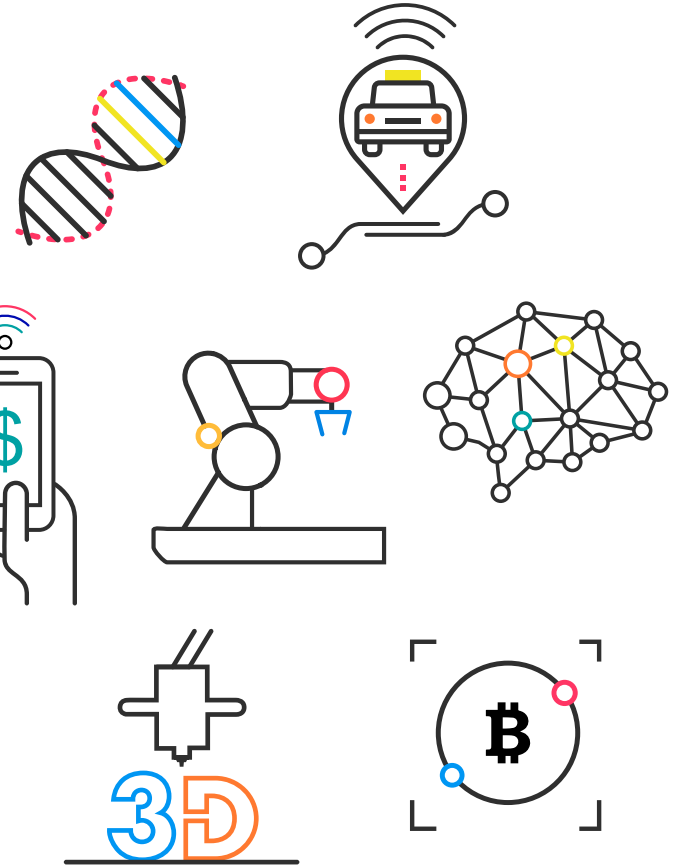ark-invest.com

ARK INVEST
DISRUPTIVE
INNOVATION

BIG
IDEAS
2017

WELCOME TO INNOVATION!

Rooted in almost 40 years of experience, ARK Invest aims to identify large-scale investment opportunities resulting from technological change. We believe innovation is key to growth.

From a broad spectrum of disruptive innovations, "Big Ideas" represents our annual breakout of technologies that we believe will accelerate significantly in the months ahead.
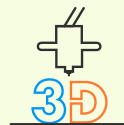
Each section provides you with a brief introduction before illustrating the opportunity. At the end of each section we list sources for additional research and insights.

1. **Deep Learning**
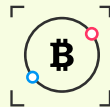
2. **Mobility-as-a-Service**

3. **3D Printing**

4. **CRISPR Genome-Editing**

5. **Mobile Payments**

6. **Robotics**

7. **Cryptoassets**

ark-invest.com

ARK's ANALYST TEAM PRESENTS BIG IDEAS 2017

Join the Conversation. Get in Touch with ARK's Analysts. More Information: ark-invest.com/ark-team

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skorus@ark-invest.com
🐦 @skorusARK

1. DEEP LEARNING
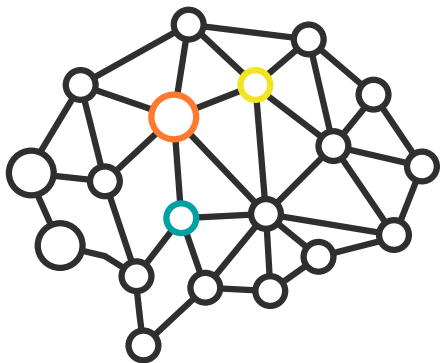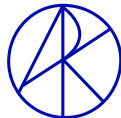
"A breakthrough in machine learning*
would be worth ten Microsofts."

— Bill Gates (2004)

*Deep Learning is a sub-category of Machine Learning

Artificial Intelligence (AI) vs. Machine Learning vs. Deep Learning

Artificial Intelligence

Machine Learning
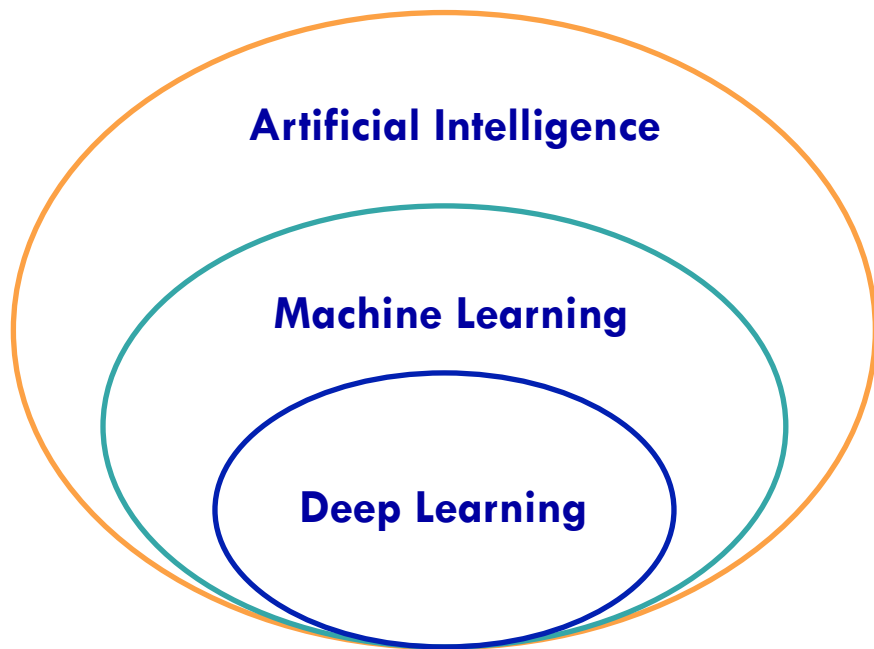
Deep Learning

○ Classic AI is based on deductive logic. Rules are based on human ingenuity.

○ Machine Learning is based on statistical inference. Rules are inferred from data.

○ Deep Learning is a type of Machine Learning modeled after the biological brain.

Wolfram Alpha

Video Game AI

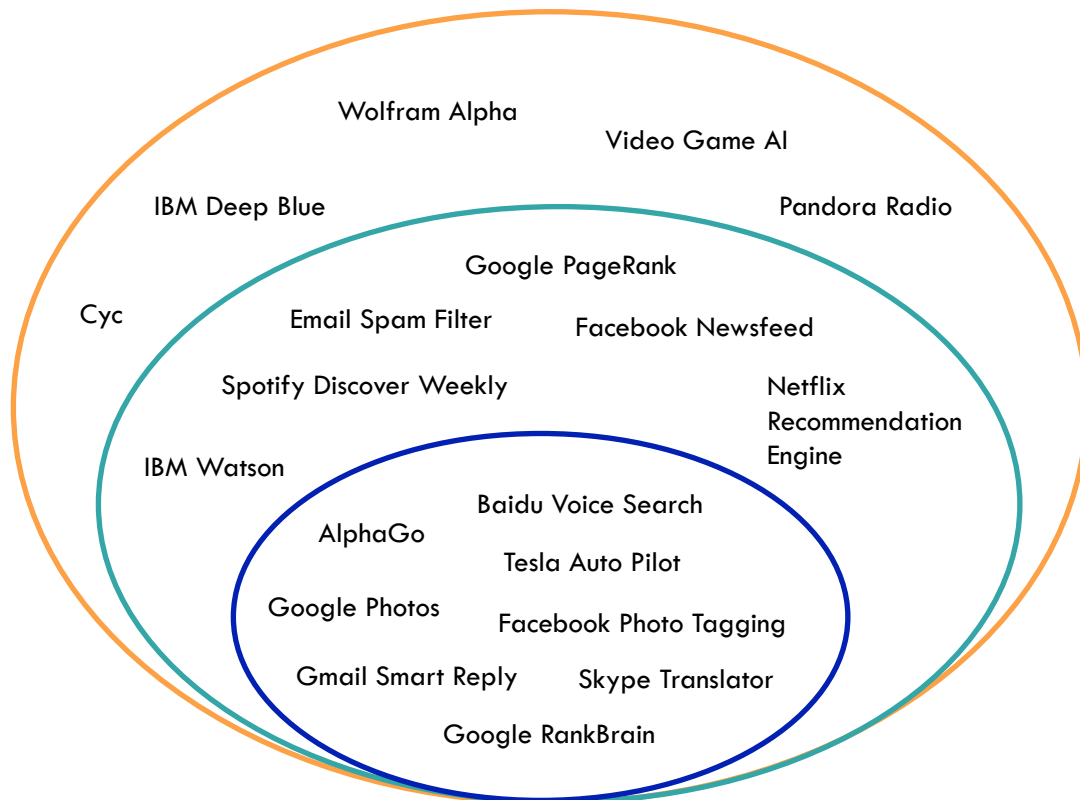IBM Deep Blue

Pandora Radio

Google PageRank

Cyc

Email Spam Filter

Facebook Newsfeed

Spotify Discover Weekly

Netflix Recommendation Engine

IBM Watson

Baidu Voice Search

AlphaGo

Tesla Auto Pilot

Google Photos

Facebook Photo Tagging
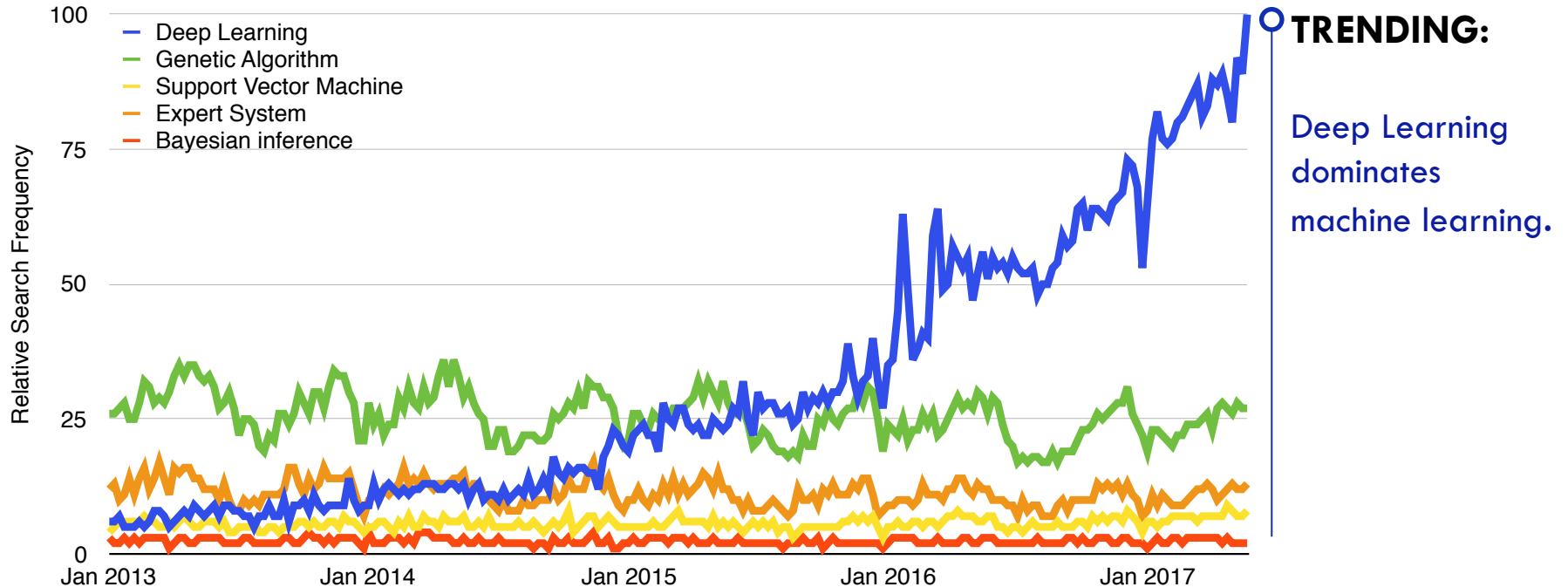
Gmail Smart Reply

Skype Translator

Google RankBrain

Mapping Products to AI

○ Artificial Intelligence

○ Machine Learning

○ Deep Learning

Different Machine Learning Algorithms: Google Search Trends
Five Tribes of AI – One Breakout Winner

TRENDING:

Deep Learning dominates machine learning.

