback, quicker releases, more innovation

↑ 60%

of decision makers expect to update code weekly or daily by 2029, up from 37% today.[19]



of respondents say it’s important to their company to develop and release new software quickly.[20]

The state of DevOps

DevOps is rapidly gaining traction among companies as a means of improving speed, efficiency, and quality. In 2018, Google sponsored DevOps Research & Assessment's (DORA)* annual survey on the state of DevOps, which polled nearly 1,900 DevOps professionals to distill the practices that set top-performing DevOps teams apart.

Some key highlights from the findings:

1. **Availability matters.**
   For the first time, DORA examined availability as a key measurement of software performance, in terms of both knowing exactly what software will be available, when, and making sure it's accessible by end users. DORA found that elite DevOps performers are 3.55 times more likely to have strong availability practices.

2. **So does your approach to cloud infrastructure.**
   The cloud improves software delivery performance, and teams that leverage all of cloud computing's essential characteristics (such as self-service functions, resource pooling, and automatic scaling) are 23 times more likely to be high performers.

3. **Open-source software improves performance.**
   Open-source software is 1.75 times more likely to be extensively used by the highest performers, who are also 1.5 times more likely to expand open source usage in the future.

4. **Outsourcing by function can hurt performance.**
   While outsourcing can save money and provide a flexible labor pool, low-performing teams are almost four times more likely to outsource whole functions such as testing or operations than their highest-performing counterparts.

5. **Key technical practices drive high performance.**
   These include monitoring and observability, continuous testing, database change management, and integrating security earlier in the software development process.

Read the full report here.

**DORA was acquired by Google as of December 19, 2018; for more information, see announcement.*

Real-time insights from streaming data

Cloud computing also makes big wins possible at each stage of the data maturity curve, allowing companies to use more of their data, more effectively. Companies that store data in the cloud are able to access a greater share of their data, faster. For example, Telegraph Media could process up to 4 TB of analytical data in less than a minute, which enables the tools they use to provide more relevant content (see sidebar for more: "The future of news").[21] Additionally, advanced analytics tools empower data scientists to quickly query structured and unstructured data from diverse sources. Cloud platforms further extend the value of a company's data by connecting it to other cloud services, such as machine-learning-trained API models.

Cloud technology isn't just for digital natives. It's helping longtime industry leaders like The New York Times turn offline artifacts into valuable digital data. For more than 100 years, The Times has archived approximately 5 to 7 million of its old photos in hundreds of file cabinets three stories below street level near its Times Square offices in a location called the "morgue." To preserve this priceless history, The Times is digitizing its archive, using Google Cloud Storage to store high-resolution scans of all of the images in the morgue. Once this data is stored in the cloud, The Times uses services like Google Cloud's Vision API to identify objects, places, and images so reporters and editors can quickly (and cost-effectively) find what they need to tell a richer story.

In the streaming enterprise, the cloud's real promise lies in its ability to unite batch and streaming data inputs to run real-time analyses using machine learning and AI. IoT devices, customer interactions, social media, and environmental data – to name just a few – all provide signals that, when properly analyzed, can create a single view of a customer, product, or interaction.

In the streaming enterprise, cloud's real promise lies in its ability to unite batch and streaming data inputs to run real-time analyses using machine learning and AI.

With the right tools and systems in place, streaming enterprises can apply these signals in real time to drive smarter decision making, richer personalization, predictive maintenance, or proactive security protections.

GO-JEK, a technology startup based in Jakarta, Indonesia, that specializes in ride hailing and logistics, offers an example of how the streaming enterprise unfolds – and its impact on the overall business. Founded as a call center for ojek (motorcycle taxis) bookings, GO-JEK used Google Cloud Platform and Google Maps Platform to establish itself as a leading on-demand multiservice platform and one of the few unicorn businesses in Southeast Asia.

In 2015, the company launched a mobile application that bundles ride hailing, food delivery, and grocery shopping. GO-JEK has now bundled more than 18 products, one loyalty program, and one electronic money service into its application.

"For ride hailing alone, we have more than 1 million drivers on our platform, and on a typical day we'll have hundreds of thousands of drivers online at the same time, servicing our customers," says Willem Pienaar, data science platform lead at GO-JEK. "We also have more than 300,000 merchants on our food delivery platform," he adds. "We call them merchants because they are not just restaurants; they are mothers and fathers selling food from their garages. Our platform supports socioeconomic mobility in Indonesia by allowing people to rise up from poverty."

