Emerging Ecosystems

The 'Outsiders' Volume 2.0

What happens when everything old becomes new again? A spate of ecosystems and concepts born as far back as the 1960s are beginning to redefine the scope and impact on industries – new and old. In the second edition of our 'Outsiders' series we dive into these eight emerging trends with a focus on helping investors understand their potential and separate the hype from reality.

Indeed, among the ecosystems we profile, facial recognition technology dates back to the 1960s, veggie burgers have been a meat alternative for decades and gaming made headlines in 1980 with Atari's National Space Invaders tournament. Digital Twins were used in NASA's space exploration days, academics have spent decades identifying market risk premia and SPACs can trace their roots back to 18th century England. Despite their history these products and platforms have reached a potential tipping point as they demonstrate real world usability and rise in adoption.

(1) Facial Recognition. Advances in machine learning are driving accuracy improvements as adoption rises across the authentication, surveillance and search advertising markets. China, to date, is in the driver's seat on use/adoption.

(2) eSports. Massive global audiences turn video games into professional sport. Monetization opportunities abound.

(3) Digital Twins. Virtualizations of physical products or processes are saving cost and quickly becoming integral to industrial IOT strategies. Adoption may soon spread beyond capital goods to insurance, social media & advertising.

(4) Meatless Meats. Rapidly rising global protein demand presents sustainability, sourcing and emissions issues, but new innovations could provide an alternative.

(5) Quantum Computing. Is this method of computing the answer to the slowing of Moore's Law?

(6) Ethereum. Builds on the concept of Bitcoin by adding programmability. Hype is high with $3bn of ICO fundraising in 18 months but can these 'distributed apps' deliver?

(7) Alternative Risk Premium. Harnessing multiple risk premia across asset classes marks the next evolution of systematic investing.

(8) SPACs. PE style investing with public market liquidity and a key role to play in today's market landscape.

Robert D. Boroujerdi
+1(212)902-9158 |
robert.boroujerdi@gs.com
Goldman Sachs & Co. LLC

Christopher Wolf, CFA
+1(212)934-4221 |
christopher.wolf@gs.com
Goldman Sachs & Co. LLC

Ronny Scardino
+1(212)357-3775 |
ronny.scardino@gs.com
Goldman Sachs & Co. LLC

THE OUTSIDERS

This is the latest in our **Outsiders series** exploring emerging ecosystems at the edge of today's investable universe.
Explore more →

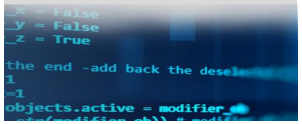


Table of Contents

Facial Recognition: Line of sight to reducing physical and cyber crime	3
eSports: Re-imagining Sports for a Digital Age	7
Digital Twins: Bridging the Physical and Digital Worlds	12
Meatless Meats: Sustainably feeding a growing population	16
Quantum Computing: Solving problems in minutes, instead of millennia	19
Ethereum: An emerging platform for distributed applications and commerce	23
Alternative Risk Premia: Where Beta Meets Alpha	27
SPACs: Back and bigger than ever	31
Disclosure Appendix	35

Analyst Team Contributors

Gabriela Borges
'Facial Recognition: Line of sight to reducing physical and cyber crime'
gabriela.borges@gs.com
212-357-2692
Goldman Sachs & Co. LLC

Christopher D. Merwin, CFA
'eSports: Re-imagining Sports for a Digital Age'
christopher.merwin@gs.com
212-357-9336
Goldman Sachs & Co. LLC

Joe Ritchie
'Digital Twins: Bridging the Physical and Digital Worlds'
joseph.ritchie@gs.com
212-357-8914
Goldman Sachs & Co. LLC

Adam Samuelson
'Meatless Meats: Sustainably feeding a growing population'
adam.samuelson@gs.com
212-902-6764
Goldman Sachs & Co. LLC

Toshiya Hari
'Quantum Computing: Solving problems in minutes, instead of millennia'
toshiya.hari@gs.com
646-446-1759
Goldman Sachs & Co. LLC

James Schneider, Ph.D.
'Ethereum: An emerging platform for distributed applications and commerce'
james.schneider@gs.com
917-343-3149
Goldman Sachs & Co. LLC

Robert D. Boroujerdi
'Alternative Risk Premia: Where Beta Meets Alpha'
robert.boroujerdi@gs.com
212-902-9158
Goldman Sachs & Co. LLC

Christopher Wolf, CFA
'SPACs: Back and bigger than ever'
christopher.wolf@gs.com
212-934-4221
Goldman Sachs & Co. LLC

Facial Recognition

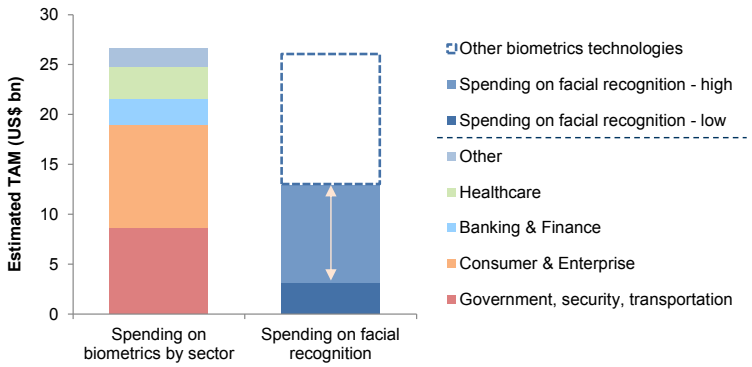
Line of sight to reducing physical and cyber crime

Gabriela Borges

Facial recognition technology has existed since the 1960s; however, advances in machine learning technology for video analytics have improved accuracy to the point where a new set of applications have become viable. We explore three "killer applications" in security and surveillance, identity and access and retail analytics which could drive facial recognition to comprise up to half of a broader global $26 bn 2020 biometrics TAM (Exhibit 1). While the adoption of facial recognition tools catalyzes a renewed debate on privacy, the reality is that governments and corporates already have access to a context-rich database of our information. The upside? Facial recognition can improve authentication processes, make the surveillance industry significantly more efficient, and ultimately reduce both physical and cyber crime.

What is facial recognition? Facial recognition identifies people by comparing digital video footage or images to a database of known records. Data is collected via official sources (such as government agencies issuing photo IDs) as well as forums where consumers voluntarily share images (such as social media sites or the configuration process on the iPhone X). When collecting the data, key features are measured and categorized, such as the distance between the eyes, or the depth of the nose (please see our 3D sensing report for more detail). These features are saved as a template. When presented with an input, facial recognition software will attempt to match the new data against the template, with machine learning algorithms adjusting for dynamic features such as haircuts or lighting. Data capture is enabled by imaging and infrared sensors, and data processing is enabled by machine learning software platforms.

Exhibit 1: Spending on facial recognition could comprise up to 50% of the 2020 biometrics TAM, primarily at government, consumer and enterprise
Estimated biometrics TAM by sector, and by technology vector



Source: ABI, Technavio, Goldman Sachs Global Investment Research

Exhibit 2: More advanced sensors and machine learning algorithms enable the next generation of facial recognition applications
Representative companies, list not comprehensive

Sensors for 3D capture - image, infrared, depth			
Finisar	Lumentum	Sony	Viavi
Smart video cameras			
Dahua	Himax	Hikvision	Netgear
Video analytics software			
Alarm.com	Amazon	Apple	Bosch
Cognitec	Facebook	Google	Honeywell
IBM	IntelliVision	Palantir	Verint
ID and authentication			
FaceFirst	Gemalto	NEC	Safran

Source: Goldman Sachs Global Investment Research

Why does it matter? By 2020, 95% of video/image content will have been analyzed by machines, rather than by humans (Gartner). We estimate that facial recognition could comprise as much as 50% of the global $26 bn biometrics market (from 12% today, Technavio). This TAM spans hardware (i.e. embedded sensors in consumer electronic devices) and software (machine learning algorithms), across facial, voice, fingerprint, vein, and iris recognition. We believe facial recognition can enable efficiencies in a number of industries (detailed below), where a significant amount of money is otherwise being spent on verifying who we are through other methods, with varying degrees of accuracy. Driving efficiencies with facial recognition technology can ultimately reduce both physical and cyber crime.

China: At the forefront of innovation, with an ambitious government rollout in turn fostering a vibrant private-company landscape. We expect Asia Pacific, led by China, to drive the majority of growth in the facial recognition market over the next 5 years. China is uniquely positioned to implement facial recognition technology: it already has a comprehensive video surveillance network and maintains image databases for all its adult citizens. The Chinese Government plans to install over 600 mn facial recognition cameras by 2020 to bolster surveillance efforts and reduce crime. Robust government demand, coupled with early adopters (enterprises and consumers), has fostered a vibrant landscape of well-funded start ups, most notably a) SenseTime ($637 mn in funding to date, valued at over $2 bn per Reuters), whose customers include China Mobile, China UnionPay, Huawei and Xiaomi, b) Megvii ($607 mn in funding to date, valued at over $1.5 bn per Financial Times), whose Face ID authentication technology sells into ~90% of China's Top 200 Internet companies, with a developer community of over 300K in 150 countries, and c) DeepGlint ($18 mn in funding to date), whose customers include the Chinese government and financial institutions.

We see three key markets to watch:

1) Streamlining the $2 bn authentication market. Facial recognition offers advantages over traditional knowledge-based passwords: it can reduce authentication time, and can be harder to trick when implemented correctly. We highlight the following applications: **A) Breach prevention:** 81% of breaches in 2016 were enabled by compromised credentials (stolen or lost passwords), and security breaches cost enterprises $400 bn globally in 2016 (Verizon, Lloyd's). By replacing passwords with facial recognition, breaches – and their associated costs – can go down. **B) Streamlined border crossings:** Homeland Security currently tracks foreigners into and out of the United States; in Australia, 90% of arrivals will be processed automatically by facial recognition technology by 2020. **C) Reducing friction in financial transactions and improving the user experience:** Chinese banks have introduced facial recognition for ATM deposits and withdrawals, including the Agricultural Bank of China which plans to roll out the technology in over 24,000 locations. Using facial recognition with a personal ID allows customers to make withdrawals and deposits without needing a physical card or wallet, and makes it harder for criminals to withdraw money with a fraudulent debit card. Similarly, facial recognition better enables secure mobile payments, such as Ant Financial using Alipay for "smile to pay" at KFCs in China, powered by Megvii. In China, third-party mobile payments account for as much as 75% of total payment value (see Future of Finance: The Rise of Chinese FinTech).

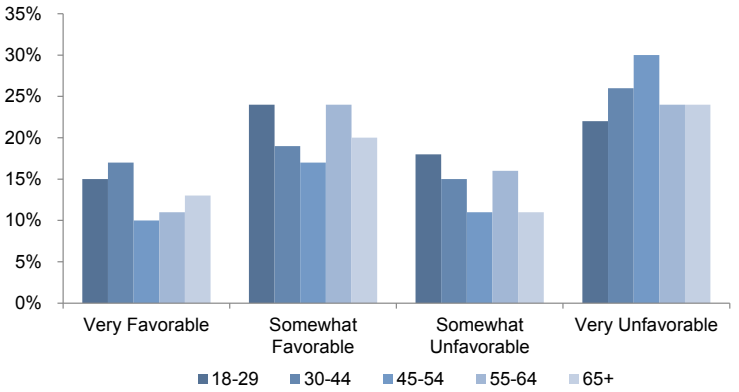
2) Reducing crime and incentivizing behavior as part of the $30 bn video surveillance market. Given today's elevated level of geopolitical risk, this technology can scan crowds for potentially "suspicious" persons, or allow "wanted" individuals to be captured more effectively. Companies like Deep Glint aim to make surveillance footage searchable and help governments scale surveillance efforts. For example, Tiananmen Square municipality produces over 1,800 TB of surveillance data daily which would be impossible for humans to monitor effectively. For commercial security, facial recognition can identify shoplifters and reduce theft, which costs retailers an estimated $33 bn per year. In the $21 bn home security market, smart security cameras can reduce false alarms rates, which can average over 90%.

3) Enabling the next generation of analytics in the $100 bn+ search advertising market. Advertising companies currently employ a range of techniques to make their ads more effective, including lifting data from browsing history, emails, and social media. Alongside digital data, solutions from vendors like RetailNext and ShopperTrak use video cameras in stores to count traffic, create heat maps in the store and glean insight on customer shopping habits. Facial recognition overlays an additional set of analytics to allow ads to be targeted based on your physical identity, and its associations with emotions, socio-economic factors, and demographics. For example, digital signs at KFC tailor menu recommendations to customers based on their age and gender. **For social media companies with business models that rely on advertising dollars, facial recognition tools overlay augmented reality and filters on digital content to ultimately improve user engagement.** Snapchat introduced selfie lenses with facial recognition powered by its $150 mn acquisition of Looksery in late 2015, and now has tools that allow users to animate digital avatars by leveraging the iPhone X's FaceID. Facebook acquired face-swapping startup MSQRD in 2016 to add similar functionality.

Exhibit 3: Facial recognition can be used to create targeted advertisements
Detecting demographic and mood data via facial recognition

Source: Goldman Sachs Global Investment Research

Exhibit 4: Users' attitude towards facial recognition in personal devices
Even with younger consumers more positive, concerns remain across age groups



Source: eMarketer, Goldman Sachs Global Investment Research

Other considerations: Privacy Concerns, cost of implementation. Survey work suggests that the majority of users have an unfavorable view toward facial recognition in personal devices, although the split skews more positive in younger demographics (Exhibit 4). High profile data breaches and upcoming data privacy regulations in the EU (General Data Protection Regulation) underscore the importance of protecting personal data and have driven heightened awareness around data privacy. Unlike passwords, biometric data — once compromised — cannot be altered or reset. To alleviate privacy concerns, the retail industry is focused on collecting anonymized data while the security industry is focused on limiting the technology to only identify persons of interest. More importantly, we believe consumers likely underestimate the degree to which governments and corporates already have collected data to enable future facial recognition applications. Further barriers to adoption could include the need for specialized hardware for 3D facial recognition including infrared cameras: even with 24% pricing compression per year in specialized smart security cameras, prices will still be 3X greater than IP-based surveillance cameras (IDC).