Legend:
- Deep Learning
- Genetic Algorithm
- Support Vector Machine
- Expert System
- Bayesian inference

Y-axis: Relative Search Frequency (0, 25, 50, 75, 100)
X-axis: Jan 2013, Jan 2014, Jan 2015, Jan 2016, Jan 2017

Source: Google Search Trends

Recent Deep Learning Breakthroughs

Question Answering Accuracy

Speech Recognition

Image Classification

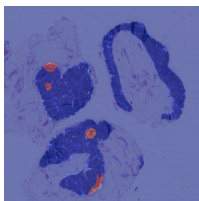Disease Prediction Accuracy

AI Game Performance
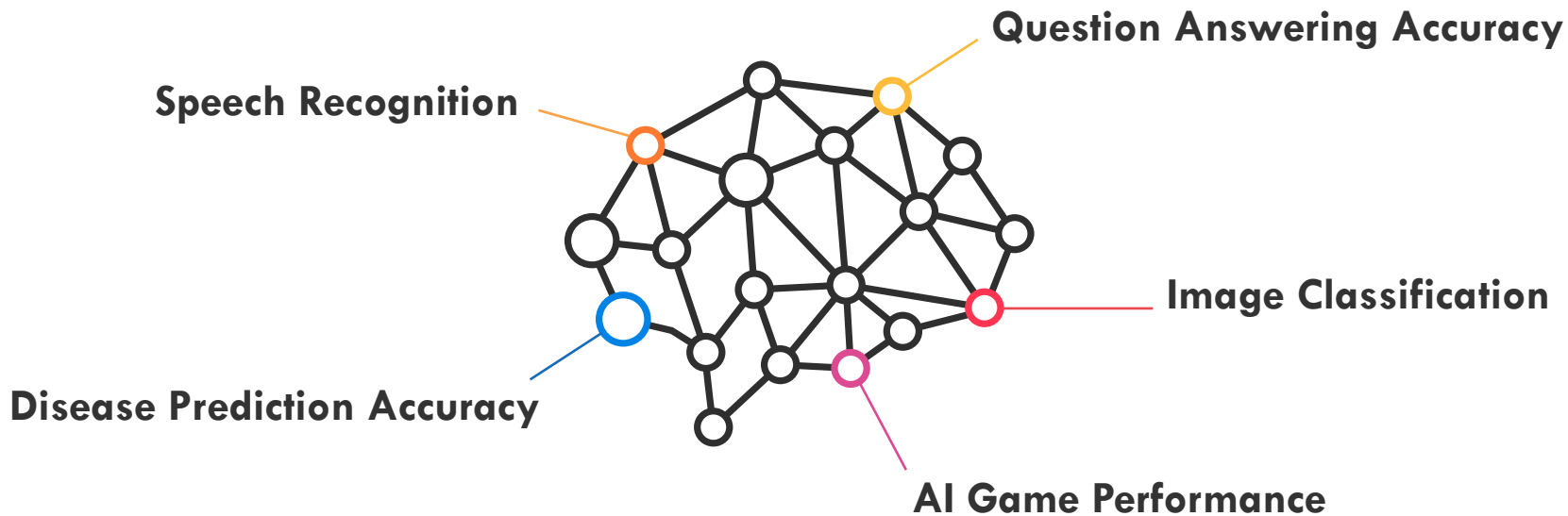
Example: Deep Learning Is Transforming Medical Imaging

	Lung Legions	Breast Cancer	Skin Cancer	Diabetic Retinopathy	Alzheimer's Disease
Global Cases Per Year	1.8M	1.7M	2.5M	93M	44M
Diagnostic Accuracy with Deep Learning	**97%**	**97%**	**72%**	**95%**	**99%**
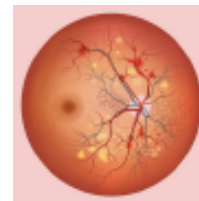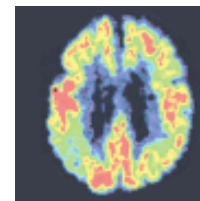
SIZING THE OPPORTUNITY

Relative to the internet, Deep Learning could impact more sectors, causing more profound disruptive innovations.

Deep Learning

Internet

Television   Advertising

Information Technology

News   Financial Services

Retail

Agriculture

New Industries

Pharmaceuticals

Manufacturing

Automotive   Health Care
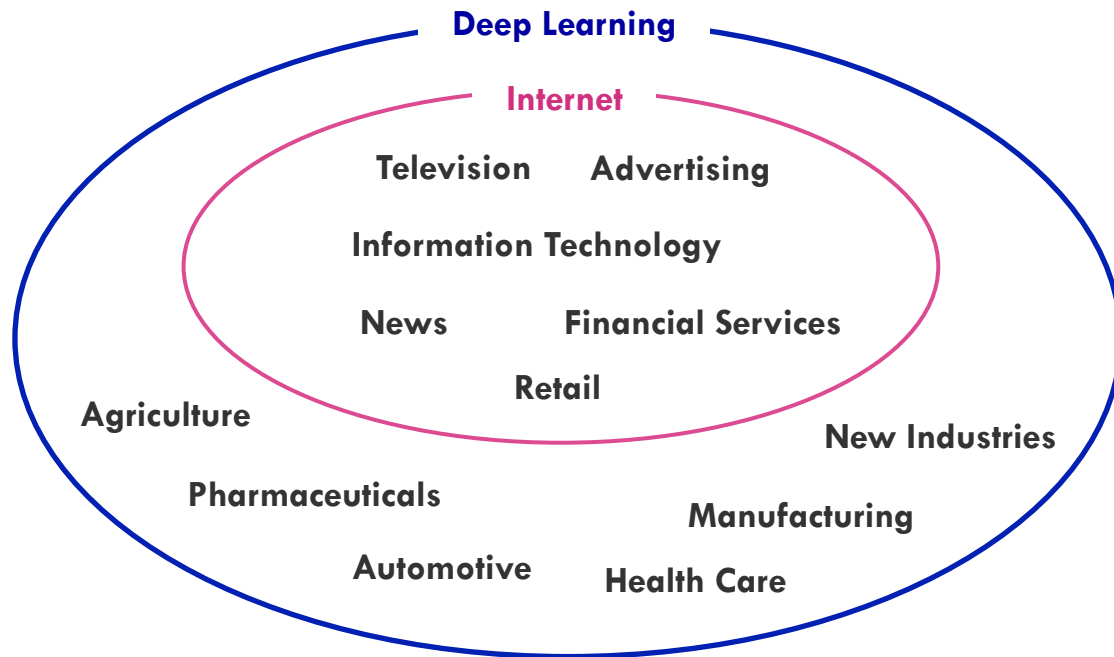
SIZING THE OPPORTUNITY

How impactful was the internet?

○   1996 Internet companies made up 0% of the S&P 500

○   2016 Internet companies made up 9% of the S&P 500

➡   **This Foundational Technology Took 9% Share In 20 Years**

SIZING THE OPPORTUNITY

S&P 500 Market Cap Created by The Internet

Company	Market Cap ($B)
Alphabet	$541
Amazon	$401
Facebook	$370
Cisco	$150
Netflix	$52
Salesforce	$51
Yahoo	$40
Ebay	$34
Akamai	$12
Juniper Networks	$11
Verisign	$9
F5 Networks	$9
Total	**$1,680**
S&P 500 Market Cap	**$19,622**
New Market Cap Creation From The Internet	**8.6%**

Pure Internet Companies As A Percent of S&P 500

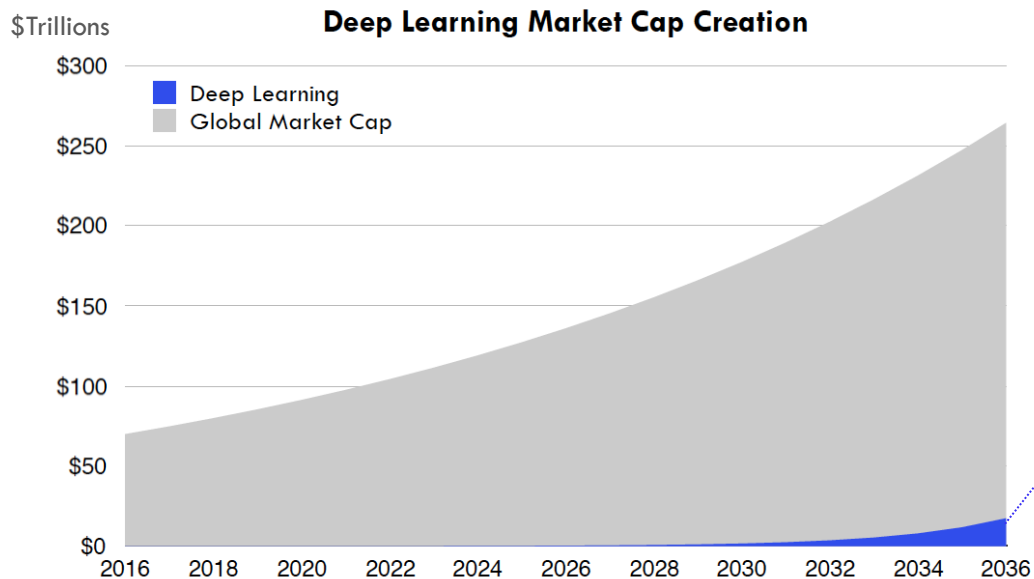US Internet Companies 9%

Others 91%
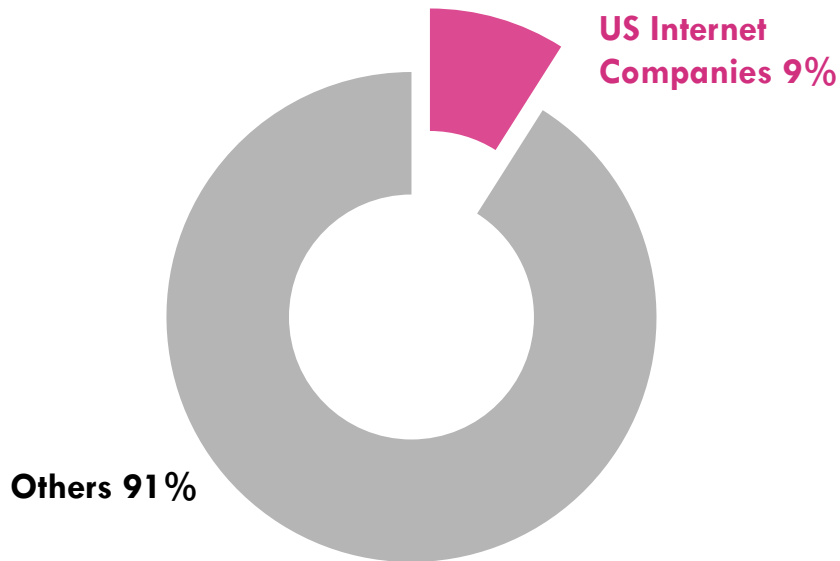
Source: ARK investment Management LLC, as of December 2016

12

SIZING THE OPPORTUNITY

Globally, Deep Learning Could Approach A $17 Trillion Market Cap in 20 Years

Deep Learning Market Cap Creation

$Trillions

- Deep Learning
- Global Market Cap

$300

$250

$200

$150

$100

$50

$0

2016 2018 2020 2022 2024 2026 2028 2030 2032 2034 2036

...creating the equivalent of 35x Amazon's.

amazon

Source: ARK Investment Management LLC,
Deep learning penetration adjusted for global market cap, assuming 6.9% historical growth rate of global equities, 6.6% deep learning share in 20 years.

Additional Research:

WHITE PAPER
Deep Learning—A Revolution in Artificial Intelligence

DOWNLOAD
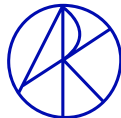
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James Wang
Analyst

jwang@ark-invest.com
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2. MOBILITY-AS-A-SERVICE

"The removal of the driver is arguably the most significant and transformative innovation ever faced by the automotive industry."

— *"The Future of Autonomous Cars", Berg Insights (2016)*

ARK expects that before 2020 fully autonomous vehicles will become commercially available, enabling the rapid rise and growth of autonomous taxi networks.
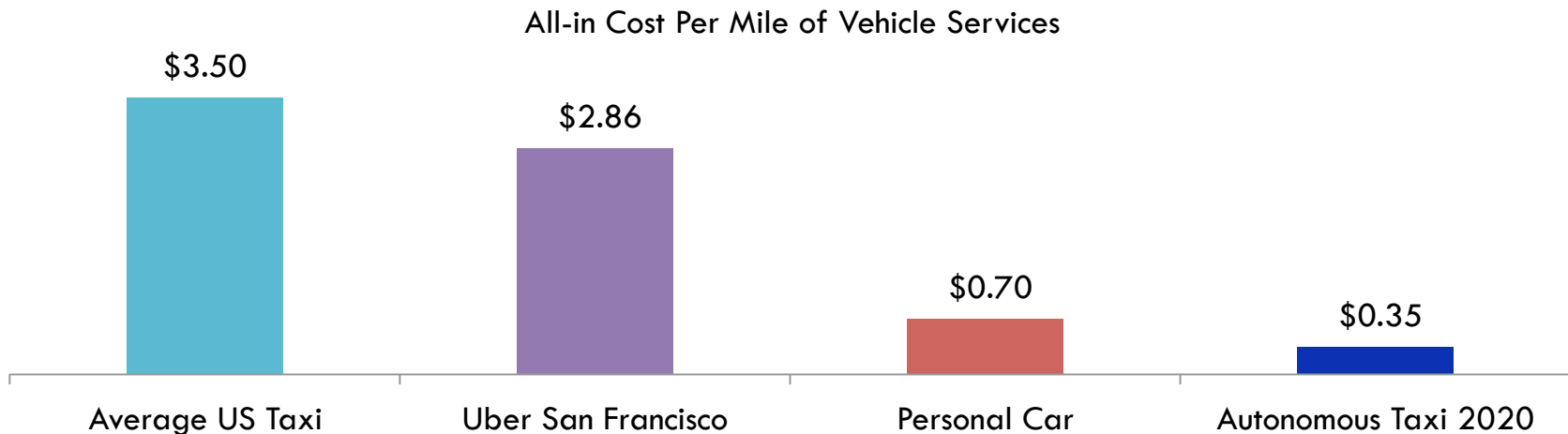
○ These networks should decrease the cost and inconvenience of point-to-point mobility dramatically, spurring a transformative boost in economic productivity.

