Citi GPS

DISRUPTIVE INNOVATIONS V

Ten More Things to Stop and Think About

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DISRUPTIVE INNOVATIONS V

Ten More Things to Stop and Think About

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As we worked this summer to start putting together our fifth edition in the Citi GPS Disruptive Innovations series, there was a concern that the entries we were receiving didn't have that "wow" factor that we felt in prior years. So we re-thought and cast our net wider, and put a new slate together. But for some reason, we still couldn't muster up a load of excitement. Mildly dejected, we started to speak to people outside of our circle and that's when we had an 'aha!' moment and realized that over the years we had immersed ourselves in so many publications and websites that much like 'innovation junkies', it was taking more and more for us to get excited about things that could be disruptive and change the future. Looking at our list with new eyes — more like the ones we had when we started this series five years ago — we now have here what we think is thought-provoking and fantastic.

Imagine going to the doctor and having a routine blood test that can scan your body for cancer tumors. Or being told that your child was born with a genetic disease but then finding out it can be 'cured' by injecting a virus which can edit the defective gene. Both of those things are possible in the near future with the advent of liquid biopsy techniques and CRISPR-based gene editing.

In transportation, robotic piloting in commercial jets could mean that your flight is unmanned and that the days of your plane being delayed because the pilot is stuck in traffic on the way to the airport are long gone. Or maybe you don't want to take that short-haul flight at all, and instead could jump into a Hyperloop pod that shoots you 700mph in a vacuum tube to your destination. Artificial intelligence-piloted planes and Hyperloop systems could be the driver of new transportation modes.

In financials, it seems like there are new breakthroughs in FinTech almost every day. The same is true for Internet of Things (IoT) where a positive environment is emerging as the number of connected devices is increasing and high-speed bandwidth is being widely deployed. We look at how adding a payments layer to any IoT construct helps the proliferation and monetization of IoT use cases. Blockchain — primarily known as the basis for cryptocurrency — could soon be used to change how we trade physical commodities, but also how our local electricity market operates. And in an attempt to take back share from passive managers, active investment managers are disrupting their pricing models by considering a performance-oriented fee structure.

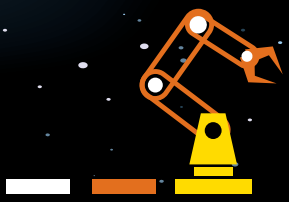
Robots designed to replace humans through the automation of factory floors has been a trend for a few years, but new developments in end-of-arm tools for robots which aim to mimic the function of the human hand could mean that we will see robots performing a new range of jobs and functions. On the flip side, new low-code development platforms are coming that will facilitate the rise of the "citizen developer" who can create software applications for the business world without the need of a traditional software developer and thereby bridge the gap between the supply of developers and the demand for application development. Finally, we look at the next generation of tobacco — Heat Not Burn tobacco — which gives the user the enjoyment of a traditional cigarette without the smell and harmful smoke.

And we start it all off with a look at what big companies can do to transform themselves into innovators. We hope you find these 'Ten More Things to Stop and Think About' as exciting as we do.

A Galaxy of Opportunities

Heat Not Burn Tobacco
Heat Not Burn products provide the taste of tobacco without the smell and harmful smoke

Unmanned Commercial Aircraft
The deployment of robot pilots on commercial flights could improve the safety record, profitability and efficiency of the airline industry



Smart Robotic Tools
End-of-arm tools that mimic human hand capabilities could change how robots are used

CRISPR-Based Gene Editing
Still in its infancy, the worldwide CRISPR technologies market is expected to grow to ~$10 billion by 2025

The Rise of the Citizen Developer
Low-code development platforms enable "citizen developers" to build professional-grade applications with little formal software development training

Passive Investing and New Pricing Models
Sliding management fees based on relative performance could help active managers compete against the growing popularity of passive funds

Hyperloop
A system of vacuum-sealed tubes are planned that can propel capsules with people or freight up to 760mph – faster than air travel

Internet of Things Payment
Adding a payments layer to IoT applications helps in the proliferation and monetization of IoT

Blockchain and Commodities
Trading of physical commodities and electricity markets could be significantly changed by the use of blockchain

Liquid Biopsy
Liquid biopsy could be a $10 billion+ market over the next decade as one of the most important clinical advancements in cancer detection

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The Big Company Innovation Dilemma

Can Big Companies Innovate?

Nathan Furr
Assistant Professor of Strategy, INSEAD

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Nathan is a recognized expert in innovation, entrepreneurship, and value creation, co-authoring *The Innovator's Method* (Harvard Business Review Press, 2014) and *Nail It then Scale It: The Entrepreneur's Guide to Creating and Managing Breakthrough innovation* (NISI Institute, 2011). His articles appear in *Harvard Business Review* and *Sloan Management Review*. In addition, Nathan contributes to *Forbes, Inc.* and other magazines on issues of innovation, value creation, and technology strategy.

Can big companies innovate? On the one hand, the roster of big companies that failed to innovate is long: we remember the fall of major titans like Kodak, Palm, Nokia, Atari, Polaroid, and others. On the other hand, the drum beats of disruption have become so all-consuming that it can be easy to forget that some big companies have reinvented themselves — companies like IBM, 3M, Netflix, The New York Times, ING, Vanguard, and Microsoft, among many others. Moreover, some companies retain their innovation capabilities from the start — giants like Amazon, Salesforce, Google, and others — are still innovators, creating impactful new products and services despite their size. Even more intriguing, some large companies have managed to regain their innovation capabilities, after losing them, including examples like Microsoft, Intuit, Procter & Gamble, and even Apple which was once pegged for imminent collapse. So what then separates the innovators from the non-innovators?

For the last fifteen years, I have been studying how established companies can innovate, whether responding to digital transformation, reinventing their core business in the face of disruption, or simply renewing themselves ahead of competitors. What I've discovered is that we all operate based on a set of myths that misshape the truth about innovations. Sometimes these myths are about the size of the company, sometimes they are about our own capabilities, but in each case these myths are built around a story that some people, or companies, are just special while the rest of us cannot innovate. But in each case, research reveals that what separates the innovators from the non-innovators is not who they are but what they do. At the risk of over-simplification, what separates out the large company innovators tends to fall into three categories: people, process, and philosophy (a catch-all that includes culture, leadership, and other organizational issues). Let me briefly summarize this research, trying to be specific but concise.

People

We often tell ourselves we need new people to respond to the waves of digital and technology. Clearly we need to recruit capabilities for a digital world — analytics, coding, and related activities — or the related disruption we face. But when it comes to innovation, big companies have far more innovation talent than they realize. Research in psychology reveals that creativity is only 33% genetic and that creativity can be increased about 30% on average just by explaining the elements of creativity to a participant. In my early research on what makes innovators like Elon Musk or Jeff Bezos creative, we discovered five key behaviors that separate these people from others.

These individuals:

1. constantly associate disparate domains,
2. question the status quo,
3. observe familiar settings to spot new problems,
4. follow their intuition to experiment in their lives, and
5. network to get ideas, not resources.

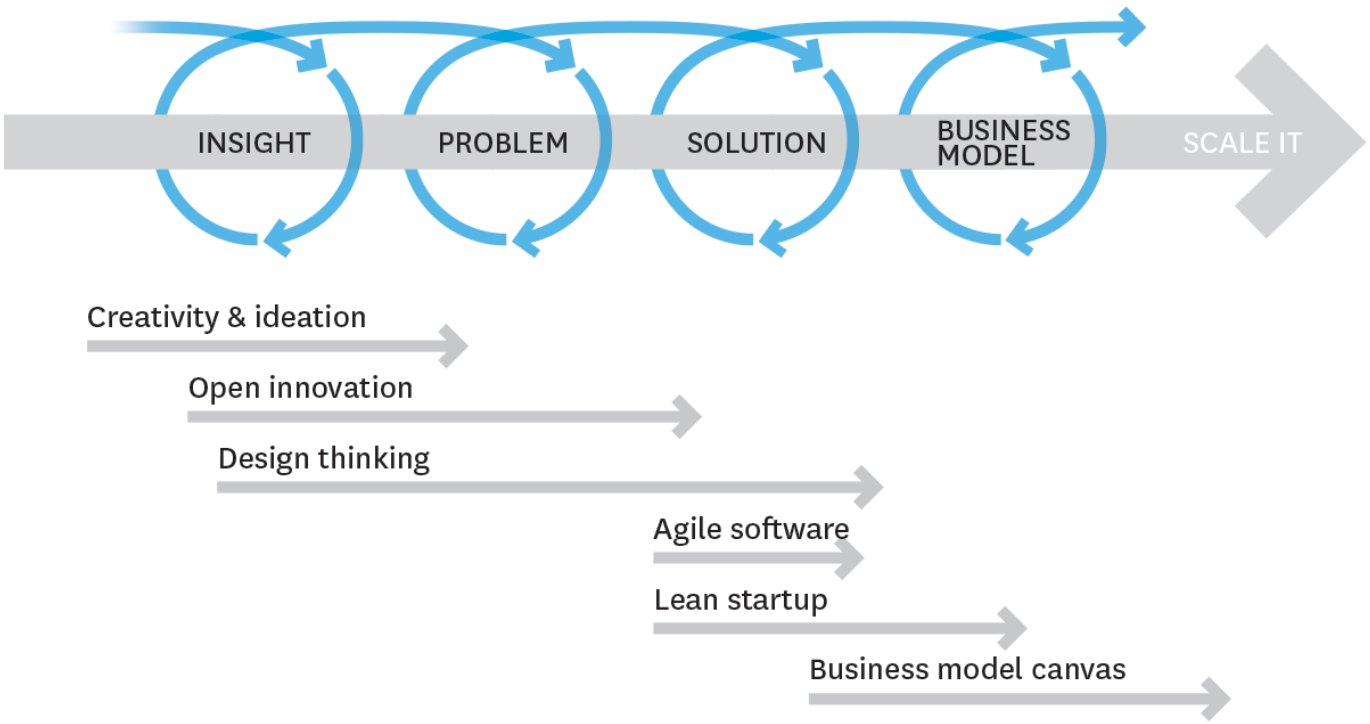
Said out loud it seems simple, but in my work I teach people how to practice, get better, and most importantly, spot the people in their organization who are already good at these things and set them free.

Process

Established companies that successfully innovate also work in different ways than those who do not. Sometimes these innovators have embraced a framework you may have heard of, such as design thinking, lean start-up, agile, or business model innovation. You may have even wondered which one is the "right" framework. The answer, frankly, is none of them. Although they all reveal something crucial about the innovation process, they are all simply different lenses on the same problem. Most big companies that adopt one, soon find they need to adopt another to fill in the missing gaps. In my research (summarized in the Harvard University Press book, *The Innovator's Method*), I synthesized these many frameworks to describe the underlying process, identify where big companies get stuck, and suggest tools to overcome these bottlenecks.

The process itself is quite simple (see Figure 1), but the magic comes from understanding how to avoid the most fatal traps. The first, may be resolving each of the elements — problem, solution, and business model before scaling up the project, perhaps the biggest source of failure in big companies obsessed by scale. But we also stumble, failing to understand the real problems we are solving (70% of corporate initiatives fail because they do not first understand the problem they are trying to solve) or because we don't truly understand the power of descoping to create radically simple minimum viable prototypes. By applying the right process, I've seen big companies turn around their innovation capabilities.

Figure 1. The Innovator's Method



Source: Nathan Furr

Philosophy

Lastly, big company innovation happens in a context—in an existing culture and structure which tend to choke innovation to death. But established company innovators tend to perform four roles well—they complement their core business activities with being the chief experimenter, architect, venture capitalist, and catalyst of innovation. Let me focus on two ideas. First, rather than seeing yourself as the chief decision maker, whose job it is to make the call or lay out the path for others to follow, innovators recognize that when they face the uncertainty of innovation, transformation, or disruption they need to become the chief experimenter. Trying to predict the future when you are in the fog of the unknown almost inevitably spells disaster because you are bound to be wrong. Scott Cook, Executive Chairman of financial software company Intuit, describes this as the moment that he realized he was not Steve Jobs … nor did he have to be. Instead, when facing uncertainty, leaders can apply what Scott Cook characterizes as "a new kind of management where instead of seeing the boss's role as the Caesar, the boss's role is to put in place a system whereby junior people can run fast and cheap experiments so ideas can prove themselves." Although it sounds simple on the surface, this represents a profound change in how you lead into the unknown.

The Bigger Picture — The New Science of Managing Innovation

As the world becomes more dynamic and uncertain, increasingly executives are feeling the demand for new ways of managing. Whereas a company making it into the S&P 500 in the 1930s could expect to be among the industry titans for 75 years, today a company joining this group can expect to endure their time on the throne for just 12 years. Our more familiar classical management tools, built in response to the demand for optimization following the industrial revolution, need to be complemented with tools to achieve our most critical tasks today—seeing and creating the future. Many of these tools have been developed only recently, some remain to be developed. But one could say the dynamic world in which we live needs an innovation school, to complement the business school (see Figure 2). Using these tools you too can invent the future, not just watch it erode the foundation on which you stand.

Figure 2. Classical Management vs. Innovation

	B-School (traditional management)	I-School (entrepreneurial management)
Core Focus	Execute in certainty	Experiment in uncertainty
Strategy	Protect existing resources Leverage existing resources Sustain competitive advantage	Circumvent resources Discover or build new resources Temporarily ignore advantage
Organizational Behavior/HR	Hire experts (I-shaped people) Hire for divisional roles Hierarchical organization	Hire generalists (I-shaped people) Hire for multifunctional roles Flat organization
Leadership and teams	Vertical team Manager-supervisee structure Maximize and optimize	Horizontal team Peer group structure Minimize and suffice
Operations	Efficient routines for execution Longer cycles Avoid errors	Flexible routines for search Radically short cycles Embrace error
Marketing	Full-featured, appealing product Quantitative market segmentation Build and protect brand	Minimum feature set product Qualitative customer interaction Temporarily ignore brand
Finance and Accounting	Marginal cost logic Fixed costs to lower average cost	Full cost logic Avoid fixed costs to be flexible

Source: Nathan Furr

Blockchain in Commodities

Revolutionizing the Physical and Financial Trading Commodities and Electricity

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Blockchain can be a substitute system that is cheaper, faster and more secure than traditional organized trading exchanges

Blockchain is best known for being the underlying technology of cryptocurrency Bitcoin. It works basically as a distributed ledger that records ownership assets through a shared registry, a copy of which is held by every entity in the network. This distributed ledger is different from a traditional market trading exchange, where a centralized ledger is maintained by a trusted third party which records, validates, clears, and guarantees the transactions. Another type of blockchain technology is an open software platform that came out of the Ethereum project, which incorporates smart contracts. A smart contract essentially involves an "if/then" process that, if A were to happen, then B would execute automatically. For more on the concept, please refer to the following reports: "US Digital Banking: Blockchain" and "Digital Disruption: How FinTech is Forcing Banking to a Tipping Point."

Given its characteristics, blockchain looks to be especially well-suited to revolutionize both physical commodity trading and the entire electricity sector (among other potential applications) by eliminating the function of organized trading exchanges and substituting it with a system that is cheaper, faster, and even more secure in diminishing counterparty trading exposures, including for banks.

Physical commodity trading — the oldest form of world trade and trade finance in the largest trading sector in the global economy — could be vastly changed by the introduction of blockchain technology by sharply reducing the amount of required processing and confirmations and significantly reducing the working capital required to facilitate trading. Additionally, blockchain could also upend the centralized control of electricity by local utilities. This is an especially important area as more of the energy sector is being electrified — cars, individual homes, commercial space, and factories — through self-generated or "distributed" energy, and as consumers become 'prosumers' because buildings and vehicles with surplus electricity gained via solar and energy storage can sell it to others in competition with central grid operators. The distributed nature of blockchain would allow electricity to trade or flow between buildings or local areas. Other areas of commodities could also potentially benefit from moving toward a blockchain-enabled environment.

Key Success Factors

Although blockchain is designed to deliver several benefits over existing solutions, such as the elimination of a trusted central authority, a few factors could determine whether blockchain will be a success:

- **Cost reduction:** In commodity trading, the elimination or reduction of various processes, procedures, and systems involved in know your customer practices, verification of credit-worthiness, payment, quality, and shipments are critical. Some financial participants estimate that the time involved in processing using blockchain would fall by 90% or more.
- **Reduction of working capital:** With blockchain, the capital tied up during the shipment of commodities would fall significantly, impacting buyers and sellers as well as bank intermediaries providing trade finance.
- **Network effect:** The more counterparties embrace blockchain, the bigger and more efficient it will become. The reduction in processing effort and working capital could help tip the scale, encouraging more market participants to join.

- **Reducing entry barriers:** In both physical commodities trading and the integration of distributed energy resources (DERs) in electricity markets, if blockchain can accommodate small players, especially in the case of DERs, then the system could become truly decentralized. In some ways, blockchain could make markets more transparent and capture the growing universe of DERs as a portion of DERs, because of their off-grid nature, currently aren't monitored. As explained below, grid operators, using blockchain, could bypass aggregators that bundle DERs together.

Physical Commodity Trading and Storage Finance

Process

Blockchain makes it difficult to counterfeit transactions

Since blockchain records every transaction and every distributed ledger in the blockchain receives a copy of the transaction, it becomes extremely difficult to counterfeit transactions. In a blockchain, each step of the transaction is recorded in unalterable blocks in the smart contract.

The bundling of each step of the process in physical commodity trading via blockchain would increase efficiency

In physical commodity trading, for example, a bank could issue letters of credit for a buyer of a commodity, while the seller and its bank could issue an invoice, all included in a smart contract in a blockchain. The midstream or shipping company would then electronically record the shipment, where inspectors, if necessary, would be on hand to examine the quality of the commodity shipments and certify it in the smart contract. For transactions involving shipping, a bill of lading, including information on the shipment itself, serves as a certificate of origin. Once the commodity is delivered, the buyer would make payment and receive title of the commodity after verifying various documents in the smart contract in the blockchain. Each step in the process requires multiple verifications, exchanges of papers, signatures, and other steps that are generally done in a slow, opaque manner, subject to delays and forgery. Blockchain bundles it into one system where each barrel of oil, for example, would have a digital code, each point of sale would be recorded and the list would be encrypted but verifiable by different counterparties.

Storage finance would benefit from the same streamlined impact and double-checks against fraud

By extension, the same streamlined impacts and double-checks against fraud would apply to storage finance, the heart of commodity finance. From the processing perspective, storage finance differs little from trade finance, with the primary variant being that stored goods can provide an element of securitized finance from the time of storage to the release from storage. Blockchain could prevent use of the same inventory for double lending and would reduce significantly the risks for banks associated with storage finance.

Use Cases in Physical Commodities Trading

Experiments using blockchain in physical commodities trading are already in the works

Major energy companies and trading houses are already experimenting with blockchain. Trafigura used blockchain to simulate their oil trading deals. Mercuria sold African oil to China. Cargill and Louis Dreyfus, major agricultural commodities traders, have been testing the use of blockchain in agriculture trading. BP, along with Wien Energie and Eni Trading and Shipping, tested an energy trading platform using blockchain as an underlying technology. BP's head of technology spoke of the competitive advantage it would have with blockchain with the speed and verification of transactions, not only in trading but also inter-company payment settlements. The Royal Mint in the U.K. and CME could start to issue digital certificates for physical gold. Citi Commodities just announced its participation in a blockchain as well.

Concerns

Concerns include bait-and-switch on quality in a trade and counterparties not wanting to be 'credentialized' to join the blockchain

Two concerns with blockchain in commodities are (1) the bait-and-switch issue of exchanging a higher-quality commodity with a lower-quality one in the physical world and (2) certain counterparties may not want to be "credentialized" to join the blockchain, such as when production or consumption comes from conflict zones. On the first point, the bait-and-switch issue already exists in the current world of commodity trading. To combat it, as discussed above, counterparties put in lots of work in know your customer exercises and employ inspectors to check on the qualities of the commodity delivered. Smart contracts could reduce the work involved. On the second, if a party decides to opt out, then it could suffer from selling its commodity at a discount, or buying a commodity at a premium, because of the extra processing and due diligence work required of a credentialized counterparty.

Finally, various legal authorities would have to become comfortable with blockchain-based transactions utilizing smart contracts, given various jurisdictions that would be involved. But as a first step, some parts of the system could be digitalized with a common standard and common input/output for market participants. For example, the International Electrotechnical Commission (IEC) has established a number of standards relevant to smart grids. The IEC 61850 standard on Power Utility Automation defines the common communication between intelligent electronics devices in the substation and the related system requirements. Data models described in this standard can be mapped to web services as well, where different electronic devices can communicate with each other.

Electricity

Increased EV use and a shift to a more distributed model in electricity generation are leading to the system moving to a more decentralized grid

The electricity system is undergoing a transformation from being a centralized grid to being a decentralized grid due to (1) the increase in electric vehicles (EVs) which require charging and potentially release electricity and (2) the shift in electricity generation to a more distributed model with an increase in rooftop solar and building-level energy storage solutions as well as distributed wind systems. Managing this multi-way electricity flow and trade could be a daunting task for utilities, but blockchain could be used to facilitate EV charging and enable electricity trade to occur not just at a regional level, but also at the local, or even building level.

'Prosumers', i.e., consumers who don't just consume electricity but can also supply it back to the grid, could eventually "trade" energy with others in the form of "transactive energy." Utilities are already developing ways to value these distributed energy resources (DERs) at the neighborhood level; and the value of electricity would differ depending on locations and also usage in order to value ancillary services.