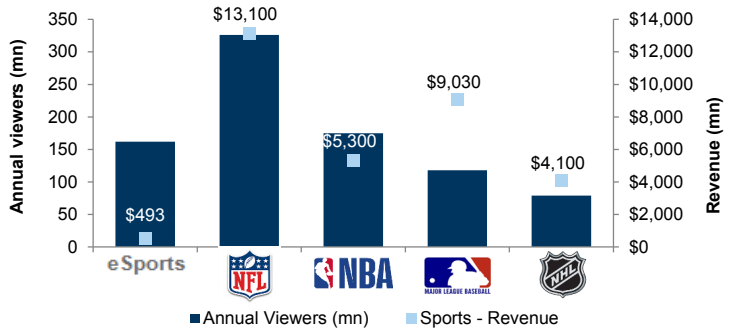
eSports Re-imagining sports for a digital age

Christopher D. Merwin, CFA

eSports have been around for as long as the video game industry itself, and collectively refer to competitive video game play by professional and amateur gamers. But in recent years, growth in gaming audience and player engagement has elevated eSports into mainstream culture as a legitimate professional sport with a massive global following. Today, the global monthly audience for eSports is 191mn people, according to NewZoo, larger than that of Major League Baseball and the NHL, and comparable to the NBA. By 2022, we estimate the eSports audience will reach 385mn, surpassing even the NFL. The rapid growth and massive scale of eSports is the result of a number of structural trends in gaming and society, as growing leisure time among consumers is re-invested in video games, and increasingly, social connections are formed and maintained through online communities. We believe it's still early days for growth in eSports, which over time should create substantial revenue opportunities – media rights, advertising, and in-game purchases – for leading game publishers.

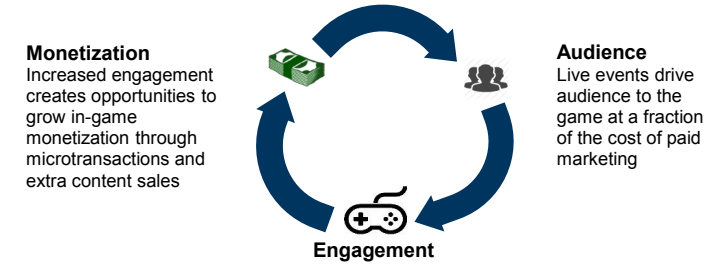
Monetization has not caught up to audience – yet. According to NewZoo, eSports will generate roughly $700mn in revenue this year, far less than established sports leagues. Part of the reason for this is structural: eSports are a collection of many video games with different IP owners across different genres (first person shooter, role-playing games, sports, etc.) that do not all collectively bargain for TV rights or sponsorship deals, as is the case with the NFL, for instance. But even so, we believe there is a long runway to close the monetization gap. We have already seen one landmark deal, as BamTech agreed to pay Riot Games $300mn over 6 years to distribute League of Legends games. As eSport leagues formalize, we expect eSports revenue can increase by multiples of its current $700mn run rate, with the economics accruing primarily to IP owners, league organizers, and players.

Exhibit 5: The eSports audience should grow at a ~15% 5-year CAGR
Annual viewership (mn) and revenue ($mn) for eSports and pro sports leagues, 2016A



Source: NewZoo, Marketwatch, CBS Sports, Forbes, Statista, Activision, Goldman Sachs Global Investment Research

Exhibit 6: The virtuous cycle of eSports – audience, engagement, and monetization
eSports should re-enforce long-term engagement and monetization



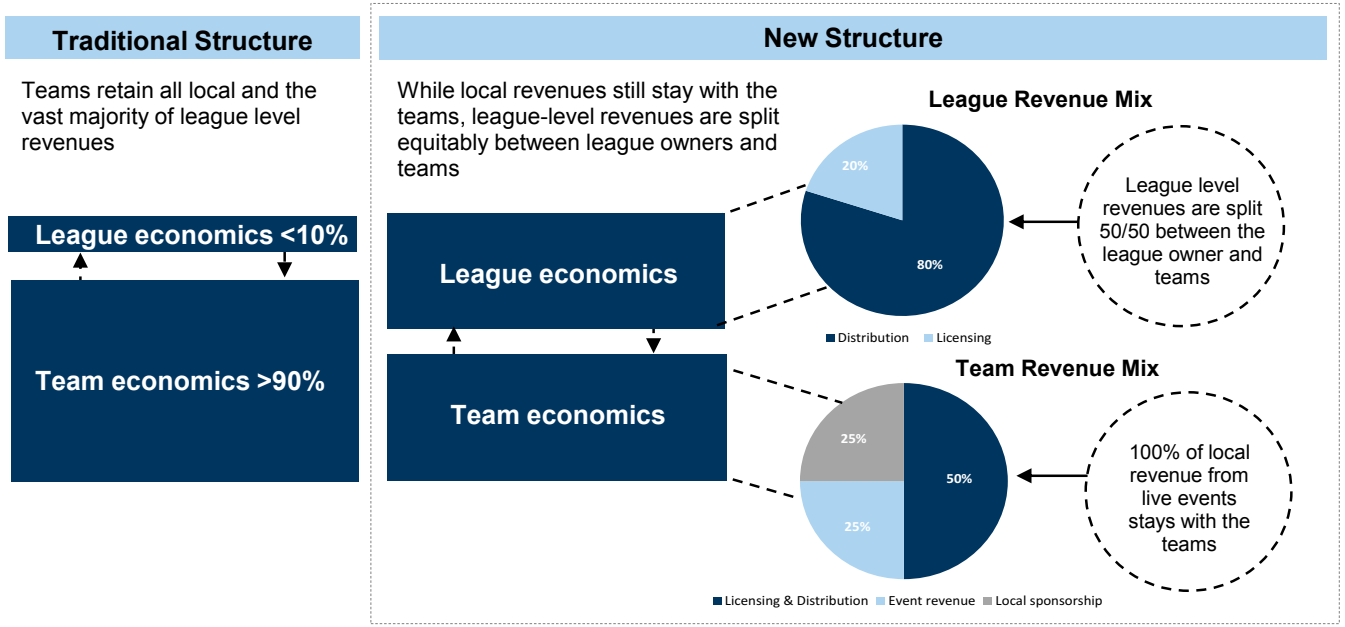
Source: Goldman Sachs Global Investment Research.

eSports should lower the cost of customer acquisition for publishers. Last year, a live stream of the League of Legends (LoL) finals attracted 14.7mn peak concurrent viewers and total unique viewers of 43mn. This compares to ~28mn viewers tuning in to see game 7 of the 2017 World Series and ~25mn viewers for game 5 of the 2017 NBA finals. For the 43mn people who watched last year's LoL final, the experience was effectively an advertisement for the game itself – and a very inexpensive ad for the publisher. Therefore, we believe eSports will help to lower the cost of customer acquisition for IP owners who no longer have to spend as much on marketing dollars to grow or maintain the fanbase for a particular game, so long as eSports tournaments can accomplish the same goal at minimal cost.

Pro leagues will help build the infrastructure for monetization. Historically, independent tournament organizers like ESL and online platforms like World Gaming have put together eSports events. But we are now starting to see IP owners organize their own leagues, given the growing opportunity to monetize eSports. Specifically, we believe video game publishers that own their IP in certain genres (FPS, MOBA, RPG) will be able to monetize eSports directly through a professional sports league. It's a good time to build a sports league from the ground up, because the new league can be created in such a way that it is well-suited for a global, fragmented, and younger audience, accustomed to consuming content on-demand through OTT platforms. Established sports leagues face the challenge of distributing content to these consumers without cannibalizing existing revenue streams from linear broadcast partners. But eSports will get to skip that transition. We believe the largest direct revenue opportunity for an eSports league will be distribution, and it will likely come from a combination of media rights deals through linear distributors and to a greater extent third-party OTT platform (YouTube, Twitch, Facebook, etc.).

Activision has already started the Overwatch World league, with gameplay set to kick off in early 2018. So far, Activision has sold 12 teams for $20mn a piece, according to EPSN, including a number of notable buyers, like Bob Kraft, owner of the New England Patriots. We except Activision will further participate in direct revenue streams from media rights deals, advertising, and licensing fees. While it will likely take several years for these revenue streams to come together, we expect to see league revenue surpass $500mn in the next few years, with Activision receiving a 50% rev share of national revenue. Take Two is also starting an eSports league along with the NBA for its NBA 2K game. While Take Two will be entitled to a share of the league economics, all revenue will be shared between Take Two, the league, and the team owners, and therefore we don't anticipate as large a direct revenue opportunity for Take Two as compared to Activision.

Exhibit 7: We expect that eSports leagues will have a different structure than traditional sports leagues
League-level profits for eSports will be split 50/50 between the league owner and teams



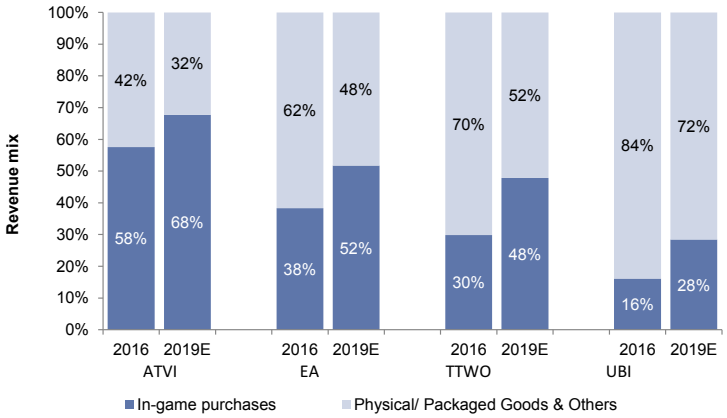
Source: Goldman Sachs Global Investment Research.

eSports consumption is digital-first. In 2014, Amazon purchased Twitch for roughly $1bn, and since that time, Twitch has become the leading Western platform for eSports consumption, with an audience of over 100mn MAUs that reaches half of millennial males in North America, according to Twitch Advertising. YouTube Gaming is another primary destination for eSports audiences, and according to Statista had roughly 1/3 the number of concurrent streamers as Twitch as of 3Q17. In addition to online video portals, linear TV has embraced eSports as well: Turner started broadcasting ELEAGUE in 2016, a regularly scheduled program with eSports competition, while ESPN has periodically aired eSports events, like the Heroes of the Dorm competition in 2016. Due to its younger audience, we believe eSports will remain a digital-first property, and therefore we see the largest opportunity for OTT platforms to monetize eSports audiences through advertising and perhaps later on a revenue share of virtual good purchases that are made on platform, like character skins associated with a particular live event.

In-game monetization will likely be the largest revenue opportunity over time. In addition to direct revenue streams from the leagues themselves, we believe IP owners will be able to monetize live events through in-game purchases by selling viewers a character skin associated with a particular event. By 2019, we believe in-game purchases (including mobile)

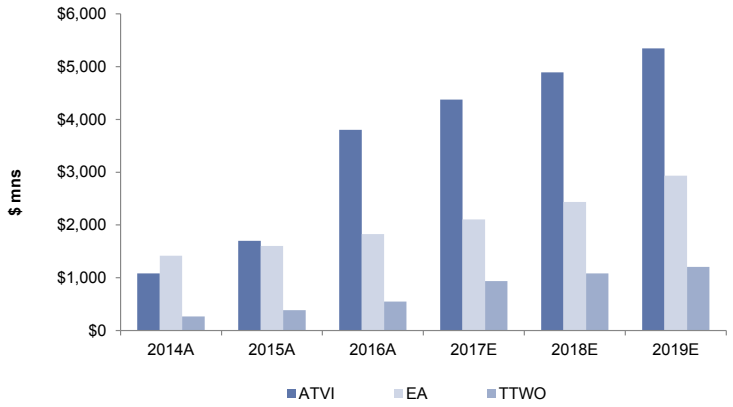
will reach 55% of total revenue for the game publishers, up from just 44% in 2016. And we believe eSports will actually help to accelerate this transition, especially if the IP owner is able to distribute live events through a platform that allows a logged-in user to purchase virtual goods that can later be utilized in game-play. This practice is already commonplace in China, and we expect to see Activision utilize a similar strategy for its Overwatch League.

Exhibit 8: In-game revenue (including mobile) should reach 55% of total on average in 2019E, up from 44% in 2016
In-game revenue as a % of total by publisher (ex-mobile)



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 9: In-game revenue (including mobile) for US game publishers should grow at a 15% 3-year CAGR (2016A - 2019E)
In-game revenue (including mobile), 2013A to 2019E



Source: Company data, Goldman Sachs Global Investment Research

The sponsors will follow the eyeballs. Of the 191mn monthly eSports viewers today, roughly 79% are between the ages of 10-35, according to NewZoo, a coveted demographic by advertisers. As a result, we expect sponsorship will be one of the largest revenue opportunities for eSports. While endemic sponsors (hardware manufacturers, platforms providers, etc) have been around since the beginnings of eSports, we now expect to see major brand advertisers sponsoring pro eSports teams as well, largely due to a change in league structure. Historically, eSports teams that didn't perform well were removed from a given league – a practice known as relegation – creating risk for any team sponsor. However, Riot Games now has permanent teams in its North American League of Legends league, and Activision also created a no relegation policy for its newly formed Overwatch World League. As a result, Geico, Nissan, and Axe are all sponsors of the North American League of Legends league, while Coca Cola sponsored last year's finals, according to AdAge. Likewise, Activision recently announced that HP and Intel agreed to sponsor the Overwatch League.

PC and console dominate the eSports landscape – but mobile is catching up. Measured by prize money, the top three eSports titles – League of Legends, DOTA 2, and Counter Strike – are all PC titles, while console games like Call of Duty, Halo, and FIFA are in the top 10, according to eSportsearnings.com. PC has historically been the preferred gaming platform in

Asia, where eSports have the largest audience, which explains why PC games still capture the lion's share of eSports audience and revenue. But now that mobile game Honor of Kings is the largest video game in China (and globally) with 200mn active players and an annual revenue run rate of $3bn, per Bloomberg, we believe mobile could start to attract more of an eSports following. Skillz is a mobile game eSports platform that has paid out over $50mn in prizes as of 2016, underscoring the growing eSports opportunity for the mobile market.