GO-JEK has relied heavily on the skills and expertise of its technology team and on selecting the right technologies to grow and expand into new markets. Google Cloud Platform solutions play an integral role in enabling GO-JEK to capture and analyze the data associated with 2.5 million customers and 1 million drivers across 167 districts and cities.

Streaming insights to feed the world

Growing up on a farm in Israel, Ofir Schlam would rise at dawn to check the fields for signs of pink bollworm, an invasive species known for devastating cotton crops. His early days spent at the farm inspired him to found Taranis, an agro-tech company that takes care of such chores while farmers are still fast asleep.

Schlam may joke that he was trying to avoid waking at 5 a.m., but Taranis' true genesis stems from a far weightier concern: solving world hunger. With a growing world population, demand for food has never been higher, yet contamination from chemical leakages, pests, and disease increasingly threaten vital food sources. Each year, an estimated one-third of the food produced for human consumption is lost or wasted, according to the Food & Agriculture Organization of the United Nations.[22] In developing countries, much of that waste and loss occurs at the early stages of the food value chain. In 2015, Schlam and his co-founders started Taranis to help farmers assess and mitigate crop loss from disease, insects, weeds, or nutritional issues. Today, Taranis collects images of 20 million acres of farmland with a sub-millimeter camera mounted on a drone that can capture details as tiny as a bug on a blade of grass in real time.

With 19,000 farms around the world using this data-intensive premium service, Taranis needs to ingest and process an enormous volume of image data with the capability for near-real-time analysis. "Farmers can't wait a week to get results, when [the blight] has already expanded and caused a lot of damage to their crops," Schlam says.

Taranis uses Google Cloud Platform to manage its image database, as well as AI tools available on GCP for data analysis. It's a business that wouldn't exist without the scale, speed, and real-time processing capabilities of the cloud – a true streaming enterprise. Taranis has already helped reduce crop loss by more than 15 percent, and this is just the beginning. As cloud computing continues to evolve, Schlam has an eye out for new opportunities, including edge processing to enable not only real-time analysis but also automated responses (such as a drone that can spray a plant as soon as it detects a pest infestation). As Schlam puts it, "There's a lot more to innovate." See how Taranis saves the world's food supply with cutting-edge AI.

Security & trust

Depending on whom you ask (and on their familiarity with cloud technology), security is either a top driver of cloud adoption, a top barrier to cloud adoption, or both.[23] Bottom line, it's top of mind – and cloud computing holds huge promise for those looking to manage security and trust more effectively.

Heather Adkins, Director of Information Security and Privacy at Google, says companies must first think of security in a more fluid way. "The boundaries in security have vastly changed," Adkins explains. "We used to imagine the boundary around a simple physical computer or room of computers. Now, as people carry their computers in their hands all around the world, we are transitioning to thinking about how the boundaries have to be around the data."

Cloud computing makes security management possible in a porous and varied ecosystem of platforms, users, and devices. By centralizing data and IT infrastructure in the cloud, Adkins says, companies can scalably and continuously manage every single asset, user, and configuration.

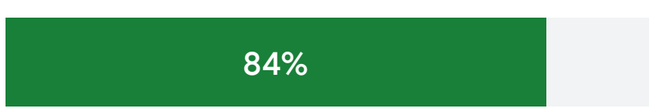
Take Ravelin, a fraud detection provider that flags fraudsters within milliseconds to online merchants using real-time behavioral analytics. Because fraudsters are constantly evolving their methods, Ravelin doesn't just demand exceptional speed, security, and scalability from its cloud provider, but openness and adaptability, too, so it can take advantage of open-source advances and stay one step ahead.

"We believe in open source and open standards and open protocols," says Leonard Austin, the company's Chief Technology Officer. "At Ravelin, we rely on a number of open-source technologies to protect our clients from fraud. With Google Cloud Platform we can do that in a fast, globally scalable, and more secure way."

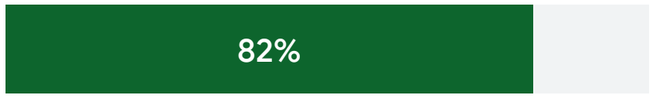
Top 3 tactics to build customer trust, according to a Google study[24]

1. Build reliable computing services (**85%***)

2. Invest in security (**84%***)



3. Enable transparent communication (**82%***)



*% of professionals who rated this option as "very important" or "somewhat important"

Culture

Realizing the promise of cloud computing requires a change not only in how teams work together, but also in how they think about their work. For example, thinking about product development in a cyclical (versus linear) way can help engineers see the bigger picture and worry less about small mistakes.