Transactive Energy could become a possibility with a truly integrated smart grid

The vision to have a truly integrated smart grid requires a key element: pricing. From the GridWise Alliance: "Transactive Energy refers to techniques for managing the generation, consumption, or flow of electric power within an electric power system through the use of economic or market-based constructs while considering grid reliability constraints… An extreme example would be a literal implementation of 'prices-to-devices' in which appliances respond to a real-time price signal." Some smart grid vendors, such as Siemens, already offer software that both manages and operates assets and forecasts demand, with the embedded capability to support energy transactions, meaning transactive energy could become a possibility. This could lead to a reduction in the need for new large physical power plants and infrastructure in the future.

Use Cases of Blockchain in the Power Sector

1. Share&Charge is a blockchain-based EV charging network, first started in Germany, where EV-owners can charge their vehicles at any charging station and the costs will be transferred from their 'Share&Charge' wallet to the owner of the charging station. This reduces the barrier to entry for charging "stations" or "spots," as any spots can join the blockchain network to sell power to EVs. It is similar to any decentralized platform, but now transactions can be standardized.

2. Grid operators could use blockchain at both the wholesale level and at the local level to bypass energy aggregators that aggregate DERs, such as smart appliances, residential solar, and battery storage. Ponton Enerchain is developing a wholesale energy trading platform with participation from a number of firms, including Enel, E.ON and Iberdrola. With more DERs, grid operators face issues managing and trusting data from numerous DERs. An aggregator's role is to manage retail customers and act as the middleman for grid operators. With blockchain, as the data are verified on the blockchain and is immutable, grid operators can trust the data. With blockchain's supposedly immutable record, customers can also see how their devices were used and compensated within the grid.

3. At an even more local level, blockchain could enable peer-to-peer energy trading. Some industrial parks in China are already experimenting with this. New York is also at the forefront of this development through its 'Reforming the Energy Vision' (REV) regulation, where one aspect involves utilities becoming a platform provider for DERs to trade on. One of New York's ex-public utility commissioners pointed out that blockchain could facilitate REV. ANew York utility, ConEd, is currently coming up with ways to price the value of particular generating and demand response resources down to the micro level. Another company, LO3, is conducting an experiment in both Brooklyn and Australia using blockchain as a basis for local electricity trading.

Concerns

Blockchain is not for everyone and for everything. There are existing systems that could very well be as or more efficient, without having to redo the entire infrastructure based on blockchain. One example is the SWIFT payment system. One key limitation of blockchain is its mechanism to verify transactions, as exhibited in the long confirmation time of bitcoin transactions. Blockchain uses a "proof-of-work" system to maintain its security, whereby different nodes compete to be the first to solve a sophisticated cryptographic problem. The process is highly time and energy-intensive and is not well-suited if there are many devices connected and ready for transactions. Different companies and startups are developing different approaches, including proof-of-stake that involves a more randomized process.

Business Models to Change

The impact of blockchain varies by sector but could be negative for utilities if it facilitates the trading of electricity at the microgrid level

The use of blockchain is likely to lead to a change in business models, subsequently leading to the creative destruction of certain sectors. Utilities, for example, could become distribution service platform providers for DERs, as New York State is already envisioning; technology companies could provide energy network optimizing software or even operate platforms; energy companies that transition to providing services could become asset-light, as they would be able to control how energy is routed and optimized; third-parties or homeowners would become energy providers through DERs; and car companies could become service and energy providers.

For the utility sector, generally, the impact from blockchain looks to be mostly negative. If blockchain technology can be used to efficiently provide price signals to facilitate the trading of electricity at the microgrid level then we think it is a potential negative for utilities.

- Peak load can flatten as individual users have the right price signals to vary their consumption and utilize storage. This flattening of peak load will reduce the profitability of utility investments by undermining peak pricing at peak use hours; hence it would reduce the magnitude of investments in the grid, effectively slowing utility growth.
- Risk of stranded assets could increase as blockchain could hasten the penetration of DERs. Utilities may need the protection of improved pricing structures like net metering and fixed charges. However, blockchain technology could bypass utilities and net metering policies by facilitating trading at the microgrid level without the need for involving a utility at all.
- Future investments in the grid might move to private companies as eliminating a utility from the DERs price formation weakens their claim to these investments.

The Rise of the Citizen Developer

The Citizen Developer: Catalyst for the 'Software-ification' of Everything

Walter H Pritchard, CFA
U.S. Software Analyst

A group of savvy business users is transforming how software is developed. This group, known as "citizen developers", is empowered by a growing set of technologies known as "low-code" tools. Low-code development platforms enable Citizen Developers to build professional-grade applications with little or no formal training in traditional software development.

The rise of the citizen developer opens up untapped development manpower, several orders of magnitude larger than the existing population of professional developers. We expect the low-code development trend will have a significant impact on driving the next wave of software applications over the next half-decade or more. This will likely bring commensurate increments in business productivity, just like we have seen with the applications written by the professional developers. The world's demand for automation through software (which we refer to as "software-ification") is insatiable and we expect the citizen developer is a key enabler to fulfill the proliferation of software-ification.

Software as a Historical Enabler

Software applications allowed more business processes to be automated

For decades, the benefit brought by computing precipitated demand from the business to automate more and more business processes with software. For example, early applications that controlled critical business functions such as automating customer billing and writing financial transactions to the general ledger drove significant initial value. This whetted the appetite for departmental applications such as customer service interaction tracking or analysis of customer spending patterns. Software applications within companies multiplied from 10s to 100s to 1000s through a nearly insatiable demand by the business for software-enabled automation. At the same time, there have been governors limiting the pace of adoption of these applications and technologies, more generally.

The high cost of hardware initially limited the pace of adoption of software-enabling automation

First, the cost of hardware was high, with the first computers costing tens of thousands of dollars (in 1960s dollars). Since then, the price of hardware has come down and, more recently, the cloud has enabled organizations to rent a slice of a computer for as little time as needed. This has eliminated hardware cost as the key rate limiting step in deployment of software applications. Instead, the spotlight for some time has been on the limited set of highly-trained, professional developers, who possess the technical skillset to build applications in a programming language of their choosing.

Shortage of Developer Talent and Training is Significant Barrier

Scarcity of software developers is the rate-limiting factor governing the proliferation of software applications

As hardware has become ever cheaper, especially with the increasingly mainstream adoption of cloud computing, the rate-limiting factor governing the proliferation of software applications is developer talent and training. Software developers generally have at least four years of college education in electrical engineering or computer science and the most productive individuals have significant on-the-job experience. As a result, their numbers are relatively scarce with estimates ranging from 11 million to 21 million professional developers worldwide. This compares to ~750 million users of Microsoft's Excel product.

Citizen developers could help bridge the gap between the supply of developers and demand for application development

We see the "citizen developer" trend advancing significantly to help bridge the present gap between supply and demand in developer resources. Gartner predicts that demand for application development will grow five times faster than the related IT capacity through 2021. There are various estimates that suggest that reduction in application development backlog is a major IT goal — according to an OutSystems survey, 62% of IT managers' report backlogs and 9% of all IT managers report 10 or more projects stacking up.

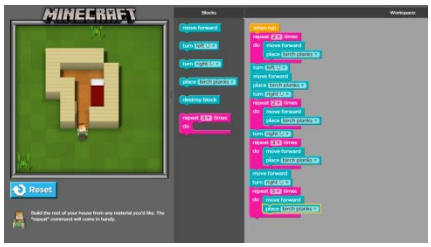
Low-Code Platforms: Democratizing Application Development

Low-code platforms are characterized by intuitive "drag and drop" assembly software

Ease of use defines high-productivity platforms and has led to their proliferation. They deploy a user interface (UI) based on the "what you see is what you get" (WYSIWYG) principle – enabling a highly intuitive "drag and drop" assembly of software. In the historical realm, high-productivity platforms offer yet another, nearly complete layer of abstraction of computer code. While these platforms are actually assembling traditional software code beneath the abstraction, the citizen developer is not made aware of this complexity. In fact, frequently the application is fully developed and deployed without the underlying code having to be examined at all.

While not a high-productivity platform, Microsoft's Minecraft video game illustrates well the technique that is applied in high-productivity platforms. Figure 3 shows Minecraft's user interface — visualization in the form of building blocks is used to transform the code underlying the game's structure. It is analogous to the structures that professional developers apply to structuring their code. Figure 4 shows an example of an actual user interface in a no-code environment by Harmony Platform. The flow chart constitutes the design for a simple mobile phone application. It is assembled in a web browser by dragging and dropping elements into a flow chart-style workspace.

Figure 3. Sample Microsoft Minecraft User Interface



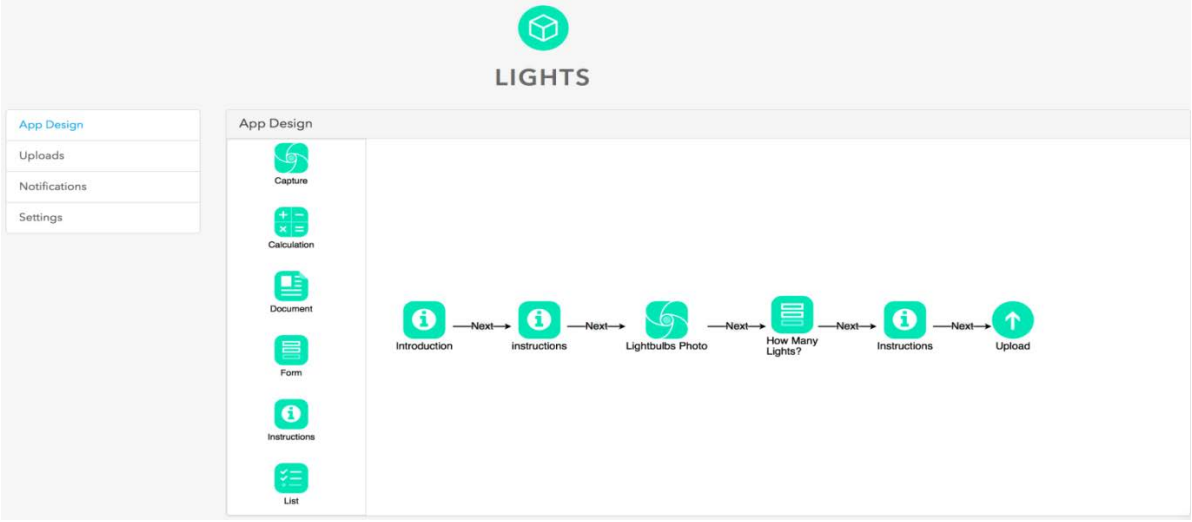
Source:https://siliconangle.com/blog/2015/11/16/microsoft-and-code-org-use-minecraft-to-teach-kids-how-to-code/

Historically, there have been several evolutions in underlying technology that have been precursors to the creation of the low-code application development platform:

- **Object-oriented development**, such as Java, created re-usable software components that were assembled into applications. While these components or objects were created and manipulated by professional developers, the model later built on with Citizen Development.
- **Enterprise mashups**, which rose in the early 2000s enabled the relative ease of combining of simply abstracted components into an application. Examples here included overlaying traffic data and route optimization algorithms on a map to create modern driving applications such as Google Maps.
- **Agile development**, beginning in the late 2000s, brought a culture of more rapid software development cycles and 12-week "sprints" as part of a developer process that focused on rapid iteration between software developers and the business. This set the stage for the business to be more closely integrated into the development process.
- **Application platform-as-a-service (aPaaS)** in the 2010s has enabled developers to create applications on top of highly variable cloud platforms where developers and production owners of an application only pay for what they consume. Most of the low-code platforms we see today are mostly used (although not exclusively) on the public cloud.

- **Propagation of public APIs**, also in the 2010s, has made it easier for any developer to bring together various cloud services, including those that abstract away the complexity of code. For example, data feeds like weather, market data, and industry-specific information (natural resource data, retail sales, healthcare data sets, etc.) and application logic can be connected in standard ways. The success of most low-code platforms is dependent on their ability to help easily manage and incorporate application programming interfaces (APIs). Note that we highlighted the public APIs in the 2015 Citi GPS Disruptive Innovations III report.

Figure 4. No-Code User Interface for a Simple Building Maintenance Mobile Application (Courtesy of Harmony Platform)



Source: Harmony Platform

Forrester estimates that there are currently over 40 high-productivity platforms that fall into the purview of low-code. We see low-code platforms democratizing the development of customer software applications, much like what Software as a Service (SaaS) did for pre-built "packaged" software applications. SaaS was a topic highlighted by us in the 2013 Citi GPS Disruptive Innovation report.

Low-Code Market is Early, But Early Use Cases Are Showing Clear Value

Over time, we expect there to be consolidation and a set of platforms that hit a sweet spot of business and IT users, as well as covering a wider range of user cases

While we believe this trend to empower the citizen developer is early, there are a number of promising use cases. We note that these generally fall into three categories: (1) event-driven response tools (simple workflow-based apps), (2) data access and visualization tools (to put data in the hands of all information works to make decisions), and (3) customer-facing solutions.

Additionally, low-code platform vendors can be broadly classified by whether they address a singular or a wider range of use cases and then whether they appeal more to business users or to those that have been trained in some software development.

We expect the market will initially be quite fragmented along these two classifications above, with most platforms starting out appealing to business users who focus on a singular use case or else IT managers who support a wide range of use cases (although not necessarily have particular merit in any given vertical or application type). Over time, we expect there to be consolidation and a set of platforms that hit a sweet spot of business and IT users, as well as covering a wider range of user cases.

Business Users Likely to Drive Adoption

We expect business users who saw the benefits of SaaS to drive adoption of low-code platforms

Low-code platforms can significantly accelerate the volume deliverables of software applications for business and reduce backlogs. We expect the business users, who are seeing the benefits of other enablers such as SaaS to drive similar benefit, will drive adoption. Figure 5 summarizes findings on the relative efficiency gains with adoption of low-code.

Figure 5. Low-Code Brings Meaningful Development Efficiencies

Low-code platforms reduction of unfulfilled request backlogs	65%	(QuickBase Survey)
Low-code applications built in less than 2 weeks	53%	(QuickBase Survey)
Average custom-code application development time	>2 months in 67% of cases >6 months in 31% of cases	(QuickBase Survey)
	>3 months in 76% of cases > 1 year in 11% of cases	(OutSystems Survey)

Source: QuickBase 2016 survey based on 205 customers and 153 non-customers attending the company's 2016 EMPOWER conference. OutSystems 2017 State of Application Development Report survey of 3,200 IT professionals

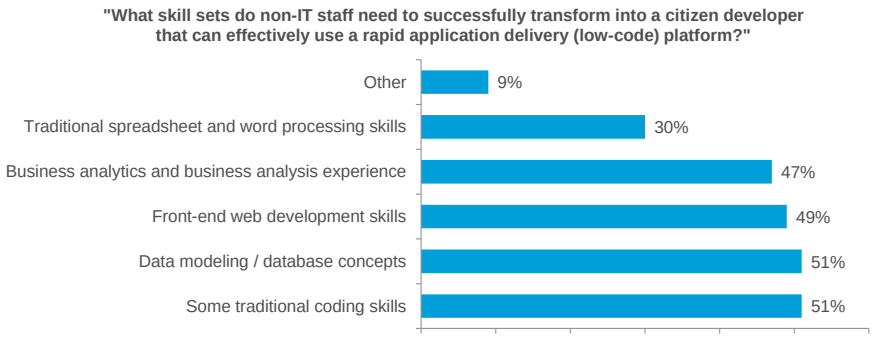
Citizen Developers: The Masses Enable the Next Wave of Software-Driven Productivity

The skills necessary to be a citizen developer often equate to those needed to operate a suite such as Microsoft Office

Citizen developers tend to be tech-savvy business users who have at least general knowledge of the categories of components that constitute an enterprise application. The skills necessary to operate low-code platforms often equate to those needed to operate a productivity suite such as Microsoft Office, as well as only basic understanding of data queries. We note estimates for Excel users (although this includes simpler users and consumers) of over 750 million, which is more than two orders of magnitude greater than the estimate for the number of professional developers.

Initial citizen developer projects usually address the most urgent pain-points in their business organizations. Over time, their focus eventually shifts to additional projects and they increasingly exercise their creativity to develop applications in new areas for proactively improving business efficiency.

Figure 6. Citizen Developer Skill Sets



Source: OutSystems and TechValidate 2016 survey of 200 enterprise IT professionals and executives who use OutSystems Platform ("Heroes or Villains? How IT Sees Citizen Developers")

Much of the value contributed by citizen developers will come in freeing up IT resources who would typically be involved throughout the lifecycle of an application

While citizen developers are usually able to begin work from scratch, more complex projects require initial preparation by IT personnel. Consultants or internal IT personnel are sometimes responsible for setting up an early version of the application that citizen developers can work on modifying. While citizen developers create new applications, much of the value contributed by them will come in freeing up IT resources that would otherwise be involved throughout the lifecycle of the application. In particular, citizen developers frequently are tasked with updating and maintaining applications in parallel with the shifting business needs. Allowing them to lead these efforts drives additional efficiencies as they eliminate the inefficiencies in iterations in the development process between the business users and developers.

IT Managers: Cautious Proliferators Who Will Be Convinced by Productivity Gains

IT managers tend to coordinate with citizen developers and not allow them to 'go rogue'

While the more romanticized view of citizen developer points to an individual "going rogue" and taking charge of IT efforts through gaining possession of application development, it is seldom the case. Our conversations indicate that deployment of low-productivity platforms is largely fueled by IT personnel who seek to maintain integrity and control over their organizations' IT resources. IT managers tend to coordinate with citizen developers in order to ensure continued data integrity, security, and containment of costs.

IT managers increasingly contend with the advent of "Shadow IT" as business users introduce software tools that risk being ungoverned by the IT organization. In particular, propagation of SaaS tools has increased business-level ability to circumvent IT management. Shadow IT has resulted in relative inefficiencies as tools brought on by business users are poorly integrated.

We expect the IT organization will focus on key differentiating factors between platforms in three areas:

- Breadth of management tools for development, delivery, upkeep, and governance of applications;
- Ensuring built-in support for modern development processes and practices; and
- Support for multiple modern cloud infrastructures, including on-premises environments, to ensure that the organization is not "locked-in" to a particular vendor's end-to-end stack.

Impact of the Citizen Developer Trend on Software and Beyond

We see a number of implications to the software space, the tech sector and, more broadly, all areas of the economy.

Cloud platforms and software development stacks will differentiate based on their support of citizen development

Around software, we believe the modern cloud platforms and software development stacks will differentiate based on their support of citizen development. In fact, we would not be surprised to see the three tier-one cloud players (i.e., Amazon, Google and Microsoft) build or buy into the market with their own flavors of low-code platforms. This is likely to extend to tier-two players such as IBM and Oracle. Similarly, we see players offering PaaS such as salesforce.com and ServiceNow, which have already pushed towards the citizen developer, to expand their capabilities further here and differentiate on this basis. For SaaS players, the same underlying trend towards citizen development has driven adoption in the SaaS category.

At the same time, we expect a lower barrier to building applications “from scratch” to potentially raise the bar for SaaS, as customers have a greater ability to build (with low-code), versus pay for SaaS apps (which can be expensive and, nevertheless, require ongoing configuration resources).

Low-code adoption could drive higher efficiency but reduce the value provided by system integrators and reduce demand for hardware

For the broader tech landscape, we expect that low-code adoption could reduce the value that systems integrators provide, as their scarce skill set is less needed. From a hardware efficiency perspective, as we noted in Quantifying the Cloud - Extending Cloud Workload View to Market Size, Deflation and Sector by Sector Impact, we expect higher levels of abstraction (such as low-code), drive efficiency higher and therefore reduce demand for hardware on like-for-like basis. The by-product of greater efficiency is likely to be elasticity driving more volume and thus the impact on hardware may be difficult to predict.

We expect early adopters of low-code technology to gain competitive advantage over peers

For the broader economy, we expect greater automation to help drive efficiency in business and better returns on labor and capital. At the same time, a by-product here is more competition, as all players in a market exploit this perceived advantage. Thus we expect early adopters of technology (like we have seen in the past), in this case of low-code, to gain competitive advantage over peers.

CRISPR-Based Gene Editing

The Holy Grail of Modern Biomedicine is Here

Yigal Nochomovitz, Ph.D.
U.S. SMID Biotech Analyst

Technology that can permanently change the genetic code of a living organism — including human beings — is upon us. Confined to science fiction until recently, genome editing technology has caught on like wildfire across the biomedical research community since its discovery in 2012. While still early and arguably very risky, the power of the technology cannot be ignored. If brought to market, gene editing has unfettered potential for "one-and-done" cures spanning a broad array of diseases and disease states.

While progress may be gradual and volatile, we expect the new science of gene editing to fundamentally change the way physicians and scientists approach disease management if a "genetic cure" becomes an option.

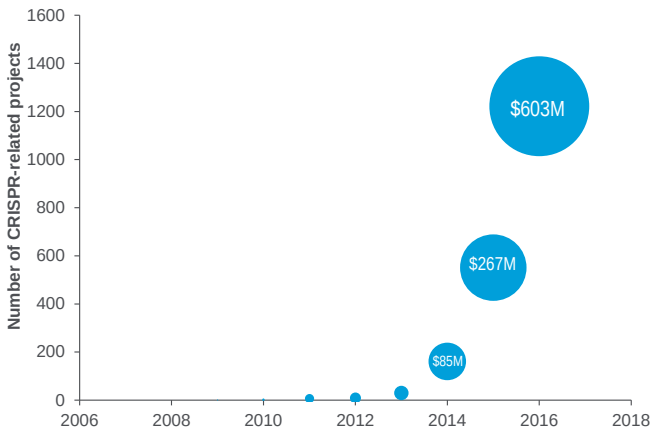
Human genome editing studies are expected to start in the U.S. in 2018

So far, scientists have not only successfully achieved gene editing in simple organisms (bacteria) but notably also in higher organisms, including monkeys, which are closely related to man. Human genome editing studies in the U.S. are expected to start later this year or early 2018, propelled by a wave of newly public companies aggressively developing the technology for human disease.