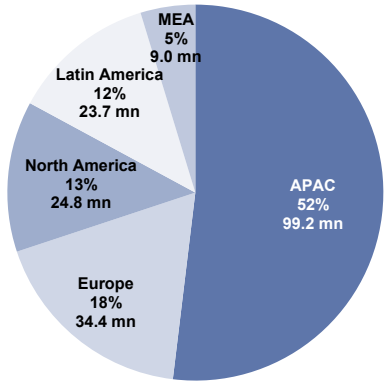
Asia Pac has blazed the trail, but North America is not far behind. According to NewZoo, Asia Pac has an eSports audience of roughly 99mn, ahead of North America at 25mn, and Europe at 34mn. The audience size of eSports is roughly consistent with the overall gaming market, of which Asia Pac has 47% share, relative to North America at 25%, according to NewZoo. But eSports are growing in popularity in the U.S., where the 2016 League of Legends playoffs attracted sell-out crowds at Madison Square Garden in New York and the Staples Center in LA. And with the recent launch of the Overwatch league – 9 of 12 teams are located in the U.S. – we expect eSports will continue to grow in popularity in Western markets.

Exhibit 10: The top 3 eSports are PC titles
Top 10 eSports titles by prize money in 2017

Top eSports titles awarding prize money - 2017					
Rank	Title	Prize $ awarded ($ mns)	Players	Tournaments	Platform
1	Dota 2	$36.0	768	134	PC
2	Counter-Strike: Global Offensive	$16.4	4152	758	PC
3	League of Legends	$11.3	1400	100	PC
4	Heroes of the Storm	$4.4	293	29	PC
5	Call of Duty: Infinite Warfare	$4.0	298	70	Console
6	Overwatch	$3.4	1462	248	PC/Console
7	StarCraft II	$3.2	279	514	PC
8	Hearthstone: Heroes of WarCraft	$2.7	592	86	PC/Mobile
9	Halo 5: Guardians	$1.6	89	9	Console
10	FIFA 17	$1.4	113	36	Console

Source: Esportsearnings.com

Exhibit 11: Asia is the largest eSports market in the world
2017 geographic mix of the eSports audience



Source: NewZoo

Key risks. eSports leagues may not necessarily have the same lifespan as traditional sports leagues. The popular eSports titles of today may look entirely different 30 years from now, and therefore IP owners will have to refresh their game portfolio and eSports leagues in order to keep pace with changing consumer tastes. As publishers focus more on a long-term engagement model, we believe the lifespan of games will continue to lengthen, with titles like World of Warcraft now entering their 3rd decade. However, all content has a shelf-life, which adds a degree of risk for investors, in our view.

Digital Twins Bridging the physical and digital worlds

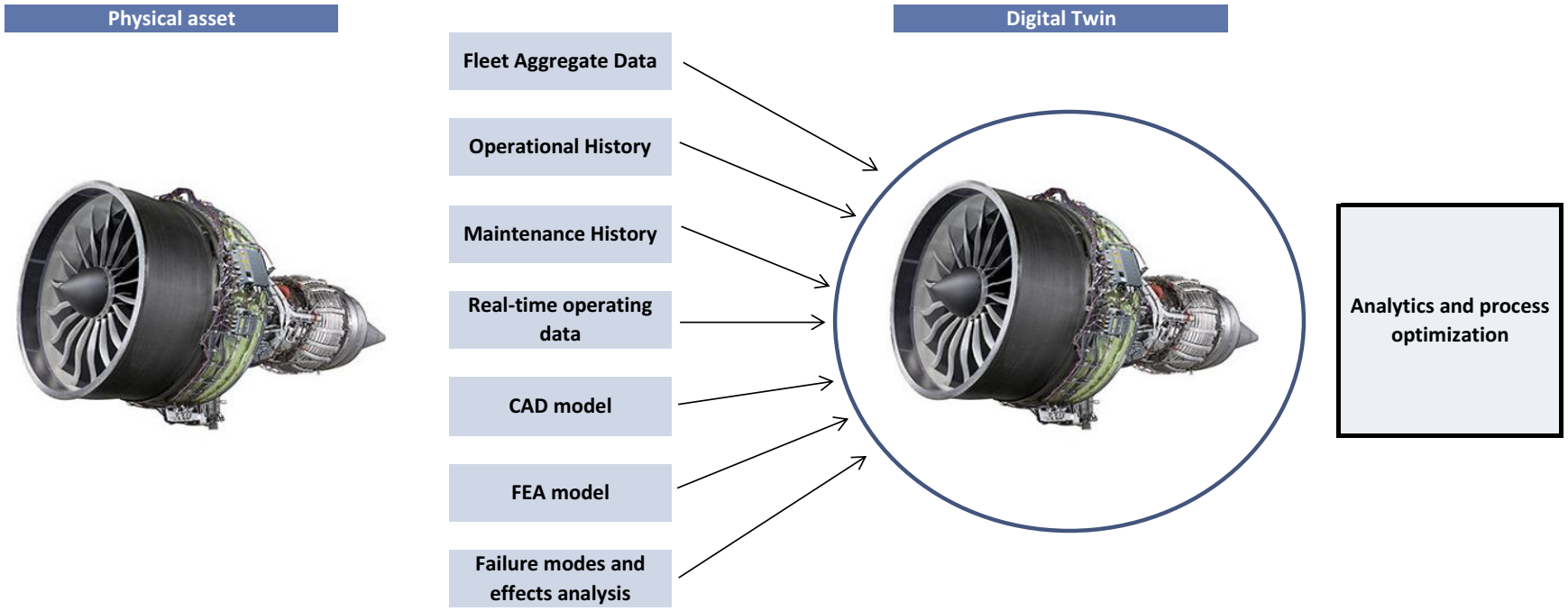
Joe Ritchie

Being able to "see it before we build it" has been considered a panacea in the manufacturing world. Digital Twins are making this a reality, aided by the proliferation of sensors, industrial connectivity and data. Indeed, a Digital Twin is the virtualization of a physical product or process that allows stakeholders to get an accurate picture of how a device or system would behave in the field. This ultimately enables better performance through predictive maintenance and enhanced product design. These features are becoming more important in a world where investments in physical infrastructure are closely scrutinized and companies are increasingly focused on driving higher returns on capital. Hence, Digital Twins are fast becoming integral to the IoT strategies of industrial companies (customers and suppliers) as they allow manufacturers to sell higher margin/more stable services while allowing customers to realize the benefits of lower lifecycle costs/defects. Longer term, we believe the data gathered from physical assets can be overlaid with consumer information, resulting in more targeted and robust go to market strategies for areas like insurance/advertising.

What is a Digital Twin? The concept of a Digital Twin traces its roots to the early days of space exploration when engineers at NASA attempted to create digital models of complex physical systems like spacecraft. This allowed tests and simulations to be performed at an earlier stage, thereby validating design beforehand and driving lower costs and better labor productivity in the long run. Fast forward to the early 2000's, and the modern day analogue of the Digital Twin started to evolve as part of Product Lifecycle Management. Today, with the proliferation of sensors (Gartner estimates 20 billion connections by 2020) and cheaper computing power/data, Digital Twins are being used for more common industrial purposes. A Digital Twin provides a real-time picture of machine/process behavior in various modeled conditions (based on the object's data structure, metadata, etc.), allowing users to visualize different outcomes over the entire product life cycle. This profile can continue to evolve as more information becomes available or as potential usage conditions change, and is more robust than a CAD model or sensor enabled IoT solution.

How does it work? The first step is the "construction" of a digital twin on 3D design software like Ansys or Dassault Systemes with accurate physics and system simulation tools. Then begins the process of replicating the environment, in which **sensors** distributed across the physical assets play a critical role as they capture operational data of the process. This **data** is then aggregated and combined with other important information like bill of materials, enterprise systems, customer complaints, designs logs etc. **Integration technologies** like Edge computing and other interfaces allow this data to be communicated and transferred between the physical/digital aspects of the process. Then come the **analytics**, which uses the asset model as well as aggregated data to help the user run simulations and visualization routines on the Digital Twin. The knowledge gained can then be applied towards predicting issues before they arise, prepare better for "worst case scenarios" and design more suitable products/processes in the future.

Exhibit 12: Digital Twin Illustration



Source: GE, Goldman Sachs Global Investment Research

Digital Twins today. Currently, the market is fairly nascent (about $2bn in associated revenues) but fast growing per MarketsandMarkets research. The majority of the revenues today are focused on asset performance monitoring to be more "predictive" vs. "condition based" maintenance in the past. Across the industrial landscape, Digital Twins are being used in several end markets, including, aerospace & defense, oil & gas, energy and power. **Select key players in the ecosystem:** Allerin Tech Pvt Ltd, Altair Engineering Inc., Amazon, Ansys, Autodesk, Cadfem Gmbh, Dassault Systemes, General Electric, IBM, Microsoft, Oracle, PTC, Robert Bosch Gmbh, SAP, Siemens, Sight Machine Inc., Tibco Software Inc., Toshiba Corporation, Virtalis Limited.

Where is the market going? Studies by the German Association for Information Technology, Telecommunications and New Media (BITKOM) indicate that the economic potential of Digital Twin technology in the manufacturing world could be close to $90bn by 2025. However, only about a fifth of this is likely to be harvested given constraints around connectivity and data security. Even at these penetration levels, the implied growth rate for Digital Twins is close to 20% annually over the next several years. A much bigger opportunity lies ahead as electronics/software controls (currently limited) become better integrated and complemented by even richer data. This will enable greater application at both the product development and

operations management level. Specifically on product development, we believe digital twins will be able to reduce the lead time for new product launches as well as fresh iterations of existing products by incorporating usage data from current devices/processes. Further, the ability to model a variety of scenarios would allow the user to identify potential issues that may arise along the different steps of the process and help facilitate better decision making around the supply chain, lead-times, components used, etc.

Key risks to adoption: Data sharing and security. As more assets become connected, they also become more exposed. In our view, the increasing amount of connectivity is a major reason for the increased cost of cybersecurity. Specifically, digital twins often use machine learning to look at past data from an existing asset and data from similar assets that are connected to the digital twin. This puts all connected assets at risk in case of breach, with the risks ranging from loss of IP, malware, unintended operations to outright physical damage.

Case Studies

General Electric: Predix-ing performance: GE's digital twin offering is geared towards core areas of expertise like turbines, power plants, jet engines and other industrial assets. The modeling features of GE's digital twin offering focus on predicting reliability and outages, fault detection and failure, thermal efficiency, and plant operational efficiency. The digital twin is built on Predix, GE's platform for the Industrial Internet, which enables modification of models with real-time information. An example is GE's "digital wind farm", which opened up new ways to improve productivity by configuring each wind turbine prior to construction in a controlled environment, resulting in a 20% efficiency gain. Beyond its customer offerings, GE is also partnering with key players in the industry to improve its own performance. For example, ANSYS and GE have partnered to connect ANSYS' simulation platform with GE's industrial Internet/Predix infrastructure. The collaboration leverages GE's vast installed base, which is equipped with sensors that collect/send data which is then analyzed by ANSYS' simulation platform. This capability gives GE the ability to automatically identify problems and determine if/when to perform preventative maintenance.

FLS collaborates with ANSYS and PTC to predict product performance: A FLS pump can sometimes have a useful life of 50 years and operates under a vast variety of external conditions. With about 3 million pumps in operation, a lot of data about operating metrics can be collected if the pumps are appropriately connected. With this in mind and in an effort to improve product performance, FLS partnered with ANSYS and PTC. The process starts with data from FLS's pumps that are equipped with sensors to collect data. This data is then fed into an IoT platform (like PTC ThingWorx) and then relayed to the pump's digital twin, which has been created using ANSYS 3D physics and system simulation tools. Based on these real-time monitoring capabilities, FLS is evaluating new growth avenues like anomaly detection and alerts, diagnostics, failure prediction and data mining. Moreover, FLS has been able to come up with better ways to build new products and service existing ones by running numerous permutations of problems that arise in the field.

Beyond capital goods

Digital twins collect vast amounts of data from physical assets or "things", and much of the attention today is focused on improving asset productivity/performance. However, as twins evolve, there will be the possibility of overlaying the data/insights from physical assets with other metadata structures as well as AI-based models, driving greater application on a day-to-day basis. We see two key areas where this could happen:

(1) Insurance contracts. Establishing the value of a contract and then accurately modifying the terms to reflect changes in the status of the asset/insuree requires the computation of a large number of variables. For an insurance company, the goal is to maximize the value of the policy while minimizing risk. Taking the example of an auto insurer, a typical policy takes into account variables like type of vehicle, how often and when the automobile is driven, frequently visited areas, driving record, credit history and other personal details. These details are often tough to get, subject to falsification and change over time. Being able to collect and then harness data on reported incidents at specific times/locations and augmenting it with information on driver behavior can be a very powerful tool for insurers to provide more tailored policies.

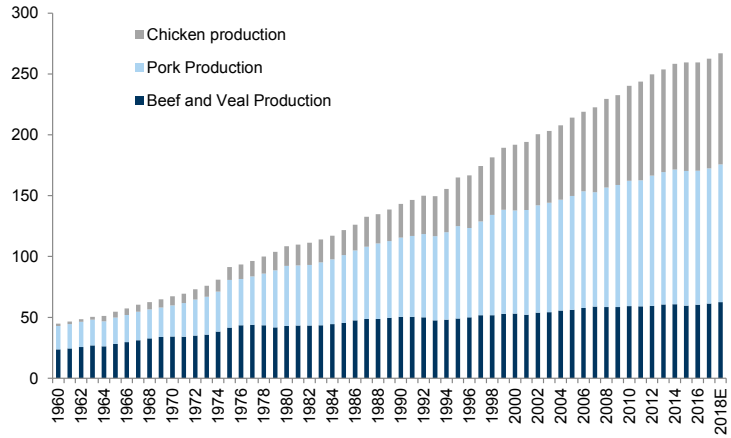
(2) Social media & advertising. Consumer data like clicks, searches, interests, etc. is already being used extensively for marketing, customer targeting, fraud detection, etc. Despite the progress in using information on customer tendencies, the limited ability to integrate a person's digital footprint with real world data (for example a grocer may want to map a customer's frequency of visits with his/her home value and education) is holding back the development of more robust customer profiles. However, connectivity is increasing, and more than half of the >20bn connections by 2020 (Gartner) are expected to be by/for consumer applications. Being able to marry the behavioral insights from these with other data structures, including data from physical assets, will enable organizations to make more targeted resource allocation, marketing and product design decisions.