“When people feel like they have each other’s back – or that the tools, the continuous integration/continuous delivery, has their back – they’re more likely to take risks,” Meckfessel says. “They’re more likely to create; they’re more likely to move faster.”

But cultural change requires leadership, and Meckfessel employs a specific methodology for scaling Google’s model. When asked about her guidelines, she recommended the following:

1. Use data to guide decisions so all the humans are looking at all the same data.
2. Be transparent; don’t hold information back.
3. Collaborate so developers and operators have shared goals.
4. Bake in blameless post-mortems and accept that writing software has risks and defects.

In this context, automating the mundane tasks isn’t just about making IT more productive. “It’s data, transparency, collaboration, and blameless post-mortems because that’s how you build trust, and that’s how you have fun together as a team. Software engineering is a team sport,” Meckfessel says.

Google Cloud

PART 4

How should leaders prepare?

In Part 1, we explored the enterprise of the future. In Part 2, we looked at how the characteristics of cloud computing will shape the enterprise. In Part 3, we examined cloud computing's impact on the business as a whole. In this section, we'll offer actionable advice for leaders looking to seize the opportunity to transform.

STEP 1

Find the cloud model that works for you.

By 2022, the top four cloud "megaplatforms" will host 80 percent of infrastructure as a service (IaaS) and platform as a service (PaaS) workloads, according to IDC.[25] As cloud adoption increases, hybrid and multi-cloud models will become the norm, with every enterprise assembling a mixture of cloud services and legacy applications to meet their needs. This approach brings the cloud to the enterprise, rather than bringing the enterprise to the cloud. We can expect a world in which cloud computing is the standard – and where open, interoperable tools play a crucial role in connecting a company's data and applications across environments.

"Organizations have seen, from their experience in the public cloud, that they can develop faster, iterate faster, and bring solutions out faster," explains Stevens, Google Cloud's CTO. "The modernization happens naturally as they increasingly integrate cloud services into their IT toolkit. It's become not an *if* or a *why*; it's become a *how*."

As CTO, Stevens works directly with companies that are figuring out their "how." Google's model is based on a partnership: Google technical teams sit with the customer's IT team to work through a new process, step by step. Recently, Stevens saw one of these partnership teams migrate three major enterprise resource planning workloads to the cloud in the space of two weeks. (The company's leadership, he says, was "stunned... people think it's harder than it is.") "The idea is, when [the Google engineers] leave, things don't stop," Stevens says. "Next workload, next workload, and then that just creates a snowball effect within the organization."

"All the machines we're offering, all of this technology, all of this code – it's really about trying to maximize the amount of human creativity we can bring to bear."

– Melody Meckfessel, VP Engineering, Google Cloud

STEP 2

Build on an open platform.

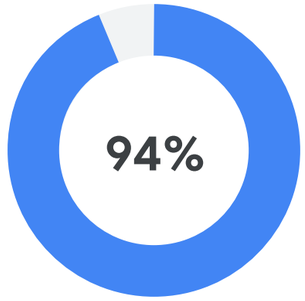
The benefits of open-source software are clear: interoperability across on-premises and multi-cloud environments, protection from vendor lock-in, and continuous innovation from a community of third-party developers. As cloud computing more deeply penetrates every company's IT stack, choosing an open, interoperable platform becomes more important than ever.

"Open, emerging technologies of today, like Kubernetes, in 10 years will become dial tone," Stevens predicts. "It's not sufficient that [public] clouds have their proprietary way of doing things. We need them to all work well together – that needs to be our north star."

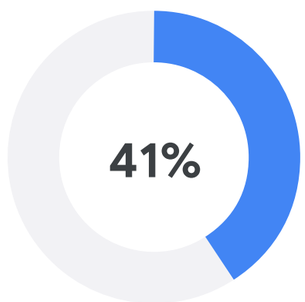
Open source has played a pivotal role in enabling standardization and interoperability across cloud providers and other technologies. In addition to incorporating OSS into the enterprise stack, Stevens advises companies to look for cloud partners that prioritize openness – by open-sourcing their own innovations, contributing to the community, or designing platforms with interoperability in mind.