CRISPR technology is much simpler and has lowered the barrier to entry for biomed labs to engage in gene-editing experiments

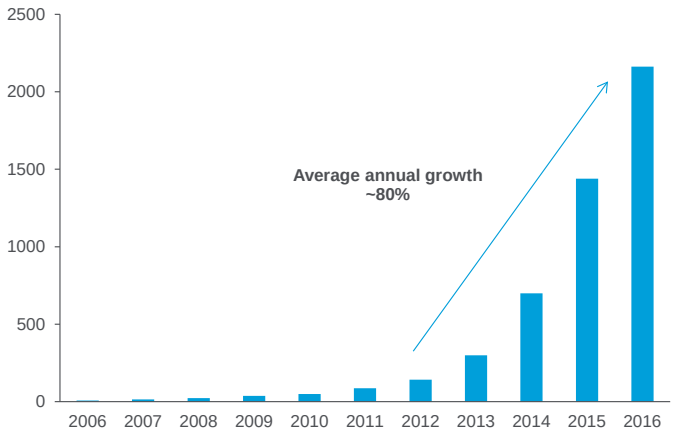
The field of genome editing has rapidly evolved since the discovery of CRISPR (clustered regularly interspaced short palindromic repeats) as a novel genome editing tool in 2012. While there have been prior attempts at gene editing technology (e.g., Zinc Finger, TALEN) they have been cumbersome. CRISPR technology is much simpler and has lowered the barrier to entry for biomedical laboratories worldwide, both academic and commercial, to engage in gene editing experiments, which is accelerating the pace of innovation (see Figure 7 and Figure 8). The shift to CRISPR genome editing and the rapid expansion of its use is expected to have a disruptive and far-reaching impact on multiple branches of science and medicine.

Figure 7. NIH Funding for CRISPR Research Growing Exponentially



Source: Citi Research, M. E. Gallo et al., Advanced Gene Editing: CRISPR-Cas9, Congressional Research Service Report, 2017

Figure 8. CRISPR-related Publications Have Skyrocketed in Recent Years



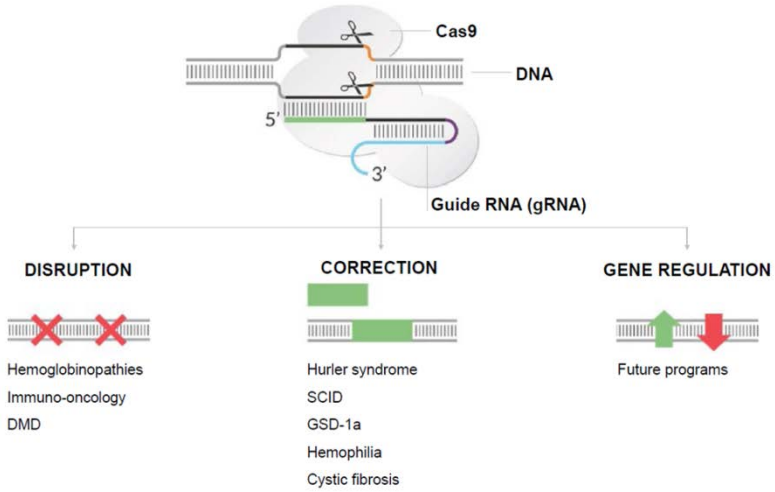
Source: Citi Research, M. E. Gallo et al., Advanced Gene Editing: CRISPR-Cas9, Congressional Research Service Report, 2017

If brought to market, gene editing has unfettered potential for "one-and-done" cures spanning a broad array of diseases and disease states

CRISPR-based genome editing differs from older approaches to gene therapy, which used viral delivery to randomly insert a corrected gene into a patient's genome. Instead, CRISPR is highly precise as specified by a genetic "zip code address" taking the CRISPR machinery directly to the gene of interest. This is a major and unprecedented technological advance.

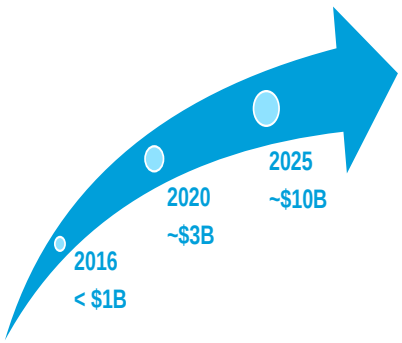
How does CRISPR work to correct a "sick" gene that causes disease?
CRISPR can be leveraged to correct the "sick" gene in one of the following ways (see Figure 9): (1) changing the DNA sequence such that it disrupts and destroys the gene's product if the gene product is the cause of the disease; (2) correcting a target gene by inserting an improved DNA sequence that will allow the gene and thus protein product to function properly; or (3) modifying the target gene's regulation (think of it as the gene's software) by adding or deleting regulatory sequences that either turn on the gene or turn it off.

Figure 9. CRISPR Can Correct a "Sick" Gene That Causes Disease in Three Ways



Source: Citi Research, CRISPR Company Presentation

Figure 10. CRISPR Product Sales Could Reach ~$10B in 2025



Source: Citi Research, Global Market Insights, Grand View Research, NKWOOD Research, Research and Markets

The worldwide market for CRISPR technologies is still in its infancy, but is expected to grow to ~$10 billion in 2025. Currently the CRISPR market is small, with its main offerings dedicated to lab work and scientific research via research toolkits. However, the real economic potential of CRISPR lies with human therapeutics. With CRISPR-based therapeutics having already entered human trials last year in China, the first CRISPR-based medicine could reach the market in ~6 years or less. The market has the potential to grow to ~$10 billion by 2025, delivering an annual compounded growth rate of ~40% (see Figure 10). And if CRISPR gene editing works in early test cases of human disease, the long-term upside for the technology could be much, much greater.

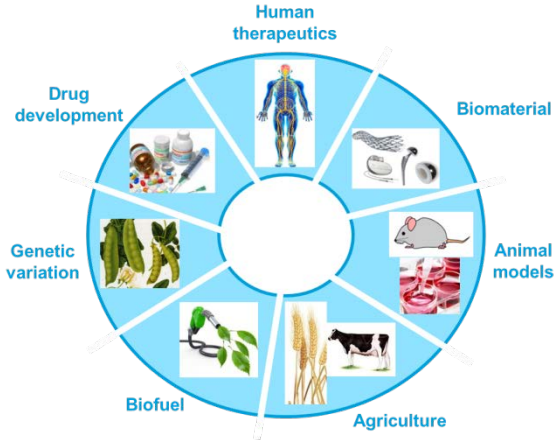
New applications for CRISPR gene editing continue to emerge. By harnessing the power of genome engineering in an unprecedented and efficient way (see Figure 11), many industries are set to benefit from the refinement of CRISPR for commercial application (see Figure 12). Our focus is biomedicine, including human therapeutics and drug development, which we expect to face the biggest transformation. However, we envision changes in bio-related industries as well, particularly in agriculture and biofuels that should expand the genetic engineering toolkit for bacteria, crops, and livestock.

Figure 11. CRISPR-Based Genome Editing Has Multiple Advantages

Attribute	Advantage
Very simple to use	Allow to scale and optimize speed
High potency and specificity	Have high success rate
Works in vivo and ex vivo; in plants and animals	Can be used in numerous applications
Ability to address any site in the genome	Can modify any desired DNA target
Ability to target multiple DNA sites simultaneously	Can perform complex editing work
Delete, insert, repair genes	Multifunction programmability

Source: Citi Research

Figure 12. CRISPR-Based Genome Editing Has Broad Applications in Multiple Industries



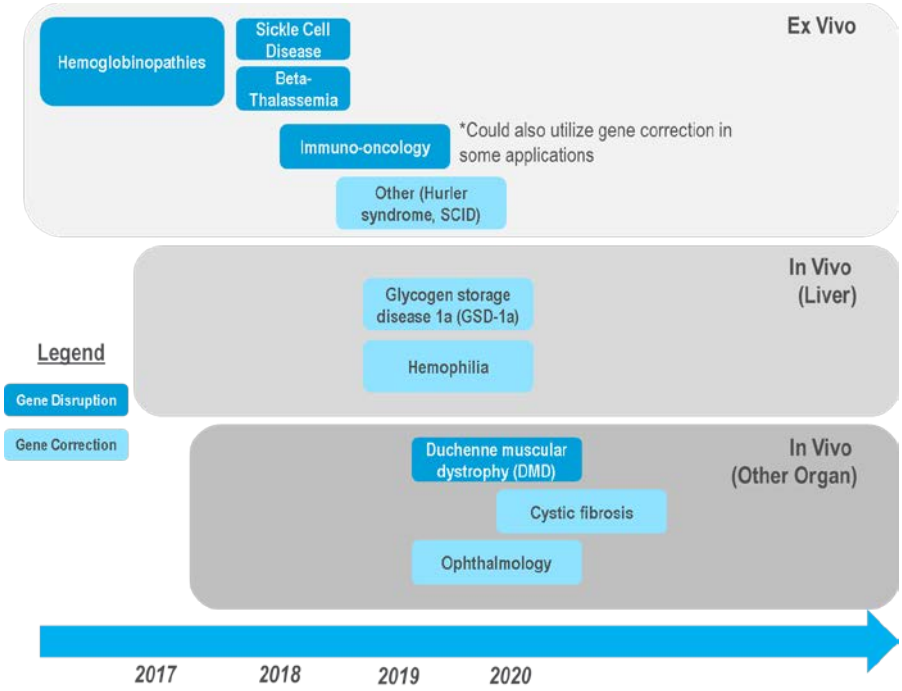
Source: Citi Research, Hsu et al, Cell, Vol. 157(6), p1262-1278

The early gene editing efforts will focus on diseases that are so called “monogenic”, meaning that they are caused by a single “sick” gene

What diseases can be targeted by CRISPR technology? The early gene editing efforts will focus on diseases that are so called “monogenic”, meaning that they are caused by a single “sick” gene (Figure 13).

Examples include blood diseases (such as sickle cell anemia, β-thalassemia), ocular diseases leading to retinal degeneration and blindness (such as Leber congenital amaurosis) or diseases involving peripheral nerve pain dysfunction (such TTR amyloidosis).

Figure 13. CRISPR Therapeutics Is Likely to Focus on Blood Diseases (Ex Vivo) in the Pipeline First

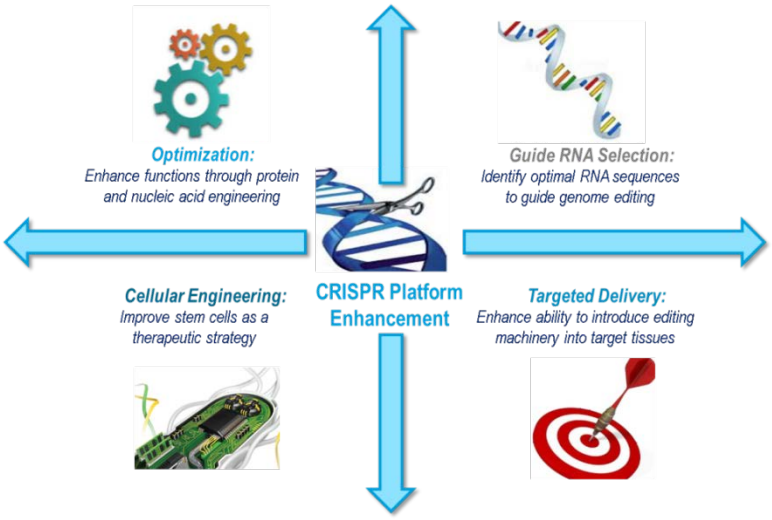


Source: Citi Research, CRISPR Company Presentation

CRISPR technologies are evolving very quickly

To further improve the efficacy and safety of genome editing, significant improvements to the technology have been made on multiple fronts. These improvements include CRISPR system optimization, superior guide RNA selection, effective cellular engineering, and improved target delivery (see Figure 14).

Figure 14. CRISPR Has Made and Should Continue to Make Significant Technological Advance

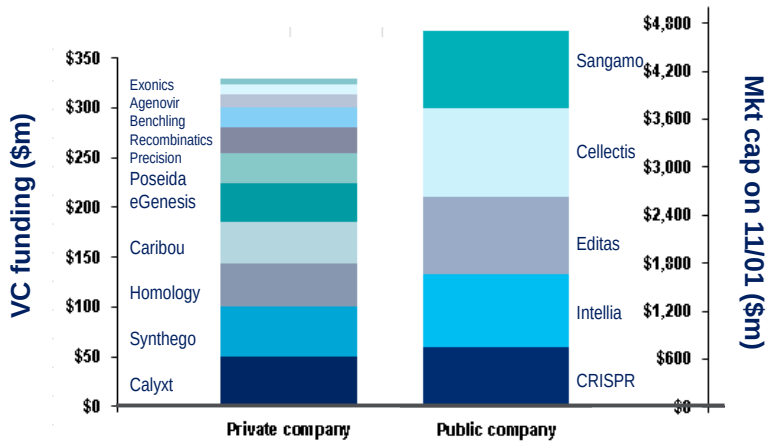


Source: Citi Research

The Players and the Opportunity

Companies utilizing CRISPR technologies, public or private, haven't reached prime time. The competitive landscape is still fairly wide open even after three CRISPR companies went public via IPOs in 2016 (see Figure 15). A number of CRISPR startups are attracting substantial venture capital funding and investors have begun to appreciate the potential economic and financial value presented by CRISPR technologies. However, relative to the worldwide market potential, we see plenty of investment opportunities ahead as CRISPR technologies begin to mature and more robust applications emerge.

Figure 15. VC Funding for Current CRISPR Startups Exceeds $300M. Market Cap for Genome Editing Companies Already Exceeds ~$4.5B



Source: Citi Research, Crunchbase, Google Finance, Bloomberg

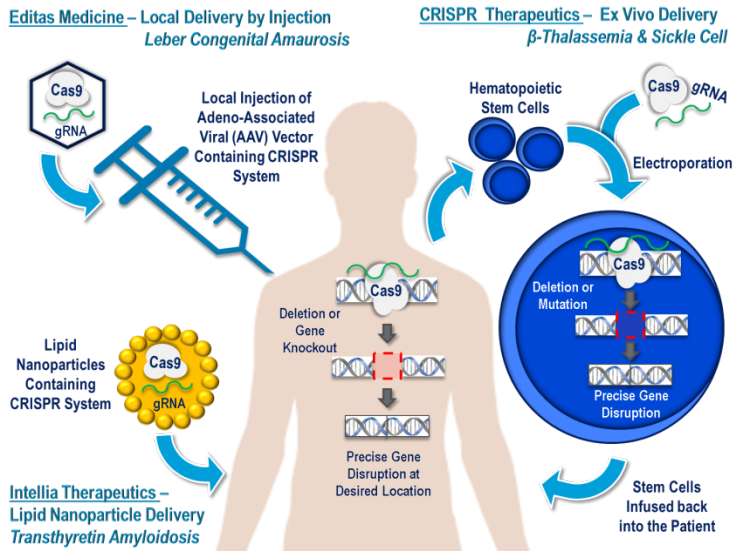
Delivering CRISPR gene editing machinery to the right place at the right time is a key challenge

A key challenge is delivering the CRISPR gene editing machinery to the right place at the right time. The three largest companies are all taking different approaches to this challenge and each has carved out their own therapeutic niche within the CRISPR market (see Figure 16). In addition to targeting very different diseases (blood disorders, eye disorders, and peripheral neuropathies), each of these companies is approaching the delivery of CRISPR gene editing therapy in novel ways.

CRISPR Therapeutics, Editas Medicine, and Intellia Therapeutics have all carved out their own therapeutic niche within the CRISPR market. In addition to targeting very different diseases (blood disorders, eye disorders, and peripheral neuropathies), each of these companies is approaching delivering CRISPR gene editing therapy in novel ways

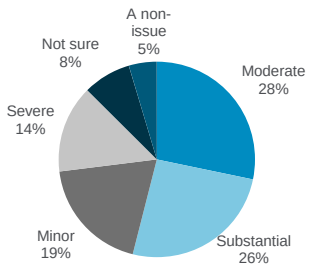
CRISPR Therapeutics is focusing on ex vivo gene editing, meaning the CRISPR therapy will be administered to a patient's cells outside of their body, and then the edited cells will be re-infused back into the patient. Editas and Intellia are both exploring methods of packaging their CRISPR system for targeted delivery into patients. Editas has opted for local delivery using a viral vector system, while Intellia is developing lipid nanoparticles that have a strong affinity for localization to the liver. Each of these approaches has the potential to become a curative therapy if developed successfully.

Figure 16. CRISPR Therapies are being Developed to Target a Wide Range of Diseases with Novel Methods for Delivery to Patients



Source: Citi Research

Figure 17. Survey Suggests Concerns Exist Around Off-target Effects of CRISPR Gene Editing



Source: Citi Research, Knoepfler Lab online poll

Safety is still the major wildcard for genome editing, especially when developing human therapeutics (see Figure 17). The CRISPR system is designed to target a specific location in the genome and its beauty lies in its ability to deliver absolute precision. However, CRISPR therapies have the potential to cause off-target effects by accidentally modifying unintended genome segments. Increasingly, promising techniques have been developed to help reduce the off-target mutation frequency to as little as ~0.01%-0.1%, and continued optimization of the system has helped to lower the frequency even further. With the rapid expansion of innovation within the CRISPR field, we expect that iterative improvements to the system will cause the rate of off-target effect to continue to trend down. Until we see long-term data in humans, the question of safety will remain a key concern for the field. However, given the promise of the technology and the relatively low rate of off-target effects already demonstrated, we believe the medical community will gain increasing comfort with the prospects for CRISPR.

An Even Bigger Question

Still the Wild West regarding ethics issues associated with genome editing

CRISPR genome editing can be used to genetically modify crops, create animal chimeras (i.e. organisms with two or more genetically different cell populations), and could potentially be used to engineer the human germline for enhancement. However, the current spate of therapeutics being contemplated by companies such as CRISPR Therapeutics, Editas Medicine, and Intellia Therapeutics would only result into modification to an individual's so-called "somatic" cells, i.e. cells in a living organism other than a reproductive cell. This means that it would be impossible to introduce the genetic edits into the patient's germline (cells that are passed on to the next generation) for propagation into his/her offspring. That being said, the ability to quickly introduce an engineered genetic trait into the general animal or human population (called gene drive) has already sparked heated ethical debate. While these debates are important and ongoing, we don't foresee these discussions derailing the potential for CRISPR to fundamentally transform the practice of medicine and human disease. As the technology approaches commercialization, we expect innovators in the field will need to clarify to the broader public that their gene editing medicines do not alter a patient's germline, minimizing concern about irreversibly changing the human gene pool in unpredictable ways.

As the technology approaches commercialization, we expect innovators will need to clarify to the broader public that their gene editing medicines do not alter a patient's germline, minimizing concern about irreversibly changing the human gene pool in unpredictable ways

Figure 18. Wide Array of Companies Exploring Opportunities to Leverage CRISPR Based Genome Editing

Industry sector	Product/application	Companies	IP
Food	Yogurt, cheese, crops	Dupont	7919277, 8361725, 13/722539, 11/990885
	Crops	Dow Agrosciences	PCT/US2013/039979 co-owned with Sangamo
	Livestock	Recombinetics	PCT/US2014/0201857
	Crops	Cellectis Plant Sciences	Boston Children's Hospital, Institut Pasteur License
Laboratory	Research tools	System Biosciences	US 14/216655
	Expression systems	Sigma-Aldrich	PCT/US2013/073307
	Research tools	GE Healthcare	Broad License
	Animal models	Sage	Caribou, Broad License
	Research tools	Thermo Fisher	Cellectis sublicense
	Animal models	Taconic	Broad License
Sublicensing	Agriculture, industrial, bio applications	Caribou	PCT/US2013/053287
Medical	Pharmaceuticals	Novartis	Caribou License
	In vitro applications only	Cellectis	Boston Children's Hospital, Institut Pasteur License
	Target validation	AstraZeneca	Open Innovation Model
	Monogenic diseases	Sangamo Biosciences	PCT/US2013/032381
	Therapeutics	CRISPR Therapeutics	PCT/US2013/032589
	Therapeutics	Intellia	Caribou License
	Therapeutics	Editas	Broad, MIT, Harvard, MGH, Duke License

Source: Citi Research; P. BG. Van Erp et al., Current Opinion in Virology, Vol. 12, 2015, p85-90

Heat Not Burn Tobacco

Lower Risk Cigarettes

Adam Spielman
Head of European Consumer Staples Research

Heat Not Burn (or Tobacco Heating System) is the most significant innovation in the tobacco sector since e-cigarettes. The devices heat tobacco without burning it, which gives the smoker a smoking experience with the taste of tobacco (and nicotine), but without the smoke or ash and without the strong smell. By not burning the tobacco, the product releases much lower levels of harmful chemicals versus traditional cigarettes, thereby potentially reducing the health risk to users.

Figure 19. Philip Morris's iQOS

Source: PMI Company Reports

The idea of heating tobacco has been around for a few decades; however it is only in the last few years that a corporate has been able to create a product — iQOS — which is satisfying to adult smokers. This product has already revolutionized the tobacco industry in Japan.

The key reasons we think the Heat Not Burn category is so disruptive to the tobacco sector and therefore significant for investors include:

- From its launch, iQOS, has taken much more market share from traditional cigarettes than e-cigarettes have been able to.
- To date, Heat Not Burn has only been truly transformative in Japan, but its success there has already been very important financially for tobacco companies. Although it is unclear how well Heat Not Burn will do outside of East Asia, it holds the potential in that region to be significant.