Meatless Meats Sustainably feeding a growing population

Adam Samuelson

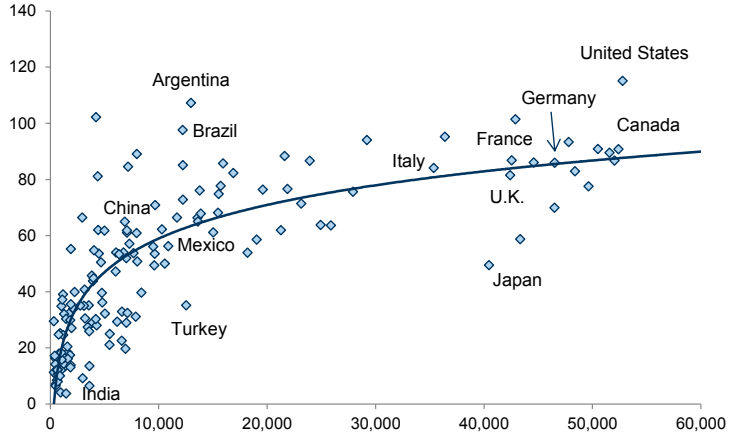
Global protein demand continues to grow as incomes rise and the size of the middle class expands. While today's farmers have increasingly turned to technology to cheat Malthus and grow crop yields, livestock broadly remains an inefficient biological resource in the conversion of grains and oilseeds to meat. With global protein demand expected to grow at least 1.5% p.a. through 2050 as developing countries consume more protein per capita, feed demand pressures and the associated sustainability questions associated with a dramatic increase in global meat production remain top of mind. "Meatless meats" have emerged as an alternative addition to the global food portfolio – with products aiming to help solve for the nexus of rising EM consumer demand, global nutritional needs, and heightened DM consumer sustainability concerns. Product offerings across the space have expanded from the black bean / veggie burger of decades past to alternative protein sources that have similar mouthfeel, taste, and "bleed" of traditional meat without the intermediary of an "inefficient animal processing machine".

Exhibit 13: Global meat production and use has grown notably (~3% CAGR since 1960)
Global beef/veal, pork, and chicken production (mn metric tons)



Source: USDA

Exhibit 14: Meat consumption typically grows with global incomes; the UN expects meat consumption to grow substantially in developing countries
Meat consumption (y-axis; kg/capita); Gross domestic product (x-axis; US$/capita)



Source: FAO, World Bank, Goldman Sachs Global Investment Research

Why are companies searching for a meat alternative? Approximately 35-40% of annual US corn production and ~45-50% of US soybean production (crushed to meal and oil) is consumed as livestock and animal feed; we estimate in advanced production systems, approximately 7.5lbs, 3.5lbs, or 1.9lbs of feed are necessary to produce each pound of live weight of beef, pork and chicken respectively. Consumers are increasingly focused on sustainability initiatives given evidence of (1) deforestation to increase arable acreage for feed production, (2) rising global agriculture emissions, with livestock, principally beef & dairy cattle, accounting for 4.2% of US GHG emissions in 2015 per EPA, notably through methane emissions, (3) concerns on wastewater impacts from both upstream crop and downstream livestock production, and (4) several environmentally-conscious groups calling on consumers to decrease beef consumption. In response, a number of companies have directed significant investment in alternative meat production systems, including vegetable, alternative-input imitations, and "lab-grown" meat.

The potential disruption of a global alternative to "meat": US net livestock production is valued at approximately $66bn and poultry production is valued at ~$48bn (per USDA 2016 figures); the FAO estimates the gross global production value of 2014 chicken, pig, turkey, and cattle at $628bn. Further, pure-play meat companies covered by GS in the Americas (TSN/PPC/HRL/SAFM/JBS/BRF) collectively account for $74bn in market capitalization. While we see adoption as most likely to begin to gain traction in developed economies as a high-value alternative to meat-based entrees, there are several lower-value but high-volume alternative use cases that could potentially have larger disruptive power longer-term (discussed below).

Venture capital funding accelerating, but still early in the adoption stage, with commerciality, scale, and cost still prohibitive: For our purposes, "meatless meat" refers to any item with a nutritionally dense high-protein value marketed as a direct meat substitute. While inputs (vegetable protein, wheat, potato starch, insect protein, etc.) vary and the ultimate end product spans many use cases, all deliver a functionally similar end result for the consumer: a diet high in protein. Several early players in the space, including Impossible Foods, Beyond Meat, and Memphis Meats, have attracted venture and strategic investments.

Impossible Foods, who claims their plant-based "Impossible Burger" requires 95% less land, 74% less water and creates 87% less greenhouse gas than a traditional cow-based burger, has received a total of $258mn of funding from Bill Gates, Google Ventures, Khosla Ventures, and Temasek, among others. Similarly, Beyond Meat, which has raised $49mn (including a 5% stage from Tyson Foods), sells plant-based products such as "The Beyond Burger", "Beast Burger" (23g of protein), "Beyond Chicken Strips" and "Beyond Beef Crumble" - a ground beef alternative.

Memphis Meats, founded by cardiologist Uma Vateli, stem cell biologist Nicholas Genovese and tissue engineer William Clem, is taking a different route by directly "growing" cell-cultured meats. Indeed these "lab-grown" or "clean meats" are

never born but rather are grown in cell cultures and bioreactors. To date, Memphis Meats has successfully grown "clean" beef meatballs, chicken and duck, and has received $20mn from Cargill, Bill Gates, and others.

The investments by traditional meat players like TSN and Cargill over the past 18 months highlights the nascent disruptive opportunity of the category. That said, cost remains well above traditional protein sources and a critical obstacle to wider adoption, with Beyond Meat burgers currently selling at retail for 2-3x ($12/lb) traditional ground beef.

A wide range of potential use cases:

- **Pure-play substitute for meat-based entrees:** We view traditional consumer servings as the most natural use case for "meatless meats", particularly given widespread meat consumption in developed countries and a large middle- and upper-class who could potentially trade-up to a higher per pound price point. We note current US products are largely aimed at a higher-end consumer, with the Impossible Burger (produced by Impossible Foods) focused on higher-end casual/fine dining while Beyond Meat products are sold directly in grocery stores. We note that "meatless meat" often hit several key consumer trends, including (1) hormone/antibiotic free, (2) traceability, and (3) plant-based protein.

- **A potential way to solve the challenge of nutritional efficiency for a growing global population:** Given a specific price and cost profile, we believe "meatless meats" could be an alternative source of high-density but nutritionally robust calories for consumers in developing countries who might otherwise lack access to protein due to local ag-sector inefficiencies.

- **"Meatless meats" as a feed input to produce traditional meat:** One of the biggest challenges for the rapid expansion of traditional meat production is the associated resource inefficiency of production inputs (particularly the resources necessary to grow feed inputs such as corn / soybeans). One alternative use case for alternative meat products (particularly insect protein) is as a more sustainable and low-cost protein feed input for livestock production. Insect protein and other "meatless meats" require less land, water, and labor than traditional crop cultivation. We see this end use category as the one with the largest disruptive power, as a switch to more efficient feed could drive widespread implications up and down the Ag value chain (upstream: seed / fertilizer / crop chem / machinery demand; midstream: merchandising and handling utilization). Further, "meatless meats" and alternative proteins can be used not just as feed for livestock, but also for aquaculture. We note that Darling Ingredients (DAR) has partnered with Intrexon to build a commercial-scale insect-based black soldier fly larvae feed production platform that is set to begin initial production capacity in 2018.

Quantum Computing Solving problems in minutes instead of millennia

Toshiya Hari

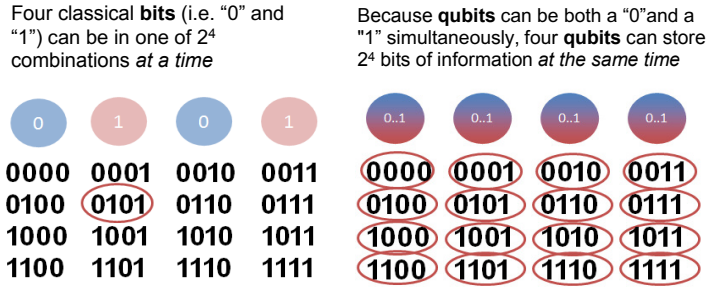
For years we have heard about the development of computers so powerful they could replace every datacenter on earth, capable of solving problems in seconds that would take classical computers millennia. What you've been hearing about are quantum computers (QC), which have the potential to enable tasks that were once unimaginable with classical computers – from developing new materials, to determining optimal traffic patterns across entire cities, to disrupting the encryption market. Quantum computer development is becoming even more urgent due the slowing of Moore's Law, or the observation that classical computing power doubles every 18 months. Today, a number of public and private companies are accelerating their efforts to be the first to achieve "quantum supremacy", or the point at which quantum computers are capable of solving problems that classical computers simply cannot.

Classical computers store information in "bits" represented by 1s and 0s.

Quantum computers store information in qubits, or quantum bits. A quantum bit can be a 1 or a 0 or both at the same time.

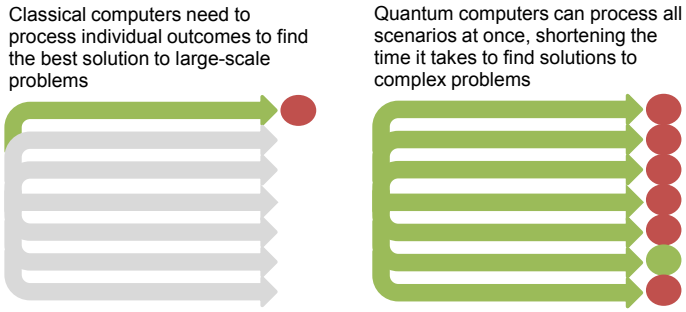
Simply put, quantum computing isn't just your classic computer on steroids – it's an entirely different computing model. Classical computers store information in binary format, using 1s and 0s. For example, the string of code "01000111" is the letter "G" in binary format and the string of code "01010011" is the letter "S". Each 0 or 1 is called a bit and computers process bits by using transistors, which are essentially switches can either be on or off (a "0" or a "1"). Chip manufacturers have been able to increase the power of computer processors by shrinking transistors in order to fit more per computer chip, increasing the amount of bits that can be processed and the amount of data that can be used to solve problems. However, chip manufacturers are rapidly approaching the limits of how small they can scale transistors, which means the return from transistor shrinking is…shrinking.

Exhibit 15: The property of superposition enables qubits to store more information



Source: Goldman Sachs Global Investment Research

Exhibit 16: Quantum computers process data in qubits, which store more information than bits, enabling them to solve problems faster



Source: Goldman Sachs Global Investment Research

In contrast to classical computers, quantum computers store information in **qubits** – or quantum bits. Qubits are capable of existing as both 1s and 0s simultaneously in a state referred to as superposition and as a result are capable of storing and processing more information than classical bits (see Exhibits above). You can think of the difference between bits and qubits similar to how you would think about flipping a coin- in one case you flip a coin, it lands, and you observe it as either "heads" OR "tails" (1s or 0s), while in the other case you flip a coin and as it spins you observe it as both "heads" AND "tails" (qubits). The distinction between bits and qubits is important because the ability to store more information means it can be processed faster, which means that quantum computers can be used to quickly solve large scale problems that would typically take classical computers years to compute. For example, if you have 4 bits of data you can store one of 16 possible combinations of 0s and 1s; however, the same amount of qubits can store all 16 possible values at the same time because qubits can exist as both 0s and 1s simultaneously.

Quantum computing: why now? Take for example the problem of finding the optimal route through a city from point A to point B. The classical approach would be to measure the time it takes to travel route A, then route B, then route C, and so on until the quickest route has been determined. In contrast, the quantum approach would be to measure routes A, B, C, through Z all at the same time and find the optimal route. Today classical computers are advanced enough to do this without you knowing – you probably use it every day when you use Google Maps. However, now consider the same scenario, but with a city full of autonomous cars that need to take into account the location of other vehicles on the road, the movement of pedestrians, the switching of traffic lights from red to green, etc. You can see how this problem scales exponentially and how it quickly becomes one that might overwhelm a classical computer. The same types of problems arise in areas such as drug discovery, weather modeling, materials development, and portfolio optimization, making quantum computers an enticing solution to many problems in a number of industries, and giving rise to potential TAM as high as $29bn (D-Wave). Below we outline some potential use cases.

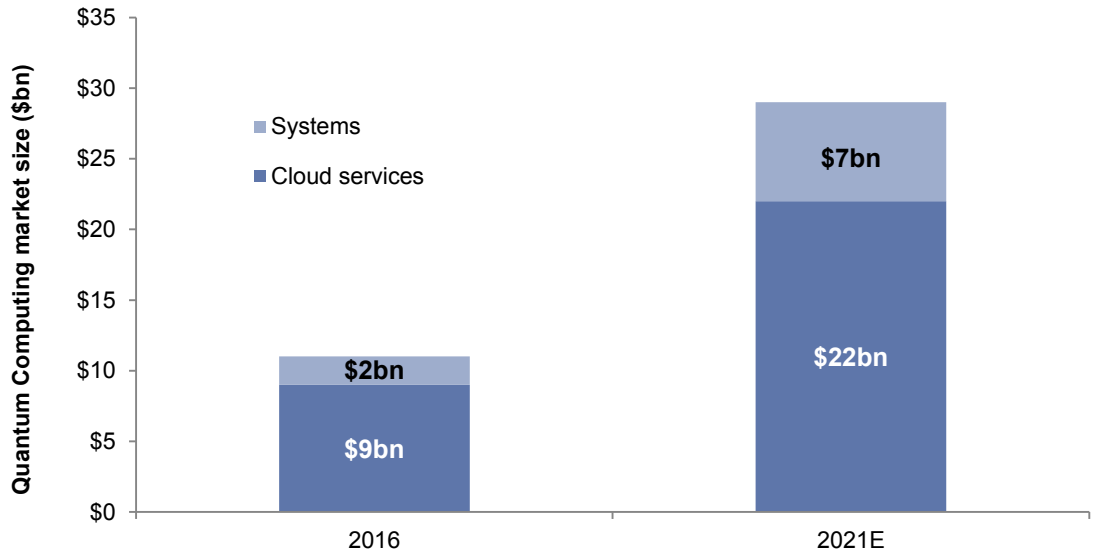
- **Logistics:** Quantum computers have the ability to lower costs for logistics companies by planning the most efficient routes for fleets. For example, if a single driver has to make deliveries to 3 cities there are 6 possible combinations of routes she or he could take between cities. Now assume that driver has to deliver packages to 15 cities – there are 1.3 trillion possible combinations. Now assume you're a national logistics company and need to optimize routes across 300 cities (i.e. the total number of cities with population > 100,000) – the possibilities are almost endless.

