Nasdaq

NASDAQ DECODES: TECH TRENDS 2019

The technology trends that are driving the world of markets forward

Foreword

When our founders launched the world's first electronic market in 1971, in many respects this was a watershed moment in the history of finance and technology. Since then, capital markets have undergone a complete transformation: they have become more globalized, fragmented, competitive, complex and heavily regulated – and the electronic exchange model is now commonplace.

The work we have done has created the foundation for new types of marketplaces to emerge. These companies are disrupting their industries by providing a platform and business model for price discovery and matching buyers with sellers of an array of financial and non-financial assets. Among them are shipping and logistics, advertising and reinsurance to name a few. Often we see them described as the "Nasdaq of" their particular sector. In many ways, we see ourselves in these platforms, as they are shaking up their traditional industry, similar to how we did it nearly 50 years ago. Like these new markets, we have proudly embraced change. Our continuous quest to identify, acquire and apply groundbreaking technologies to evolve the markets – our own as well as our clients' – has been key to our approach.

2019 is the third year that we have published our report on the technologies that we believe are having the most impact on our industry, and our outlook for the year ahead. Five key trends have led us to where we are today, and are reflected in our priorities:

First, financial services is known for its technological prowess, and companies in other industries have implemented technologies that we have pioneered, such as blockchain. But innovation is coming out of other industries – including telecommunications and gaming – that can be applied to our business as well, and we are keen to explore and exploit those opportunities. We are seeing a true convergence of technologies, and it is for this reason we strategically removed the word "fintech" from the title of our report this year.

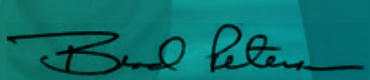
Second, the open source model is allowing all types of companies to solve common technology problems as a community. We are contributing and sharing our knowledge and expertise, and we are also benefiting from the contribution of others. The economics and flexibility of open source is compelling, especially as more products become available in the cloud.

Third, the demand for data-driven solutions has increased significantly. The volume of structured, unstructured and alternative datasets continues to explode, and companies are increasingly applying machine learning, artificial intelligence and data analytics to gain new insights in real time and improve decision making. Data governance and management is critical for regulatory compliance. Meanwhile, the ability to make data immutable, share it and protect it is of utmost importance.

Fourth, "platformification" is having an impact on financial services and other industries. Products are being bundled together and monitored to see how customers interact with them to deliver a differentiated customer experience. This could generate new customers and revenue streams.

Fifth, the previous four trends are contributing to the rapid adoption and increasing maturity of cloud offerings and the software as a service delivery model. Marketplaces of all sizes can launch solutions in the cloud with an extremely lean IT setup, minimal capital expenditures and optimal operational expenses. Instead of going through their internal IT procurement and deployment cycle, they can deploy products and services in the cloud as a proof of concept (PoC) and decide later if they want to go on-premise or even remain in the cloud.

Given the opportunities presented by these trends, we are pleased to offer you our view on the current state of technology of the capital markets and beyond. At Nasdaq, we work with these technologies and developments every day. They energize us and keep us focused on our path forward into an exciting future.



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Technologies are converging across multiple industries.

The financial services industry pioneered technology that enables very high speed marketplaces and machine-to-machine communications. Some of these technologies are now being applied in other industries as well as in non-financial markets everywhere. Take general-purpose time series databases and Field Programmable Gate Array (FPGA), software embedded on hardware to allow a much more deterministic speed, as examples. These technologies have been essential to financial services firms for some time. Now cloud providers are deploying both, and automakers are using FPGA within their vehicle systems.

Simultaneously, the financial services industry is looking at how other industries are leveraging technology to increase efficiency, reduce risk, improve customer service and gain competitive advantage. To illustrate, the Internet of Things (IoT) is taking machine-to-machine communications to the next level in many areas including agriculture and supply chain management. GPUs used in gaming are enabling machine learning, which is being applied across all industries.

Financial firms are moving away from technology islands and leveraging technology architectures and designs in their core infrastructure that are similar to those used in other industries. Examples include distributed global connectivity solutions used in telecommunications, and global networks and platforms that have been within the purview of Google and Facebook.

Tech convergence is all about applying technology in creative ways to solve problems, accelerate innovation and meet customer needs. Nasdaq is working constantly to spot new trends and exploring opportunities to adopt new technologies where appropriate.