How Does it Work?

The tobacco in a conventional cigarette burns at a temperature in excess of 900˚C. Heat Not Burn cigarettes are carefully heated to between 240-350˚C using an electric heat source, which creates tobacco vapor rather than smoke. The lower heating temperature releases a similar taste to tobacco but with reduced levels of harmful chemicals compared to cigarette smoke.

Figure 20. BAT's glo

Source: BAT Company Reports

Currently, existing products in the market are sold as reusable, rechargeable systems (with either one part or two), where consumers purchase the device and then buy additional packs of special cigarettes.

The first two products launched in the space were 'iQOS' from Philip Morris (Figure 19) and British American Tobacco's product 'glo' (Figure 20). The main differences between the two devices are:

- iQOS is a two-part device versus glo which is a single part;
- iQOS heats the cigarette at 350˚C, whereas glo heats the cigarette at 240˚C; and
- Using the glo device, you can smoke another cigarette immediately after finishing one, while the iQOS device requires you to recharge part of the device.

Japan Tobacco is currently in the process of developing its own Heat Not Burn product, "Ploom TECH", which is slightly different from existing offerings as it uses tailor-made tobacco capsules.

It Is a Reality in Several Markets, with More on the Horizon

iQOS is expected to be launched in over 30 countries by the end of 2017

iQOS was first launched in Nagoya, Japan in 2014 before rolling out nationally in September 2015. It since has been launched in many markets, as Figure 21 shows, and is now available in 31 countries. Philip Morris claims that 3.7 million consumers have switched from traditional cigarettes to iQOS.

Figure 21. Markets Where iQOS is Available

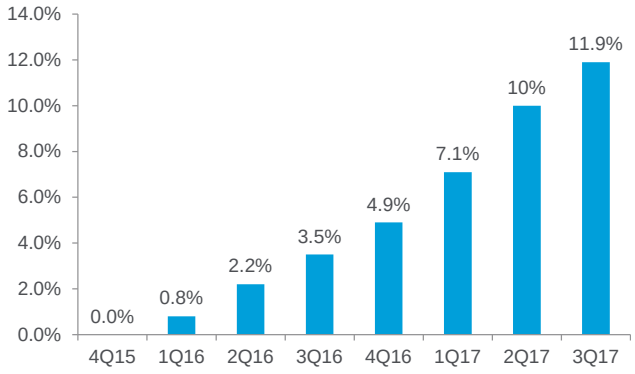
Note: Status on October 19, 2017. Map excludes Duty Free.

Source: Philip Morris International Inc. website (www.pmi.com).

In Japan, iQOS has taken about 10% market share from traditional cigarettes

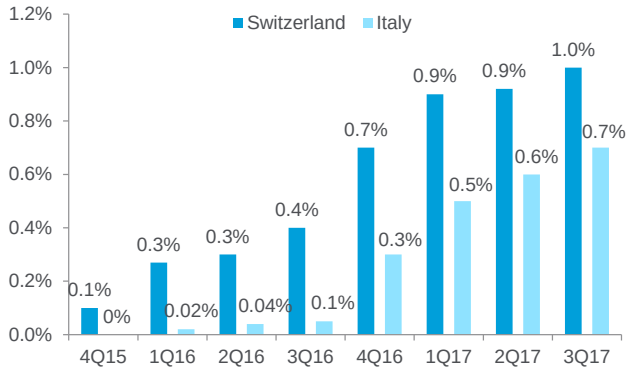
In Japan, Heat Not Burn such as iQOS has been successful in taking market share from traditional cigarettes and the category currently has about a 12% market share, as Figure 22 shows. In 2016, the Japanese cigarette market declined about 5%, but Japan Tobacco (the market leader in Japan) forecasts the overall market to fall ~13% in 2017, due to the growth in Heat Not Burn. Clearly, this technology has disrupted the market in Japan, but what about other geographies? Figure 23 shows the next two markets that Heat Not Burn has been in the longest — Switzerland and Italy — and demonstrates that market share progress in these two countries has been significantly slower.

Figure 22. Heat Not Burn Market Share – Japan (IMS)



Source: Philip Morris Company Reports

Figure 23. Heat Not Burn Market Share – Italy and Switzerland (IMS)



Source: Philip Morris Company Reports

How Big Could the Opportunity Be?

Japan should continue to be the most important market and driver of demand for Heat Not Burn tobacco

The charts above show that growth so far has been very different across different geographies. Going forward, we believe there is a wide range of possibilities for the Heat Not Burn market. However, we think Japan will continue to be the most important market and driver of demand over the next two years due to the size of its market (about 175 billion cigarette sticks are sold there every year) and the arguable view that Heat Not Burn is uniquely suited to the Japanese consumer (perhaps over other Western consumers). What makes it attractive to Japanese consumers?

- **Reduced tobacco odor and ash** is more important for Japanese consumers than for European or U.S. consumers (according to BAT). Japan Tobacco believes this is the number one selling point for Next Generation Products in Japan. In Europe, the health and cost advantages of the product are more important.

- **Japanese smokers disproportionately favor low nicotine and high menthol** cigarettes, which means converting to Heat Not Burn cigarettes is less noticeable. About 70% of Heat Not Burn cigarettes sold in Japan are mentholated, and Japan has the greatest percentage of cigarettes with menthol of any major market (outside the U.S.) and the second largest percentage of ultra-low tar cigarettes.

- **Japanese consumers like tech/innovation, but e-vapor is banned.** Innovation plays a much bigger role in Japan for marketing cigarettes than in Europe or the U.S. As e-vapor is banned (as it is classed as an unlicensed medical product), a consumer wanting to try "the new way to smoke" in Japan, Heat Not Burn is the only option. The equivalent European or U.S. consumer may have already tried (and possibly converted to) e-vapor.

The characteristics of Japanese consumers are not present across all markets that Heat Not Burn has launched in. We think Korea is most similar to Japan, and could be quite meaningful by 2018-19, but we are less convinced that these characteristics exist in Western and Eastern European markets therefore risking that Heat Not Burn will not be as successful.

Figure 24. Favorable Market Characteristic for Heat Not Burn

	Japan	Korea	Germany	Romania	Russia	U.S.	Switzerland	Italy	U.K.
Consumers like technology and innovation	X	X	X	X	X				
E-vapor not present	X								
Light marketing environment	X		X			X	X		
Focus on reducing tobacco odor	X								
High prevalence of low nicotine/low tar	X	X							
High prevalence of menthol cigarettes	X	X				X			X
High population density	X	X							X

Source: Citi Research

Scenario Analysis

We outline a scenario analysis for Heat Not Burn based on forecasts for Japan, Korea, Europe, and the U.S.

We have built up Low, Base and High scenarios for Heat Not Burn, based on separate forecasts for Japan, Korea, Europe, and the U.S.

- Our Low Growth Scenario assumes that demand starts to slow in Japan, and Europe and Korea are fundamentally lower growth markets. In the U.S. it assumes a product launch in 2019 and a slow rollout.
- Our Base Scenario assumes that growth continues at roughly the current rate in Japan. In Europe it assumes growth picks up as Heat Not Burn is launched in more markets, and as demand in certain markets accelerates. In the U.S. it assumes products are launched from the second half of 2018, and steady, but moderate growth.
- Our High Growth Scenario assumes an acceleration of consumer demand in all markets, as more capacity leads to increased availability. In the U.S. it assumes a product launch in the first half of 2018, and strong growth from the start.

Figure 25. Citi's Low, Mid, and High Growth Scenarios for the Global Heat Not Burn Market, 2016A-2022E

	2016	2017E			2018E			2019E			2020E			2021E			2022E		
	Actual	Low	Base	High	Low	Base	High	Low	Base	High	Low	Base	High	Low	Base	High	Low	Base	High
Mkt Share (%)																			
Japan	3%	12%	12%	13%	19%	25%	32%	24%	35%	46%	26%	41%	55%	26%	45%	62%	27%	48%	66%
Korea	0%	1%	1%	2%	3%	9%	13%	6%	16%	32%	8%	22%	41%	10%	29%	47%	12%	35%	53%
Europe	0%	0%	0%	0%	1%	1%	1%	1%	1%	2%	2%	3%	5%	4%	4%	8%	4%	6%	11%
US	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	2%	2%	3%	5%	3%	6%	9%
IMS Volumes (B Sticks)																			
Japan	5	21	21	22	33	43	56	40	59	78	42	68	91	42	73	100	42	77	105
Korea	-	1	1	1	2	6	9	4	11	22	5	15	28	7	19	32	8	23	34
Europe	-	1	1	2	4	5	6	9	9	15	16	17	31	23	26	50	28	35	70
RoW	-	1	1	1	2	2	2	2	3	4	3	4	6	5	7	9	6	12	14
US	-	-	-	-	-	0	0	0	1	1	2	2	3	3	7	10	6	12	18
Total Global In Market Sales	5	24	24	26	41	56	74	56	83	120	68	107	160	79	132	201	90	159	242
Pipeline Filling	2	10	11	10	2	6	8	1	5	8	1	8	10	1	10	12	1	10	12
Total Global Shipments	7	34	35	36	43	62	82	57	88	128	69	115	170	81	142	213	91	169	254

Source: Philip Morris Company Reports (2016) and Citi Research Estimates (2017-2022)

What are the Barriers to Adoption?

Regulatory issues are likely to be the primary barriers to adoption

The primary barriers to adoption of Heat Not Burn are likely to be regulatory initiatives. As Heat Not Burn has only been materially successful to date in one country (Japan), there isn't a huge amount of specific regulation around the product. However over the next few years, if Heat Not Burn does take off in more countries, we would expect more, and clearer, regulation.

- **U.S.:** In the U.S., authorization is required to launch any new tobacco product. However, the Food & Drug Administration (FDA) does want to encourage innovations of less harmful products. On August 28th, the agency announced that it would make the application process easier.
- **International:** International regulation of Heat Not Burn varies. In Japan, where the technology has been most successful, regulation is very light. Companies like Philip Morris can communicate relatively freely in stores about the lower toxicants and run promotions without interference. However in most European markets, legal restrictions make it very hard to communicate with consumers, for example in the U.K., where it is illegal to display tobacco products. Other countries, such as Germany and Switzerland in Europe, are relatively liberal markets.

Regulation and Tax Policy Will be Key

We expect Heat Not Burn to be the primary focus of the tobacco industry but outcomes could be altered by regulation and tax policy

We think the long-term answer to whether the Heat Not Burn category itself is truly disruptive to conventional cigarettes will depend on regulation and tax policy. The regulatory picture is still developing. The U.S. has made the most notable positive stance on reduced harm tobacco products in its recent FDA Proposals, and it is possible that other countries follow their lead. Regarding tax, currently Heat Not Burn cigarettes have a tax benefit relative to conventional cigarettes in all countries where it has been launched. However, Korea's National Assembly recently passed a bill to raise taxes on Heat Not Burn sticks, the first government to do so. In addition, if Heat Not Burn was present in the U.S., there would be no tax advantage relative to traditional cigarettes.

Hyperloop

A Cross between a Concorde, a Railgun, and an Air Hockey Table

Christian Wetherbee
U.S. Airfreight, Surface & Marine Transportation Analyst

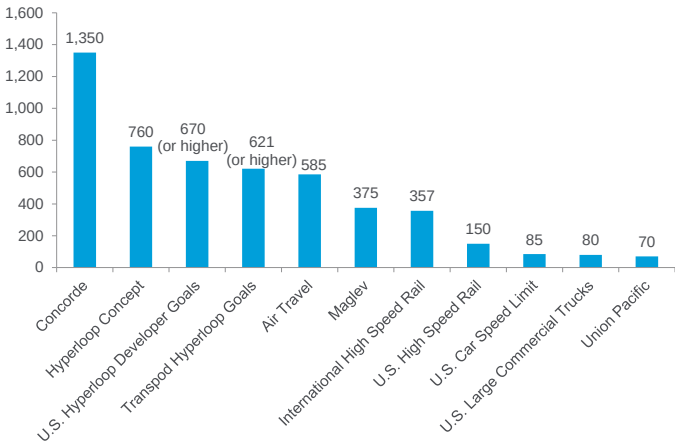
The origin of the idea that ultimately led to the current development of a Hyperloop transportation system can be traced back to the 19th century, but Elon Musk brought the idea for a Hyperloop firmly into the 21st century when he published a white paper ("Hyperloop Alpha") on the topic in August 2013 and invited others to develop the system. At a conference in May 2013, Musk succinctly described a Hyperloop as a "cross between a Concorde, a railgun, and an air hockey table."[1]

The original concept designs for Hyperloop transportation systems involved either passengers or freight being placed in capsules that use a combination of induction motors and magnetic levitation & air propulsion systems to travel at high speeds (up to 760 mph) through a network of vacuum-sealed, low-pressure tubes. The network of tubes in a Hyperloop transportation system can be placed either above or below ground, but to achieve maximum speeds, and their resulting benefits, the tubes need to be designed with as little change in direction and incline as possible. The Hyperloop developers in the U.S. are working on designs very similar to Musk's original concept, despite now believing their systems will have marginally lower maximum speeds (670 – 760 mph), but Canada-based Hyperloop developer TransPod is designing a system that will propel capsules using electromagnetic fields instead of compressed air, with maximum speeds projected at over 621 mph. Achieving maximum speeds of 621-760 mph would make a Hyperloop transportation system significantly faster than other currently available modes of transportation.

Figure 26. Hyperloop Concept Image

Source: Citi Research, TransPod website

Figure 27. Max Speed by Type of Transportation (mph)



Source: Citi Research, Company websites, CNN, Amtrak, BBC, SH 130, The Balance

[1] Source: Elon Musk discussing the Hyperloop at the D11 Conference in May 2013.

The Players

Although there are at least seven companies around the world working to develop a Hyperloop, for simplicity, we are going to focus on just two in-depth.

Figure 28. Virgin Hyperloop One Company

Virgin Hyperloop One
Company Name: Virgin Hyperloop One (previously "Hyperloop One") **Founding Date:** June, 2014 **Headquarters:** Los Angeles, California **Total Known Equity Funding:** $245,000,000
Notable Investors: Virgin Group invested in Series B-1 round ($85 million) that closed in September 2017. DP World Group invested $50 million in October 2016 through a convertible note. SNCF and GE Ventures invested in Series B round ($80 million) that closed in May 2016. Sherpa Capital lead Series A (February 2015) and Series B (May 2016) rounds and its co-founder is also the co-founder and Chairman of the company.
Strategic Partners: Colorado Department of Transportation (feasibility study in Colorado), AECOM, Amberg Group, Arup, Bjarke Ingels Group, SYSTRA, General Electric (GE), Parsons, Ramboll, SNCF, Deutsche Bahn Engineering and Consulting, FS Links, McKinsey, KPMG, and PA Consulting Group.
Progress On Hyperloop Development: Full-scale testing was first publicly performed in May 2017 and another test was performed in July 2017 that broke company speed records. All testing is done at the company's "Development Loop (DevLoop)" test track in Apex, Nevada, which was completed in March 2017. The July test was done over a maximum distance of 437 meters, with top speeds of 192 mph.
Recent Developments: Virgin Hyperloop One launched its "Hyperloop One Global Challenge" in May 2016 to receive Hyperloop project proposals from around the world and 10 winners were selected in September 2017. Of the 10 winners, 4 routes are in the U.S., 2 routes are in the U.K., 2 are in India, 1 is in Canada, and 1 is in Mexico. In November 2016, the company announced Dubai's Roads and Transport Authority had agreed to evaluate a Hyperloop One route from Dubai to Abu Dhabi.

Source: Citi Research, Company Reports, Crunchbase, The Independent

Figure 29. Hyperloop Transportation Technologies Company

Hyperloop Transportation Technologies
Company Name: Hyperloop Transportation Technologies (HTT) **Founding Date:** November, 2013 **Headquarters:** Los Angeles, California **Total Known Equity Funding:** $31,800,000 ($100+ million when including "in-kind investment")
Notable Investors: HTT received its initial funding through JumpStartFund. Edgewater Capital Partners was the sole identified investor in HTT's only known funding round ($30 million) that closed in December 2016. HTT has also given equity to companies that provide it with strategic services, instead of direct financing. See below for a list of such strategic partners, some of whom have equity in the company.
Strategic Partners: Carbures S.A, Atkins, Anomaly Communications LLC, RE'FLEKT GmbH, and Leybold GmbH.The company also has many strategic relationships with engineers and other organizations through its collaborative, payment "in-kind" business structure.
Progress On Hyperloop Development: In March 2017, HTT announced it had started production on "the world's first full-scale passenger Hyperloop capsule," which will be a joint project with Carbures S.A and is intended to be unveiled in early 2018. HTT has multiple agreements in place with organizations and governments in foreign countries to study (and eventually build) Hyperloop systems, but construction has not started.
Recent Developments: In September 2017, HTT announced the signing of a Memorandum of Understanding (MoU) with the state Economic Development Board of Andhra Pradesh in India that was the first step in a process to develop a Hyperloop transportation system - process starts with a 6 month feasibility study that could potentially lead to construction. Early-stage agreements and partnerships have also been announced in other countries including Indonesia (March 2017), France (January 2017), Czech Republic (January 2017), and the UAE (December 2016).

Source: Citi Research, Company Reports, TechCrunch, Crunchbase

In addition to these two companies, a small Canadian startup named TransPod is also making quick progress in the Hyperloop development space, with a focus on being the first to construct a Hyperloop in Canada. TransPod was founded in 2015, has raised $15 million to date, completed at least two feasibility studies for Hyperloop routes in Canada, and has formed multiple strategic partnerships that will aid in its development efforts.

Hyperloop design competitions should help to further development and testing of Hyperloop pods

Hyperloop developers are not the only companies active in this space; Elon Musk recently became more involved in aiding Hyperloop development, with the founding of The Boring Company (in December 2016) and the creation and sponsorship (through SpaceX) of a Hyperloop pod design competition that began in January 2016 and will continue into the summer of 2018.[2] The Boring Company plans to design custom-made, innovative drills that can dig underground tunnels faster and at a fraction of the cost of competing product offerings, with the goal of using those drills to create an underground transportation network (one potential design strategy for a Hyperloop transportation system) at a total cost that is 1/10 of what competitors would charge. SpaceX's Hyperloop pod design competition has furthered the development and testing of Hyperloop pods, with the winning team in the second round of the competition in August 2017 designing a pod that recorded a test speed of 201 mph, which was slightly higher than the maximum test speed recorded by Virgin Hyperloop One's pod in July 2017 (192 mph). Musk later claimed the system ("pusher pod") he designed to help participants get their pods started on the test track achieved a maximum speed of 220 mph and that he would continue to develop the technology.

Potential to Disrupt Traditional Transportation Markets

Hyperloop could conceivably disrupt both passenger and freight transportation

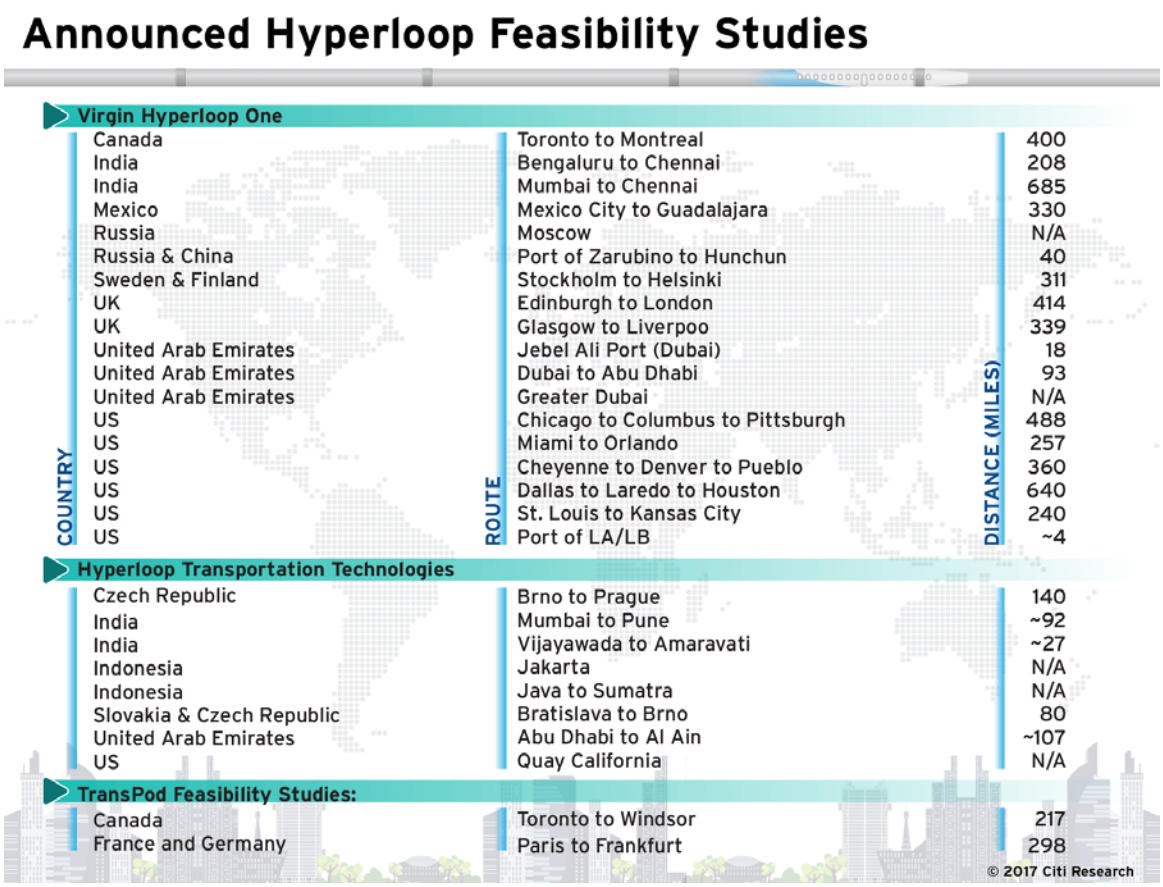
While still experimental, two markets that a Hyperloop system could conceivably disrupt are passenger and freight transportation, however, we choose to focus on the potential for the Hyperloop system to disrupt traditional modes of freight transportation.