- **Chemistry/Pharmaceuticals:** One key use case for quantum computers would be improving molecular simulation. While classical computers are capable of solving such problems, molecular modeling is one problem area that scales rapidly. Note if you were modeling a molecule with 20 electrons you would need to model 20! electron interactions. With a classical computer capable of 500 calculations per second it would take you ~154 million years to model the molecule. However, with a quantum computer you are likely to be able to do this significantly faster, which is important in the

context of drug discovery because of the need to determine how different molecules of varying sizes react to different drugs.

- **Financial Services:** Key quantum computing applications within the financial services industry include scenario analysis, risk modeling, and portfolio optimization. For instance, take the case of an asset manager rebalancing a portfolio, which incurs transaction costs. Quantum computers have the potential to calculate a portfolio that is optimal over a number of time horizons, reducing the need to rebalance and the associated costs.

Exhibit 17: Quantum computing could potentially be a $29bn industry by 2021
Potential quantum computing TAM



Source: D-Wave

Who gets disrupted? Not every computing problem is as complex as the example above, which means you're as unlikely to need a quantum computer to stream YouTube videos as you are to need a Ferrari to plow snow. For this reason we don't think the PC or server market is likely to disappear overnight. Rather, our discussions with a number of companies in the space indicate a sort of hybrid hardware infrastructure, where quantum services are offered through the cloud and quantum-specific tasks are accelerated by quantum computers as they arise- the same way a computer might accelerate high-res video game rendering with a GPU, but use a CPU for browsing Amazon. That said, there are companies (Intel,

Nvidia, Cray, etc) with portions of their business that could be disrupted– specifically those with exposure to the supercomputing market, where the types of problems being investigated could greatly benefit from quantum acceleration. However, we would note that for some of the larger companies, the likely impact would be small relative to the overall size of their remaining businesses.

When do I get my quantum computer? The time for achieving "quantum supremacy" is closer than it has ever been, with numerous companies, including Microsoft, IBM, Google, Intel, D-Wave, Rigetti, working on solutions. In fact, as recently as October 2017 Google indicated that it expects to soon achieve "quantum supremacy" with a 50 qubit computer it has developed. **That said, "quantum supremacy" remains a moving target, given difficulties around system stability (quantum computers need to be kept at temperatures colder than outer space in order to function properly), architectural complexities (note Microsoft's QC is built around a particle some scientists aren't even sure exists), and ongoing improvements in current hardware offerings (i.e. GPUs and ASICs). Commercialization remains even further out, in our view, given the nascent state of the quantum software ecosystem.**

We would note that a number of obstacles to broad adoption remain:

- On the hardware side, specific obstacles include a) system stability and b) architectural complexities. With regards to (a) we note that creating an environment capable of supporting quantum computing processes is much like trying to balance a bowling ball on a pencil – to say it's no easy task, requiring temperatures as low as 15 millikelvin (or 180 times colder than outer space). As for (b) we would note that not all quantum computers share the same architectures. Some approaches, such as the "gate model" approach used Google and Rigetti, require error-correcting qubits, meaning more physical qubits are required per computational qubit in order to ensure greater accuracy. Other approaches, such as Microsoft's "topological" model, require far less error correct, but rely on quasi-particles (non-abelian anyons) that some scientists continue to debate the existence of.
- On the software, our discussions with quantum software companies indicate that attracting talent remains a bottleneck to broadening the software ecosystem, with most top developers choosing instead to focus their efforts on areas like AI and machine learning, where cloud companies have already proved that these technologies can be monetized. Moreover, without a robust software ecosystem, companies face a chicken and egg problem similar to when classical computers were first commercially introduced in the 1970s, namely "what do I do with this thing?".

We think quantum computers are likely 5-10 years out from being deployed at commercial scale given 1) technological hurdles that need to be overcome, 2) the pace of progress around identification of problems large enough to justify quantum investments, and 3) the importance of establishing a large enough software ecosystem to support a diverse customer base. In the meantime, we expect companies like Intel and AMD to continue to explore ways to scale transistors, while companies like Nvidia and emerging ASIC vendors benefit by offering solutions to help offset the slowing of Moore's Law.

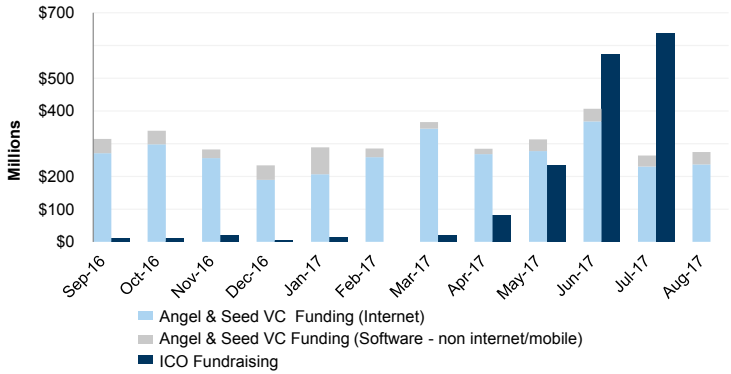
Ethereum An emerging platform for distributed applications and commerce

James Schneider, Ph.D.

The core technology innovation of blockchain has given rise to a broad range of derivative technologies, business models and even asset classes (for more, see our report Blockchain: Putting Theory into Practice). Ethereum is a distributed platform that innovates on Bitcoin by adding the concept of programmability. Ethereum has attracted significant interest from individual investors, and companies have raised over $3bn in 18 months for a variety of applications – many solely based on a concept without a proven product or market. Ethereum has the potential to fragment dominant internet franchises and even traditional venture capital if it overcomes technical, legal, and regulatory challenges which are not immaterial.

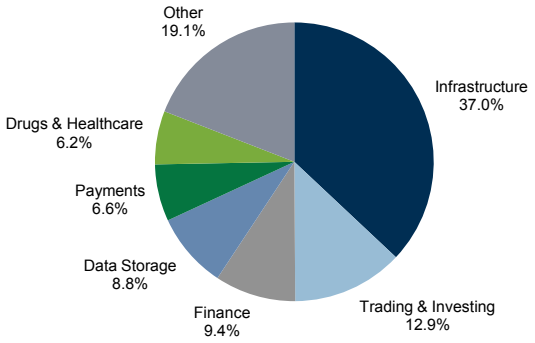
What is Ethereum? It's like Bitcoin, but programmable. Similar to Bitcoin, Ethereum is a decentralized, secure public database where copies are maintained by many parties. Like Bitcoin, any transaction must be agreed to and signed by counterparties with their private keys before being verified by multiple parties across the network and added to the database. While the Bitcoin blockchain only stores information about the amount of the transaction, Ethereum allows for "smart contracts" to be created where actions can be taken using a pre-determined algorithm based on the actions of third parties or inputs from external data sources. Using these features, Ethereum enables developers to program code which can be turned into applications, such as distributed file storage, social messaging, and trading platforms – all of which take on different characteristics in a distributed context.

Exhibit 18: Ethereum application fundraising has exceeded Internet & Software Angel & Seed VC funding over each of the last four months
Dollars in millions; angel and seed funding excludes crowdfunding



Source: CoinSchedule, CB Insights, Goldman Sachs Global Investment Research

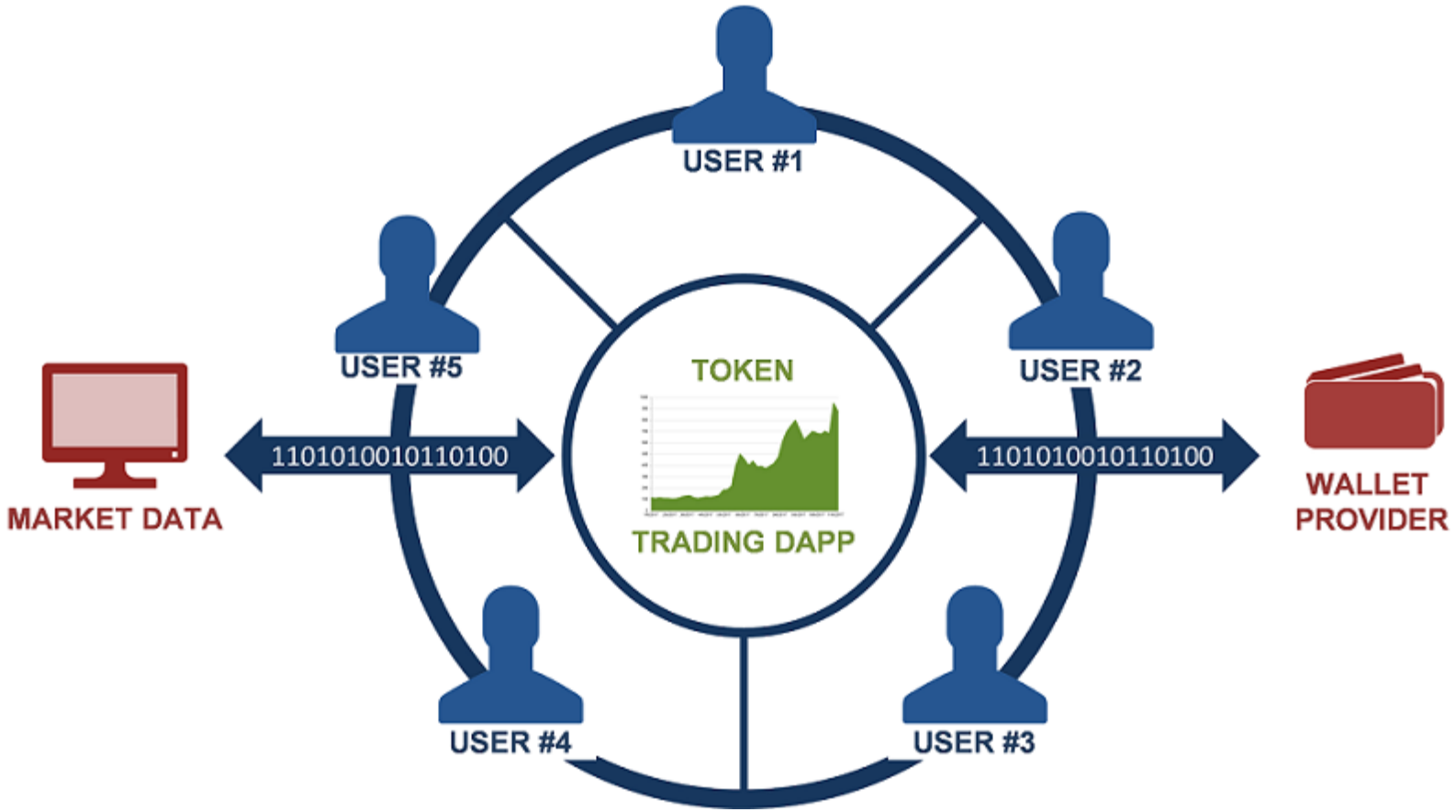
Exhibit 19: Over 65% of the funding raised for distributed apps has come in a few categories: infrastructure, storage, social media, trading, and commerce
2017 YTD funding by application category



Source: CoinSchedule, Goldman Sachs Global Investment Research

What is a distributed application? Distributed applications are software where execution depends on the input of multiple individuals or computers across the network. Like Bitcoin (which is operated by miners who verify transactions on the network in exchange for a small amount of Bitcoin), distributed applications run on Ether, the unit of value on the Ethereum network. They are written by individuals or companies that are pre-funded for their idea through an Initial Coin Offering (ICO), which may be augmented by traditional investors. In an ICO, the developer creates a "white paper" stating the purpose of the project and the intended market for the application. Investors provide Ether to the developer and are granted special-purpose tokens tied to the ICO, which can later be freely traded on the open market (see below on regulatory risks and the increased scrutiny of ICOs).

Exhibit 20: Distributed Ethereum applications execute based on user inputs, and can incorporate external data "oracles"
Example of Ethereum trading application which draws on inputs from individual users as well as data "oracles" outside the network



Source: Coindesk, Goldman Sachs Global Investment Research

Over $3 billion has been raised for distributed apps in the past 18 months, outstripping VC internet investments

What do these distributed applications do? Ethereum is still in its infancy as a development platform, and distributed applications based on the platform are just 18 months old. However, ICOs have raised over $3bn for application development over this period – outstripping the amount raised from traditional internet venture capital in that period. Thus far, the core functionality of these applications has not broken new ground – and most look and feel like their traditional centralized counterparts. Some have delivered on the promise of novel functionality. However, there have been many distributed applications created that could be considered trivial from a technical perspective, but for their distributed characteristics. Although over 200 distributed applications have raised funding, the categories thus far have been concentrated in core infrastructure for application development, social media, and trading/commerce platforms, examples of which include the following:

- **Infrastructure: Plumbing the distributed web.** With the concept of smart contracts and distributed applications comes the need for developer tools. For example, **Filecoin** is designed to be a distributed file storage service similar to Dropbox, but without dependence on a single service provider. **EOS** is working on a tool for developers to optimize their applications given resource constraints imposed by the ecosystem. **Status** is intended to be a next-generation browser for Ethereum for users to navigate and experience different distributed applications.
- **Trading and Payments: New platforms offer a "call option" on blockchain.** Because Ethereum is capable of supporting numerous token types, a number of trading applications are being developed. **Bancor** is a wallet provider allowing users to store multiple token types. **TenX** incorporates wallet and payment functionality to facilitate the movement of various token types. **Electroneum** is a cryptocurrency mining application which allows users to mine tokens on their mobile devices.
- **Commerce: Breaking down legal and regulatory barriers.** Given uneven regulatory frameworks with respect to the sale of goods (at times illicit goods) on a regional basis, some apps aim to create a decentralized forum for information and transactions.

Who could be impacted? Internet, social media, venture capital. Most major internet and social media platforms rely on the network effects of large numbers of users to extract economics from transaction traffic and users' online time and attention, particularly through advertising. The substantial amount of "underground" traffic on the internet and social media sites has long been recognized. However, questions over potential foreign interference via social media in the last US election and the use of social media by terrorist organizations has raised the possibility of substantially greater regulatory scrutiny of these sites, including censorship of certain individuals and views based on region or topic. This raises clear questions of whether some communities could move their interactions to a "censorship-proof" environment, thereby fragmenting "mainstream" social media platforms.