○ As a result, the traditional automotive industry may be subsumed by Mobility-as-a-Service (MaaS) platforms that could become one of the most valuable investment opportunities in public equity markets.
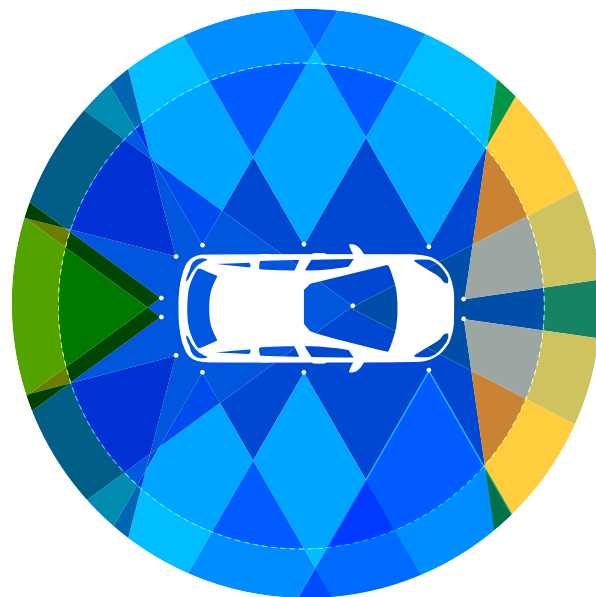
ARK's research shows that the price of autonomous travel will be roughly half the cost of driving a personal car today.

All-in Cost Per Mile of Vehicle Services

$3.50 — Average US Taxi
$2.86 — Uber San Francisco
$0.70 — Personal Car
$0.35 — Autonomous Taxi 2020

- These compelling economics will drive consumer adoption
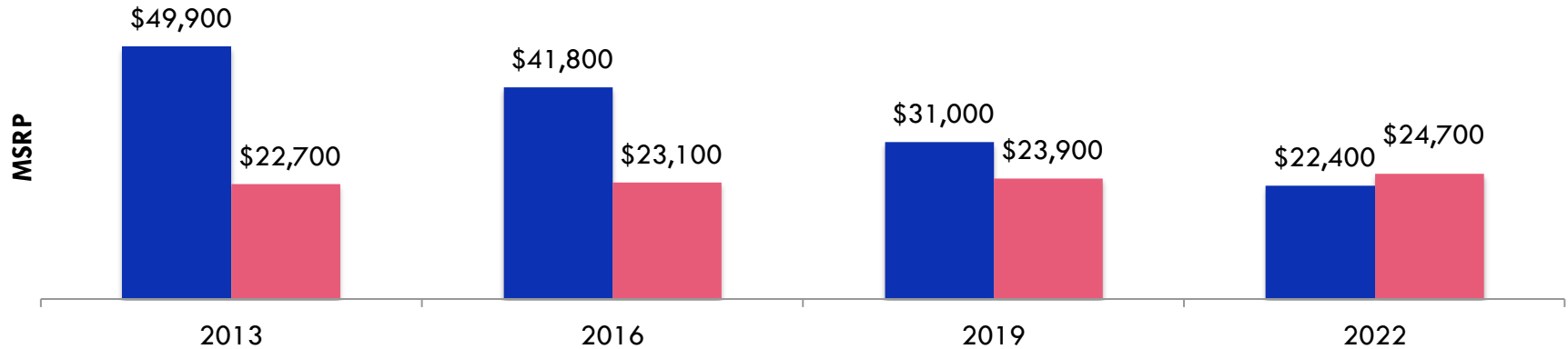- Autonomous taxis should become the dominant form of vehicle transportation in urban areas

Source: ARK Investment Management LLC

Because battery costs have declined faster than most analysts anticipated, ARK foresees a wholesale shift to electric vehicles (EVs). By 2022 EVs should be cheaper than comparable gas-powered cars.

Projected Price Parity for 200-Mile Range EV

■ 200 Mile Range EV   ■ Toyota Camry MSRP

MSRP

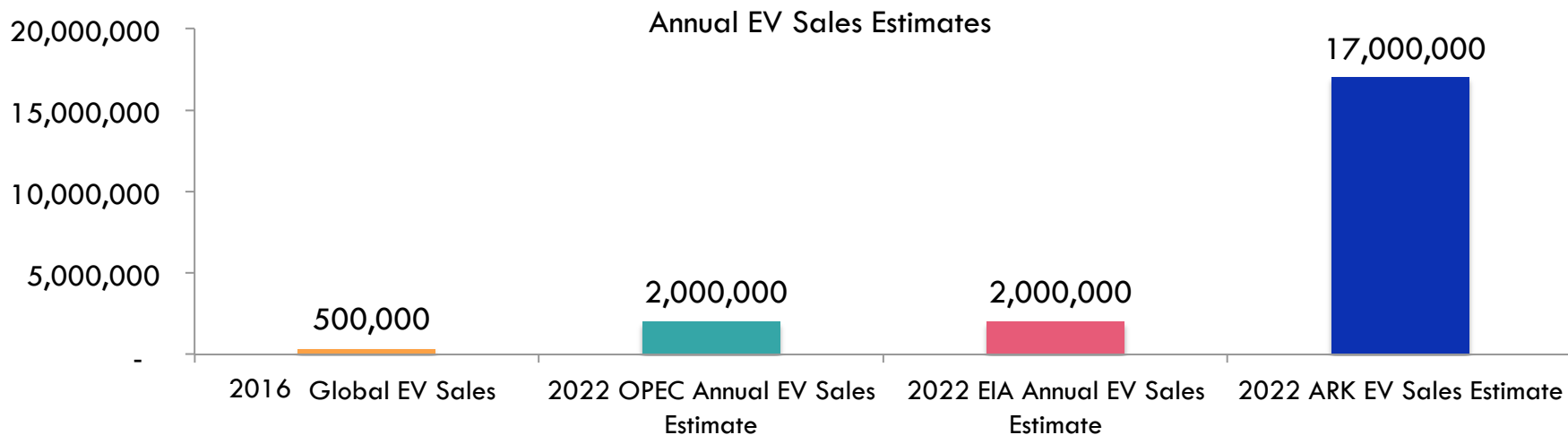| Year	200 Mile Range EV	Toyota Camry MSRP
2013	$49,900	$22,700
2016	$41,800	$23,100
2019	$31,000	$23,900
2022	$22,400	$24,700

ARK's expectation for EV MSRP (manufacturer's suggested retail price) parity is largely based on decreasing lithium-ion battery costs. Other factors could influence MSRP. The MSRP prices shown do not include any government subsidies.

Source: ARK Investment Management LLC

Based on ARK's Research, The Demand For EVs Will Be Orders Of Magnitude Higher Than Current Consensus Forecasts.

Annual EV Sales Estimates

	2016 Global EV Sales	2022 OPEC Annual EV Sales Estimate	2022 EIA Annual EV Sales Estimate	2022 ARK EV Sales Estimate
	500,000	2,000,000	2,000,000	17,000,000

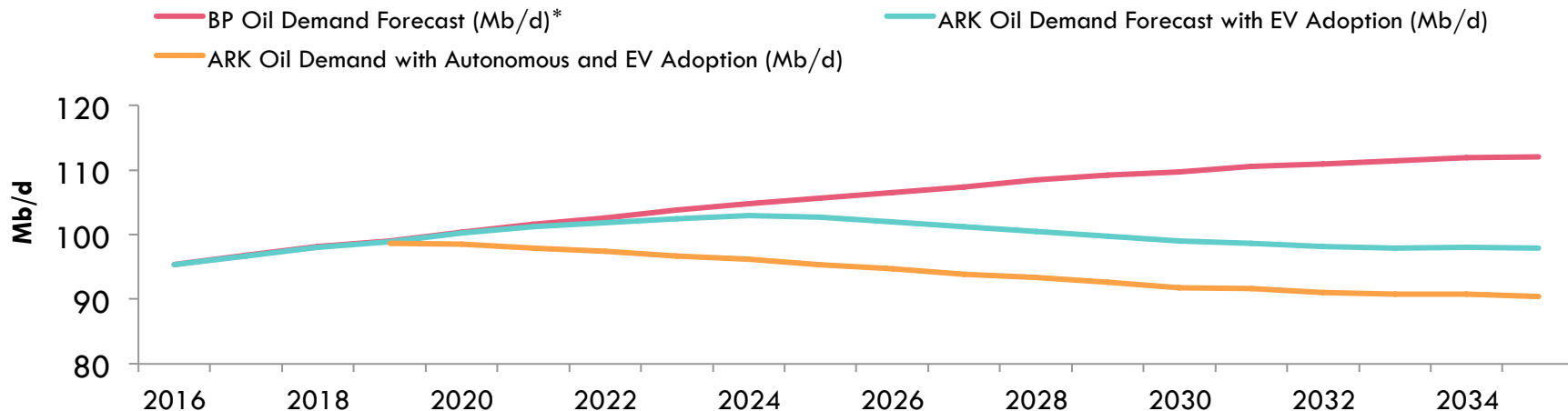# What will happen to oil prices?

EVs and autonomous technology could cause oil demand to peak before the end of the decade.

Oil Demand Forecast
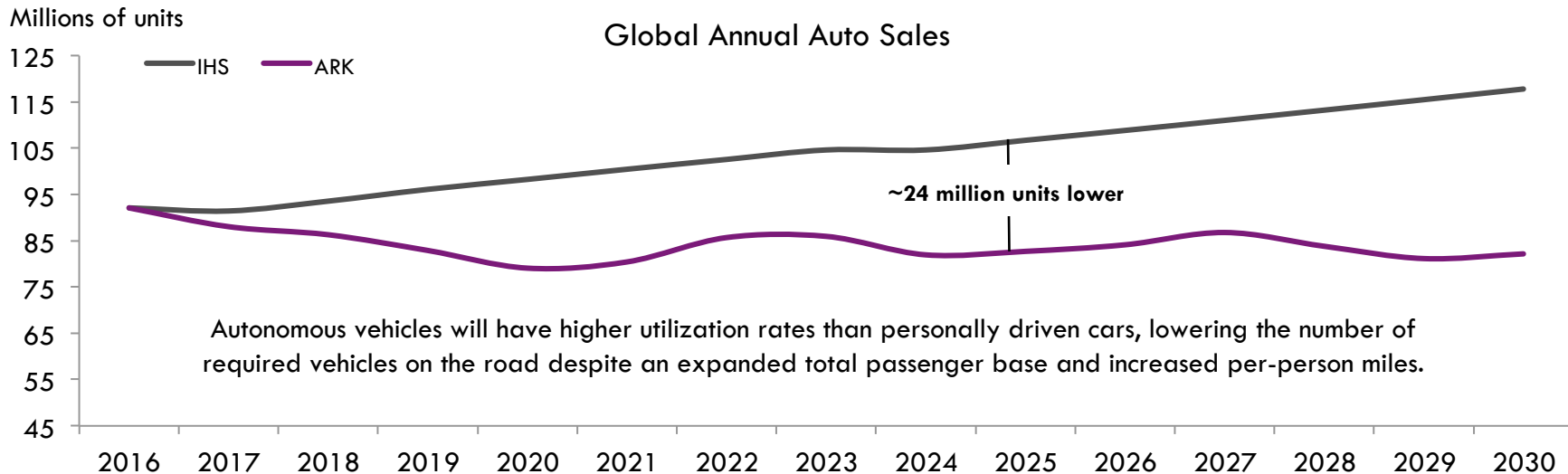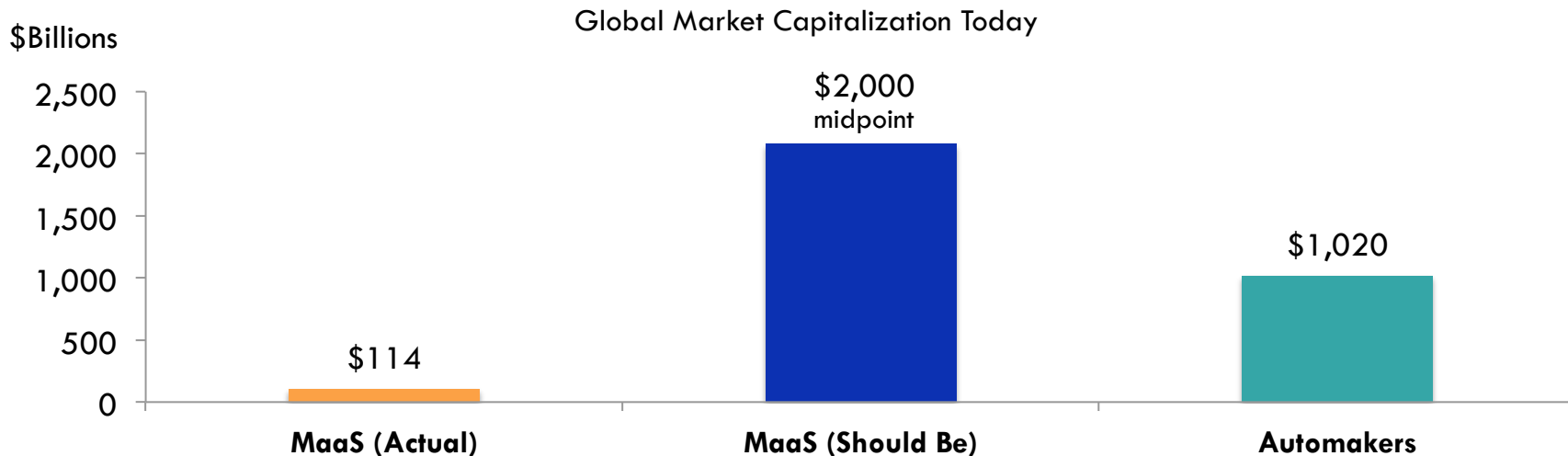
— BP Oil Demand Forecast (Mb/d)* — ARK Oil Demand Forecast with EV Adoption (Mb/d)
— ARK Oil Demand with Autonomous and EV Adoption (Mb/d)

*Mb/d = Millions of barrels per day.