28 possible Hyperloop routes across 15 different countries have been identified as feasible

The two main Hyperloop development companies and TransPod have collectively announced feasibility studies for a total of 28 possible Hyperloop routes across 15 different countries, with seven of the proposed routes being located in the U.S.

[2] Source: SpaceX website

Figure 30. Announced Hyperloop Feasibility Studies on Potential Routes



Note: This includes the 10 winning routes from the "Hyperloop One Global Challenge"
Source: Citi Research, Company Reports, KPMG, Google, The Verge, livemint, Forbes

International Markets

Hyperloop routes being considered in India and the UAE have huge potential in freight transportation

We believe that the Hyperloop transportation routes being considered in India and the United Arab Emirates (UAE) have among the greatest freight transportation potential of all the international markets in which the three Hyperloop developers currently have ongoing feasibility studies. India has been modernizing its infrastructure but its highways still experience significant congestion, contributing to its total spending on logistics and transportation (as a percent of GDP) being nearly double that of other developing countries, which threatens the ability of India's freight transportation market to meet expectations for double-digit growth through 2020 to a total of $308 billion.[3] India has the potential to reduce congestion on its roads if Hyperloop systems become a common means of transportation, improving highway travel times for trucks, and potentially improving e-commerce fulfillment (India's e-commerce market is estimated to reach $33 billion in 2017[4]). In the UAE Hyperloop transportation systems also have the ability to fit into the "UAE Vision 2021 National Agenda", with its hi-tech and near-zero environmental impact design fitting into the Agenda's duel focus on sustainable environment and infrastructure.

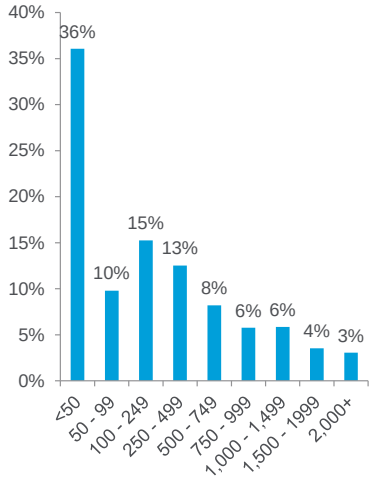
[3] Research and Markets (29 May 2015). India Freight Transport Market Analysis and Forecasts Report 2015-2020. CISION PR Newswire. Retrieved from PR Newswire.
[4] The Economic Times (29 July 2017). India's e-ecommerce market to touch $33 billion this fiscal: Government. *The Economic Times.*

Virgin Hyperloop One believes its addressable market in the Gulf Cooperation Council region is $12 billion

Both Virgin Hyperloop One and HTT are working to bring a Hyperloop to India, with two routes in India winning the "Hyperloop One Global Challenge" and HTT currently engaging in two of its own route feasibility studies in India. In addition, HTT signed a MoU with the Andhra Pradesh Economic Development Board in September 2017 that is expected to lead to the construction of the company's first Hyperloop in India, between the centers of Vijaywada and Amaravati.[5] Similarly, both companies have plans to bring a Hyperloop to the UAE, yet Virgin Hyperloop One appears to be in the best position given that DP World Group, one of the largest port and terminal operators in the world, is a large shareholder (~20%+ of total funding) and plans to work with the company to install a container offloading Hyperloop in its Port of Jebel Ali. The size of the Gulf Cooperation Council (GCC) freight transportation is estimated to be $35 billion, and Virgin Hyperloop One believes its addressable market in the GCC is $12 billion.[6]

U.S. Markets

Figure 31. Percentages of Total U.S. Shipment Value by Shipping Distance



Note: Data is as of 2012

Source: Citi Research, U.S. Departments of Transportation and Commerce

In the U.S., the Hyperloop could conceivably provide a solution to shippers' desire for faster delivery times, yet we believe that such a freight transportation system would need to overcome significant challenges before being commercialized (see below). Assuming for simplicity sake that Hyperloop systems are commercialized along the four U.S. winning routes from the Hyperloop One Global Challenge and that the systems are solely used to haul cargo, which Virgin Hyperloop One has already stated is not their intended purpose, we estimate that ~7% of all goods shipped in the U.S. (by value) could theoretically be shipped through the four Hyperloop routes based on the routes' locations and lengths. In reality, those four routes' percentage of total U.S. shipments will be significantly smaller, as the many hurdles facing Hyperloop systems would likely prevent many shippers from using them extensively.

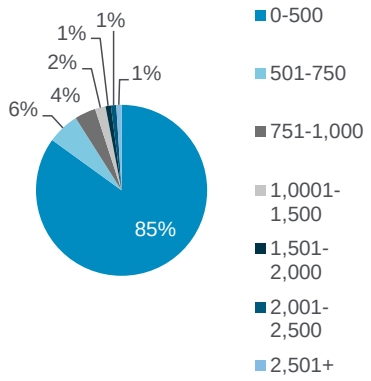
A January 2017 conceptual feasibility study of the Hyperloop published by NASA's Glenn Research Center found that a Hyperloop would be a faster and cheaper alternative to short-haul flights (250-500 miles), which accounted for 57% of commercial aircraft operations in 2012, according to the study. As a result, we believe the U.S. airfreight market, which we estimate generated $30 billion in revenue in 2016, is the most likely transportation market to be disrupted by a Hyperloop freight transportation system. Long-haul trucking is a second transportation market that we believe could be disrupted by Hyperloop systems, with routes in the 250-750 mile length of haul (LOH) range being most susceptible, which we estimate accounts for ~30% of total trucking revenue (or ~$200 billion in 2016). This conclusion is based on the fact that although trucks have an advantage over a Hyperloop in terms of directional flexibility, with longer LOHs the speed and potential cost advantages of a Hyperloop would make it a more preferable alternative for expedited deliveries and the transportation of temperature controlled shipments (~14% of total truck shipments by value).

A final market that could be disrupted by the Hyperloop is port and terminal operations, where the Hyperloop can be used to offload freight. This market is likely the first to be disrupted by the Hyperloop, given that Virgin Hyperloop One already has feasibility studies underway for three routes based in a total of four ports (Jebel Ali, Los Angeles, Long Beach, and Zarubino). We see the likelihood of Hyperloop

[5] Hyperloop Transportation Technologies (6 September 2017). *HTT to Launch India's First Hyperloop*. Hyperloop press release.

[6] Hyperloop One (28 March 2017). *Hyperloop One Shares Transformative Vision for the Future of Manufacturing.* Hyperloop One press release.

Figure 32. Truck Revenue Moves By LOH



Source: Citi Research, IANA ETSO, FTR

systems eventually being used in some ports around the world as high, with the biggest obstacles to commercialization being cost/benefit analysis, port operator acceptance, pod design challenges (i.e., making the size of the pods capable of fitting containers), and the development of new support operations.

Hurdles to Commercializing a U.S. Hyperloop

Despite the progress that has been made on Hyperloop development, there are still significant hurdles that developers would need to overcome in order to commercialize a Hyperloop system in the U.S.

1. **Cost:** The initial cost estimates of building a Hyperloop transportation system in the U.S. made by Elon Musk ($17-$21 million/mile) are now believed to be significantly lower than the true costs of building such a system. Based on our analysis of publicly available Hyperloop feasibility studies and third party reports, we estimate that many routes in the U.S. could cost $60-$70 million per mile (roughly within the cost/mile range of recent feasibility studies), with the variance being largely attributed to potential differences in the estimated cost of land acquisition. At this cost range, we estimate the four U.S. routes that won the Hyperloop One Global Challenge would cost ~$18-$38 billion in total to construct.

Figure 33. Hyperloop Route Feasibility Studies & Investor Documents and Citi Estimates of Hyperloop Global One Challenge Winners' Route Costs

	U.S. Bay Area Loop Route		Dubai-Abu Dhabi Route	Stockholm-Helsinki Route	
	Low	High	Total Cost	EUR	USD
Total Cost	$9.0 billion	$13.0 billion	$4.8 billion	€ 19.0 billion	$22.5 billion
Cost / Distance	*$84 million*	*$121 million*	*$52 million*	*€ 38 million*	*$73 million*
Distance	107 miles	107 miles	93 miles	500 km	311 miles
Description	VHO docs for investors (Forbes)		VHO docs for investors (Forbes)	VHO feasibility study	

	Toronto-Windsor Route	Paris-Frankfurt Route		Hunchun–Port of Zarubino Route	
	Total Cost	EUR	USD	Low	High
Total Cost	$10 billion	€ 8.3 billion	$9.8 billion	$1.5 billion	$2.3 billion
Cost / Distance	*$47 million*	*€ 17 million*	*$33 million*	*$34 million*	*$53 million*
Distance	217 miles	480 km	298 miles	43 miles	43 miles
Description	TransPod feasibility study	TransPod feasibility study		VHO feasibility study	

	Chicago-Columbus-Pittsburgh Route	Miami-Orlando Route	Dallas-Laredo-Houston Route	Denver-Pueblo-Vail-Cheyenne Route
	Citi Estimate	Citi Estimate	Citi Estimate	Citi Estimate
Total Cost	$34 billion	$18 billion	$38 billion	$24 billion
Cost / Distance	*$70 million*	*$70 million*	*$60 million*	*$65 million*
Distance	488 miles	257 miles	640 miles	360 miles
Description	Citi estimate of VHO Challenge winner	Citi estimate of VHO Challenge winner	Citi estimate of VHO Challenge winner	Citi estimate of VHO Challenge winner

Note: VHO is an abbreviation Virgin Hyperloop One

Source: Citi Research, Forbes, KPMG, Company Reports

2. **Regulatory Challenges:** Regulatory agencies are likely to pose a greater hurdle in the U.S. than in foreign countries, as large scale multi-state highway development projects in the U.S. have historically faced lengthy zoning processes and review under the National Environmental Policy Act, which have lasted 6.6 years on average[7] before construction begins. Regulators would also be highly sensitive to safety risks, and even if the technology is safe enough for freight use, regulators could delay construction of a Hyperloop until studies have been done on the effect on the average human body from traveling

[7] 40 Proposed U.S. Transportation and Water Infrastructure Projects of Major Economic Significance (AECOM, 2016) – prepared under contract for the U.S. Department of the Treasury.

through a vacuum-sealed, low-pressure tube at (potentially) nearly the speed of sound when at or below ground level.

3. **Land Acquisition and Underground Tunnel Feasibility:** A Hyperloop is able to maximize speed when its tubes are designed to minimize changes in direction and incline, yet the acquisition of sufficient land meeting these criteria is a significant hurdle. As a result, underground tunnels have been proposed as an alternative to above-ground tube networks. However, current tunnels used for transportation purposes in the U.S. are only a fraction of the length of the proposed Hyperloop routes in the U.S., making acquiring land rights for drilling and the speed/cost of drilling long tunnel networks significant hurdles. Although not a true comparison, it is worth noting that recent underground subway expansions in major cities have taken years to complete at total costs of over $1 billion/mile.

Potential Commercialization Timeline

Executives at all of the North American Hyperloop development companies believe the first fully operational commercial Hyperloop will be built by 2020/2021,[8] although they acknowledge that regulatory hurdles must be overcome (particularly in the U.S.) before a Hyperloop system can be built. We believe a 2020/2021 timeline for the commercialization of the first Hyperloop transportation system is optimistic, given the fact that both Virgin Hyperloop One and HTT have missed internal development timeline goals in the past and the fact that the main party responsible for in the Stockholm-Helsinki feasibility study estimated that building a Hyperloop on the route would take 12-15 years.[9]

The first commercial Hyperloop's location is subject to debate, yet we believe the most likely location of the first Hyperloop is the United Arab Emirates (UAE), given that both Virgin Hyperloop One and HTT have been working with government officials and local transportation departments in Dubai and Abu Dhabi since November 2016 and December 2016, respectively. Virgin Hyperloop One's partnership with DP World Group puts it in a good position to bring the first Hyperloop to market in Dubai, and it is worth noting that the company's November 2016 agreement with the Dubai Roads and Transport Authority (RTA) reportedly included a plan to have a 20km-long prototype (~1/7 of proposed route) capable of operating at top speeds of ~750mph by 2020,[10] which is only slightly shorter than the proposed 29km distance between docked ships and a new container depot in DP World's Jebel Ali Port.[11] The first commercial Hyperloop in the U.S. will likely come years after the first Hyperloop in a foreign country, given that Hyperloop development in the U.S. lacks many of the tailwinds that will benefit its development in a foreign country (e.g. a highly motivated government, fewer regulations, and a clear focus on developing sustainable infrastructure).

[8] Virgin Hyperloop One's website states the "the company is working aggressively to meet a goal of having three production systems in service by 2021." TransPod's press releases say the company's goal is to create commercially viable Hyperloop by 2020. The CEO of HTT reportedly stated in May 2017 that the company plans to have a Hyperloop system operational by 2020.

[9] KPMG (2016). *Pre-feasibility study Stockholm –Helsinki using HyperloopOne technology: Short summary.* KPMG presentation.

[10] Gulf News (16 November 2016). Dubai to have hyperloop prototype by 2020. *Gulf News Transport.*

[11] Source: Upbin, B. *Hyperloop and the Hyperefficient Port.* Hyperloop One blog post.

IoT Payments

Frictionless…Connected…Commerce

Ashwin Shirvaikar, CFA
Head of Payments, Processors & IT Services Research

The term "Internet of Things" (IoT) was first introduced in 1999 by MIT's Kevin Ashton in a presentation to Procter & Gamble where he talked about empowering computers with their own means of gathering information. Since then several factors have steadily contributed to making the concept a reality, including:

1. Growth in uniquely identifiable devices or end-points, with most estimates pointing to tens of billions of devices by 2020 (i.e., Cisco estimates 50 billion, Juniper 37 billion, Gartner 20 billion);
2. Successive generations of mobile telecom networks with 4G and 5G deployments crucial to enabling the needed bandwidth and latency requirements of emerging use-cases;
3. Development and mainstream adoption of technology innovations such as smartphones, cloud, social networks, phone cameras, and storage;
4. Software innovations in areas such as artificial intelligence (AI) and real-time analytics; and
5. Regulatory changes such as ensuring the availability of GPS for commercial use.

IoT cases exist in a wide range of consumer and business application areas and can be enhanced by adding a payments layer

Use cases for IoT that are either currently proposed or in some cases nascent/growing, exist in a wide range of consumer and business application areas including Connected Health, Connected Home, Car of the Future, and Smart City in addition to specific industrial and retail applications. These applications are likely to have common elements such as sensory or measurement capabilities, localized data storage and analytics/intelligence, and a communications layer.

Consider a set of sensors on a truck. They can monitor truck engine diagnostic codes at a regular frequency (measurement), search for problems (intelligence), and then convey any problems found to a network of repair shops (communication). These are the necessary technical components of an IoT system.

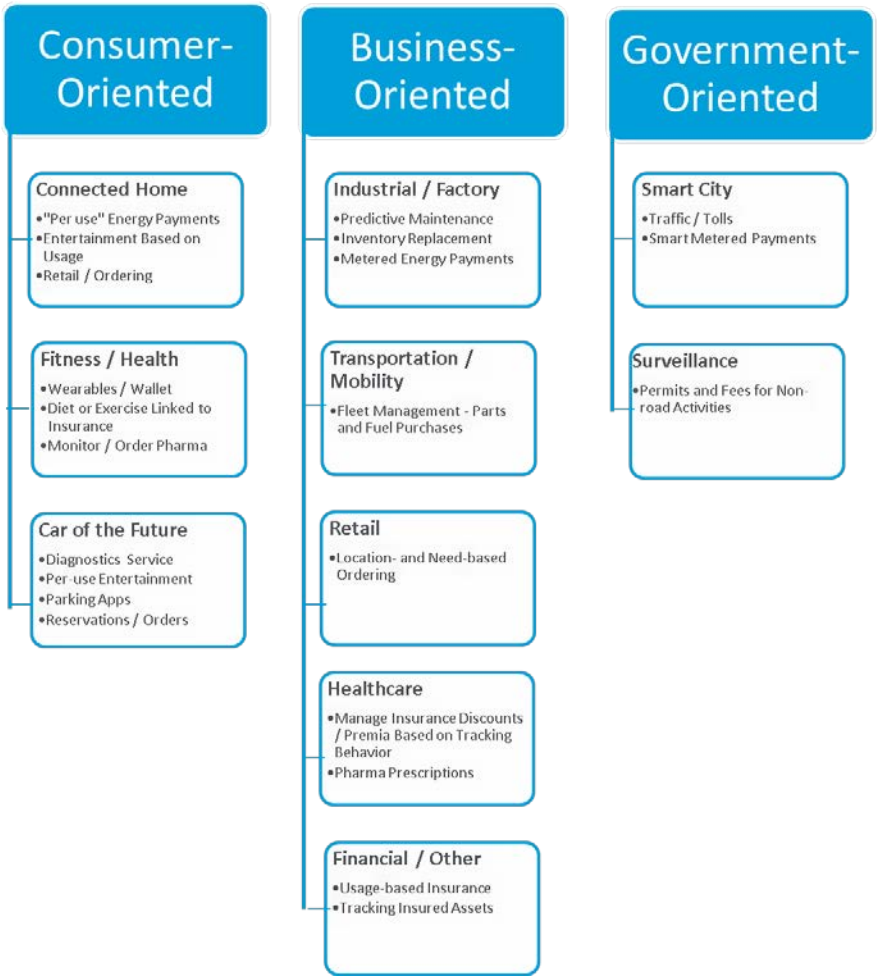
Now consider an enhancement to the above set-up — instead of merely conveying the need for a repair to the garage, what if there was a payments layer with the truck owner's payment credentials built into the system, which ordered the part when needed and perhaps even checked to see if the part was covered by a warranty and applied for the necessary price adjustment? This additional payments/commerce layer illustrates the idea of "IoT Payments". It dramatically enhances the value proposition of the basic IoT layer by adding both convenience and cost efficiency to the list of traditional benefits, which in this case might also have included safety. The comparison between IoT and IoT Payments is similar to a comparison between the early days of the Internet (static, mostly informational web pages) and today's Internet (vibrant, indispensable, with a rapidly growing e-commerce market). With multiple reasons to encourage businesses and consumers to make the IoT investment when the IoT Payments layer is added, we believe it can help in the proliferation and monetization of IoT use-cases.

IoT Payments Taxonomy

IoT Payments end-markets fall into three categories — consumer, business, and government

An easy way to break down the emerging IoT Payments end-market is to look at it through the lens of the end-user. With this viewpoint, the high-level categories include: (1) Consumer-oriented IoT payments; (2) Business-oriented IoT payments; and (3) Government-oriented IoT payments. The next level beyond this consists of families of IoT applications – for example Connected Home, Connected Health and Connected Car — which are commonly pursued consumer IoT applications and a payments layer is central to each of them. Our classification scheme is illustrated in Figure 34 below.

Figure 34. Types of IoT Payments



Source: Citi Research

IoT Payments Market Size Estimates

The markets size for the overall IoT market is wide, ranging from $662 billion to $4.3 trillion

Estimating the exact market size is difficult for any emerging and disruptive technology (i.e. one in which use cases are still being developed and the concept of net market size exists due to some of the market potential being directed towards “replacement”). Accordingly, the wide dispersion in estimates for the total IoT market size is not surprising. At the low end, MarketsandMarkets estimate the overall IoT market to be $662 billion by 2022 while IDC and Machina have higher estimates at $1.3 trillion by 2019 and $4.3 trillion by 2024, respectively.

Although none of these estimates disaggregate "IoT Payments" estimates, we believe 1%-2% of the total IoT market size seems to be a reasonable proxy. To be clear, this would represent payments revenues, not payments volume.

IoT Payments Emerging Use Cases

Real IoT announcements have a well-defined payments component to them

The list of proposed IoT use cases that have emerged over the past five years is a very long one. An interesting observation we have is that, with the possible exception of public safety applications, these use-cases correlate well to IoT Payments. A second observation is that "real" (as opposed to "proposed") IoT announcements have a well-defined payments component, i.e., it is the payments layer that makes these applications practical.

1. Mastercard and GM collaborate on the OnStar Go mobility platform, which uses Masterpass payment technology and Mastercard Digital Enablement Services (MDES) to enable drivers to pay in advance for food pickups and to fill up their tanks at gas stations. Mastercard's payment gateway has also been integrated with General Motors' OnStar system. The gateway enables both credit and debit card processing to pay for parts and accessories at more than 4,000 Chevrolet, Buick, GMC, and Cadillac dealerships in the U.S.

2. Mastercard announced it is working with Samsung to allow consumers in the U.S. to order items from FreshDirect and ShopRite supermarkets, via Samsung's Family Hub refrigerator.

3. Visa is working with ParkWhiz, one of the largest mobile parking apps in the U.S. The app can be integrated with in-car systems where payment credentials have been added. The parking app helps a driver pay only for the time used and helps avoid under- and over-paying. Once a parking session is ended, the elapsed time and amount paid are shown on the car's dashboard, requiring the driver to simply press a button to complete the transaction. It eliminates the need for drivers to take tickets or check out at pay boxes, which is frictionless and also more secure (roughly 7% of all U.S. violent crimes occurred in parking lots, according to the Bureau of Justice Statistics).