By the same token, traditional venture capital models rely on a centralized group of investment experts providing conditional funding tied to a specific product. In the classical sense, venture capital provides gradually increasing amounts of funding over time, based on a company reducing specific technical and market risks tied to a product. With the amount of funding for ICOs outstripping traditional VC internet investment over the past 12 months – despite completed products or demonstrated market traction – it raises the question of whether promising entrepreneurs will decide to opt for ICOs and circumvent traditional venture capital.

What are the biggest risks? Legal, regulatory, technical. Despite the promise of blockchain protocols in general, Ethereum as a platform presents a unique and diverse set of challenges and obstacles, including:

- **Technical: Is performance another fork in the road?** Underpinning all distributed apps is the step-by-step, dependent nature of their code and algorithms. This raises the question of what level of performance distributed applications can achieve, with some estimating that no distributed app can perform computations faster than a conventional app running on a five-year-old smartphone. Also, while the Ethereum network has proven relatively stable thus far, it has been subject to a number of service outages based on "forks" or improvements to the underlying protocol meant to improve the network.

- **Legal: Caveat emptor?** Despite its significant technical promise, Ethereum has already been a forum for unscrupulous individuals seeking to extract personal profits in the ICO process. For example, in 2016 The DAO raised $168mn for a distributed infrastructure application. However, the application's source code was later found to have an intentional vulnerability which allowed its creators to extract tokens from the system, resulting in the theft of $55mn of the ICO proceeds (Bloomberg, 6/22/17).

- **Regulatory: What rules should govern ICO offerings?** There have been varying responses to ICOs and distributed applications worldwide. In the United States, the SEC has stated that token sales may be subject to the Securities Exchange Act of 1934, and that investors should be aware of the risks. Regulators from several government agencies (Bloomberg, 11/30/17) have delivered public warnings regarding the lack of transparency for investors, and the inconsistency in disclosures provided. In some cases, the SEC has stated that it is investigating whether certain ICOs constitute offerings or unregistered securities. Press reports (Bloomberg, CNBC, 9/4/17) have suggested that China has banned the practice of raising money through ICOs. Even within the industry (as cited at the recent Consensus: Invest conference), hedge funds have noted that ICOs require special levels of technical due diligence beyond the capability of most retail investors.

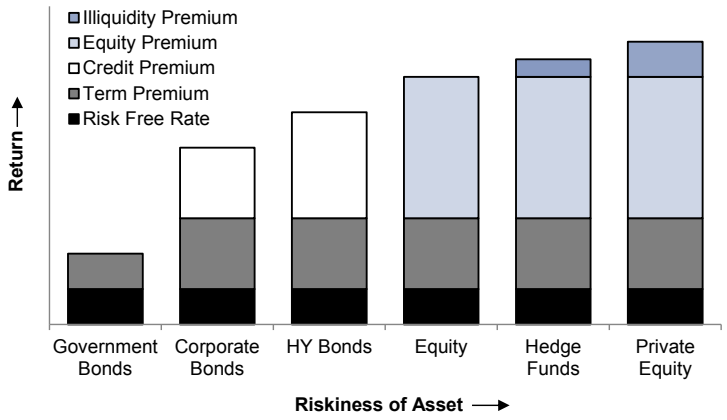
Alternative Risk Premia Where beta meets alpha

Robert D. Boroujerdi

The rise of the machines and the accompanying acronym onslaught has created angst among active managers as they move to better understand the role of ETFs, factors and quant/systematic strategies on their portfolios. Concurrent with this rise has been increased demand by both institutional and retail investors to better understand what constitutes 'alpha' and 'beta' and more importantly what they pay for it, how transparent is it and how much they can control of it. Enter 'Alternative Risk Premia (ARP)' where burgeoning investor demand is driving material category AUM growth at investment banks, asset managers and increasingly hedge funds. Indeed ARP products are constructed to offer uncorrelated returns to the market at lower costs than hedge funds with more transparency. Once the denizen of academia these solutions are gaining a practical appreciation and applicability for allocators of capital.

Risk Premia 101. To start let's dust off those college Finance textbooks. Put simply risk premium is a compensation for bearing risk. As seen in Exhibit 21 select assets hold premia which sit on top of the risk free rate and indicate the potential return for an asset. As one would imagine risk premia exists across asset classes, time periods and markets and arguably cannot be fully hedged out or diversified. It can, however, be viewed though through the lens of 1) risk-based explanations (e.g. merger arbitrage), 2) behavioral-based explanations (e.g. momentum or crowding) and 3) structural-based considerations (e.g. volatility carry).

Exhibit 21: Mind Your Risk Premium
Illustrative Risk Premia Associated with Select Assets



Source: Goldman Sachs Global Investment Research

Exhibit 22: Alternative Risk Premia Decomposition
Select Risk Premia and whether typically considered to exist within asset class

		Select Risk Premia					
		Value	Momentum	Carry	Vol Carry	Quality	Liquidity
	Intuition	Undervalued outperforms overvalued	Winners keep winning (& vice-versa)	Higher yields outperforms lower yields	Realized vol is lower than implied vol	High quality outperforms low quality	Less liquidity outperforms more liquidity
Asset Classes	Equities	✓	✓	✓	✓	✓	✓
	Credit	×	✓	✓	×	×	×
	Commodities	×	✓	✓	✓	×	×
	Currencies	✓	✓	✓	✓	×	✓
	Rates	✓	✓	✓	✓	×	✓

Source: Goldman Sachs Global Investment Research

Not a Factor and also not Smart? Post Factormageddon in Q1:16 our clients by and large were awoken to the rise of smart beta products and factor exposure in their portfolios if they hadn't been already. With that as a background it is important to note that alternative risk premia are not the same as factor exposure or smart beta (noting there is a range of opinions on the topic). Factor exposures are the risks that explain the reason the risk premia exist in the first place. For instance if one was long a portfolio of 30 year US Treasuries they have taken on term premium given the potential for inflation to impact the value of the holdings. In this example inflation is the factor exposure and the risk premium sits in the nature of the term. Smart beta strategies are structured by changing the relative weight of a group of stocks in a benchmark based on a characteristic such as value, the strength of a balance sheet or carry. ARP, or 'Alt-Beta' or 'Dynamic Beta', differ from smart beta in that they are not directionally long by design (e.g. they take short positions but aren't necessarily always market-neutral), invest within and across a multitude of asset classes and use leverage among other considerations (sound like a flavor of a hedge fund to anyone?). These solutions aim to systematically harvest premia across asset classes based on a set of rules historically born of prior performance and/or academic literature (e.g. Momentum/Trend, Volatility). See Exhibit 22.

Sizing Alternative Risk Premia. While the total assets under management invested in ARP is difficult to pinpoint (given limited visibility and the broad definition of the strategy) we note that this several hundred billion dollar market is growing in excess of 30% a year per Mizuho Alternative Investments and Wilshire. They estimate that bank sponsored risk premia now hold in excess of $200bn in notional exposure. Other publicly available survey figures put this number as high as $300bn.

The Investment Case for ARP. There are several potential benefits of investing in ARP strategies, including:

- **Persistence, Diversification and Control.** The ability to take both long and short positions allows ARP strategies to have lower volatilities across many types of economic and market environments (such as rising/falling inflation, rates, equity prices, etc.). Consequently, the risk premia are able to be captured over a long horizon. From the perspective of a multi-asset portfolio proper use should provide diversification benefits and if the strategy works, improved returns. In addition because of the rules-based nature of these solutions an investor would effectively have greater control over the risk profile for the return they are targeting (e.g. expressing a view on an asset or exposure).

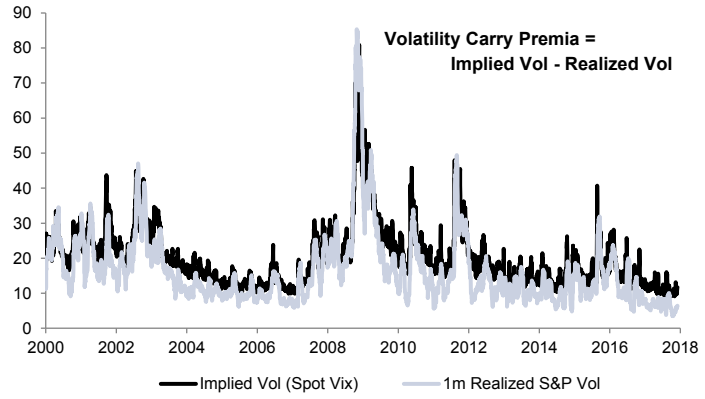
- **Hedge Fund Complement or Replacement?** ARP shares many of the same characteristics as traditional hedge funds and uses similar trading mechanisms to implement. However, ARP returns are designed to be less correlated to the market. Further they don't deal with, in many cases, lock-up terms, associated performance fees and lack of transparency. With that said risk-adjusted returns for outperforming hedge funds managers would be superior. In many cases ARP can be a replacement for a Fund of Funds strategy versus a single manager allocation; to the degree they can be separated.

Case Study Snapshot: Risk Premia Captured in ARP Strategies

Volatility Carry Risk Premia. Volatility Carry is the investment strategy-based premia earned from selling volatility and is one of the most well studied and implemented risk premia. Volatility Carry profits when an asset's realized volatility is lower than expected/implied. Because investors are risk averse and value protection from future volatility (and thus will pay a premium for certainty), implied asset volatility has historically exceeded realized volatility, on average (see Exhibit 23). Volatility Carry is unsuccessful in scenarios where realized volatility unexpectedly spikes.

Value Risk Premia. Value factor risk premia is earned through buying cheap assets (i.e. undervalued) and selling those that are expensive (i.e. overvalued). The theory is that companies with low valuation tend to outperform companies with high valuation over time. Value strategies will assume a reversal to fair value post market under/over reactions (see Exhibit 24). The most commonly used Value metric in academia is to compare stocks based on price-to-book ratio (high ratio = expensive; low ratio = cheap). However, Value is less well defined when applied to other asset classes. For example, a metric such as purchasing-power-parity level may be used to quantify Value for currencies.

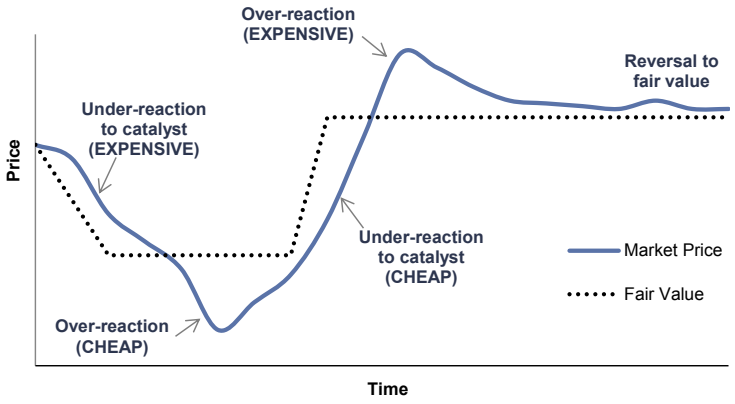
Exhibit 23: Volatility Carry Risk Premia persists over time
Implied Vol (Spot VIX) vs. 1m Realized S&P Vol



For more on vol risk premia, refer to Rocky Fishman's *The Volatility Controversy: Target Low-Carry Hedges*, Oct 23, 2017.

Source: Goldman Sachs Global Investment Research

Exhibit 24: Market under/over reactions creates opportunities for Value investors
Illustrative example of behavioral under/over reactions to catalysts



Source: Goldman Sachs Global Investment Research

Portfolio Implementation. Market beta is easily captured through low cost vehicles such as index funds, but for those seeking alpha it is widely understood to be much more costly. Alternative beta falls somewhere in the middle and is becoming increasingly available to investors. One way to implement an ARP strategy is to create a volatility and correlation constrained portfolio that selects several diversified long/short factors ranging in styles and asset classes. ARP portfolios can also be designed to solve for wanted or unwanted exposures and therefore may consider the portfolio's broader allocation.

Investors will either construct ARP strategies in-house or outsource portfolio construction to an investment bank or asset manager. Execution may require the use of leverage since a certain threshold of risk must be assumed in order to have an impact on the portfolio. Like any other strategy considerations are optimized for liquidity, market impact and costs.

Investment and Selection Risks. Selecting an appropriate ARP strategy based on historical performance can be tricky due to their relatively short track records as tradeable products (despite back-tested performance) and the risk of overfitting[1]. Further, methodology and factor definitions may vary significantly between strategies. While strategies may market under the same name, the industry lacks universal methodology and, consequentially, can deliver conflicting return and risk profiles. Definitions on strategies as simple as "Value" could showcase a multitude of different approaches and applications. Lastly one very hotly debated topic is the frequency and nature of rebalancing in achieving targeted results.

[1] Overfitting occurs when random fluctuations (i.e. noise) in historical data are integrated as concepts in the model. As a result, the model is negatively impacted when presented with new data.

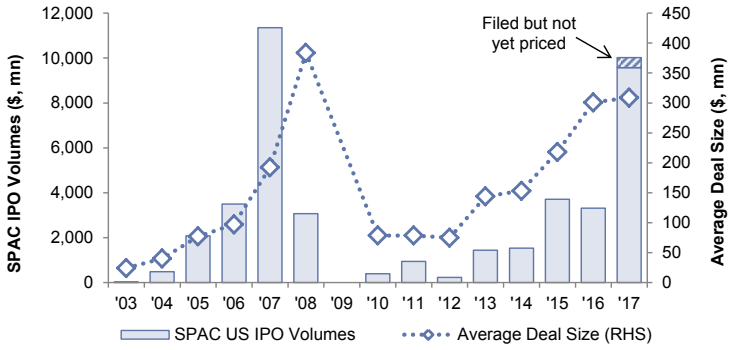
SPACs Back and bigger than ever

Christopher Wolf, CFA

Special Purpose Acquisition Companies are a (re)emerging investment vehicle growing in size, number and scope. Indeed, SPACs have witnessed a resurgence of issuance YTD and are increasingly playing a key role in today's backdrop of tepid IPO activity, declining supply of publicly-listed stock, aging private equity portfolios, ample dry powder and slowing exit activity. These corporations, representing one-quarter of US IPO volumes YTD, come to market with no operating assets, intangible property or revenues. The pitch? Private equity style investing alongside seasoned industry veterans in a liquid vehicle that typically offers cash-back redemption rights after a proposed target is identified. Notable acquisitions, e.g. Burger King and Hostess Brands, and the pace of supply in 2017 are driving increasing investor questions on the potential of SPACs as an asset class. Like other assets, SPACs have had mixed performance and bring unique structural considerations for investors to evaluate. To that end, we address current trends, historical performance and key considerations for this reemerging and evolving asset class.