Open source is enabling community problem solving and differentiation.

Often a problem is widely experienced by many different firms. Instead of solving it individually and sub-optimally, it makes sense to band together and solve it as a community.

The open source model enables companies to tap into a community dedicated to building modern software, and to align with vibrant, active projects. As such, companies can accelerate innovation on the differentiating parts of their platform while leveraging the underlying foundational innovation of the broader open source community. The open source model lowers costs and in some cases achieves vendor independence. Notably, the cloud providers' embrace of open source is leading to lower cost for additive cloud services as well as more robust competition. Open source also helps to attract the next generation of talent, who want to work on cutting-edge projects and have a positive impact on the world.

Linux, an open source solution that modernized and replaced an outdated alternative, is a great success story. But not all projects achieve that level of success, and it is important to identify which ones are likely to remain vibrant and viable. One indicator is when the founders remain involved and the project is growing, as in the case of Confluent and Databricks with Apache Spark and Apache Kafka. Another positive sign is when open source projects are widely adopted across the major cloud providers, such as Docker and Apache Spark.

Perhaps one misperception is that the acquisition risk is lower with open source technology. IBM bought Red Hat recently, and VMWare bought Heptio. As a result, companies that have decided to migrate toward an open source technology may find themselves bound to a large incumbent vendor once again. If this trend continues, the full benefits of tapping into open source may not be long-lasting. Moreover, some new license frameworks prohibit companies from reselling what they have built on open source.

Given these trends, Nasdaq plans to contribute to a select group in the open source community. In particular, open source makes it easier for exchange customers to access data and derive insights from it in real time. If market participants handle data in a common way and with a common set of tools, individual firms do not have to devote resources to building those tools. Importantly, data can be shared in a way that does not compromise security and integrity to the benefit of all.

Innovation in the cloud is prolific.

Innovation in cloud product offerings has been prolific as cloud providers compete to gain market share. Two significant advances over the past year are the integration of time series databases and the introduction of parallel streaming in milliseconds, giving companies a comprehensive view of activity like never before.

Specifically, Apache Spark is a fast, in-memory data processing engine with development APIs to allow data workers to efficiently execute streaming, machine learning or SQL workloads that require fast, iterative access to datasets. Apache Kafka is a community distributed streaming platform capable of handling trillions of events per day. Both technologies are available in the cloud, and will be foundational for next generation surveillance, risk management and generally keeping up with the high-speed information on trading and clearing systems.

It is notable that the cloud providers are embracing and supporting open source alternatives in addition to the enterprise software and proprietary solutions that are available currently. Importantly, customers are benefitting in terms of better availability and cost effectiveness of product. Some cloud providers have conceived of products that extend their offering to the customer's premises. Other offerings allow large customers with many accounts the ability to give their employees autonomy while still maintaining control.

Regulatory compliance is a key consideration for companies, and concerns about data residency are driving some global players toward a true multi-cloud offering. One implication of GDPR, for example, is that companies may not be willing to cross borders with their products and data if a cloud provider has not built out in Europe and in the company's region.

In many firms, the multi-cloud strategy is still taking shape, and the fear of traditional vendor lock-in is ever present. That said, open source foundational technologies as well as emerging ones such as Apache Kafka may be adopted across all major cloud providers. For now, firms appear to be adopting the leading cloud provider in their region plus a second one, but the right cloud strategy is a matter of perspective. For technology providers, having a multi-cloud strategy is important for product distribution and customer reach. Many financial firms, however, are still operating in a hybrid cloud mode, focusing on connecting to one cloud provider as well as their own data centers. Nasdaq will continue to monitor progress in this area.

Alternative data, machine learning and artificial intelligence are a powerful combination.

Enterprises need to become data driven to succeed in the current business environment. The ability to make both structured, unstructured and alternative datasets actionable can be a significant differentiator. In some cases it is necessary just to stay relevant. This is true across all industries, including finance.

Traditionally, investor analysis involved looking at a company's 10Ks and 10Qs, market data and the technical analysis of the trading activity. Nowadays, investors see an opportunity to use alternative datasets from sources such as Quandl to make better decisions. For example, they might look at month-over-month sales and compare those figures to the company's peer group, and track the company's supply chain for insight into future production flows, sales and sources of risk.