"If we built the best cloud for containers, because we invented the container model and orchestration with Kubernetes, it'll just mean we've got a great cloud. We won't have changed the industry," he says. "The open-sourcing of Kubernetes, Istio, and Tensorflow is the path to helping the whole industry move along together."

Open-source software (OSS) establishes a seat at the table[26]



of companies plan to use OSS by 2029.



of companies plan to use OSS for the majority of their software platform by 2029.

STEP 3

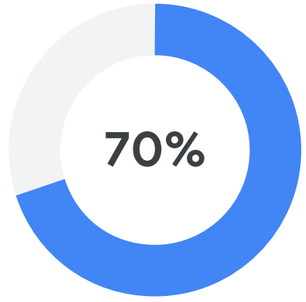
Rethink IT security.

Currently, many companies approach IT security with a pre-streaming mentality: protect the perimeter, patch vulnerabilities as quickly as possible, and go back to hoping the perimeter won't be breached again. Adkins advises companies to turn this model on its head: assume constant vulnerability, and you'll never be surprised.

"Just as we've started thinking about streaming medicine (always-accessible healthcare personalized to our bodies), we should think about IT streaming security on a constant basis," Adkins advises. "Development will need to move into a continuous feedback model so that code can be pushed (refreshed, fixed, and updated) at any time. The benefit is that if there is a security issue, it can be dealt with immediately as opposed to waiting quarterly, yearly, or any other time down the road. This will reduce and eventually get rid of the periods of vulnerability when an adversary can exploit the company."

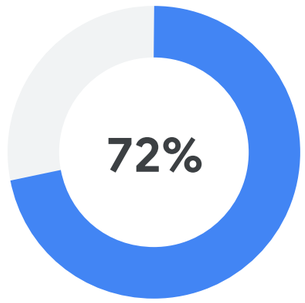
Adkins also emphasizes the importance of continuous learning and a no-blame culture in which it's OK to make mistakes as long as they're exposed, studied, and fixed for the long term. She thinks of security as "a workplace revolution" in which an innovative IT department dedicated to running advanced data analytics at scale can be a critical force in protecting a company's data and customers.

Automation to speed up security



of decision makers expect a majority of security operations to be automated in 10 years.[27]

Security is shifting to the left



of decision makers expect to see more security implementation pre-development by 2029.[28]

STEP 4

Lead the change.

As with any new approach, leadership and change management are critical factors in the new model's success. A recent survey from the Harvard Business Review found the vast majority of decision makers (83 percent) believe that a change-embracing culture is extremely important to their organization's ability to successfully adopt new digital technology capabilities quickly.[29]

For most companies, making the transition to the cloud will require not only rethinking talent strategy and organizational structure, but also a reconsideration of a company's overall culture.

At Google, Meckfessel describes a shift "to really connect everything back to people... helping people realize their ideas, helping people create." As access to computing resources grows and cloud technology penetrates new markets, she adds, diversity plays an increasingly important role in product development (see sidebar, "The case for diversity").

And while Meckfessel's focus is on developers and operators, even those definitions are expanding. By 2024 a new class of professional developers producing code without custom scripting will expand the developer population by 30 percent, according to IDC[30] – further expanding what it means to build on cloud platforms in the streaming enterprise.

"There's something magical in understanding what makes people productive, helping them with that, collaborating with them, and then they are empowered to influence themselves," Meckfessel says. "The culture for the developers and operators is a significant part of what makes them happy, productive, and focused on those business outcomes."

Air cover from senior leadership is crucial, Stevens adds, particularly when the changes may be viewed by some as disruptive. He also advocates securing easy wins wherever possible: "Pick some initial workloads, create a few tiger teams, bring in an experienced partner, and build toward a positive outcome measured in weeks rather than quarters."

> **"There's something magical in understanding what makes people productive, helping them with that, collaborating with them, and then they are empowered to influence themselves."**
>
> **– Melody Meckfessel, VP Engineering, Google Cloud**

The case for diversity

Compute is becoming more affordable. Ease of access to compute is increasing across different communities and different geographies all over the world. We're at a very interesting point in cloud computing where we're on a journey with customers that are migrating to the cloud.

What I think is happening and what we'll see happen in the next five to 10 years is as cloud technology offers more solutions to our customers, we're going to see different types of developers coming into cloud computing. There is an openness and an access that is going to open up a diversity of educational backgrounds for developers. The number one job [in 2030] is going to be for developers.