Source: ARK Investment Management LLC, BP Energy Outlook 2016

What will happen to auto sales?

ARK expects auto sales to be much lower than anticipated, thanks to autonomous taxis.
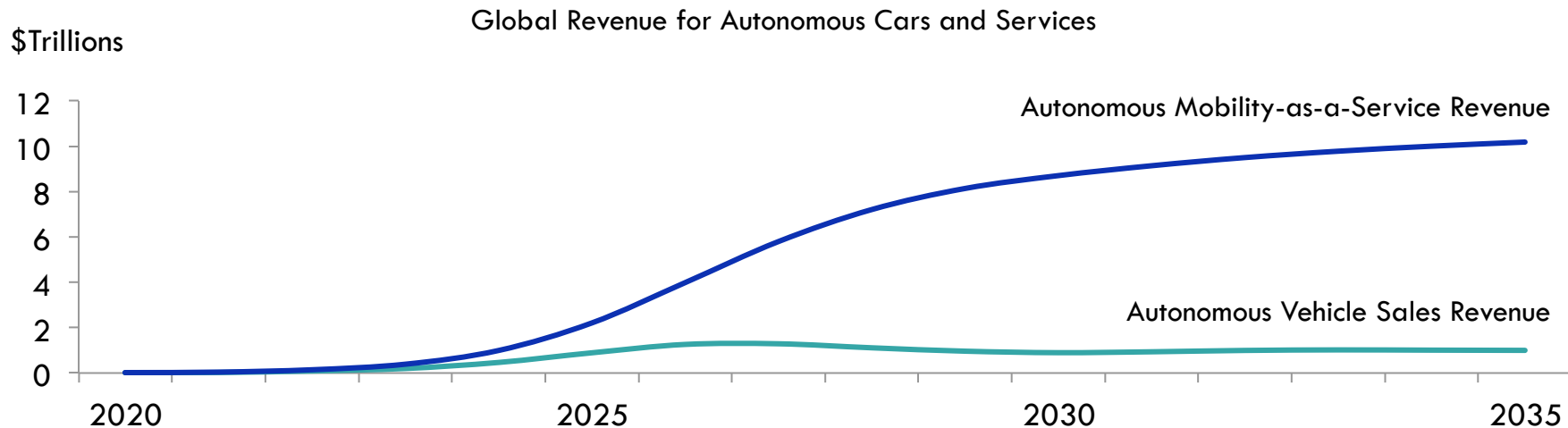
Millions of units

Global Annual Auto Sales

IHS   ARK

~24 million units lower

Autonomous vehicles will have higher utilization rates than personally driven cars, lowering the number of required vehicles on the road despite an expanded total passenger base and increased per-person miles.

2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

SIZING THE OPPORTUNITY

Based on ARK's research, mobility-as-a-service (MaaS) should be valued at $1-3 trillion today.

Global Market Capitalization Today

$Billions

	MaaS (Actual)	MaaS (Should Be)	Automakers
	$114	$2,000 midpoint	$1,020

Source: ARK Investment Management LLC

SIZING THE OPPORTUNITY

ARK estimates autonomous MaaS will reach $10 trillion in gross sales by the early 2030s, 20% of which could accrue to service operators.

Global Revenue for Autonomous Cars and Services

$Trillions

Autonomous Mobility-as-a-Service Revenue

Autonomous Vehicle Sales Revenue

Source: ARK Investment Management LLC

Additional Research:

WHITE PAPER
Mobility-as-a-Service: Why Self-Driving Cars Could Change Everything

DOWNLOAD

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skorus@ark-invest.com
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3. 3D PRINTING
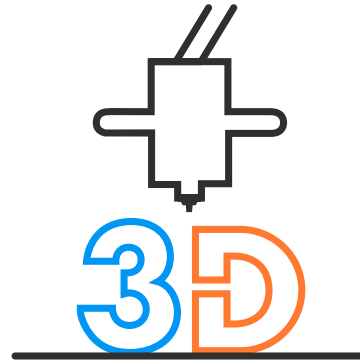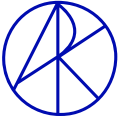
"3D printing is already shaking our age-old notions of
what can and can't be made."

— *Hod Lipson, Director of Columbia University's Creative Machines Lab (2013)*

3D printing has the potential to revolutionize traditional manufacturing.

By building objects layer-by-layer, instead of removing material from a larger block or using a mold, 3D printing offers a range of benefits:
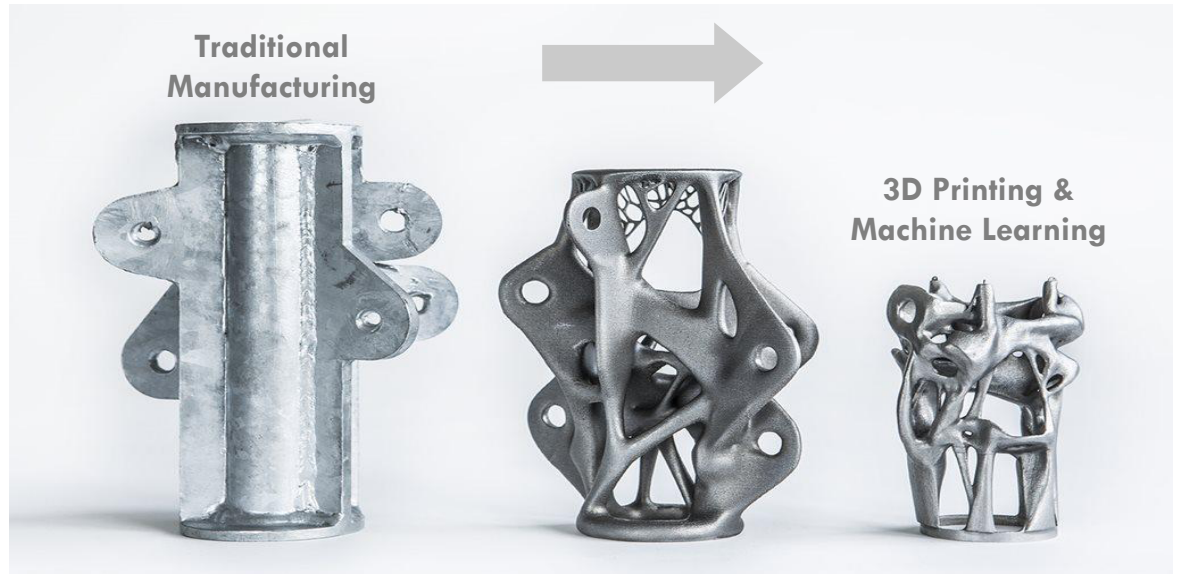
- **Shortens design-to-production time**

- **Shifts power to the designers**

- **Creates products with less waste**

- **Enables radically new architectures**

- **Reduces the cost of manufacturing significantly**

Source: ARK Investment Management LLC

3D printing and machine learning create better designed parts that humans never would have imagined.

For example, these structural nodes all support the same weight, but the part on the right weighs 75% less and is 50% smaller than the original part on the left.

Traditional Manufacturing

3D Printing & Machine Learning

Source: ARK Investment Management LLC

Use Case: Aerospace & Aviation

GE expects additive manufacturing to generate $1 billion in revenues by 2020, and it expects to save $3 – 5 billion in costs.

Proof point: Advanced Turboprop Engine (ATP)

Combustor test schedule reduced from **12 months** to **6 months**

No structural casting

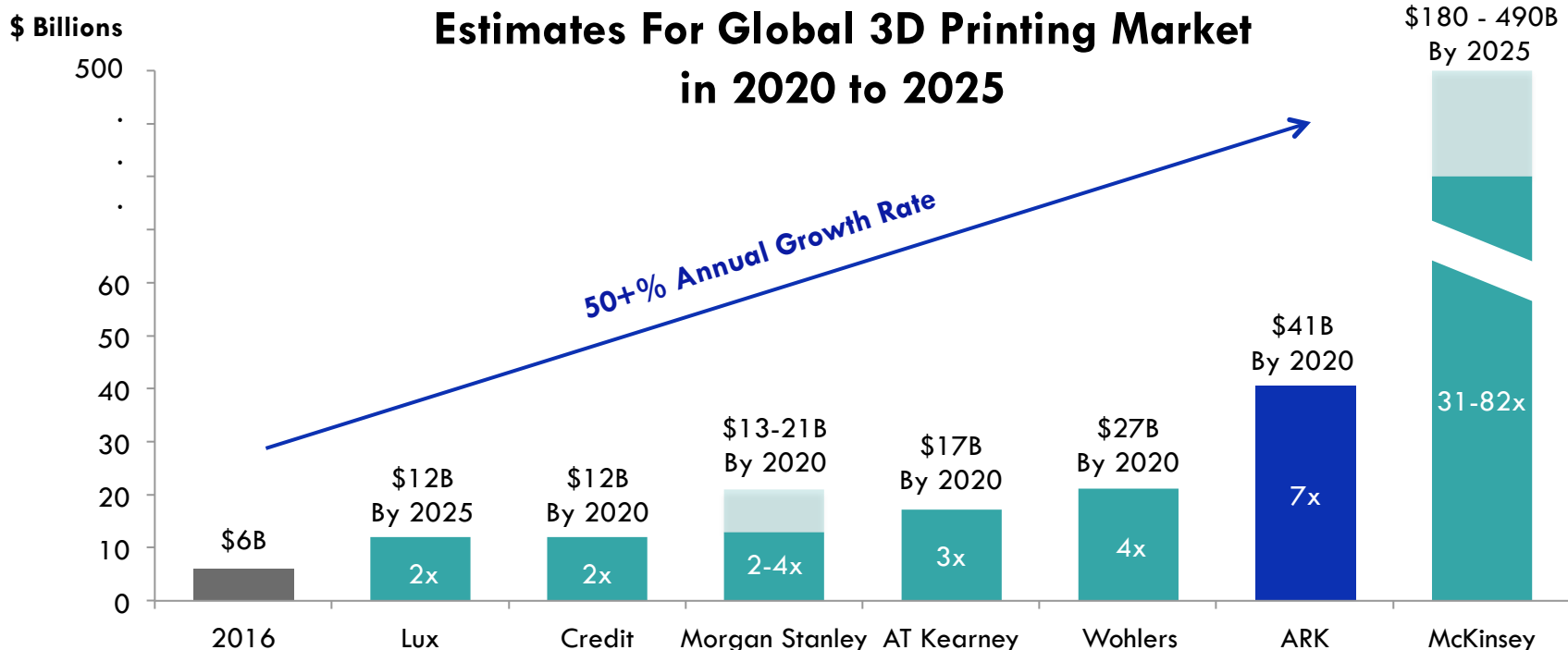**5%**
WEIGHT
REDUCTION

20%
LOWER MISSION
FUEL BURN
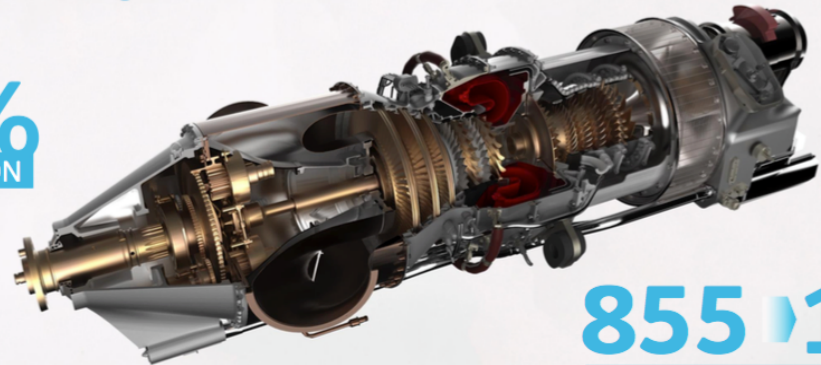
855▶12
PARTS

SIZING THE OPPORTUNITY

Estimates For Global 3D Printing Market in 2020 to 2025

$ Billions

$180 - 490B
By 2025

50+% Annual Growth Rate

$41B
By 2020

$13-21B
By 2020

$17B
By 2020

$27B
By 2020

$12B
By 2025

$12B
By 2020

$6B

Value	Label
2016	$6B
Lux	2x
Credit	2x
Morgan Stanley	2-4x
AT Kearney	3x
Wohlers	4x
ARK	7x
McKinsey	31-82x

Source: ARK Investment Management LLC

29

SIZING THE OPPORTUNITY

The final frontier for 3D printing will be the finished product market.