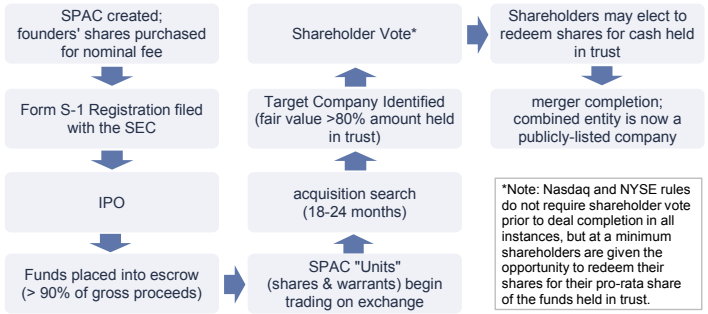
What is it? Often referred to as "Blank-Check Companies" (BCCs), SPACs are corporations with no operating assets that raise capital via an IPO to fund a future acquisition. Typically founded by experienced management teams with expertise in a particular industry or sector, these vehicles employ a private equity like approach to investing, aiming to complete a significant acquisition (usually representing at least 80% of the funds raised) within a mandated time frame (normally 18-24 months). Upon completion of the acquisition the target becomes a publicly traded company and the resulting shareholder base is often a combination of the target's pre-existing shareholders and SPAC investors. Deals are typically structured such that the SPAC founders' stake amounts to 20% equity ownership of the target post deal completion.

Exhibit 25: SPAC IPO volumes are making a resurgence
SPAC US IPO volumes by year ($, millions); Average Deal Size (RHS)



Source: Dealogic, Goldman Sachs Global Investment Research

Exhibit 26: SPACs 101: The Process
Illustrative Example of SPAC Structure & Timeline



Source: Goldman Sachs Global Investment Research.

Why it matters… At their peak in 2007 SPACs raised more than $11bn of capital across 59 offerings, representing 20% of US IPO volumes. After fading from use in the years following the crisis, this asset class has made a comeback, raising nearly $9.6bn of equity capital across 31 offerings YTD per Dealogic. With an average deal size now in excess of $300mn, the potential scope and reach of these vehicles is rising upmarket. Consider for example the recent Social Capital Hedosophia Holdings Corp, which raised $690mn in its September IPO and whose founder has suggested an acquisition target may ultimately be one of the 100+ tech unicorns, potentially as large as $20bn in size. Indeed the SPAC pool of capital continues to grow and stands to compete with other strategic and financial buyers in an already competitive M&A market.

The SPAC structure offers some clear advantages. Put simply, SPACs provide a private equity-like investment vehicle with public market liquidity. The ability to invest alongside an experienced management team absent the high investment minimums and long lock-up periods offers a risk-return profile not accessible to many investors. Further, the escrowed funds held in cash prior to acquisition coupled with voting and redemption rights upon acquisition announcement offer investors relatively risk-free optionality, whereby they can simply redeem their shares if they do not wish to become a shareholder of the identified target. For the target company, the ability to achieve a public listing via a merger with the SPAC offers relatively hassle-free access to public market capital. Further, the knowledge and experience of the SPAC's founders should, in theory, help drive operational improvements.

Why are they making a comeback now? In many ways SPACs have an important role to play in today's market environment. Indeed, tepid IPO activity, elevated valuations (both public and private), and financial sponsors that are flush with dry powder yet facing aging portfolio companies has created a void of activity that SPACs are able to help fill. Consider the following:

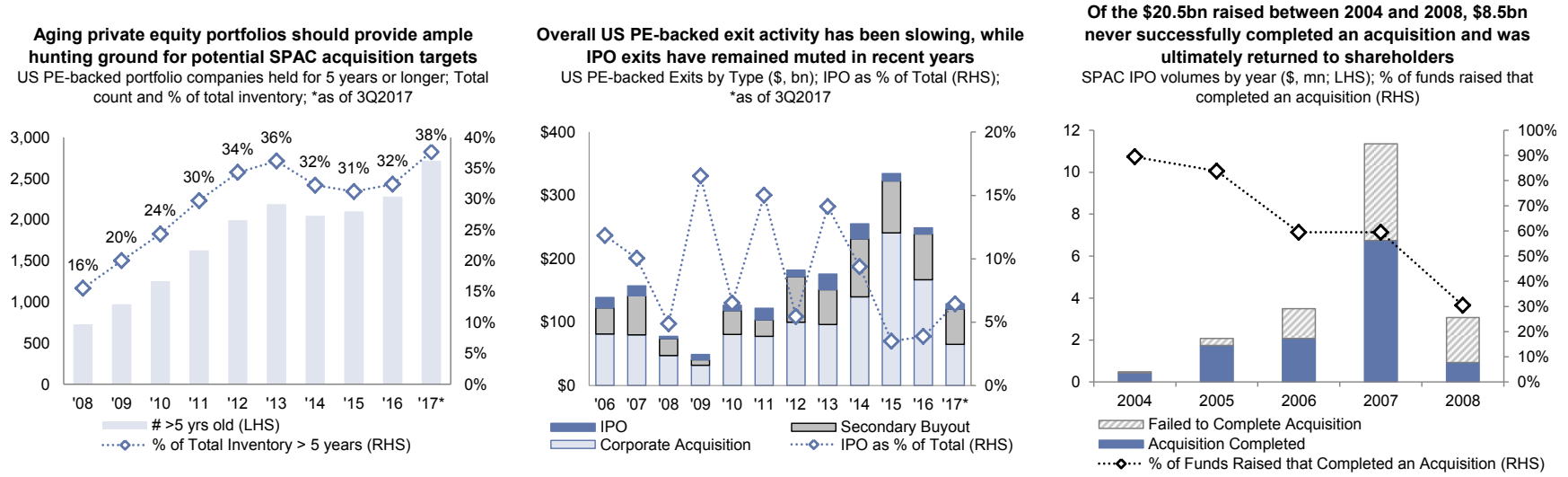
- **Aging Private Equity Portfolios and Slowing Exit activity.** There are more than 2,700 companies that have already been held by financial sponsors for 5 years more. That figure is up +30% in less than 2 years and represents 38% of total PE inventory, the highest share since at least 2008. At the same time, we've seen just $129bn of US PE-backed exits YTD, a 32% yoy decline and the slowest pace since 2011 (as of 09/30/17 per PitchBook; see exhibit 27). Meanwhile, North American Buyout funds are sitting on a record $365bn of unlevered dry powder waiting to be put to work (Prequin).

- **IPO Activity has been tepid.** From 2004 to 2014, the average run-rate for US IPO volumes was $42.5bn per year. Since 2015 that run-rate has slowed to ~$30bn/year ($33bn, $18bn, $39bn in '15, '16, '17ytd respectively) against a backdrop of record high equity markets (Dealogic). Further, according to PitchBook there's been only $29.6bn in US PE-exits via IPOs since 2015, a significant deceleration from the cumulative $58.7bn from 2012-2014 (see exhibit 27).

- **Elevated valuations could be slowing activity.** With the market at record highs, median middle-market M&A multiples hitting 10.7x EV/EBITDA (record highs, per PitchBook) and the "unicorn" count (private companies valued at more than $1bn) now exceeding 200 in number (CB Insights) concerns over market conditions and frothy valuations could be

slowing activity. Indeed, we note there is a backlog of 27 IPO's that have registered but not yet priced. SPACs help ease this gridlock by first achieving a public listing, allowing the SPAC founders to do the value hunting and then the shareholders to vote on the transaction.

Exhibit 27: SPACs have a key role to play in today's market environment



Source: PitchBook, Dealogic, Goldman Sachs Global Investment Research

Deploying capital can be a challenge. One area worth watching based on the track records of prior SPACs is the challenge of deploying capital. Indeed, of the 142 SPAC IPO's priced between 2004 and 2008, only 86 (representing $11.9bn of capital) completed an acquisition, while 56 ($8.5bn of capital) were liquidated and the funds returned to shareholders. See Exhibit 27. For many of these, timing of the global financial crisis made it difficult for founders to garner the shareholder approval often necessary to complete a deal. Further, in that market environment, a full (or nearly full) return of investor capital is a relatively benign outcome.

Key Considerations. For investors a key question on SPACs is ensuring there is a long term alignment of interests. Indeed, these vehicles are typically structured such that should the founders complete an acquisition within the mandated time period, their compensation amounts to a 20% equity ownership of the acquired company (often referred to as the sponsor's "promote"). Thus, the incentive to do a deal can be very large, especially when compared to the alternative of losing their invested capital should they fail to complete an acquisition. Further, SPACs are usually comprised of both shares and warrants. The purpose of the warrants is to incentivize IPO investors to tie up their capital while the founders seek an acquisition. These warrants, however, also bring a dilutive overhang on post-acquisition share price performance.

Third party brands used in this presentation are the property of their respective owners, and are used here for informational purposes only. The use of such brands should not be viewed as an endorsement, affiliation or sponsorship by or for Goldman Sachs or any of its products/services.

Disclosure Appendix

Reg AC

I, Robert D. Boroujerdi, hereby certify that all of the views expressed in this report accurately reflect my personal views about the subject company or companies and its or their securities. I also certify that no part of my compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

We, Christopher Wolf, CFA and Ronny Scardino, hereby certify that all of the views expressed in this report accurately reflect our personal views, which have not been influenced by considerations of the firm's business or client relationships.

Unless otherwise stated, the individuals listed on the cover page of this report are analysts in Goldman Sachs' Global Investment Research division.

GS Factor Profile

The Goldman Sachs Factor Profile provides investment context for a stock by comparing key attributes to the market (i.e. our coverage universe) and its sector peers. The four key attributes depicted are: Growth, Financial Returns, Multiple (e.g. valuation) and Integrated (a composite of Growth, Financial Returns and Multiple). Growth, Financial Returns and Multiple are calculated by using normalized ranks for specific metrics for each stock. The normalized ranks for the metrics are then averaged and converted into percentiles for the relevant attribute. The precise calculation of each metric may vary depending on the fiscal year, industry and region, but the standard approach is as follows:

Growth is based on a stock's forward-looking sales growth, EBITDA growth and EPS growth (for financial stocks, only EPS and sales growth), with a higher percentile indicating a higher growth company. **Financial Returns** is based on a stock's forward-looking ROE, ROCE and CROCI (for financial stocks, only ROE), with a higher percentile indicating a company with higher financial returns. **Multiple** is based on a stock's forward-looking P/E, P/B, price/dividend (P/D), EV/EBITDA, EV/FCF and EV/Debt Adjusted Cash Flow (DACF) (for financial stocks, only P/E, P/B and P/D), with a higher percentile indicating a stock trading at a higher multiple. The **Integrated** percentile is calculated as the average of the Growth percentile, Financial Returns percentile and (100% - Multiple percentile).

Financial Returns and Multiple use the Goldman Sachs analyst forecasts at the fiscal year-end at least three quarters in the future. Growth uses inputs for the fiscal year at least seven quarters in the future compared with the year at least three quarters in the future (on a per-share basis for all metrics).

For a more detailed description of how we calculate the GS Factor Profile, please contact your GS representative.

M&A Rank

Across our global coverage, we examine stocks using an M&A framework, considering both qualitative factors and quantitative factors (which may vary across sectors and regions) to incorporate the potential that certain companies could be acquired. We then assign a M&A rank as a means of scoring companies under our rated coverage from 1 to 3, with 1 representing high (30%-50%) probability of the company becoming an acquisition target, 2 representing medium (15%-30%) probability and 3 representing low (0%-15%) probability. For companies ranked 1 or 2, in line with our standard departmental guidelines we incorporate an M&A component into our target price. M&A rank of 3 is considered immaterial and therefore does not factor into our price target, and may or may not be discussed in research.

Quantum

Quantum is Goldman Sachs' proprietary database providing access to detailed financial statement histories, forecasts and ratios. It can be used for in-depth analysis of a single company, or to make comparisons between companies in different sectors and markets.

GS SUSTAIN

GS SUSTAIN is a global investment strategy focused on the generation of long-term alpha through identifying high quality industry leaders. The GS SUSTAIN 50 list includes leaders we believe to be well positioned to deliver long-term outperformance through superior returns on capital, sustainable competitive advantage and effective management of ESG risks vs. global industry peers. Candidates are selected largely on a combination of quantifiable analysis of these three aspects of corporate performance.

Disclosures

Distribution of ratings/investment banking relationships

Goldman Sachs Investment Research global Equity coverage universe

	Rating Distribution			Investment Banking Relationships		
	Buy	Hold	Sell	Buy	Hold	Sell
Global	33%	54%	13%	64%	57%	53%

As of October 1, 2017, Goldman Sachs Global Investment Research had investment ratings on 2,717 equity securities. Goldman Sachs assigns stocks as Buys and Sells on various regional Investment Lists; stocks not so assigned are deemed Neutral. Such assignments equate to Buy, Hold and Sell for the purposes of the above disclosure required by the FINRA Rules. See 'Ratings, Coverage groups and

views and related definitions' below. The Investment Banking Relationships chart reflects the percentage of subject companies within each rating category for whom Goldman Sachs has provided investment banking services within the previous twelve months.

Regulatory disclosures

Disclosures required by United States laws and regulations

See company-specific regulatory disclosures above for any of the following disclosures required as to companies referred to in this report: manager or co-manager in a pending transaction; 1% or other ownership; compensation for certain services; types of client relationships; managed/co-managed public offerings in prior periods; directorships; for equity securities, market making and/or specialist role. Goldman Sachs trades or may trade as a principal in debt securities (or in related derivatives) of issuers discussed in this report.