4. Both Garmin and FitBit have announced a wearable fitness watch with payment capabilities. Garmin's device is powered by the FitPay Payment Platform, a proprietary technology platform that uses tokenization to transact in a secure fashion.

5. Members of workspace-sharing company WeWork can pay for the actual time they use their digitally-connected "hot desks" and the company's snack and beverage service using Mastercard payment technology, Cisco's Kinetic IoT data platform, and WeWork's own AVA SmoothShop technology.

6. PayPal's contextual commerce investments including the provision of online "Buy" buttons are an example of IoT Payments.

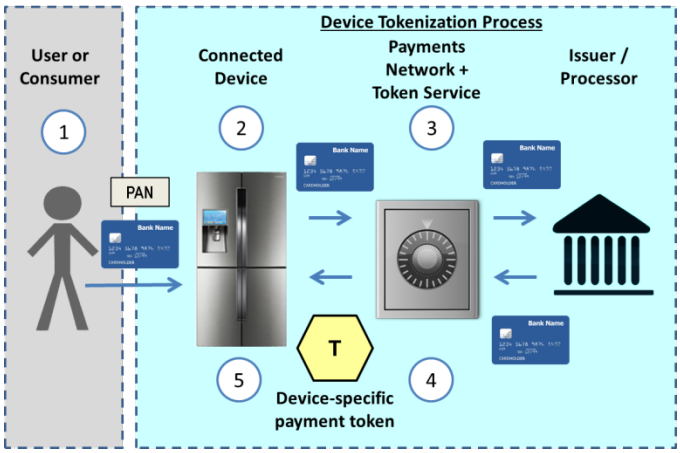
7. According to Ernst & Young, there are an estimated 5 million active usage-based insurance (UBI) policies in 35 different countries. From this relatively low base, EY estimates that UBI policies will reach 15% market penetration by 2020 in Europe, Asia, and the Americas primarily based on the adoption of "pay as you drive" and micropayments capabilities being incorporated into Life, Property & Casualty (P&C), and other insurance company business models. Cryptocurrencies are often considered as viable options when building our micropayments capabilities.

Breaking Down an IoT Payments Process

Payments automation is a key attribute of IoT Payments. Identity management, payment security (generally using a form of tokenization) and localized and context-specific intelligence are the problems that must be solved for before payments can be automated. In other words, the payment credentials (or a representation thereof, i.e., a token) must be readily available and the transaction must be authorized in an IoT context.

Figure 35 and Figure 36 illustrate the IoT payment building blocks for a smart appliance scenario, where a refrigerator is placing an order, presumably based on contextual knowledge (running low on specific items) as well as the buyer's payment credentials and knowledge of who the right seller is for those items.

Figure 35. Tokenization is a Preliminary Building Block of IoT Payments

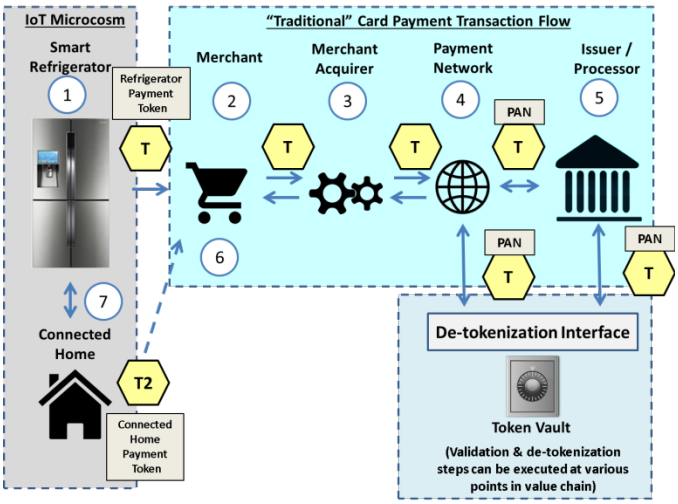


Note: PAN = Primary Account Number

1. Cardholder loads account to connected device.
2. Device / token requestor request payment credential from Token Service for account.
3. The token request is shared with the account issuer (e.g. consumer's bank).
4. With issuer approval, the account number is replaced by a unique identifier (e.g. token).
5. The token is shared with the device / token requestor. A payment token can be limited to a specific device or number of purchases before expiring.

Source: Citi Research

Figure 36. IoT Smart Appliance Payment Flow with Integrated Tokens



Note: PAN = Primary Account Number

1. Smart refrigerator senses that food inventory is low. Initiates payment for specific SKUs with a merchant for a replenishment order.
2. Merchant sends token to acquirer.
3. Acquirer receives token and routes it to proper network.
4. Payment network either passes token along payment credentials (tokenized or de-tokenized) to issuer / processor.
5. Once de-tokenized, the payment authorization request is passed to the issuer's authorization system with the real primary account number. The authorization response is then returned.
6. Merchant receives authorization message, notifies smart refrigerator, and fulfills order.
7. Refrigerator reports transaction and inventory levels to "Connected Home" service, which manages connected functions. Connected home autonomously pays recurring fees for service.

Source: Citi Research

New Roles for Traditional Payments Players

Card networks, processors (both issuer- and merchant-side), digital wallet providers, and various software and services companies which enable value-added solutions are the major categories of payments players in a traditional commerce system.

Human input is an integral part of the traditional commerce system, whether for a consumer-based or a business-based transaction, because humans exercise judgment for what to buy, where to buy, how much to buy, what form of payment to use, where to ship the product or service, and so on. Some of these decisions are likely to be automated in an IoT Commerce scenario, albeit based on human input. As the pre- and post-transaction process changes for IoT, there is likely to be a broader impact on the commerce value-chain that is worth mentioning.

What changes do we expect to see within the payments ecosystem with the adoption of IoT payments?

1. The categories of payments industry participants within an IoT Payments set-up are likely to be the same as we see within traditional payments.

2. The card networks are already stepping up and making investments to support security — particularly tokenization and biometrics needed in an IoT environment.

3. Two categories of IoT transactions should emerge. Many transactions will likely be replacement transactions, e.g., if a smart appliance is placing a grocery order instead of a human going to a grocery store, it does not add to the regular transactions. But IoT also expands the electronic payments market — perhaps in a traditional B2B environment, there might have been a set of paper-based purchase orders and invoices, but in an IoT context, the underlying rules and actions must be codified and there is an automated identity management and authorization task to be carried out for the payment to process. Card networks, merchant acquirers as well as issuer-side bank IT processors can handle this additional responsibility.

4. Merchant acquirers should continue in a familiar role in an IoT ecosystem but it will likely require an additional investment in terms of integration with IoT developers, adding cross-channel payments capabilities and so on. Essentially if connected devices are to take on the role of humans in many of these transactions, the merchant acquirer's system must adapt to receiving and processing a different type of input. Reliable, high-speed processing is crucial given the adverse impact latency can have on an automated payments transaction. In many cases, the bulk of the transaction does not change – similar to what happened when various digital wallets were introduced to the market and only the point of sale needed to be modified to accept the change.

5. Digital wallet and prepaid account providers can initially benefit from increasing consumer IoT payments as consumers may desire a dedicated "walled" account or extra layers of protection for IoT payments. "Digital first" payments platforms may benefit given the ease at which a digital wallet or merchant acceptance products can be integrated with IoT channels.

6. Software companies that provide payments security, analytics, and artificial intelligence/machine learning capabilities should benefit. As always, systems integration and consulting companies benefit from the need to integrate the added functionality.

Disruption and Other Factors to Consider

Given that IoT Payments are closely linked and dependent on IoT, several of the risks and challenges of the latter can understandably be stated as concerns for IoT Payments as well. Examples include security concerns; fears about data privacy; overly rosy expectations (i.e., hype cycle) that lead to disappointment; fear about loss of control (especially to inanimate machines and devices) as financial transactions become automated; and technical considerations such as a lack of network bandwidth to fully support IoT data transfers. Additionally, specific to payments, there can be concerns around its unproven business model, "top of wallet" concerns, the need for standards and the recognition that an ecosystem approach is needed.

- **The Need for Standards:** We expect the number of IoT solutions to proliferate and in line with this, business models and complexity may also increase. Tactically, this means there is a need to agree upon a schema to represent and protect customer information, device-to-device communication and connectivity protocols, end-to-end security standards, and governance to ensure fairness as well as rollback capability in case of errors.

- **Security and Data Privacy:** The focus here is the weakest link, not necessarily about just one set of devices being secure. Failure to secure one device can bring an entire system down i.e., the Target data breach which affected millions of U.S. consumers was enabled through the retailers HVAC system. To make it more personal, what if a hacker was spying on your child through the baby monitor, which you connected to your firm's network so you could check in on the baby and nanny while at work?

- **Why is a Partnership/Ecosystem Required?** This may seem obvious but a successful IoT Payments application needs hardware expertise and integration; firmware knowledge; software development capabilities; security know-how; payments and data analytics proficiency, and much more. It is difficult for a single entity to have all these capabilities under one roof.

- **Branding and Loyalty:** Input devices, i.e., wearables, smart phones, sensors, beacons etc., continue to proliferate. These translate to consumer choice and greater convenience, which can put pressure on established brands. Beyond this, there is a more insidious factor to consider – who will be "top of wallet"? There is considerable pressure on being the first to market an app and be embedded. After all, once you load a particular card on your FitBit, are you really going to swap payment choices in and out from week to week? This also extends to B2B payments for industrial applications and supports the notion of disruption at a brand level rather than for an entire application category. In other words, issuer banks that fall behind in deploying this technology and networks and acquirers that do not adapt will likely lose share to those that invest and partner for IoT.

These are not insurmountable challenges but they must be considered in the design of an IoT Payments systems.

Investment Management

Disruptive Active Pricing Battles Passive Investing

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Head of European Diversified Financials Research

There is a seismic shift going on across global equity markets. According to EPFR, passive equity funds have seen global inflows of $620 billion in the past 12 months. Active funds have seen outflows of $359 billion. Many think that this will create major inefficiencies across markets, but there is little evidence (yet) of serious dysfunction. The shift partly reflects the difficulties of generating excess returns when information dissemination is instant, technology is cheap, and other fund managers are highly skilled. It also represents a profound reassessment of the fee that savers are willing to pay asset managers to invest their capital in global stock markets. The current split between U.S. active and passive equity funds is around 60%:40%. We estimate that this could shift to 50%:50% in coming years. Other equity markets and asset classes will lag, but are heading in a similar direction.

Why Now?

Why are passive equity funds becoming so fashionable now? After all, Jack Bogle started the first index-tracking mutual fund back in 1975. The efficient market hypothesis, and its implication that trying to beat the market is futile, has been around for even longer.

It also seems strange that passive investing is on such a roll after two historic bubbles (housing in the last cycle, tech stocks in the late 1990s) and subsequent ferocious bear markets. If that didn't prove to asset owners that markets are inefficient then we are not sure what will.

Passive is Cheap

In a low return world, investors are focusing on asset management costs

We suspect the switch to passive partly reflects greater investor focus on asset management costs, especially in a low return world. If equity markets are generating 10% returns per year then paying 100 basis points to an active manager may be tolerable, but if returns drop to 5% then it is not. And, for all the controversy surrounding passive funds, one thing cannot be denied — they are cheap. The Investment Company Institute (ICI) estimates that the average charge for U.S. active equity mutual fund is currently 84 basis points, compared to a passive fund at 11 basis points.

ETFs have increased the cost advantage of passive over active investing

The cost advantages of passive over active investing have been made even more evident by the rise of exchange traded funds (ETFs). These have been around for less time than passive mutual funds — the first U.S. ETF, which tracks the Standard & Poor 500 Index (S&P), was started in 1993. Nowadays, ETFs come in many forms, but simple market capitalization tracking passive funds make up the majority of assets under management. Fees are even lower for passive ETFs (4 basis points to track the S&P) than they are for passive mutual funds and pressure on fees is likely to be downwards. If costs are to remain a focus for end-investors then it seems likely that expensive active funds will remain at a disadvantage.

Active Funds Have Struggled

Underperformance by active managers has been an issue over the past few years

The financial pages are full of stories about active managers failing to keep up with benchmarks. Within equities, the U.S. looks the most challenging with over 85% of active managers underperforming their indices over the past five years. It seems that life is a little easier elsewhere where in emerging markets, Japan, and the U.K. only 70% of funds have underperformed.

While depressing if you are in the active management business (or advise the active management business), this data should not be too surprising. Given that we would expect the collective of non-passive investors to return the market less their costs, it makes sense that the majority lag their benchmarks. And even if 80% underperform, that will mean 20% outperform. Also, it doesn't sound so bad if we point out that, after costs, 100% of passive funds should underperform.

Stock Market Ownership Cycle

The rise of passive funds can be partly explained by the stock market ownership cycle

The high costs and questionable performance of active managers have left them very vulnerable to the low costs and predictable (in a relative sense at least) performance of passive managers. This is especially the case in the U.S.

Perhaps this is inevitable in the life cycle of stock market ownership. At first it is largely owned by individuals. Then those individuals shift their capital to professionally-managed active funds, which offer the benefits of diversification and the opportunity for the more skilled active manager to outperform those who have not moved into active funds. But as more individual investors make this move, there is less 'dumb money' for professional managers to pick off and professional fund managers get sucked into a zero-sum game where another well-trained, well-informed professional is on the other side of every trade.

This presents an opportunity for passive funds that offer similarly diversified equity exposure but at a much lower cost. The shift in stock ownership from individuals to active funds fades but the shift from active to passive funds begins.

Picking Funds is Hard

Finding a skilled active manager that will outperform in the future is not easy

Even if 80% of active funds underperform, rather than just giving up and going passive, surely it is still worth putting in the effort to find the 20% that will outperform. After all, an extra 100 basis points above index performance can make a huge difference. However, picking a skilled manager is not easy. The obvious strategy is to put your money into a fund with a strong track record. Unfortunately for active managers, research suggests that the best single indicator of future fund performance is fees (Morningstar 2016).

There is no magic formula for picking a fund manager that will outperform in the future. In fact, the odds may be that you will pick one that underperforms. In this situation, it is hardly surprising that asset owners give up and move to low cost passive equity funds. At least you know what you're going to get.

A Strategic Response to Pressure from Passive Investing

To respond, active managers can cut fees, merge, or reinvent themselves with a more performance-oriented fee structure

Many active management companies are responding to the passive threat by cutting fees. This may be an unpopular option for shareholders, but is a surefire way to improve returns relative to benchmarks.

Another option for active fund management companies is to merge. This allows them to support profits by combining revenue lines and cutting costs. We are often told by asset management CEOs that there are positive returns to scale in the business. Of course that is true when they are talking about company costs, but most of the academic literature suggests that it is not true when looking at fund performance. Alternatively, scale does benefit both shareholders (higher revenues) and fund holders (lower fees) in the passive investment business. At one passive giant, mutual ownership takes away this shareholder/fund-holder tension completely. That makes them even harder to compete against.

The rise of passive investment management has undermined the profitability of the asset management industry. The stock market has recognized this. In the old days, asset managers used to outperform the bull market. That is no longer the case. Companies need to reinvent themselves: as alternative managers, solutions providers or partners of choice for key distributors. A more performance-oriented fee structure might help.

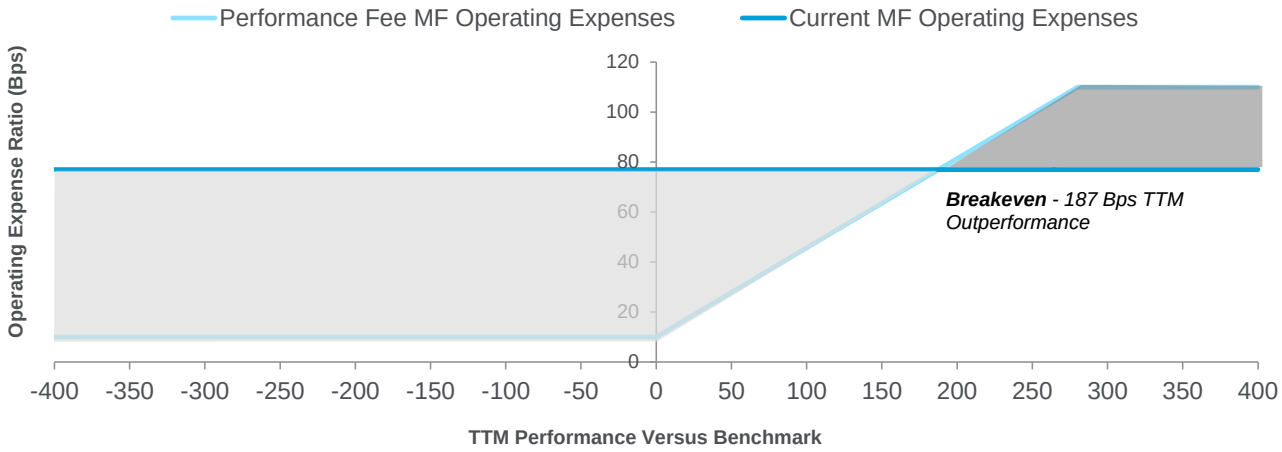
Variable Pricing Mutual Funds

New variable fee mutual funds have a sliding management fee based on the fund's relative performance

In 2017, active asset manager AllianceBernstein announced a series of variable fee mutual funds, where the management fee will slide depending on the fund's relative performance. While the new fee structure varies by fund, it conceptually works as follows:

- If the firm simply matches the benchmark, the management fee will be 5 basis points;
- If the firm outperforms by 140 basis points, the management fee will be 55 basis points; and
- If the firm outperforms by 280 basis points (or more) the fee will cap out at 105 basis points.

Figure 37. Client's Should See a Net Benefit to the New Fee Structure Under Most Scenarios



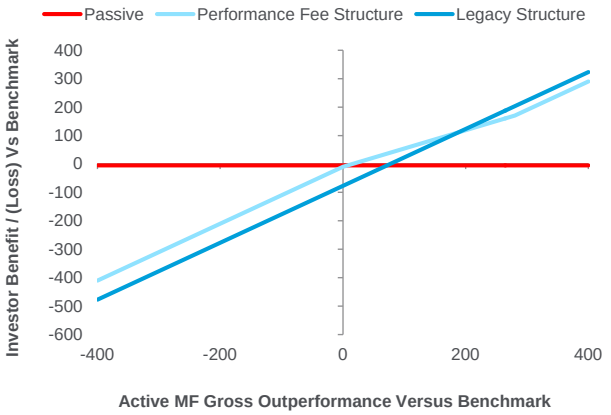
Note: Based on Large Cap Growth Portfolio Fee Disclosures: Shaded green area shows investor fee benefits versus current fixed fee structure; red area reflects increased fees versus current fixed fee structure. Assumes 5 basis points of "Other Fund Expenses". MF = Mutual Fund
Source: Mutual Fund Filings, Citi Research

There is incentive for distributors to sell these funds as they uphold a fiduciary standard, limits the risk of manager selection and are likely an easier sell to investors

Favorably, such funds may appeal to distributors and create significant growth in assets under management. Why might distributors be willing to sell these funds? Several reasons:

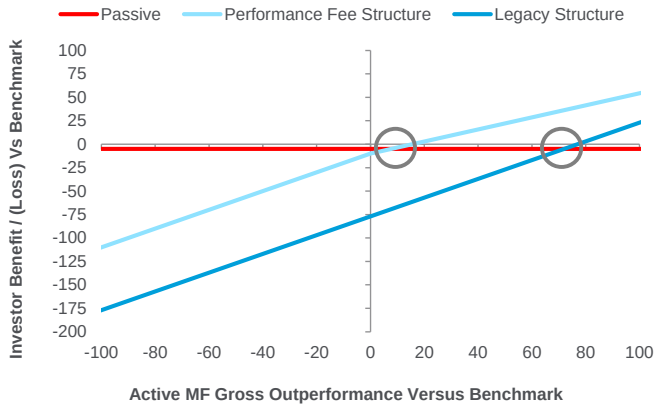
- It may better align with fiduciary standards;
- It limits the risk of manager selection particularly as the industry continues to underperform; and
- It is likely to be an easier sell to investors. As constructed, the AllianceBernstein fund would seemingly do no worse than a market capitalization-weighted ETF that simply offers 'index minus ETF cost' return if the fund simply replicates the index. Or the same value proposition of the market capitalization-weighted ETF. However, AllianceBernstein's structure offers option value to both the investor and the distributors should the fund outperform, particularly with the outperformance/management fee capped to the upside. Within the current structure, there is no "giveback" should they underperform the benchmark.

Figure 38. End Investors Generally Receive Better Net Returns in New Performance Fee Structure than Legacy Active Structures, Except in period of Substantial Outperformance...



Note: We assume passive replicates the benchmark under all scenarios, less a 5 basis point fee. In this example, the new structure would provide a higher pre-tax return to investors than Passive after only 8 basis points of gross outperformance, versus 72 basis points of outperformance for the legacy structure.
Source: Citi Research

Figure 39. ...With the New structure Outperforming Passive on a Net Basis After Only 8 Basis Points of 'Alpha' vs 70 Basis Points Previously



Note: We assume passive replicates the benchmark under all scenarios, less a 5 basis point fee. In this example, the new structure would provide a higher pre-tax return to investors than Passive after only 8 basis points of gross outperformance, versus 72 basis points of outperformance for the legacy structure. MF = Mutual Fund
Source: Citi Research

But the funds may radically alter the industry:

- Given the industry has consistently underperformed the market, management fee rates and thus revenues would likely tumble for many players;
- While perhaps a (very) long-term positive, such underperformance would rapidly consolidate the market should the product find mass adoption – though in theory this might then make it hard for those remaining players to sustain outperformance;
- Such funds will raise execution risks around compensation and expense management, capital management, and introduce significant P&L volatility. Of course, the counter to this would be that if the firm has a wide enough array of funds across asset classes, such risks may get diffused, calling for greater scale; and
- We suspect the industry's multiple would likely compress.