The diversity of who's creating the product for end users has not represented the user community. There have been some real misses, and I think we need to do a better job of representing the users that we're developing these solutions for. The path toward that is not just what we offer the humans within Google Cloud, but that we have an opportunity to enable inclusive, respectful behaviors for diverse software developers and operators within the software development lifecycle. That will continue to increase the level of conversation, the sharing of ideas – whether it happens in code review or if it happens earlier on in the software development process – that will lead to better products for users out in the market.

Developers have different requirements and constraints that they're working in, and at Google Cloud we want to offer them the tools, the underlying platform components, to be able to do what they need to do within whatever segment, or identity, or community, or ecosystem that they're living in, and we know that those communities change over time. And the identities of developers and operators change over time.

Melody Meckfessel

VP of Engineering,
Google Cloud

Conclusion

Increasingly, technology, data, and human interactions will follow a new model of real-time inputs, enabling change without interruption and positive iteration. Cloud computing powers an important shift for information technology, and it will usher in new and better ways to serve customers, make discoveries, and build great products and services.

As part of this transformation, technology models will become more flexible, interoperable, and open; office cultures will shift toward transparency, collaboration, and constant learning. That means innovation and team building – the best parts of work – can happen more frequently and efficiently. Customer focus can sharpen and become more responsive. Corporate knowledge gained over decades of competing and innovating can be brought to bear more easily and meaningfully.

To compete effectively in this changing landscape, business and technology leaders must find ways to embrace the potential of cloud computing – whether in the tools and systems they choose, the institutional cultures they create, or the business strategies they prioritize. Today's enterprises can set the stage for future success by infusing their unique assets – such as customer relationships, excellent service capabilities, strong partnerships, market knowhow, and technology investment – with the power of innovative IT.

We're excited about the future, and we're eager to partner with companies to share our vision of openness, excellence, and innovation.

Get in touch

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Appendix

1. RightScale, 2018 State of the Cloud Report, January 2018

2. IDC FutureScape, Worldwide IT Industry 2019 Predictions, November 2018

3. IDC Market Forecast, Worldwide and Regional Public IT Cloud Services Forecast, 2018–2021, March 2018

4. Smarter With Gartner, "What Edge Computing Means for Infrastructure and Operations Leader", October 3, 2018

5. IDC FutureScape, Worldwide IT Industry 2019 Predictions, November 2018

6. IDC FutureScape, Worldwide IT Industry 2019 Predictions, November 2018

7. IDC Market Forecast, Worldwide and Regional Public IT Cloud Services Forecast, 2018–2021, March 2018

8. Google Internal Study analyzing predictions and trends in cloud computing among IT and business decision makers at global mid-market (500 to 999 employees) and large companies (1,000+ employees), January 2019

9. Google Internal Compute Study, January 2019

10. Google Internal Compute Study, January 2019

11. Google Internal Compute Study, January 2019

12. IDC White Paper, sponsored by Seagate, The Digitization of the World From Edge to Core, November 2018

13. Cisco White Paper, Global Cloud Index: Forecast and Methodology, 2016–2021, November 2018

14. MIT Technology Review Custom and Google Cloud, Machine Learning: The New Proving Ground for Competitive Advantage, 2017

15. The New Stack, Survey: Open Source Programs Are a Best Practice Among Large Companies, August 2018

16. IDC FutureScape, Worldwide IT Industry 2019 Predictions, November 2018

17. Google Internal Study analyzing adoption pathways to public cloud through containerization for the Enterprise segment (January 2019)

18. Harvard Business Review Analytic Services, Competitive Advantage through DevOps, January 2019

19. Google Internal Compute Study, January 2019

20. Harvard Business Review Analytic Services, Competitive Advantage through DevOps, January 2019

21. https://cloud.google.com/customers/telegraph-media-group/

22. Food & Agriculture Organization of the United Nations, Key facts on food loss and waste you should know!

23. Mckinsey & Company, Making a secure transition to the public cloud, January 2018

24. Google Internal Compute Study, January 2019

25. IDC FutureScape, Worldwide IT Industry 2019 Predictions, November 2018

26. Google Internal Compute Study, January 2019

27. Google Internal Compute Study, January 2019

28. Google Internal Compute Study, January 2019

29. Harvard Business Review Analytic Services, Leading in a world of continuous change, 2018

30. IDC FutureScape, Worldwide IT Industry 2019 Predictions, November 2018

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