DESIGN FOR MANUFACTURE

3D Printing Global Market Penetration:

	PROTOTYPES	MOLDS & TOOLS	NON-CONSUMER PRODUCTS	CONSUMER PRODUCTS
MARKET SIZE	$12.5B	$30B	$230B	$260B
1ST APPLICATIONS	1980'S	1990'S	EARLY 2000'S	
CURRENT PENETRATION	23%	2%	- - - - - - 0.1% - - - - - -	
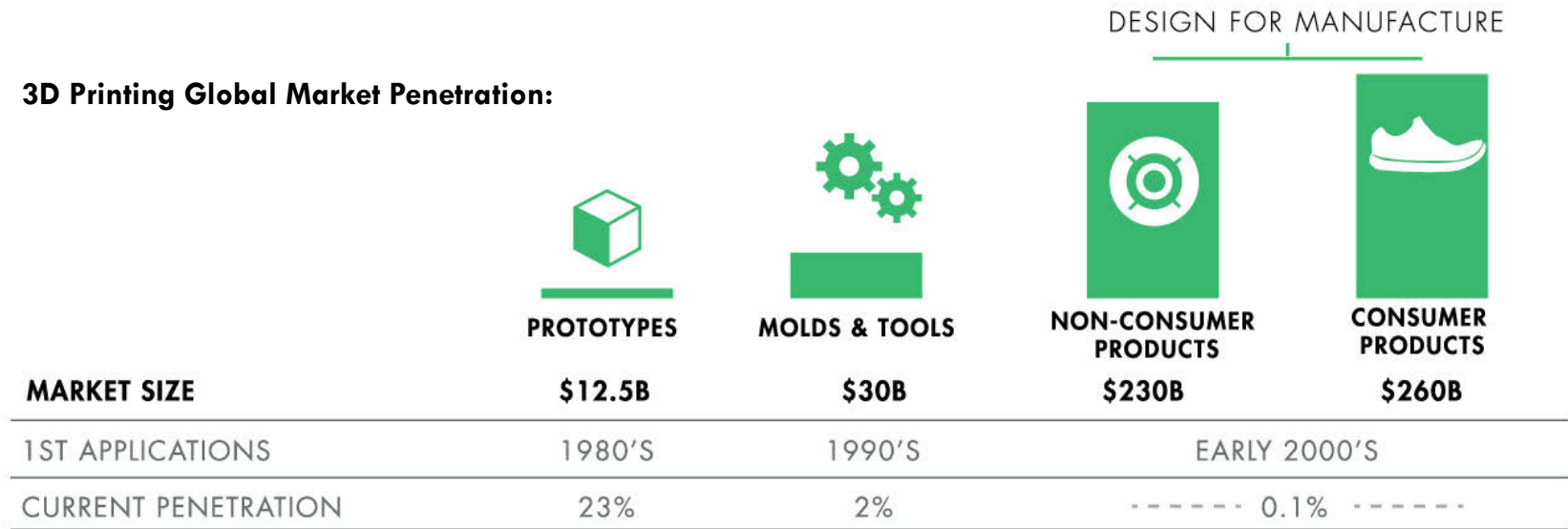
Source: ARK Investment Management LLC, Data from McKinsey, Fredonia Group, US Congressional Research Service
*Source: ARK Investment Management LLC; http://www.avplastics.co.uk/3d-printing-history
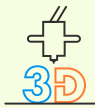
Additional Research:

WHITE PAPER

3D Printing: A Disruptive Innovation In Its Infancy

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Tasha Keeney

Analyst

akeeney@ark-invest.com

@tashaARK

4. CRISPR GENOME-EDITING

"The idea of gene correction is not new at all, but before CRISPR it never worked well enough so that people could do it routinely."

— Carl June, Biologist University of Pennsylvania (2016)

CRISPR is one of the breakthrough technologies of the century and will increase the pace of innovation in biotechnology.

Cheap, Easy, and Rapid DNA "Write" Capabilities:

Derived from bacteria, Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR for short) is a new genome-editing platform technology that can correct mistakes in the genome.

Genomic DNA

PAM

Cas9 Nuclease

5'

3'

sgRNA
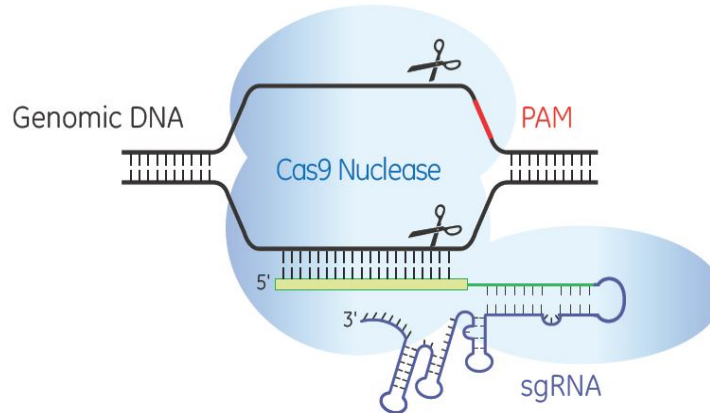
Previously	
1980's	Gene expression manipulated
2001	First whole human genome sequenced
2013	Next generation sequencing platform enabled $1,000 per genome
2020	Improved sequencing platforms enables $100 per genome

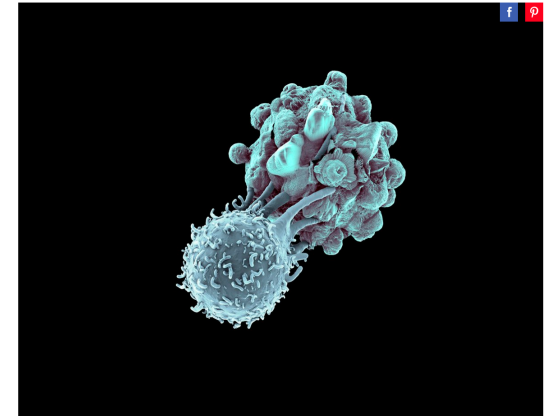# CRISPR technology has emerged as a winner in genome-editing.

Edible CRISPR Could Replace Antibiotics
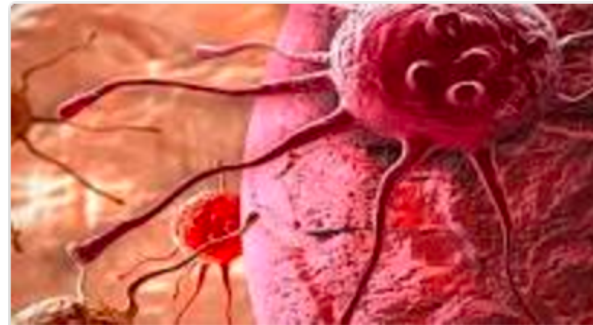
CRISPR kills HIV and eats Zika 'like Pac-man'. Its next target? Cancer

CHINA USED CRISPR TO FIGHT CANCER IN A REAL, LIVE HUMAN

Source: Time Magazine, MIT Technology Review, Wired Magazine

Genome-Editing Technologies

	ZFNs[1]	TALENs[2]	CRISPR
Year of First Human Cell Modification	**2003**	**2009**	**2012**
Time to Manufacture (days)	22	10	**5**
Cost (per pair of nucleases)	~$5,500	~$360	**~$30**
Efficient Editing?	**Yes**	**Yes**	**Yes**

Newer Genome-Editing Technique

CRISPR TECHNOLOGY IS:

✓ Easier to use thanks to simple manufacturing process and faster learning curve.

✓ More cost effective as research capacity expands.

✓ Comparable to legacy genome-editing technologies in editing efficiencies.

[1] ZFNs: Zinc Finger Nucleases   [2] TALENs: Transcription activator-like effector nuclease   Source: ARK Investment Management LLC

The cost of genome-editing has declined by 28x–52x* in the last 4 years.

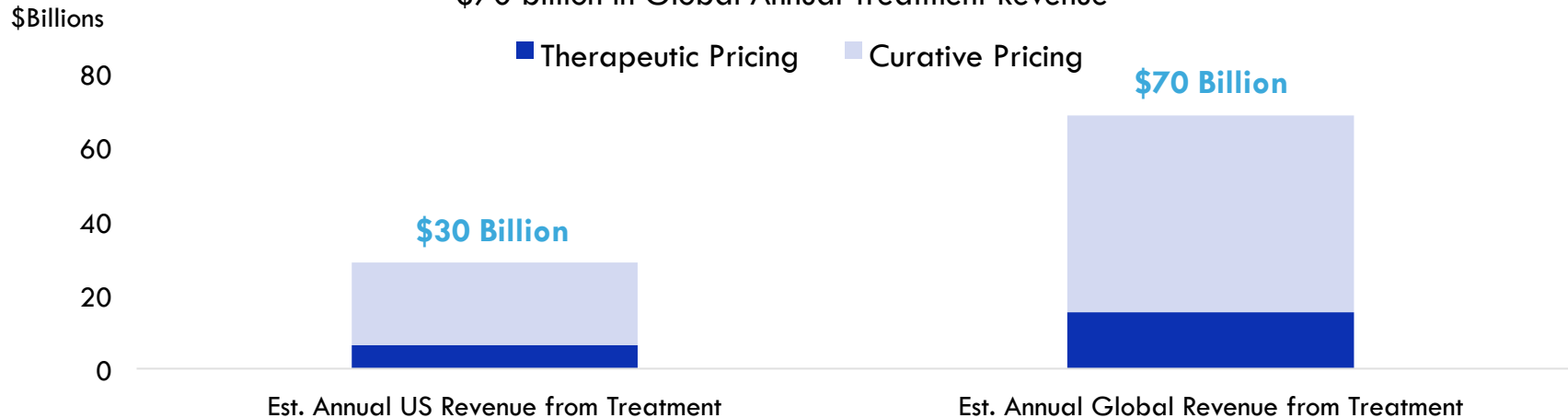### TALENs Gene Editing Cost Decline ~50-60% Compounded Yearly
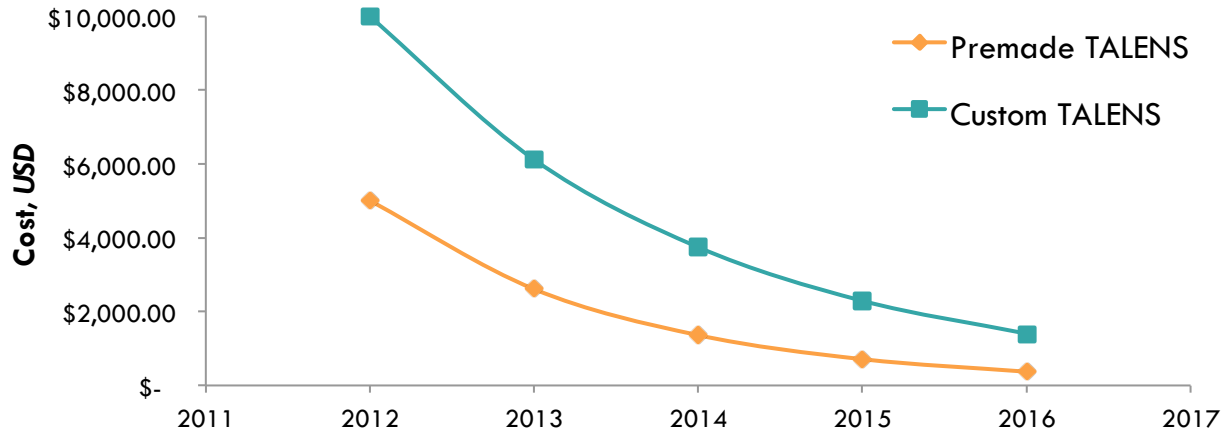
- Cost of TALENs genome-editing has fallen 50-60% per year since 2012

- CRISPR is four times cheaper than TALENs based genome-editing

- CRISPR costs should continue to decline

Subject to pre-made versus custom-made editing reagents

SIZING THE OPPORTUNITY

CRISPR could address 10,000 monogenic diseases[*],
only 5% of which are treatable today.

CRISPR Opportunity: Addressing all Monogenic Diseases Could Yield
$70 billion in Global Annual Treatment Revenue

$Billions

■ Therapeutic Pricing   ▨ Curative Pricing

$70 Billion

$30 Billion

80
60
40
20
0

Est. Annual US Revenue from Treatment

Est. Annual Global Revenue from Treatment

*A disease acquired by a single gene mutation

Source: ARK Investment Management LLC

SIZING THE OPPORTUNITY

Today, ~18% of publications focused on stem cells involve genome-editing, up from 1% in 2012 when CRISPR was discovered.