Why Would this Product Be Tougher to Manage?

Despite the positives, the concept of charging performance on retrospective performance raises a few risks

As we understand it, AllianceBernstein will continue to heavily set compensation on rolling three and five year returns, effectively reducing the risk of portfolio managers to 'game' the system and take on excessive tracking error risks. However, in periods of outperformance during down markets, margins may come under pressure. In turn, such funds may create significant cultural pressure on compensation given the risk of the management fee potentially dropping to 5 basis points. In turn, since the industry has effectively failed to deliver outperformance, we believe capital management policies would likely become much more variable.

Additionally, the concept of charging performance on retrospective performance does raise a few risks. First, should investors allocate to the fund following a period of sizable outperformance, they would pay a premium price for alpha they did not participate in — and should the fund subsequently underperform, investors could potentially be caught paying above-market fees for below benchmark returns. Second, there is the potential issue of "free riding" where investors allocate to the fund following periods of underperformance when the fee rate is low, only to withdraw funds following periods of strong performance to avoid paying premium pricing.

One Existential Risk of Adoption

Another risk to the new structure is that behavioral finance would come under major change

A variable pricing model raises performance recourse risk to both the manufacturer and the distributor. Currently, other than elevated redemptions, there is no other major economic risk to the manufacturer should they underperform. Under this new fund structure, such behavioral finance would come under major change. Such a move would seemingly blow apart the closet index value proposition, pushing the industry into more concentrated Alpha mandates — for which we believe industry capacity is far more constrained. Such a move may help to offset the encroachment of passive by leaving a wake of discarded players and/or heavily concentrated market shares to the very large players.

Liquid Biopsy

Tackling the Big C: Advancements in Cancer Detection

Daniel Arias
U.S. Life Science Tools & Diagnostics Analyst

Cancer is the leading cause of death worldwide, accounting for almost 9 million deaths each year. As such, the need for better ways to combat the disease is apparent. While a key requirement in the fight against cancer is access to better drugs for treatment, so too is access to better diagnostic testing capabilities that can improve the ability to detect and monitor tumors. Blood-based genetic testing, known as a liquid biopsy, is showing signs of filling that need and has the ability to dramatically improve cancer care in the coming years. All told, we think liquid biopsy testing could grow to become a $10+ billion market over the next decade, en route to becoming one of the most important clinical advancements in decades.

What is Liquid Biopsy?

Liquid biopsy allows the detection of generic material from a tumor to be analyzed non-invasively — through, for example, a blood draw

Cancer develops as the DNA within the cells of the body undergo deleterious (damaging) changes that cause healthy tissues to mutate into tumors. For decades, the standard laboratory procedure for assessing a tumor has called for surgery to be performed, after which a piece of tumorous material is removed and analyzed by a pathologist. The discovery, however, that tumor cells often break away from the original tumor and enter into the blood stream has resulted in strong interest in an alternative approach — whereby the biopsy is performed non-invasively in a manner that confers several advantages to the standard approach. As such, oncologists and pathologists are increasingly looking to analyze the genetic profile of a patient's tumor primarily not only through a blood draw — but within other body fluids such as urine, saliva, or cerebrospinal fluid.

The Tissue Is the Issue

Tissue biopsies have been the norm but require an adequate amount of sample tissue and give only one "genetic view" of the cancerous cells

Tissue biopsy has formed the backbone of cancer diagnosis for some time as it is well-established, and lends itself to both microscopy-based and molecular-based (DNA or RNA) analysis. The method, however, also has clear drawbacks. For one, acquiring an adequate amount of tissue that allows for initial and follow-on genomic analysis is not always possible. One study found that as many as 30% of non-small cell lung cancer (NSCLC) patients do not have accessible tissue that can be collected and analyzed. Additionally, the analysis of DNA from a tissue sample usually presents only one "genetic view" of the cancerous cells. One hallmark of a tumorous tissue is the heterogeneity that exists throughout as the genetic make-up from one part of a tumor is often quite different from that of another. Because of this, a tissue biopsy often does not allow for the full spectrum of relevant DNA mutations to be captured. The genetic profile of a tumor is also dynamic — i.e. it changes as the tumor evolves and responds to treatment. A tissue biopsy performed once as a part of initial diagnosis may therefore reveal a different genetic profile than what exists after a patient has undergone multiple rounds of therapy, which can impact the effectiveness of a particular drug.

There Will Be Blood

Liquid biopsy provides ample sample volume, is easy to draw, provides a comprehensive picture of a tumor DNA and can be performed serially as it is non-invasive

Liquid biopsy assays tackle several of these issues. Since the test is performed via a blood-draw, sample volume is not a limiting factor, and complication risk is limited. Additionally, the analysis of tumor DNA via a blood sample can paint a more comprehensive picture of a patient's tumor heterogeneity, as the DNA shed from a tumor into the blood represents the full spectrum of genetic variation within the cancer. Plasma-based testing can also be performed serially (at successive time-points) due to the non-invasive, lower-cost nature of the approach. This means that the genetic changes that a tumor undergoes can be followed closely during the

course of the treatment. This "window" into treatment response can give the clinician a better chance at using a drug that works and allows for developed resistance to be more quickly recognized than what is inferred through radiological imaging.

But sensitivity and specificity are challenges in broad-based liquid biopsy and it lacks a high level of standardization across the industry

Despite these advantages, the current state of the approach does face challenges. From a technical perspective, the sensitivity (i.e., the ability to correctly identify true positives) and specificity (i.e., the ability to identify true negatives) still need to improve due largely to the low concentration of tumor-DNA often found in the blood. Additionally, broad-based liquid biopsy assay usage lacks a high level of standardization across the industry, and there is a clear need for more comprehensive coverage by insurance companies.

Figure 40. Comparison of Key Features for Liquid and Tissue Biopsies

LIQUID BIOPSY	
Positives	**Negatives**
Minimally invasive	Further assay validation needed
No sample volume limitations	Low level of test standardization
Enables repeatable testing	Lack of comprehensive reimbursement
Provides complete genetic picture	
Faster turnaround time	
TISSUE BIOPSY	
Positives	**Negatives**
Well-established as practice	Invasive procedure
Allows for both microscopy-based and genomic interrogation	Difficult to repeat
	Longer turnaround time
	Requires preservatives that denature DNA
	Provides "localized" genetic picture

Source: Citi Research

Market Factors Are Coming Together

Recent advances lend evidence to believe that we are approaching an inflection point in the market for liquid biopsy

To be clear, liquid biopsy approaches have been potential clinical oncology tools for several years. The first paper on the PubMed database describing the technique in the cancer setting dates back to 2010. Over the last 12-24 months, however, advances in several areas have been made that have served to accelerate the pace of progress within the field, and lend evidence to the belief that we are approaching an inflection point within the market:

- **Technological Improvement**: Perhaps the most significant change has been the improvement in technical capabilities. Next-generation DNA sequencing (NGS) and droplet digital PCR (ddPCR) based methods have been developed that allow for "deep" analysis at very high levels of sensitivity, and sample preparation techniques have been tailored specifically to enable plasma-based mutation detection. With respect to the biology, multiple approaches have emerged that allow for DNA to be effectively interrogated: circulating tumor cells (CTC), cell-free DNA (cfDNA), and exosomes are biological components that can each be probed for genetic changes.

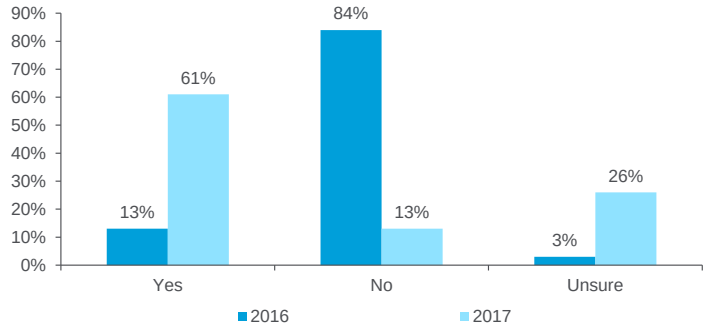
- **Reduced Cost**: The cost of analysis has fallen precipitously in recent years, allowing for labs to analyze samples efficiently and effectively. Next-generation sequencing instruments can now be purchased for well under $100,000, and (more importantly) the cost per experiment has decreased by a factor of 5x in the last three to four years.
- **Growing Acceptance by Payors**: The overall economics of testing are also improving as insurers increasingly recognize the value of genomic profiling. Reimbursement of NGS-based assays has gone from being non-existent a few years ago, to nearly universal for small panels in certain types of lung cancer. In May, Medicare contractor Palmetto GBA became the first payor to cover a liquid biopsy test via a limited coverage decision (LCD) specific to lung cancer patients.
- **Targeted Drug Development and Companion Diagnostics**: The number of drugs that target specific biomarkers continues to grow, increasing the utility of genomic assays. Additionally, tests that identify targets for treatment are progressing through the regulatory process. In June of 2016, the first liquid-biopsy-based companion diagnostic (a test to determine the appropriateness of a particular drug) was approved by the U.S. Food & Drug Administration (FDA).

Is This Approach Ready For Prime-Time?

We believe the stage is set for liquid biopsy testing to increasingly serve as a complement to tissue-based testing

Within five years, we believe liquid biopsy-based approaches will constitute a critical part of routine cancer care. The path that the method takes towards implementation, however, depends largely on the application. Within the clinical community, the overall view from many is that, broadly speaking, liquid biopsy testing for cancer detection is not ready to be fully integrated into clinical practice today. At the recent meeting of the American Society of Clinical Oncology (ASCO) in May, several experts called the approach an important step forward — but also stated that many issues (such as those highlighted above) need to be explored. That said, progress is being made with respect to incorporation into treatment and clinical trial strategies, and the outlook amongst clinicians is positive. To this point, we note that a Citi survey administered last year to a group of U.S. pathologists revealed high hopes for assay usage in 2017: whereas only 13% of respondents (n=40) offered a plasma (blood)–based assay as of mid-2016, 61% expected their lab to offer a liquid biopsy in 2017. Going forward, we believe the stage is set for liquid biopsy testing to increasingly serve as a complement to tissue-based testing — first in post-diagnosis applications, and later in early-stage assessment of asymptomatic individuals.

Figure 41. 2016 Citi Survey: Will You Implement a Liquid Biopsy Assay in Your Institution in 2016/2017?



Source: Citi Research

Key Applications

- **Serial Monitoring**: We see serial monitoring as the application most ready for regular implementation into routine practice. Liquid biopsies can be used to regularly monitor disease progression, response to therapy, and development of treatment resistance. If a repeat test suggests that the cancer is not responding to or becoming resistant to treatment, the clinician may be able use the information to adjust the patient's treatment plan. Blood-based monitoring is both cheaper and safer than repeat tissue biopsies and data suggests that genetic changes in cfDNA often occur before signs of tumor growth are apparent on a scan, making it a more effective method of monitoring progression

- **Minimal Residual Disease (MRD):** Similar to serial monitoring during cancer treatment, liquid biopsy can also be used to monitor patients after initial therapy to detect signs of microscopic disease and cancer recurrence. Since the detection limit of ctDNA is lower than that of imaging studies, liquid biopsy can be used to identify patients with minimal residual disease at the end of therapy that is undetectable by imaging, thereby enabling earlier treatment. Studies on feasibility have shown that circulating tumor DNA can be used as an effective marker for MRD (though the cost and time associated has been high) and data at the 2017 ASCO conference showed the ability to track multiple mutations and identify patients at high risk of recurrence.

- **Early Detection & Screening: The Holy Grail**: The ultimate goal is to use a blood-based test to screen to detect cancer at its earliest stages — certainly before it has metastasized and spread to other areas/organs, and possibly before a tumor has formed at a primary site. Successful application in this way would clearly represent a monumental step forward, as it would offer clinicians the ability to intervene and monitor early in order to halt disease progression. Application in this way, however, is viewed as still in need of significant additional work — particularly with respect to the refinement of signal-to-noise ratios and the elimination of false positives. Nevertheless, encouraging proof-of-principal data sets were presented by both academic and commercial parties at this year's ASCO meeting, and a commercialized assay is expected to be launched in 2019 that will target asymptomatic patient populations.

Smart Robotic Tools

Not Your Regular Robot

Martin Wilkie
Head of European Capital Goods Research

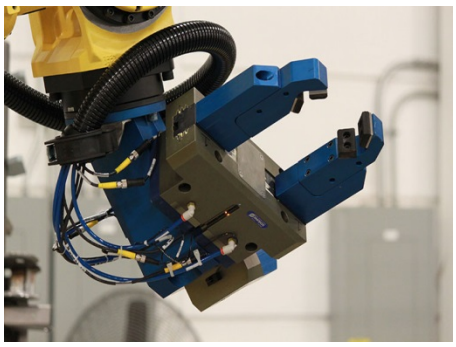
Graeme McDonald
Japanese Machinery & Shipbuilding Analyst

The rise of collaborative robots (cobots) is well documented but still in its relative infancy, accounting for <3% of industrial robots delivered in 2016 in volume terms. After Rethink Robotics and Universal Robots launched the first cobots in 2012, we estimate that there are now at least 15-20 suppliers of cobots, including the incumbent providers of industrial robots. Straight out the box however, these cobots need the equivalent of a hand at the end — often called an End-of-Arm Tool (EOAT) — typically provided by a specialist tool manufacturer.

End-of-arm tooling for large scale industrial robots is typically used for tasks such as welding, material handling, and painting, but cobots need to be much more dexterous if they are going to mimic human capabilities. These end-of-arm tools are often used for gripping, clamping, picking up work pieces, or to directly hold industrial tools like drills. Vision and a sense of touch can be mimicked by wrist cameras and force torque sensors, but these tools are not yet nearly as capable as the human hand.

Cobots themselves vary in price depending on functionality and payload, and are typically in a $20,000-$50,000 price range per cobot. Key applications currently include pick & place (selecting an item from a conveyor belt for example) and machine tending (loading and unloading parts and material from an injection molding machine, lathe, or machining center). Basic end-of-arm tool prices start not much more than $100, but smart end-of-arm tools can be closer to $1,500-$4,500, or about 10% of the cobot cost. Their importance should not be underestimated. Modern Materials Handling, a trade magazine, commented in 2015 that “the end-of-arm tooling, or gripper, is the place that can make or break a robot’s success.”

Figure 42. Parallel Gripper



Source: Bastian Solutions

Figure 43. Three-Fingered Gripper

Source: Bastian Solutions

Figure 44. Angled Gripper

Source: Robotiq

Grippers have historically had three basic designs – a parallel gripper where the two sides close to grip the object, a three-finger gripper where the three sides close to hold the object, and angled grippers which are used where there is a space constraint. These tools are a far cry from the human hand. According to the 2016 edition of *A Roadmap for U.S. Robotics*, a report by academia to the U.S. Congress, *“dexterity can be measured by a range of grasp types, scale, strength, and reliability”,* areas in which basic clamping technology fail. Other technical challenges include two point discrimination (the ability of the human hand to identify two distinct touch points), contact localization (the ability to detect and estimate the positions and directions of these contact points), actuation (the physical triggering of

movement given limitations of both electric and pneumatic methods), and back-drivability (controlling the interactive, rather than one-way, transmission of force).

How Close to Reality?

A 15-year path towards high-complexity robotic hands has been outlined for U.S. robotics

The coordination, dexterity, and flexibility of the human hand cannot be replaced by robots quite yet. *The U.S. Roadmap for U.S. Robotics* (see Figure 45) outlines a 15-year path towards high-complexity hands being available.

Amazon still runs its Amazon Robotics Challenge in order to bring together academic and industrial know-how to improve picking technologies. Amazon notes that "commercially viable automated picking in unstructured environments still remains a difficult challenge." Separately, the CEO of Adidas highlighted his own challenge — how to create a robot "that puts laces in the shoe", adding that it is "a complete manual process today. There is no technology for that." One area where some progress has been seen is in robot towel folding such as the Foldimate robot that was on display at CES 2017 and the Laundroid from Japan.

Figure 45. Roadmap for Human-Like Dexterous Manipulation

Timeframe	Expected Evolution
5 Years	Low-complexity hands with small numbers of independent joints will be capable of robust whole-hand grasp acquisition
10 Years	Medium-complexity hands with tens of independent joints and novel mechanisms and actuators will be capable of whole-hand grasp acquisition and limited dexterous manipulation
15 Years	High-complexity hands with tactile array densities approaching that of humans and with superior dynamic performance will be capable of robust whole-hand grasp acquisition and dexterous manipulation of objects found in manufacturing environments used by human workers

Source: *A Roadmap for U.S. Robotics: From internet to Robotics 2016 Edition*, Computing Community Consortium

Tools such as suction cups, adaptive tools and soft manipulation grippers are progressing robot arms towards the human hand

There are some tools that have already progressed beyond the standard grippers, but fall short of the human hand.

- **Suction:** Suction cups can also be used for picking, either in isolation or combined with other technologies. These are not without problems, including limitations with surface types. The winner of Amazon's 2016 picking challenge however used a combined two-fingered gripper and a suction cup.
- **Adaptive tools:** Unlike basic tools, adaptive tools react and adjust to the task depending on measurements that the tool itself makes (through sensors) while performing its task. Adaptive tools are already on sale.
- **Soft manipulation:** Delicate objects are easily damaged by standard grippers, with soft grippers aiming to manipulate delicate objects that vary in size — particularly important for food picking, for example. The "SoMa project" explores the robotic picking and packing of shopping orders. Short for "Soft Manipulation", the project is a European Union-funded program that aims to be fully implemented by 2020 in collaboration with various research institutions across Europe. The project aims to develop a gripper compatible with existing industrial robot arms, but able to handle more fragile objects such as eggs, fruits and vegetables.

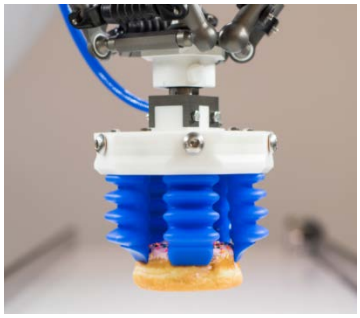
Figure 46. Three-Fingered Adaptive Tool

Source: Robotiq

Figure 47. Suction Cups

Source: Rethink Robotics

Figure 48. Soft Manipulation



Source: Soft Robotics Inc.

How Well Known?

In some ways, robots aren't as advanced as they are often perceived

One oddity in the perception of robotic penetration is that robots are not quite as advanced as often perceived. Foxconn had targeted to have 1 million robots by 2014 to replace its assembly workforce, a target not reached, although the company has been adding over 30,000 robots annually. It's not clear how much of the slower-than-expected adoption is cost-related versus technology-related.

How Big Could the Opportunity Be?

Industrial robot growth of 13% is expected in 2017019 while cobots are still in relative infancy

The International Federation of Robotics (IFR) expects the overall industrial robotics market (in unit terms) to grow at an average 13% annually during the 2017-19 period, where "compact and easy-to-use collaborative robots will drive the market in the coming years". The IFR's World Robotics 2016 report comments that it expects human-robot collaboration to have a "breakthrough" in this period. We would argue that the emergence of smart tools will act as the catalyst for this breakthrough.

The cobot market is in its relative infancy, with Universal Robots estimating the market is currently <$200 million and set to grow to $2 billion by 2020. Various industry sources expect the market to continue to grow at a rate over 25% and put the market size at ~$7 billion by 2025. This could put the smart tool market at up to $2 billion annually, with further opportunities in software, putting the direct overall opportunity in excess of $10 billion annually.

We also see this as an enabling technology for far larger markets:

- We estimate the warehouse automation market at ~$20 billion, but this is a market where picking is almost 100% manual and smart picking tools can be an enabler of further growth.
- We estimate the factory automation market at $90 billion, although adding robots, manufacturing software, machine vision, and sensors soon takes the "factory of the future" addressable market to close to $200 billion. Smart tools, in addition to sensing, vision, data, and software, will be key enablers of growth.
- While we have focused on industrial applications, further advancements could see convergence and use in prosthetics markets.

Barriers to Adoption

The advancement of technology itself is the primary barrier to adoption as the human hand is quite complex

The technology itself is a barrier to adoption until sufficiently advanced. As highlighted by analysis from the Oxford Martin School in a previous GPS report, Technology at Work v2.0, *"…manipulating an object with some understanding of its material characteristics, to make sure that it is not damaged in the process, requires a deep understanding which is difficult to reproduce within software. Thus, in time-varying, heterogeneous environments, the tacit knowledge and pliable hands possessed by humans are likely to remain superior to robotic labor for some time.*" The *Roadmap for U.S. Robotics* report referred to earlier also notes that substantial progress is still needed in materials, sensors, and controls "*to allow us to get closer to the dexterity of a young child."*

The human hand is also available to hire by the hour, and a minimum wage employee possesses dexterity not yet attainable by robots. Even the lowest end $25,000 cobot + tool reflects a capital cost equivalent to about 4 months of work as calculated using the fully loaded hourly manufacturing labor cost in the U.S. (at $38/hour in 2015 according to the U.S. Conference Board). In China, this payback period is over two years. Universal Robots estimates the average robot payback period at 195 days. While these paybacks may be acceptable in developed markets for standard shifts, human hands may still be preferred for seasonal surges in activity especially with regards to the handling of food.