The following are additional required disclosures: **Ownership and material conflicts of interest:** Goldman Sachs policy prohibits its analysts, professionals reporting to analysts and members of their households from owning securities of any company in the analyst's area of coverage. **Analyst compensation:** Analysts are paid in part based on the profitability of Goldman Sachs, which includes investment banking revenues. **Analyst as officer or director:** Goldman Sachs policy generally prohibits its analysts, persons reporting to analysts or members of their households from serving as an officer, director or advisor of any company in the analyst's area of coverage. **Non-U.S. Analysts:** Non-U.S. analysts may not be associated persons of Goldman Sachs & Co. LLC and therefore may not be subject to FINRA Rule 2241 or FINRA Rule 2242 restrictions on communications with subject company, public appearances and trading securities held by the analysts.

Distribution of ratings: See the distribution of ratings disclosure above. **Price chart:** See the price chart, with changes of ratings and price targets in prior periods, above, or, if electronic format or if with respect to multiple companies which are the subject of this report, on the Goldman Sachs website at http://www.gs.com/research/hedge.html.

Additional disclosures required under the laws and regulations of jurisdictions other than the United States

The following disclosures are those required by the jurisdiction indicated, except to the extent already made above pursuant to United States laws and regulations. **Australia:** Goldman Sachs Australia Pty Ltd and its affiliates are not authorised deposit-taking institutions (as that term is defined in the Banking Act 1959 (Cth)) in Australia and do not provide banking services, nor carry on a banking business, in Australia. This research, and any access to it, is intended only for "wholesale clients" within the meaning of the Australian Corporations Act, unless otherwise agreed by Goldman Sachs. In producing research reports, members of the Global Investment Research Division of Goldman Sachs Australia may attend site visits and other meetings hosted by the companies and other entities which are the subject of its research reports. In some instances the costs of such site visits or meetings may be met in part or in whole by the issuers concerned if Goldman Sachs Australia considers it is appropriate and reasonable in the specific circumstances relating to the site visit or meeting. To the extent that the contents of this document contains any financial product advice, it is general advice only and has been prepared by Goldman Sachs without taking into account a client's objectives, financial situation or needs. A client should, before acting on any such advice, consider the appropriateness of the advice having regard to the client's own objectives, financial situation and needs. **Brazil:** Disclosure information in relation to CVM Instruction 483 is available at http://www.gs.com/worldwide/brazil/area/gir/index.html. Where applicable, the Brazil-registered analyst primarily responsible for the content of this research report, as defined in Article 16 of CVM Instruction 483, is the first author named at the beginning of this report, unless indicated otherwise at the end of the text. **Canada:** Goldman Sachs Canada Inc. is an affiliate of The Goldman Sachs Group Inc. and therefore is included in the company specific disclosures relating to Goldman Sachs (as defined above). Goldman Sachs Canada Inc. has approved of, and agreed to take responsibility for, this research report in Canada if and to the extent that Goldman Sachs Canada Inc. disseminates this research report to its clients. **Hong Kong:** Further information on the securities of covered companies referred to in this research may be obtained on request from Goldman Sachs (Asia) L.L.C. **India:** Further information on the subject company or companies referred to in this research may be obtained from Goldman Sachs (India) Securities Private Limited, Research Analyst - SEBI Registration Number INH000001493, 951-A, Rational House, Appasaheb Marathe Marg, Prabhadevi, Mumbai 400 025, India, Corporate Identity Number U74140MH2006FTC160634, Phone +91 22 6616 9000, Fax +91 22 6616 9001. Goldman Sachs may beneficially own 1% or more of the securities (as such term is defined in clause 2 (h) the Indian Securities Contracts (Regulation) Act, 1956) of the subject company or companies referred to in this research report. **Japan:** See below. **Korea:** Further information on the subject company or companies referred to in this research may be obtained from Goldman Sachs (Asia) L.L.C., Seoul Branch. **New Zealand:** Goldman Sachs New Zealand Limited and its affiliates are neither "registered banks" nor "deposit takers" (as defined in the Reserve Bank of New Zealand Act 1989) in New Zealand. This research, and any access to it, is intended for "wholesale clients" (as defined in the Financial Advisers Act 2008) unless otherwise agreed by Goldman Sachs. **Russia:** Research reports distributed in the Russian Federation are not advertising as defined in the Russian legislation, but are information and analysis not having product promotion as their main purpose and do not provide appraisal within the meaning of the Russian legislation on appraisal activity. **Singapore:** Further information on the covered companies referred to in this research may be obtained from Goldman Sachs (Singapore) Pte. (Company Number: 198602165W). **Taiwan:** This material is for reference only and must not be reprinted without permission. Investors should carefully consider their own investment risk. Investment results are the responsibility of the individual investor. **United Kingdom:** Persons who would be categorized as retail clients in the United Kingdom, as such term is defined in the rules of the Financial Conduct Authority, should read this research in conjunction with prior Goldman Sachs research on the covered companies referred to herein and should refer to the risk warnings that have been sent to them by Goldman Sachs International. A copy of these risks warnings, and a glossary of certain financial terms used in this report, are available from Goldman Sachs International on request.

European Union: Disclosure information in relation to Article 4 (1) (d) and Article 6 (2) of the European Commission Directive 2003/125/EC is available at http://www.gs.com/disclosures/europeanpolicy.html which states the European Policy for Managing Conflicts of Interest in Connection with Investment Research.

Japan: Goldman Sachs Japan Co., Ltd. is a Financial Instrument Dealer registered with the Kanto Financial Bureau under registration number Kinsho 69, and a member of Japan Securities Dealers Association, Financial Futures Association of Japan and Type II Financial Instruments Firms Association. Sales and purchase of equities are subject to commission pre-determined with clients plus consumption tax. See company-specific disclosures as to any applicable disclosures required by Japanese stock exchanges, the Japanese Securities Dealers Association or the Japanese Securities Finance Company.

Ratings, coverage groups and views and related definitions

Buy (B), Neutral (N), Sell (S) -Analysts recommend stocks as Buys or Sells for inclusion on various regional Investment Lists. Being assigned a Buy or Sell on an Investment List is determined by a stock's total return potential relative to its coverage. Any stock not assigned as a Buy or a Sell on an Investment List with an active rating (i.e., a stock that is not Rating Suspended, Not Rated, Coverage Suspended or Not Covered), is deemed Neutral. Each regional Investment Review Committee manages various regional Investment Lists to a global guideline of 25%-35% of stocks as Buy and 10%-15% of stocks as Sell; however, the distribution of Buys and Sells in any particular analyst's coverage group may vary as determined by the regional Investment Review Committee. Additionally, each Investment

Review Committee manages Regional Conviction lists, which represent investment recommendations focused on the size of the total return potential and/or the likelihood of the realization of the return across their respective areas of coverage. The addition or removal of stocks from such Conviction lists do not represent a change in the analysts' investment rating for such stocks.

Total return potential represents the upside or downside differential between the current share price and the price target, including all paid or anticipated dividends, expected during the time horizon associated with the price target. Price targets are required for all covered stocks. The total return potential, price target and associated time horizon are stated in each report adding or reiterating an Investment List membership.

Coverage groups and views: A list of all stocks in each coverage group is available by primary analyst, stock and coverage group at http://www.gs.com/research/hedge.html. The analyst assigns one of the following coverage views which represents the analyst's investment outlook on the coverage group relative to the group's historical fundamentals and/or valuation. **Attractive (A).** The investment outlook over the following 12 months is favorable relative to the coverage group's historical fundamentals and/or valuation. **Neutral (N).** The investment outlook over the following 12 months is neutral relative to the coverage group's historical fundamentals and/or valuation. **Cautious (C).** The investment outlook over the following 12 months is unfavorable relative to the coverage group's historical fundamentals and/or valuation.

Not Rated (NR). The investment rating and target price have been removed pursuant to Goldman Sachs policy when Goldman Sachs is acting in an advisory capacity in a merger or strategic transaction involving this company and in certain other circumstances. **Rating Suspended (RS).** Goldman Sachs Research has suspended the investment rating and price target for this stock, because there is not a sufficient fundamental basis for determining, or there are legal, regulatory or policy constraints around publishing, an investment rating or target. The previous investment rating and price target, if any, are no longer in effect for this stock and should not be relied upon. **Coverage Suspended (CS).** Goldman Sachs has suspended coverage of this company. **Not Covered (NC).** Goldman Sachs does not cover this company. **Not Available or Not Applicable (NA).** The information is not available for display or is not applicable. **Not Meaningful (NM).** The information is not meaningful and is therefore excluded.

Global product; distributing entities

The Global Investment Research Division of Goldman Sachs produces and distributes research products for clients of Goldman Sachs on a global basis. Analysts based in Goldman Sachs offices around the world produce equity research on industries and companies, and research on macroeconomics, currencies, commodities and portfolio strategy. This research is disseminated in Australia by Goldman Sachs Australia Pty Ltd (ABN 21 006 797 897); in Brazil by Goldman Sachs do Brasil Corretora de Títulos e Valores Mobiliários S.A.; Ombudsman Goldman Sachs Brazil: 0800 727 5764 and / or ouvidoriagoldmansachs@gs.com. Available Weekdays (except holidays), from 9am to 6pm. Ouvidoria Goldman Sachs Brasil: 0800 727 5764 e/ou ouvidoriagoldmansachs@gs.com. Horário de funcionamento: segunda-feira à sexta-feira (exceto feriados), das 9h às 18h; in Canada by either Goldman Sachs Canada Inc. or Goldman Sachs & Co. LLC; in Hong Kong by Goldman Sachs (Asia) L.L.C.; in India by Goldman Sachs (India) Securities Private Ltd.; in Japan by Goldman Sachs Japan Co., Ltd.; in the Republic of Korea by Goldman Sachs (Asia) L.L.C., Seoul Branch; in New Zealand by Goldman Sachs New Zealand Limited; in Russia by OOO Goldman Sachs; in Singapore by Goldman Sachs (Singapore) Pte. (Company Number: 198602165W); and in the United States of America by Goldman Sachs & Co. LLC. Goldman Sachs International has approved this research in connection with its distribution in the United Kingdom and European Union.

European Union: Goldman Sachs International authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority, has approved this research in connection with its distribution in the European Union and United Kingdom; Goldman Sachs AG and Goldman Sachs International Zweigniederlassung Frankfurt, regulated by the Bundesanstalt für Finanzdienstleistungsaufsicht, may also distribute research in Germany.

General disclosures

This research is for our clients only. Other than disclosures relating to Goldman Sachs, this research is based on current public information that we consider reliable, but we do not represent it is accurate or complete, and it should not be relied on as such. The information, opinions, estimates and forecasts contained herein are as of the date hereof and are subject to change without prior notification. We seek to update our research as appropriate, but various regulations may prevent us from doing so. Other than certain industry reports published on a periodic basis, the large majority of reports are published at irregular intervals as appropriate in the analyst's judgment.

Goldman Sachs conducts a global full-service, integrated investment banking, investment management, and brokerage business. We have investment banking and other business relationships with a substantial percentage of the companies covered by our Global Investment Research Division. Goldman Sachs & Co. LLC, the United States broker dealer, is a member of SIPC (http://www.sipc.org).

Our salespeople, traders, and other professionals may provide oral or written market commentary or trading strategies to our clients and principal trading desks that reflect opinions that are contrary to the opinions expressed in this research. Our asset management area, principal trading desks and investing businesses may make investment decisions that are inconsistent with the recommendations or views expressed in this research.

The analysts named in this report may have from time to time discussed with our clients, including Goldman Sachs salespersons and traders, or may discuss in this report, trading strategies that reference catalysts or events that may have a near-term impact on the market price of the equity securities discussed in this report, which impact may be directionally counter to the analyst's published price target expectations for such stocks. Any such trading strategies are distinct from and do not affect the analyst's fundamental equity rating for such stocks, which rating reflects a stock's return potential relative to its coverage group as described herein.

We and our affiliates, officers, directors, and employees, excluding equity and credit analysts, will from time to time have long or short positions in, act as principal in, and buy or sell, the securities or derivatives, if any, referred to in this research.

The views attributed to third party presenters at Goldman Sachs arranged conferences, including individuals from other parts of Goldman Sachs, do not necessarily reflect those of Global Investment Research and are not an official view of Goldman Sachs.

Any third party referenced herein, including any salespeople, traders and other professionals or members of their household, may have positions in the products mentioned that are inconsistent with the views expressed by analysts named in this report.

This research is not an offer to sell or the solicitation of an offer to buy any security in any jurisdiction where such an offer or solicitation would be illegal. It does not constitute a personal recommendation or take into account the particular investment objectives, financial situations, or needs of individual clients. Clients should consider whether any advice or recommendation in this research is suitable for their particular circumstances and, if appropriate, seek professional advice, including tax advice. The price and value of investments referred to in this research and the income from them may fluctuate. Past performance is not a guide to future performance, future returns are not guaranteed, and a loss of original capital may occur. Fluctuations in exchange rates could have adverse effects on the value or price of, or income derived from, certain investments.

Certain transactions, including those involving futures, options, and other derivatives, give rise to substantial risk and are not suitable for all investors. Investors should review current options disclosure documents which are available from Goldman Sachs sales representatives or at http://www.theocc.com/about/publications/character-risks.jsp. Transaction costs may be significant in option strategies calling for multiple purchase and sales of options such as spreads. Supporting documentation will be supplied upon request.

Differing Levels of Service provided by Global Investment Research: The level and types of services provided to you by the Global Investment Research division of GS may vary as compared to that provided to internal and other external clients of GS, depending on various factors including your individual preferences as to the frequency and manner of receiving communication, your risk profile and investment focus and perspective (e.g., marketwide, sector specific, long term, short term), the size and scope of your overall client relationship with GS, and legal and regulatory constraints. As an example, certain clients may request to receive notifications when research on specific securities is published, and certain clients may request that specific data underlying analysts' fundamental analysis available on our internal client websites be delivered to them electronically through data feeds or otherwise. No change to an analyst's fundamental research views (e.g., ratings, price targets, or material changes to earnings estimates for equity securities), will be communicated to any client prior to inclusion of such information in a research report broadly disseminated through electronic publication to our internal client websites or through other means, as necessary, to all clients who are entitled to receive such reports.

All research reports are disseminated and available to all clients simultaneously through electronic publication to our internal client websites. Not all research content is redistributed to our clients or available to third-party aggregators, nor is Goldman Sachs responsible for the redistribution of our research by third party aggregators. For research, models or other data related to one or more securities, markets or asset classes (including related services) that may be available to you, please contact your GS representative or go to http://360.gs.com.

Disclosure information is also available at http://www.gs.com/research/hedge.html or from Research Compliance, 200 West Street, New York, NY 10282.