Share of Genome-Editing Based Stem Cell Research Is Accelerating

Publication Volume

■ iPSc OR Stem Cells   ■ Gene-Editing AND Stem Cells

2006: Technique to derive induced pluripotent stem cells first described in Japan

2012: CRISPR for genome-editing first described

Pre-CRISPR

Post-CRISPR
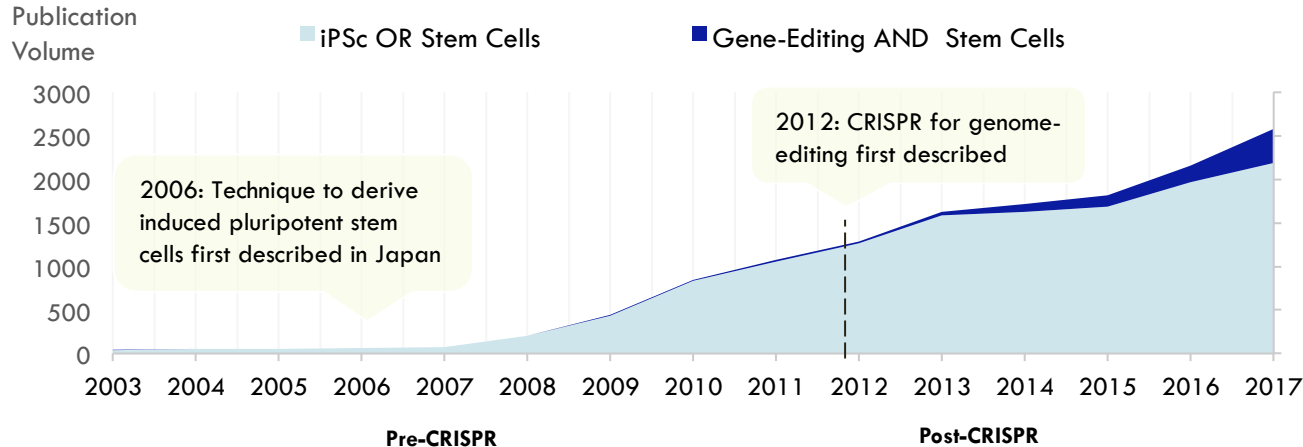
51% of new CRISPR users are focused on stem cell therapy research

Source: ARK Investment Management LLC

SIZING THE OPPORTUNITY

CRISPR Applications Extend Beyond The Therapeutics Space

Gene-Silencing

Agriculture

Biofuels

Biodefense

Personalized Medicine

Diagnostics

Materials

Animal Models

Drug Development

Source: ARK Investment Management LLC
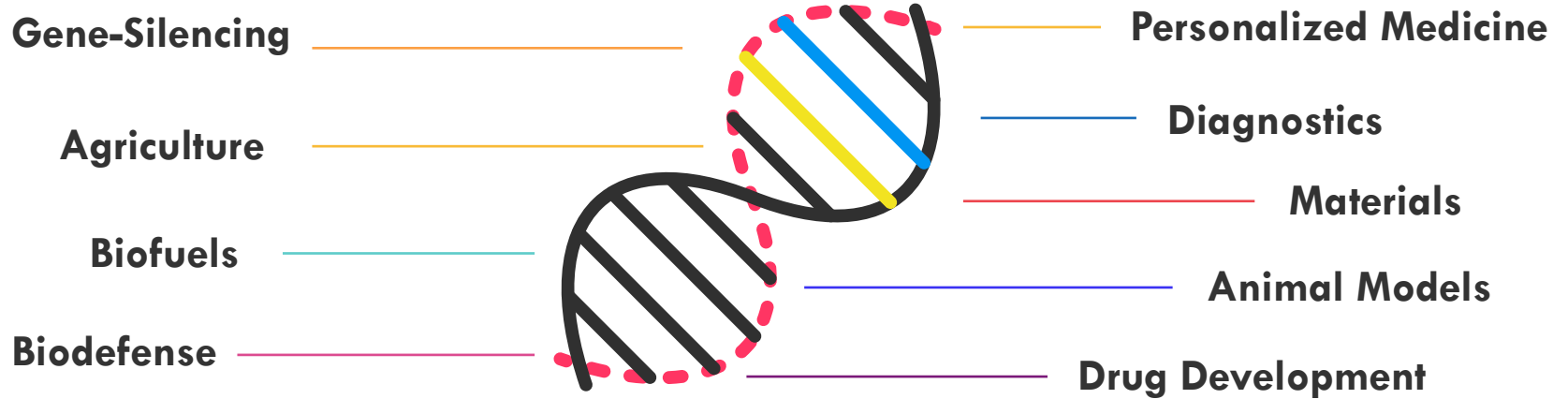
SIZING THE OPPORTUNITY

Genentech's market capitalization increased 11-fold in 6 years largely due to its strong IP position for recombinant DNA.

Market Cap
$ Millions

Genentech Market Capitalization

CAGR: 47%

**1980: Genentech IPO
1982: Patent Granted for human insulin using recombinant DNA**
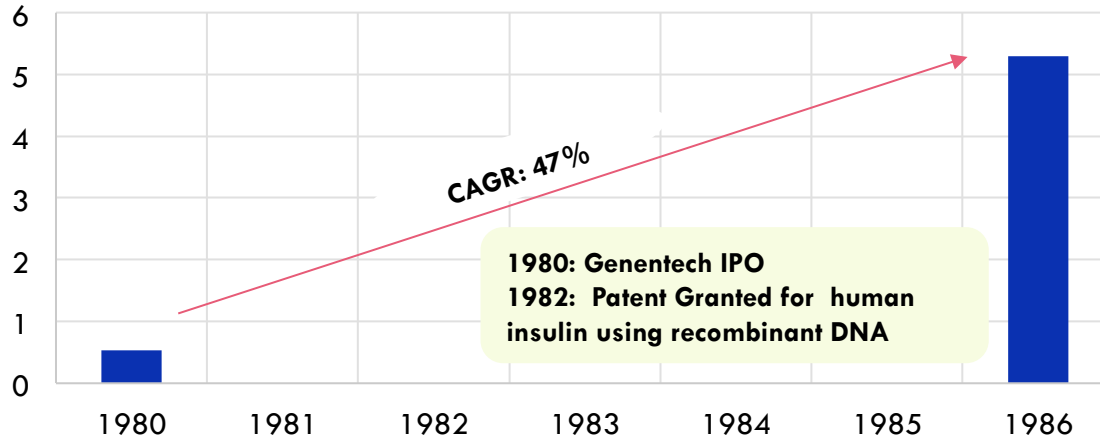
The scope and scalability of CRISPR technology should continue to expand rapidly across different applications, with several companies vying for CRISPR intellectual property rights.

Source: ARK Investment Management LLC

Additional Research:

RESEARCH BLOGS:
The CRISPR Gene Editing Approach to Treating and Curing Diseases

Spell-Checking the Language of Life: CRISPR Gene Editing In Living Animals

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Manisha Samy

Analyst

msamy@ark-invest.com

🐦 @msamyARK

5. MOBILE PAYMENTS
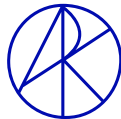
"Future of Payments is Mobile."

— Dan Schulman, CEO PayPal (2016)

Smart phone penetration and technological innovations are supporting the growth of mobile payments.

Smart phone penetration should reach 75% of the world population by 2020

In Millions

5600

2065

500

2010   2015   2020
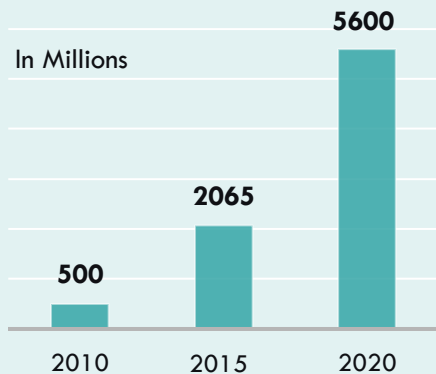
New technologies such as Biometrics, NFC* & POS** will boost security and usage

Biometric enabled smartphones

2020   2 Billion

2015   .2 Billion

2010   ≈ 0
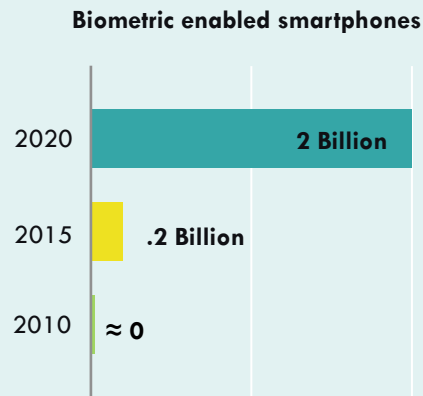
New regulations are supporting the shift to mobile payments

- Demonetization in India and the introduction of a unified digital payments interface.

- China Regulatory Authority encouraging development of digital payment platforms.

*NFC: Near Field Communications, **POS: Point of Sale

Source: ARK Investment Management LLC

Mobile payments are key to financial inclusion in developed and emerging markets.

Mobile Payments

Digital Transaction Data

Economic Development

Credit Investing Insurance

Financial Inclusion

Source: ARK Investment Management LLC
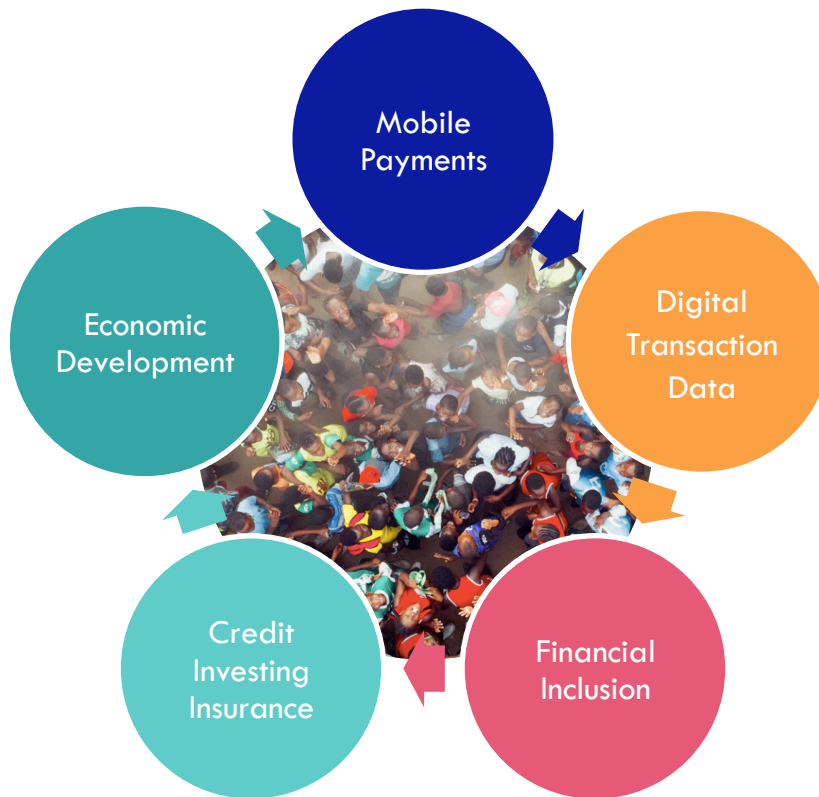
Mobile payments will enable frictionless payments in the sharing economy.

SHARING ECONOMY

Frictionless Mobile Payment Platforms

airbnb

UBER

kakaotaxi

instacart

Improved Asset Utilization

+

Better Customer Experience
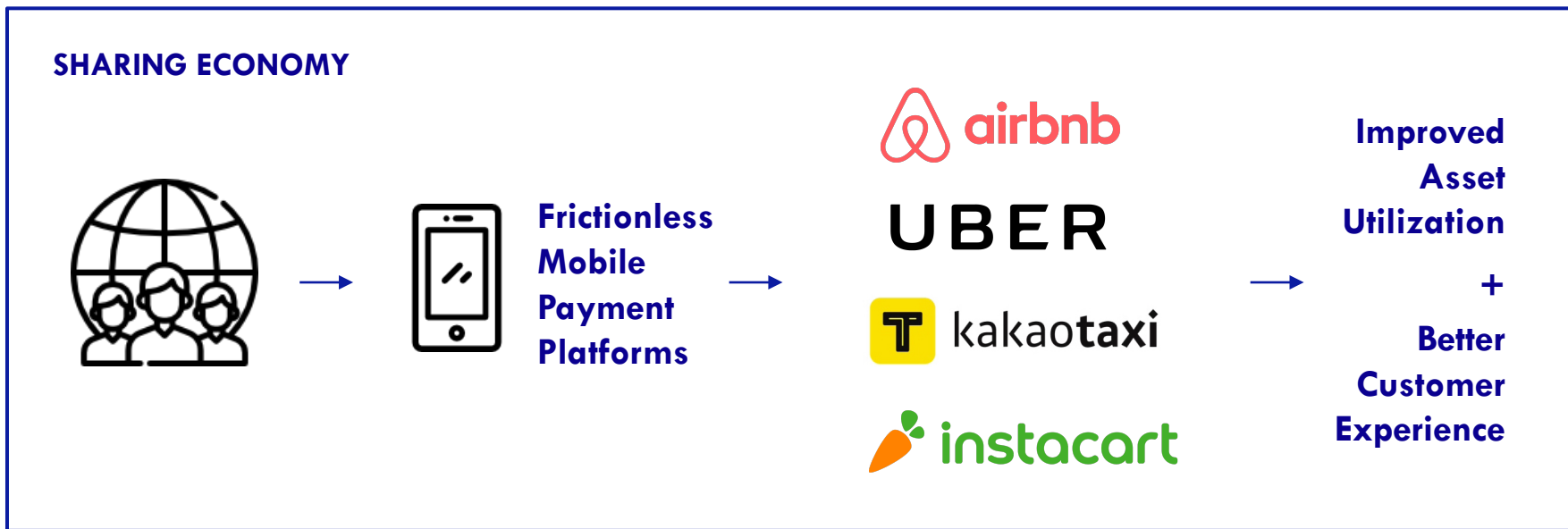
SIZING THE OPPORTUNITY

Mobile Payments Are Reaching An Inflection Point

The transaction value that flows through mobile should grow
by 15X from 2015 to 2020.