The human hand also doesn't need re-programming when it switches from picking fruit to tying shoelaces, meaning the flexibility of task-switching (and related re-programming costs) will be key. Finally, the human hand doesn't need a safety assessment each time it starts a new task, in contrast to the ISO 10218 standard specifications for robots.

Winners and Losers

- **Tool providers:** The suppliers of existing tools are in most cases different to those who supply the robots, though one exception is Universal Robots. The nascent development of the technology means there are many start-ups, including both corporates and university labs. The Robo-Cup 2016, which has four categories including industrial, had 1,200 robots entered for its challenge, in many cases from universities.

- **Software suppliers:** Most tools are currently controlled via the robotic arm, although this may be changing. More dexterous tools require more control, and in turn gather more data to be fed back to the broader factory automation systems. Tool suppliers are launching "smart" tools that bypass robot control systems and link directly to the programmable logic controllers (PLCs) that dictate control of the broader factory. We see PLC suppliers as a potential key winner from smart tool adoption.

- **Robot and component suppliers:** Robot suppliers should benefit from the volume growth of increased adoption, although we see some risk that the robotic arm becomes commoditized. Smart tools still rely on the cobot taking the tool to specific coordinates, but the fine motor control is wirelessly managed between the PLC and the tool itself. In this scenario, there are risks that the robotic arm becomes a commodity, and cobot producers will need to respond in other ways, through ease of installation, and making the robotic arm part of a broader system in order to differentiate. Hand-eye coordination needs an eye as well as a hand, meaning the machine vision market should benefit from increased robot penetration. Suppliers of key components like servo motors and precision speed reducers are also set to benefit.

Unmanned Commercial Aircraft

Robot Pilots, So Close and Yet So Far

Stephen Trent
Latin American Transportation Analyst

The deployment of robot pilots on commercial flights could improve the airline industry's safety record, as well as the sector's profitability and efficiency. Over the long-term, robots — or artificial intelligence (AI)-piloted planes — could revolutionize commercial air travel. Robot pilots could greatly reduce risks that are associated with human error, while efficiency improvements could also translate into higher aircraft utilization rates. (Utilization refers to the number of hours per day that an aircraft is actually in the air — planes in the air generate revenue while those on the ground do not.)

Flights can get delayed or cancelled when human flight crews become ill, are incapacitated, go on strike or take downtime when safety rules require a certain amount of rest after extended work shifts. Robot pilots would not be vulnerable to any of these issues, even as they might be at least somewhat vulnerable to the issues that afflict other advanced computer programs.

The concept of AI-guided vehicles has already crept into other industries. Companies such as Google have driverless car programs such as Google X, Uber launched its first driverless vehicle in Pittsburgh last year, while companies such as Rockwell Collins have been experimenting with pilotless fighter aircraft.

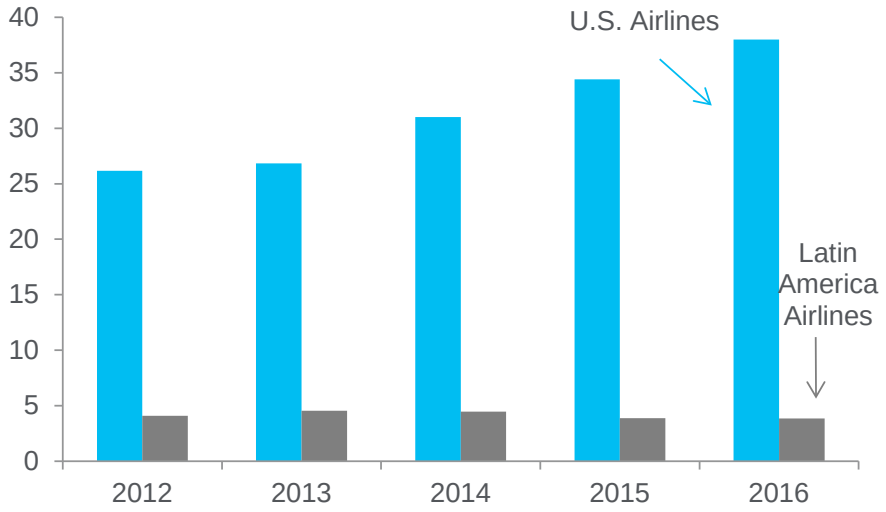
Although AI-guided vehicles are showing up in other industries, Citi does not see AI-guided commercial planes getting rolled out over the next decade. Passenger apprehension regarding robot pilots might be the greatest impediment to the airline industry embracing this technology. Powerful pilots' unions, along with their lobbyists and congressional representatives, are also likely to resist this technological rollout. Once a rollout does occur, it is bound to be very gradual, and might initially entail flights with a human pilot and an AI co-pilot on certain routes.

Commercial Airlines Could See Efficiency, Profitability Boosts

Replacing human pilots with robots could materially reduce labor expenses, which make up one-third of labor costs for the aviation industry

Figure 49 shows that the big four U.S. airlines spent a combined $38 billion last year on salaries, wages, and benefits, while six of their Latin America-based counterparts spent $3.9 billion on these items over the same period. As pilots are airlines' most expensive employees aside from the executive teams, replacing human pilots with robots could materially reduce these expenses, even as the transition to fully AI-piloted aircraft could take years. Citi estimates that pilots account for approximately one-third of the aviation industry's labor costs.

Figure 49. Selected Americas-Based Airlines' Salaries, Wages and Benefits Expense (US$bn)

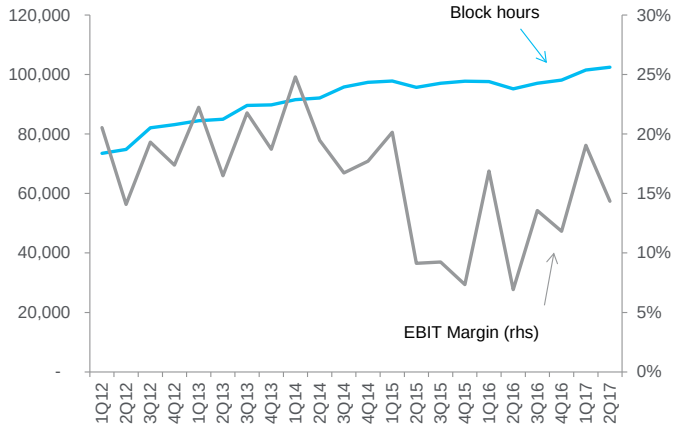


Note: The U.S. airlines include American Airlines, United, Delta, and Southwest. The Latin America-based airlines include Avianca, Azul, Copa, COL, LATAM Airlines and Volaris.
Source: Company reports, Citi Research

Improved utilization through robotic pilots could also lead to higher EBIT margins

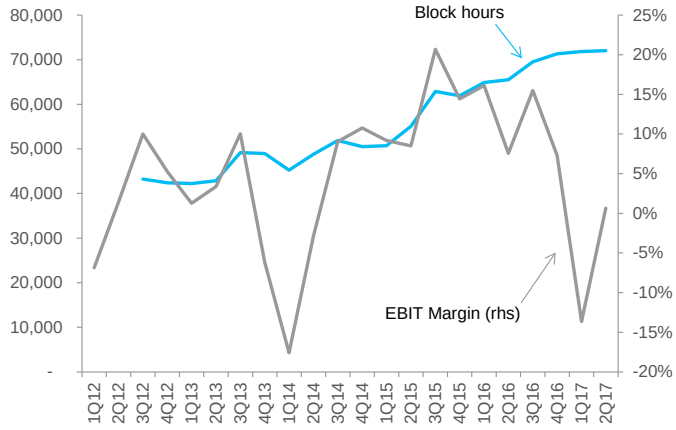
Looking beyond potential labor cost savings, commercial airlines could also benefit from improved utilization. This could mean quicker turnaround times — or planes spending less time accumulating airport fees sitting on tarmacs or docked at gates, and more time revenue-generating flight time. Figure 50 below shows a correlation of 0.57 between sequential changes in utilization and earnings before interest and tax (EBIT) margins for Panama's Copa Airlines, with Figure 51 showing a 0.29 correlation between utilization changes and the more volatile margins of Mexican ultra-low-cost-carrier (ULCC) Volaris.

Figure 50. Copa's Block Hour Utilization vs. EBIT Margins



Source: Company reports, Citi Research

Figure 51. Volaris' Block Hour Utilization vs. EBIT Margins



Source: Company reports, Citi Research

Both full-service and low-cost carriers look to benefit from higher utilization rates

Although the data shown in Figure 50 and Figure 51 does not represent an exhaustive list of global airlines, it shows airlines that have two very different business models and both benefit from higher utilization rates. While Volaris operates a single class of service and charges for on-board items, as well as checked bags on some flights, Copa Airlines has planes with business and economy class cabins and the carrier does not charge for food and drink on its core flights. Copa does separately operate a ULCC called Wingo, but Wingo represents less than 1% of the carrier's consolidated capacity.

Although commercial airlines and AI/tech companies screen as obvious beneficiaries of this rollout, industries that could be hurt are those that are associated with pilot unions and flight schools.

Significant Automation Already Exists on Commercial Flights

Commercial flights are statistically the world's safest passenger transportation mode but pilot error bears some of the blame when an accident does occur

Statistically speaking, commercial flights are already one of the world's safest passenger transportation modes, with the probability of being involved in a fatal commercial airline accident running at 1 in 29.4 million. In contrast with aviation, the odds of being killed in an automobile accident are approximately 1 in 30,000. Still, commercial airline accidents do occur and pilot error bears some of the blame. Aside from pilot error, other factors in commercial airline accidents and incidents include unexpected meteorological events such as wind shear, air traffic control errors, mechanical failures, bird strikes, sabotage, and terrorism.

Some degree of automation has been on airplanes for decades

Although the traveling public will probably need a long time to get comfortable with the idea of AI-guided aircraft, it is worth noting that commercial flights have been operating with some degree of automation for decades. This includes autopilot systems and fly-by-wire, as shown in Figure 52.

Figure 52. Common Flight Control Automation in the Commercial Aviation Industry

Automation	What Is This?	Commercial Introduction
Fly-by-wire	Redundant computer programs that are situated between mechanical flight controls and an aircraft's actual movement	1959
Autopilot	An automatic flight control system that allows the pilot to fly the plane, without continuous hands-on control. In these instances, a pilot would typically input data such as heading, altitude, etc.	1930s
Instrument landing	An electronic system that allows an aircraft to land, even if pilots are unable to establish visual contact with the runway	1938

Source: Flyingmag.com, Airbus, Morgridge Institute of Research, Airservicesaustralia.com, Centennialofflight.net, Citi Research

Maintenance of emergency readiness skills of human captains is a concern with the addition of robot co-pilots

With respect to whether increased automation of commercial flights is a good thing, there are concerns that human pilots become too complacent with automated systems — under these circumstances, pilots that are reliant on significant automation might have trouble acting decisively during emergencies. The presence of AI co-pilots might exacerbate this problem. Therefore, as robot co-pilots get integrated into the system, the industry would need to address how they would maintain emergency readiness skills of their human captains.

It is hard to forget US Airways Flight #1549, when Captain Chesley "Sully" Sullenberger safely splashed his plane down onto New York City's Hudson River, after bird strikes had disabled both engines of his A320 commercial aircraft shortly after takeoff in January 2009. Sullenberger's quick thinking and steady nerves resulted in all passengers and crew surviving what could have otherwise been a tragic event. This incident provided a powerful example of the value of a human pilot's emergency response.

Fly-by-Wire Planes Don't Always Have Lowest Accident Rates

There is some evidence that fly-by-wire aircraft have marginally higher fatal accident rates vs. manually controlled aircraft

There is some evidence that shows that aircraft with fly-by-wire systems have marginally higher fatal accident rates than their manually controlled counterparts. Of the major commercial aircraft original equipment manufacturers (OEMs), Airbus uses fly-by-wire technology on all of its planes. On the other hand, rival Boeing only started using fly-by-wire on its recently introduced 777 and 787 twin-aisle aircraft. However, Boeing's best-selling narrow-body (single-aisle) 737 family does not use fly-by-wire.

Airsafe.com shows that the Airbus 318, 319, 320, and 321 single aisle jets have a fatal accident rate of 0.11 per million flights. Airsafe.com includes flights with at least one passenger fatality in its criteria for this study — fatalities of pilots, crew members, terrorists, etc. are excluded. This data also doesn't consider non-fatal accidents or incidents.

The same source shows that Boeing's newest narrow-bodies — the 737 Next Generations (NGs), or the 600, 700, 800 and 900 series planes — have a fatal accident rate of just 0.08 per million flights. Older Boeing 737 Classics — or the 100s through the 500s — have a fatal accident rate of 0.15 per million flights. Of course, the 737 Classics entered commercial service in the 1960s — and flight crew training, maintenance policies, air traffic control systems, anti-collision software, etc. have become more sophisticated in recent decades.

Global aviation data on non-fatal accidents is harder to find. However, Quora.com puts Airbus A318 / A319 / A320 / A321 total accident rates at 0.26 per million departures. For Boeing's manually controlled 737 600s, 700s, 800s and 900s, the accident rate is just 0.20 accidents per million departures.

AI-Pilot Technology Faces Barriers

Passenger acceptance of robot-piloted or co-piloted aircraft is the biggest hurdle to roll-out

Passenger acceptance of traveling in robot-piloted or co-piloted aircraft seems to be the biggest barrier to this technological rollout.

Aside from passenger aversion, other potential impediments to the introduction of robot pilots are significant. These barriers could include how to seamlessly interface this new technology with commercial aircraft, as well as safeguarding the AI against network outages, power outages or cyberterrorists.

Disruptive Innovation Ideas from the Past

There's big opportunity out there

Disruptive Innovations

The **3D printing** market is expected to be worth **$6.5bn** by 2019

The **e-cigarette** market could have compound annual **growth of near 50%**

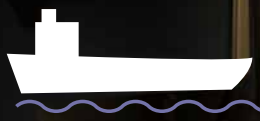
US sales for **compressed natural gas (CNG)** vehicles could surpass **100,000** by 2020

100,000,000

10,000

The **cost per genome** in DNA sequencing has fallen from $100m in 2001 to < $10k today

Pay **TV industry** only added **200k subs in 2012 vs. 2mn at its peak** while **streaming subs** are increasing **exponentially**



Subsea processing equipment has potential to be a **$100bn pa** market by the next decade

Mobile Payments could see a transaction value of **$1trn by 2016**

Software as a Service (Saas) currently 8% of total software wallet is expected to **grow to 70%** of budget over time

2013
$360mn

2016
$3,700mn

Software Defined Networking (SDN) is expected to grow from just under $360mn in 2013 to $3.7bn in 2016

Solar could see **$1.3trn** of investment in new capacity from 2012-35

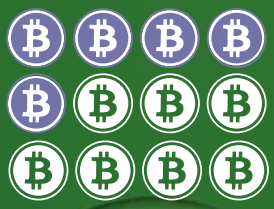
There's big opportunity out there

4D Printing

4D printing takes 3D printing to the next level by directing the object to **change shape and potentially self-assemble**

Digital Banking

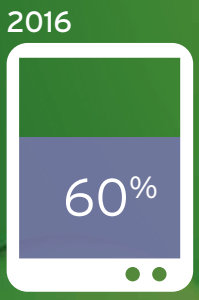
Global **m- payment** volumes are expected to total **$447 billion by 2016**, a **3-year CAGR of 86%**



$5m

Digital Currency (i.e. Bitcoin)

.More than 200 digital currencies exist today, with **12 having marketing capitalizations > $5 million**



Digital Marketing

Real-time bidding-based digital ad spend is expected to reach nearly **60% of total display and mobile spend by 2016**, a 3-yr CAGR of 66%

Electric Vehicles

Introducing a battery operator servicing model could reduce the cost of an **electric car to the $10k** range

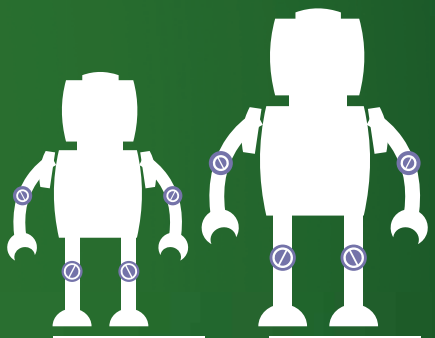
$35 billion

Immunotherapy

Immunotherapy has the potential to **turn cancer into something akin to a chronic disease** – a $35 billion opportunity

Energy Storage

The economic value of energy storage over a 10-year period in the US could be $228 billion, **21% of the $1 trillion global economic benefit**



2012 $25bn

2016E $30bn

Insurance Securitization

Since 2012, the new issue market for insurance -linked securities has grown by 30% per year and **issuance could be $60 billion by 2015**

Robots

The market for industrial robots is forecast to grow with almost **200k units expected to be sold in 2016**

Precision Agriculture

To support a **population that is growing by ~75 million people per year**, agricultural producers will need to **boost production of key crops by 20%**, on average, over the next decade

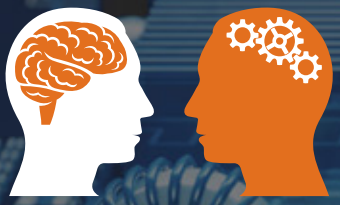
There's big opportunity out there

Disruptive Innovations III

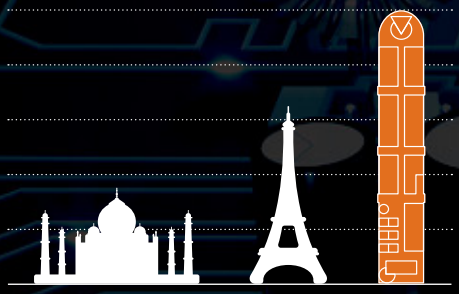
Autonomous Driving
By 2030, driverless cars could be a $100 billion market

Drones
Almost 800 million small packages could be delivered by drones in the US

Machine Learning/Artificial Intelligence
Humans can manage about seven variables in their working memory vs. computers which have no limit



Biosimilars
Biosimilars are poised to take over $110 billion in revenues from drug innovators over the next 10 years.



Floating LNG
The length of Shell's new FLNG facility is equivalent in size to the Eiffel Tower standing on top of the Taj Mahal

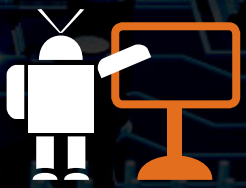
Public API
The rate of adoption for APIs has increased exponentially, similar to the adoption rate for smartphones

Sharing Economy
The five most prominent sharing economy sectors could rise to $335 billion from just $15 billion today

Virtual Reality
Starting with game makers and goggle-like game terminals in 2016, the VR/AR market could rise to $200 billion in the first 5 years

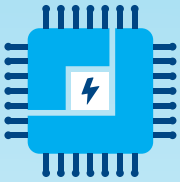
Marketplace Banking
The total addressable market for P2P lending is $254bn, or 8% of the total US consumer credit market

Robo-Advisors
From just $19 billion at end-2014 the target addressable market for Robo Advisors could rise to $5 trillion over the next 5 to 10 years



There's a big opportunity out there

Disruptive Innovations IV



Wide Bandgap Semiconductors
Wide bandgap semiconductors let devices operate at much higher temperatures, voltages, and frequencies while being smaller and more reliable.

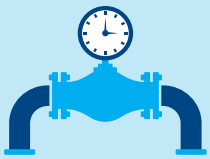
The Future Look of Devices
Consumer devices by 2021 could look like a thin and flexible piece of paper through the use of flexible OLED technology.

Home Networking
Consumer media devices could be the focal point of the "connected home", integrating a variety of services and connectivity into one location.

Energy: The Big Data Revolution
Big data analytics would make producing oil/gas faster and cheaper, renewables forecasting more accurate, and the transport-generation-storage model more integrated.

Epigenetics
Epigenetic approaches in cancer treatment could become a $10bn market by 2025.

Thermoplastic Subsea Pipes
Switching from traditional steel pipes to new thermoplastic pipes decreases subsea costs by 30-40% and total deepwater costs by 10%, enough to lower the breakeven oil price by $4/bbl.



Direct-to-Consumer Marketplace
Moving from proximity-sourced product to a direct-to-consumer marketplace would create a $200bn annual revenue opportunity for apparel manufacturers.

Open-Source Robotics
The use of open-source software in robots can accelerate robot penetration by lowering customer adoption cost.

Next Gen Ocular Drug Delivery
New delivery methods will increase the ease and effectiveness of drug delivery for the growing number of people with ocular disease.

Contextual Commerce
Increasingly, online purchases will be suggested and transacted through non-traditional e-commerce sites such as social media.

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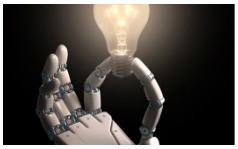

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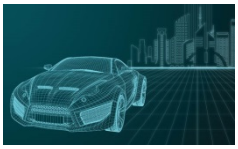

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Key Insights regarding the future of Disruptive Innovation

COMMODITIES

In physical commodity trading, each step in the process requires multiple verifications, exchanges of papers, signatures, and other steps that are subject to delays and forgery. / The bundling of each step of the process in physical commodity trading via blockchain would increase efficiency and make it difficult to countefeit transactions.

INNOVATION

For decades, the standard laboratory procedure for assessing a tumor has been surgery to remove a piece of tumorous material and have it analyzed by a pathologist. / Oncologists and pathologists are increasingly looking to analyze the genetic profile of a patient's tumor primarily not only through a blood draw — but within other body fluids such as urine, saliva, or cerebrospinal fluid.

TECHNOLOGY

End-of-arm tooling for large scale industrial robots is typically used for tasks such as welding, material handling, and painting, but collaborative robots (cobots) need to be much more dexterous if they are going to mimic human capabilities./ Tools such as suction cups, adaptive tools and soft manipulation grippers are progressing robot arms towards the human hand.