Clearly, alternative datasets, analytics, and machine learning/ artificial intelligence (AI) are a powerful combination. The advancements in AI are coming rapidly. New techniques such as reinforcement learning as well as generative adversarial networks (GANs), which are a type of deep learning neural network, are starting to attract attention. They are also extending capabilities beyond what was possible with standard machine learning and deep learning algorithms. GANs for instance will allow AI to compete with itself to come up with an optimal model in real time, resulting in greater accuracy. A potential application is in risk management.

All these technology enhancements have not brought us much closer to having a generalized AI (capable of super-human-like intelligence across any subject). However, companies are achieving success by focusing on narrow AI applications where an algorithm can be trained to do one thing extremely well, surpassing the capabilities of what a human could do on their own. Financial firms are doing this to detect spoofing behavior or risky trading activity. For example, they use these narrow AI algorithms to build applications that are much more sophisticated and accurate than their traditional counterparts.

Generalized AI – the ability for a machine to successfully perform any intellectual task that a human being can – is still about a decade away. Yet it is becoming easier to interact with Siri, Alexa and Google Assistant, and every question people ask is another narrow AI application. Before long, it will be possible to put together millions of questions and answers, drawing us farther down the path to generalized AI – especially as the technology improves.

Until then, the greatest opportunity and challenge is knowing the right narrow AI applications to develop. Commercial success is dependent on having a clear understanding of how, when and why people will use something new rather than relying on their tried and tested human intelligence. Behavioral science methods are becoming recognized as the differentiator to deliver this understanding, and the way forward could be through "collaborative intelligence", involving a reimagining of people and machines working together. Achieving this requires behavioral scientists to do a new depth of analysis of clients' cognitive and manual working processes. This ensures the best of human and machine capabilities can be leveraged to deliver this new way of working.

In the meantime, Nasdaq's strategy is to build a community of data suppliers and connect them with a community of data consumers, and then provide the services they need to make the data actionable. As we build up our data repositories, and we connect them to Nasdaq Financial Framework, those datasets and technologies will become available to an array of market participants.

Blockchain projects produce early results.

Many financial institutions and blockchain/distributed ledger technology labs have been working on proof of concept (PoC) and pilot projects, and some are starting to produce early results. A goal of this work is for parties to form consortia and set up commercial networks on shared infrastructure based on the blockchain.

Multiple blockchain technologies are now emerging with different implementations and consensus algorithms. As certain projects may require interoperability between these different implementations, Nasdaq recently completed a PoC with the Singapore Exchange (SGX) and the Monetary Authority of Singapore (MAS) demonstrating cross-blockchain settlement. This indicates that blockchain can provide a supporting role in the next generation CSD and the transfer of digital asset ownership.

The emergence of different types of tokens is another trend. Some link directly to a fiat currency, while others are tokenized assets. In response, regulators worldwide are trying to build a legal framework for payment, security and utility tokens.

Going forward, blockchain will likely be used as a solution for managing new types of financial and non-financial assets in markets everywhere – potentially including real estate, insurance and loyalty points. The token ecosystem will support the entire life cycle of the asset – from issuance and price discovery to execution and settlement, and perhaps corporate actions. Payments will either be done on the same network, via a link to an external payment network such as T2S or Swift, or via a utility settlement coin.

Yet, some important questions remain unanswered. Who will take on the custodial aspects of dematerialized physical assets and digitized tokens on a blockchain, and manage know your customer and anti-money laundering compliance? The traditional custodians could assume that role, but disrupters could appear in markets that do not have custodians. Another question is who will be the arbitrator if and when a smart contract goes wrong?

The smart contract hype cycle has nearly peaked, and the trough is about to begin. Technologists need to think about where smart contracts make sense and whether the programming languages should be Turing complete so they can run any program given enough time and memory. In the next few years, expect to see the major cloud providers supply the infrastructure for blockchain, and blockchain software companies consolidate as funding becomes more difficult.

Cryptographic technologies are ensuring data integrity.

Regulations such as GDPR in Europe and the misuse of personal information on social media highlight the importance of trust in a system where data is shared between different parties. Yet data needs to be protected in a way that adds value to the end user.