$15 Trillion

$0.04 Trillion

$1.1 Trillion

2010

2015

2020

Source: ARK Investment Management LLC
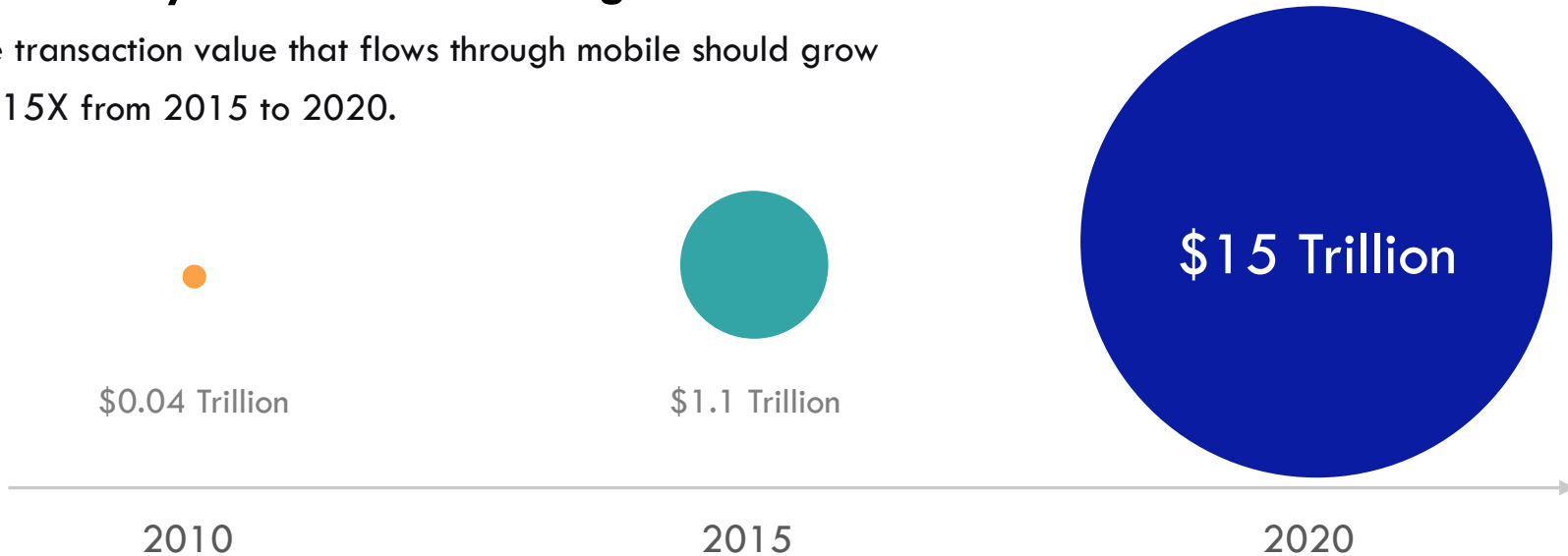
SIZING THE OPPORTUNITY

Mobile Transaction Data Is A Hidden Asset

ARK estimates a $125 billion opportunity from transaction data:

- 20% of global transactions are already digital, providing a roughly $25 billion monetization opportunity.

- The remaining 80% of cash transactions are moving increasingly into mobile, adding $100 billion to the transaction data opportunity.

$125 B
Total Opportunity

$100 B
From cash transactions that are yet to be digitized

Source: ARK Investment Management LLC
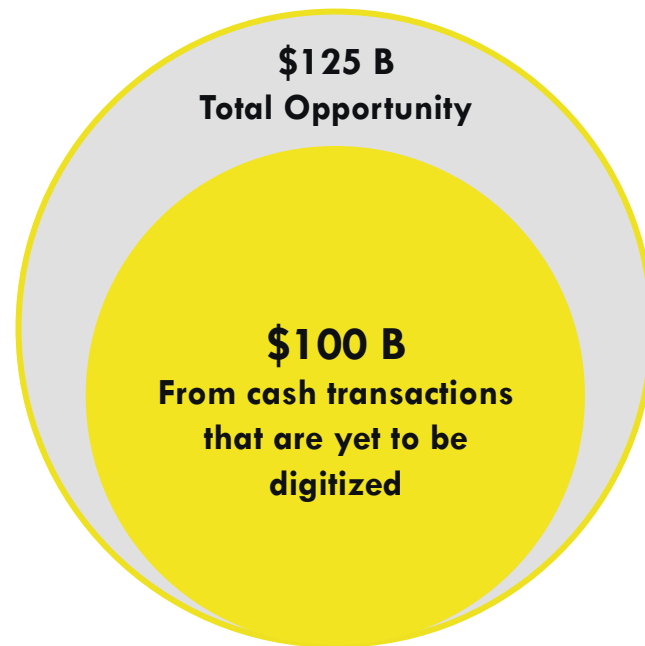
Additional Research:

RESEARCH BLOGS

Data from Cash Disruption: A Clear Advantage for Fintech Firms

Fintech Explained—The Financial Revolution Has Just Begun

Join the Conversation. Get in Touch with ARK's Analysts.

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Julia Hemmendinger, Analyst
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@juliahARK

6. ROBOTICS
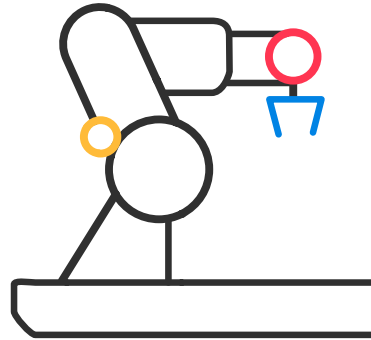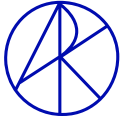
"Closely coupled machine-human manufacturing capabilities will drive accelerating productivity throughout the physical economy."

— Brett Winton (2017)

Industrial robots are continuing to decline in cost and are thereby expanding the addressable market.

Industrial Robot Cost Decline (2015 Dollars)

— ARK Cost Decline   — BCG Cost Decline   ● Historic Prices

Unit Cost

$131,433
$119,677
$67,656
$45,476
$31,312
$24,309
$10,800

Source: ARK Investment Management LLC, Data from: Sources: United Nations Economic Commission for Europe, International Federation of Robotics, Boston Consulting Group,
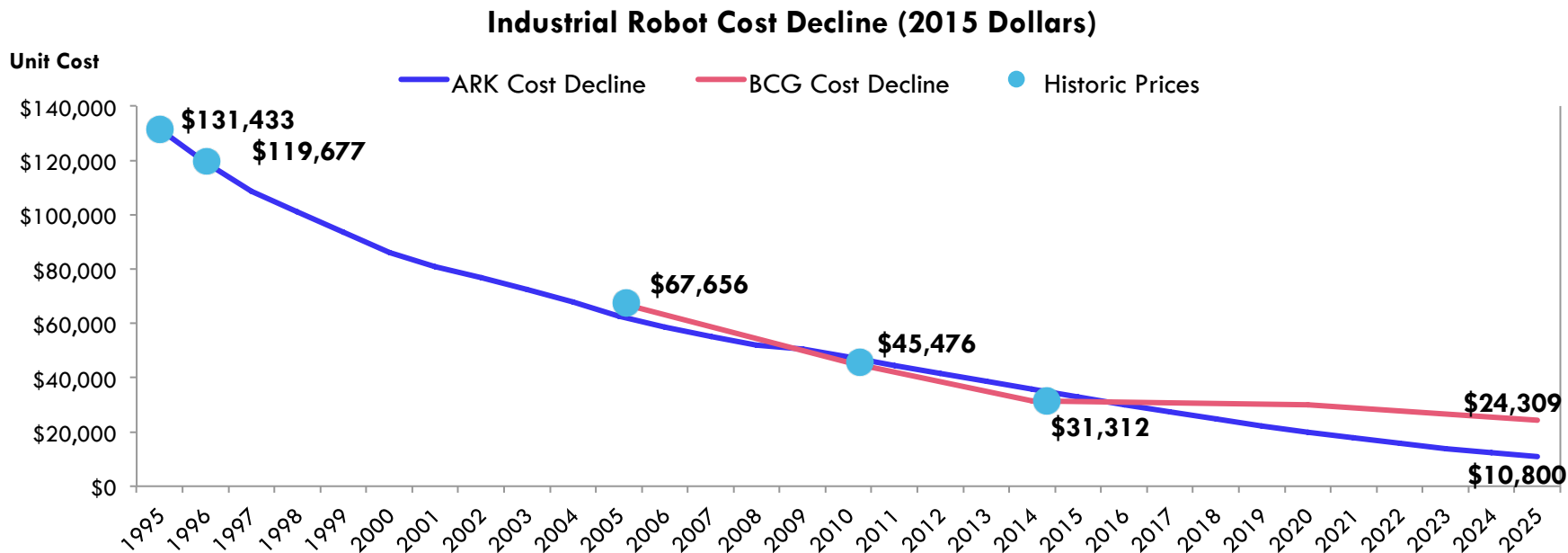
Collaborative robots and deep learning are shrinking programming costs and increasing use cases for robotics.

Robot vs. Human Performance For Picking Household Items

Time To Program Robots For New Tasks

Source: Amazon | Preferred Networks
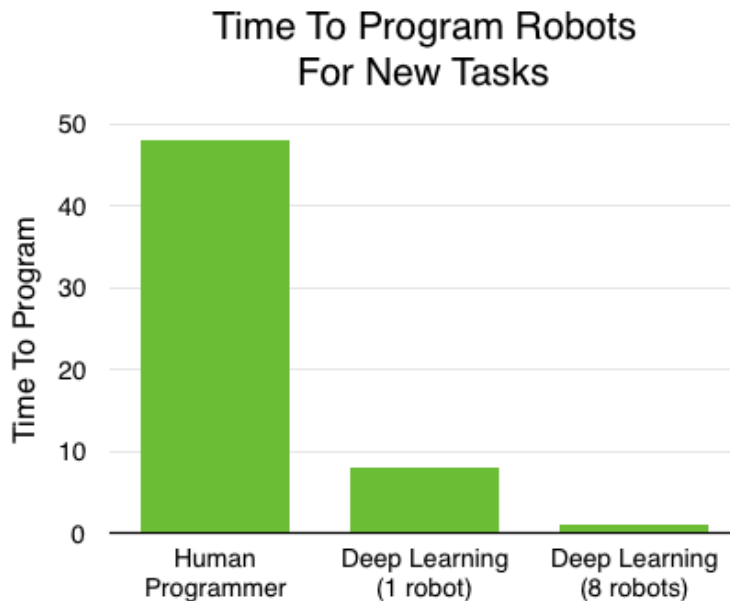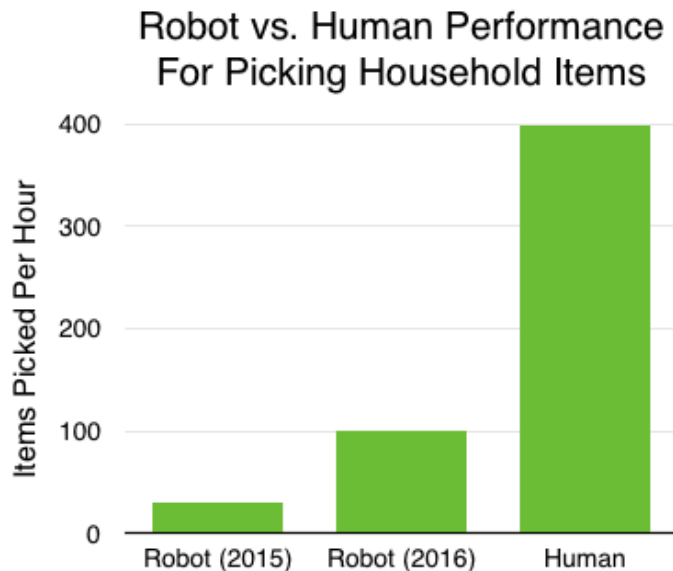
Employment in the auto industry has continued to grow even as the number of robots has increased.

Employment and Operational Stock of Robots in Auto Manufacturing

Operational Stock of Robots in Auto Manufacturing ▬▬ Annual Avg. of Seasonally Adjusted Auto Manufacturing Employment

Sources: Bureau of Labor Statistics, International Federation of Robotics

SIZING THE OPPORTUNITY

ARK anticipates increased adoption of automation in many industries.

Industrial robot sales have been driven by the auto industry, but as upfront capital costs and programming costs decline, all manufacturing firms should be increasing adoption.

2015 Manufacturing Employment Breakdown

913,500
(7%)

11,421,750
(93%)

- Auto Manufacturing
- All Manufacturing Less Auto Manufacturing
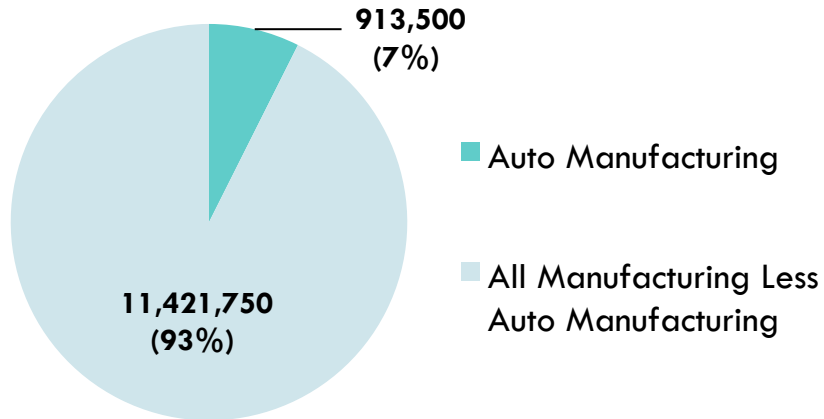
2015 Stock of Industrial Robot Distribution

111,264
(44%)

143,033
(56%)

- Robots in Auto Manufacturing
- Robots in Other (Assumed Mostly Manufacturing)

Sources: Bureau of Labor Statistics, International Federation of Robotics
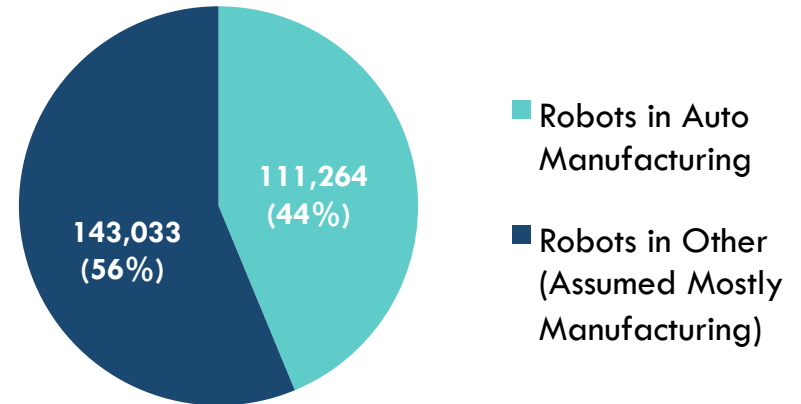
SIZING THE OPPORTUNITY

Robot sales growth should accelerate, thanks to decreasing capital costs, lower programming costs, and many more use cases.

Annual Industrial Robot Sales Forecast

Legend: BCG Low — BCG High — ARK Model

Sources: ARK Investment Management LLC, Boston Consulting Group, International Federation of Robotics
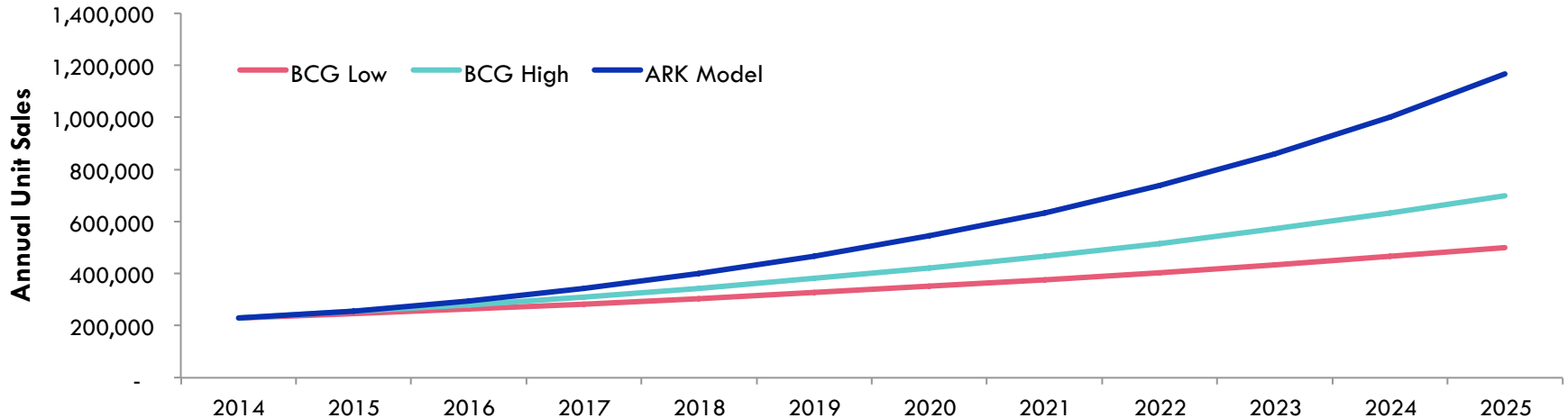
Additional Research:

WHITE PAPER
The Future of Automation

DOWNLOAD

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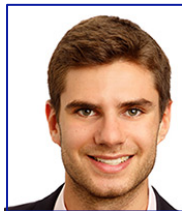
Sam Korus
Analyst

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Twitter: @skorusARK

7. CRYPTOASSETS
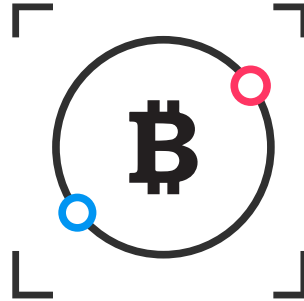
"Blockchain could slash the cost of transactions
and reshape the economy."

— Harvard Business Review (2017)

Cryptoassets

We believe that bitcoin and other cryptocurrencies are not just "currencies". Traditional asset classes differ in three ways: politico-economic features, correlation of price movements, and risk-reward profiles. "Cryptoassets" can be considered a new assert class entirely.[1] Verticals within cryptoassets include:

Cryptocurrencies

Uses: means of exchange, store of value, unit of account

Examples: bitcoin, litecoin, monero, zcash

Cryptocommodities

Uses: cloud storage, compute cycles, bandwidth

Examples: ether, golem, storj, sia

Cryptotokens

Uses: consumer facing distributed applications

Examples: augur, gnosis, swarm city, steemit

For more information Read ARK's whitepaper "Bitcoin: Ringing The Bell For A New Asset Class", http://research.ark-invest.com/bitcoin-asset-class

Bitcoin: From a $3B to a ~$38B Market Capitalization in Two Years

Shown below is the total USD value of bitcoin supply in circulation, as calculated by the daily average market price across major exchanges.

Bitcoin Market Capitalization

Source: blockchain.info, as of 05/31/2017
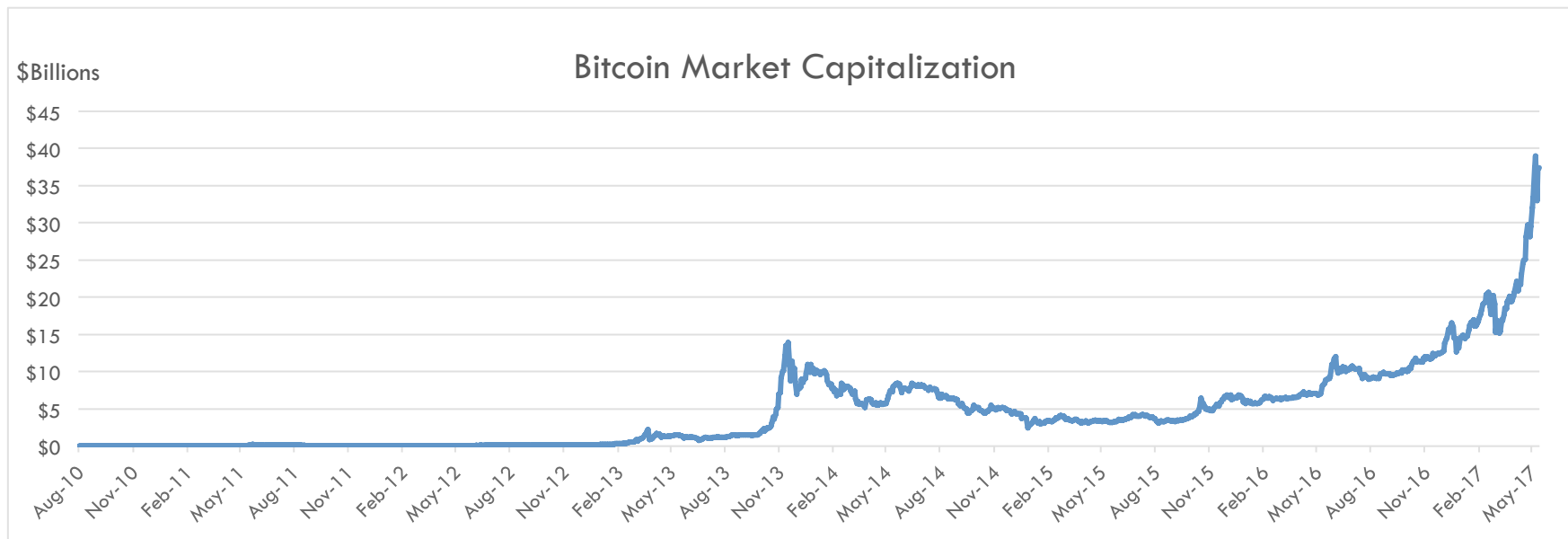
At ~$43B, Other Cryptoassets Now Rival Bitcoin's Market Capitalization

Total Market Capitalization (Excluding Bitcoin)

Source: https://coinmarketcap.com/charts/, as of 05/31/2017

The 'Crypto World' includes 700 Assets, and Counting

Top 20 Cryptoassets in May 2017

1	Bitcoin	6	Ethereum Classic	11	Dogecoin	16	Augur
2	Ethereum	7	Dash	12	Zcash	17	Gnosis
3	Ripple	8	Bytecoin	13	Golem	18	Siacoin
4	NEM	9	Monero	14	Steem	19	BitShares
5	Litecoin	10	Stellar Lumens	15	Waves	20	Stratis

Source: https://coinmarketcap.com/, as of 05/31/2017

How does blockchain technology compare to the web?

Unlike the web, blockchain based systems incorporate native units, like bitcoin, within a protocol. In order for the protocol to function, those units must have value. As more applications are built on top of the protocol, the value of the native unit appreciates, and the value accrues to the protocol layer more than the application layer.

Source: http://www.usv.com/blog/fat-protocols
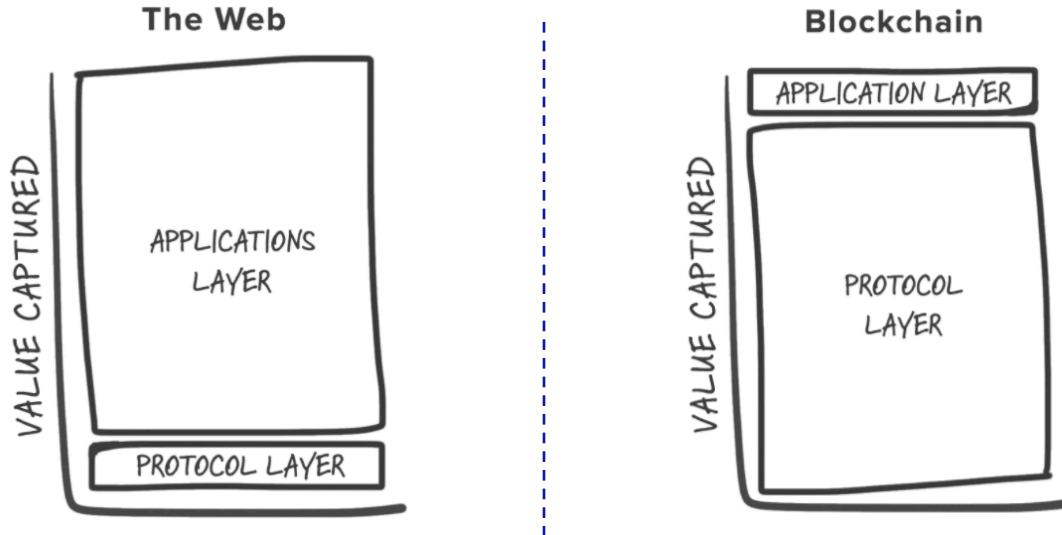
SIZING THE OPPORTUNITY

Blockchain technology is still in its infancy, so cryptoasset markets are characterized by enthusiasm, uncertainty, and speculation.

The nascent community expects the aggregate cryptoasset market cap to grow at a compound annual rate of 35%, from $50 billion to $1 trillion, during the next 10 years.

Chris Burniske
@ARKblockchain

The aggregate #cryptoasset market cap in 10 years is:

8% zero

8% $100B

21% $500B

63% $1 trillion or greater
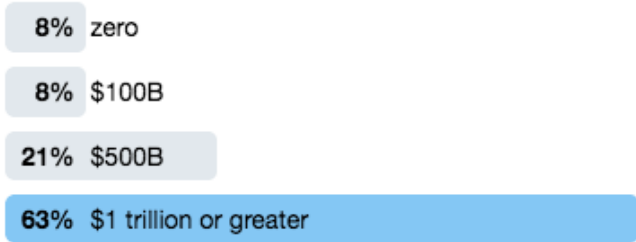
1,735 votes • Final results
6:05 PM - 8 May 2017

↩ 11   🔁 45   ♥ 66

Source: Survey via Twitter by ARK Investment Management LLC

SIZING THE OPPORTUNITY

51% of the people who participated in our survey think that the aggregate cryptoasset market cap will scale 100X to $5+ Trillion in the next 10 years.

If they are correct, the value of cryptoassets would compound at a 50-60% annual rate for the next 10 years.

While exciting, we point out that rarely has an asset class seen that rate of growth in such a short period of time.

Chris Burniske
@ARKblockchain

Round #2: The aggregate #cryptoasset market cap in 10 years is

14% $0 to 999 billion

35% $1 to 4.99 trillion

17% $5 to 9.99 trillion

34% $10 to 👤 trillion

452 votes • Final results
9:20 PM - 9 May 2017

↩ 3   ⇄ 7   ♡ 8

Source: Survey by ARK Investment Management LLC

Additional Research:

WHITE PAPER:
Bitcoin: Ringing The Bell For A New Asset Class

DOWNLOAD

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