Financial firms' data is often shared internally and externally. Many workflows are regulated, and firms must follow a proof of process when it comes to the custody and provenance of data. They must demonstrate to auditors, regulators and customers that systems are functioning as prescribed, workflows are completely auditable, repeatable and immutable, and measures are established to prevent security breaches. Data lineage, a data lifecycle that includes the data's origins and where it moves over time, is becoming more critical and can become a competitive advantage.

A recent trend is to leverage cryptographic libraries, public key infrastructure, blockchain and zero knowledge proofs to record who did what, when and where in workflows in an immutable, persistent, auditable and impermeable fashion. These technologies ensure integrity starting with the first person who enters data through all its transfers and transformations.

Potential applications include managing the publication of earnings reports, anti-money-laundering and know-your-customer compliance, risk and surveillance. The technologies could also help to improve customer service. For example, money that is held captive on margin could be freed up by allowing a prime broker and executing broker to contribute data to a secure multiparty compute service that calculates a credit score. That could help to reduce the margin requirement.

The technologies could be used to create a certificate authority in the cloud, so users could verify that the service that they are about to run came from the correct source and was unmodified in transit. Together, they could also be used as a formative technology to create a data marketplace where the fidelity, integrity and lineage is guaranteed.

A zero knowledge proof is a severable technology, allowing for secure multiparty computation to occur. Let's say two people each have a dataset that neither wants to share. But they would like a mechanism so they can contribute those datasets into a piece of compute that would transform it privately into a result that both people would find mutually beneficial. This technology would prevent data sharing, and the result would redact all information that would prescribe the origin, who owned it, or any details of it.

One can imagine valuable use cases in research and development work across many industries and functions including healthcare clinical trials and supply chain management.

Cybersecurity technologies and processes are helping to combat unabated threats.

Advances in technology reduce the risk of a bad actor penetrating systems, but the threat is still there, and is not going away. To this end, cybersecurity remains in the limelight, and with newer regulatory disclosure requirements, 2019 could be a tumultuous year.

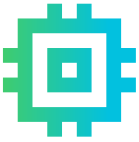
Over the past few years, several high-profile events caused by cyberattacks and geopolitical tensions have elevated the threat of cyber warfare. Significantly, public perspective has shifted from identity theft to general privacy and the misuse of personal information obtainable on social media. With increased public awareness, there is also concern about breach fatigue: people could become so accustomed to cybersecurity events that they lower their defense against them.

Training, engaging and testing employees is the cornerstone of any cybersecurity strategy. This helps to breed a culture of security so people do not fall victim to phishing or violate policies by clicking on links embedded by hackers.

From a technology perspective, employees are being empowered to operate securely without impacting their productivity. Newer authentication technologies such as YubiKey, one-touch single sign on and one-touch multifactor authentication are driving down the poor user experience associated with legacy security products. With YubiKey, the user inserts a USB device into a port and presses a button to send a code to the service that the user is authenticating. Some apps on iOS and Android offer a similar experience where the user receives prompts during the authentication process. The user clicks allow, and if that device is trusted, the authentication succeeds.

Another notable trend is security feature development being moved toward the beginning of the development lifecycle instead of tacking it on at the end, known as "shift left". This is being driven partially by the adoption of the development and operations (DevOps) model, in which there is an agile relationship between product development and IT operations. Another driver is the use of application containers and container automation, which provides isolated environments for running software services and the means to maintain security governance with fewer costly and time consuming manual reviews. Ultimately, the time to remediation for vulnerabilities is being reduced dramatically, making it easier for organizations to maintain a secure posture on their network perimeter.

Quantum computing continues to advance.



Quantum computing continues to make strides toward quantum supremacy – the point at which a quantum computer does something faster than an ordinary computer. The race to build commercially viable quantum computers is largely motivated by the shear amount of technological disruption this machine is expected to bring. Yet, several breakthroughs will be necessary before construction of a fault-tolerant universal quantum processor capable of surpassing present-day supercomputers can be built.

It is possible, however, that "imperfect" quantum computers can find interesting applications long before fully fault-tolerant quantum computers are available. In fact, the quest for "quantum supremacy" has paradoxically led to a boom in quasi-quantum classical algorithms. Further, hybrid approaches using both a classical and quantum computer in parallel will allow for running algorithms that demonstrate quantum advantage.

Quantum computers may never perform some functions as well as classical computers. For example, no one anticipates streaming a film with a quantum computer. To this end, certain classes of problems will likely remain in the classical domain, and other classes of problems will be handled by quantum computers, such as cryptography, modeling and optimization, machine learning and prediction, and searching big data.

Similar to the GPU co-processors that operate alongside classical CPUs, a quantum computer may take on much the same role for co-processing of problems that they are good at. As such, we may be headed toward a landscape of specific purpose quantum computing where classical machines do much of the heavy lifting and sub-portions of problems are handled by quantum machines. This capability is expected to initially be available in the cloud - Quantum Computing as a Service - which will lower the barrier to entry and provide an ability to quickly climb the learning curve.

As with all disruptive technologies, quantum computers are both an opportunity and a threat, and Nasdaq is doing R&D to understand their impact on financial services. Our analysis indicates that concerns about quantum computers disrupting existing security solutions are real, and the time to prepare is now. Moreover, programming of quantum computers requires a significant learning curve and a different technical skill set. Finally, there is a need to identify business solutions and design quantum algorithms to solve them.

UI/UX and VR/AR are improving productivity and the customer experience.

Financial firms, as well as companies in other industries, are allocating significant resources to improve the online presentation of, and interaction with, their products. To this end, they are investing in User Interface (UI) Design technology to improve the look of their site and User Experience (UX) Design technology to improve how the site works.

There have been major advancements in UI and UX over the last 10 to 15 years. Several frontend frameworks compete with each other nowadays, although JavaScript is among the most popular ones. Many products that were initially developed for commercial use are now open source, and this has accelerated adoption. React, Vue.Js and AngularJs are examples of this trend. They make applications faster, more attractive and user-friendly, and designers have to write less code.

The UI/UX design process has been taken to the middle tier instead of full-stack development where the front end would be connected to the back end, and debugging was a challenge. Designers are using Single Page Applications (SPAs), which load a single HTML page and dynamically update that page as the user interacts with the web app. There is no need for constant page reloads, it is mobile responsive, and multiple teams can work on it simultaneously.

With componentization in the JavaScript framework, multiple teams can work on different components of an application at the same time, and a common component can be reused by different applications.

The JavaScript frameworks were initially created for the web development, but now they are extended to support building native mobile applications. Many companies have built their entire mobile applications using a JavaScript framework to further reduce the cost and accelerate the development. Further, these component-based frameworks support serverless application development running in the edge.

These advancements in UI/UX have improved performance and enabled more consistency, resulting in higher employee productivity and a better customer experience. Yet this comes with some challenges. Transforming legacy products into the new way of doing development involves a multi-disciplinary

team and a different mindset. Moreover, the toolsets change constantly, so firms need to be very adaptable and create a flexible, evolutionary architecture – thus the shift toward microservices. The emergence of Web Component standards is making it possible to simplify composing applications from microservices and enabling User Interface as a Service architectural models, which can help further facilitate reuse.

Companies are also experimenting with virtual reality (VR) and augmented reality (AR) solutions to develop marketing applications that bring experiences to life. Inexpensive solutions such as Google Cardboard can be used to create 360-degree videos, which bring a whole company into the emotional IPO Listing experience, for example. Microsoft HoloLens and Unity could enable users to more deeply and efficiently explore datasets. In 3D, users can experience another dimension of complex datasets and explore them in new ways to drive new insight.

UI/UX and VR/AR offer huge opportunities for innovation, and it will be an exciting space to watch over the next few years.

Conclusion.

Financial firms are leveraging innovative and potentially disruptive technologies to increase efficiency, reduce costs, enhance security, improve the customer experience, generate revenue and facilitate regulatory compliance. Many of them are already building cloud, machine learning and AI, blockchain and cybersecurity technology into their strategy. They are actively participating in industry working groups to figure out how they can make the best use of technology, and ensure their implementations comply with regulations. They are looking toward other industries for fresh ideas about how to leverage technology to achieve objectives. Moreover, they are following developments in emerging technologies such as quantum computing with a view to implementing them when and if it makes sense. It is fascinating to watch these technologies converge into the solution for the future.

In 2019, we will continue to roll out the Nasdaq Financial Framework and evolve our core products that are already running at over 250 market organizations globally. We look forward to partnering with market participants, issuers, regulators and other technology companies to create a stronger, more efficient and transparent capital market ecosystem ready for change.