Rooted in almost 40 years of experience, ARK Invest aims to identify large-scale investment opportunities resulting from technological change. ARK Invest focuses solely on offering investment solutions that capture disruptive innovation in the public markets.

WE BELIEVE INNOVATION IS KEY TO GROWTH.

“Big Ideas” is ARK’s annual publication showcasing a selection of innovations that we believe will accelerate the pace of change. The research presented in the following slides aims to illustrate how these ideas are transforming the way the world works and delivering outsized growth opportunities across different industries.

Each section highlights a technologically enabled innovation and provides a short research analysis, before briefly sizing the investment opportunity.

About ARK Invest

About Big Ideas

Mobility-as-a-Service (MaaS)
Robotics
Deep Learning
CRISPR Genome-Editing
Cryptoassets
Frictionless Value Transfers
3D Printing
ARK’s Research Team

ARK’s analysts are organized by cross-sector disruptive innovation themes. Each analyst is focused on different innovation elements.

JOIN THE CONVERSATION AND GET IN TOUCH WITH ARK’S ANALYSTS.

Brett Winton
Director of Research
@wintonARK

James Wang, Analyst
Artificial Intelligence, Mobile, Cloud
@jwangARK

Manisha Samy, Analyst
Beyond DNA, Targeted Therapeutics, Agricultural Biology, Stem Cells
@msamyARK

Bhavana Yarasuri, Analyst
Payments, Blockchain, Bitcoin, Cryptocurrencies
@bhavanaARK

Tasha Keeney, Analyst, CFA
3D Printing, Autonomous Vehicles, Mobility-as-a-Service
@tashaARK

Sam Korus, Analyst
@skorusARK

Catherine D. Wood
Founder, CEO/CIO
@CathieDWood

Julia Hemmendinger, Analyst
Big Data and Analytics, Cloud Computing, Lending and Insurance
@juliahARK

Bhavana Yarasuri, Analyst
Payments, Blockchain, Bitcoin, Cryptocurrencies
@bhavanaARK
MOBILITY-AS-A-SERVICE

Research by Tasha Keeney and Sam Korus
1. Mobility-as-a-Service

A Review

- DARPA launches Grand Challenge, a Competition to Foster the Development of Self-Driving Ground Vehicles
  (*Defense Advanced Research Projects Agency)
- Google Self Driving Car Project Begins
- Tesla Launches First Version of Autopilot Software
- Tesla and Chevy Launch the First “Mass Market” Electric Vehicles
- Large Automakers Begin Making Commitments to Phase Out Fossil Fuel Cars
- Planned and Announced Global Battery Production Capacity Doubles from Previous Year to 273 GWh
- Waymo Begins Testing Autonomous Cars on Public Roads Without Safety Drivers

Source: ARK Investment Management LLC, 2017 | A selection of events, achievements and innovation milestones.
1. Mobility-as-a-Service

Today, We See Two Transformations In The Mobility Space

1. GAS-POWERED → ELECTRIC
2. HUMAN-DRIVEN → AUTONOMOUS

Autonomous platforms, or Mobility-as-a-Service (MaaS), will come in many different forms, including:
### Personal Mobility Should Become More Affordable

The price of personal mobility has not changed since the Model T.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cost of Point-to-Point Mobility Per Mile (Inflation Adjusted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1871</td>
<td>$1.70</td>
</tr>
<tr>
<td>1934</td>
<td>$0.70</td>
</tr>
<tr>
<td>1950</td>
<td>$0.70</td>
</tr>
<tr>
<td>2016</td>
<td>$0.70</td>
</tr>
<tr>
<td>2021</td>
<td>$0.35</td>
</tr>
</tbody>
</table>

Sources: ARK Investment Management LLC, 2017 | Morton Salt Company Records, American Automobile Association (AAA)
1. Mobility-as-a-Service

ARK’s Research Shows...

...that MaaS should be valued today at $1-3 trillion dollars.

Sources: ARK Investment Management LLC, 2017
1. Mobility-as-a-Service

Platform Providers Could Be The Big Winners

ARK believes autonomous platform providers will be roughly 9 times more valuable than the automakers. Likely candidates are Baidu, Alphabet, and Tesla.

<table>
<thead>
<tr>
<th>Revenues of Automakers and Autonomous Platform Providers ($ Trillions)</th>
<th>EBITDA for Automakers and Autonomous Platform Providers ($ Trillions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>2030</td>
</tr>
<tr>
<td>Global Automaker Revenue</td>
<td>2.1</td>
</tr>
<tr>
<td>Net Fees on Autonomous Taxi Services</td>
<td>1.9</td>
</tr>
<tr>
<td>EBITDA on Autonomous Taxi Services</td>
<td></td>
</tr>
<tr>
<td>Global Automaker EBITDA</td>
<td></td>
</tr>
</tbody>
</table>

Sources: ARK Investment Management LLC, 2017
1. Mobility-as-a-Service

The Revenue From Autonomous Taxi Services Will Be Shared

Autonomous MaaS revenue probably will be split among owners, platform providers, manufacturers, and lead generators.

- **Lead Generation:** A share of revenue-per-mile could go towards lead generation and/or traffic acquisition.
- **Hardware Manufacturer:** Today vehicle manufacturers earn roughly 1 penny per mile traveled. In the autonomous MaaS market, hardware manufacturers should benefit either from upfront sales or a recurring revenue stream from autonomous taxis with much higher utilization rates.
- **Platform Provider:** Much like ridesharing firms take a cut of per mile revenues today, we expect MaaS platforms to take a similar, if not higher, share of revenues because they are offering more value than today’s ridesharing firms. The share of revenue that MaaS platform firms will command will depend on how much of the technology stack and data pool they control.
- **Owner/Operator:** Owners of the vehicles could be individuals, auto companies, taxi firms, or commercial fleet operators. We expect them to garner most of the revenues and be responsible for most of the maintenance.

Sources: ARK Investment Management LLC, 2017
1. Mobility-as-a-Service

**Electric Vehicles Likely Will Dominate Transportation**

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

<table>
<thead>
<tr>
<th>Year</th>
<th>200 Mile Range EV Price</th>
<th>Toyota Camry MSRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>$49,900</td>
<td>$22,700</td>
</tr>
<tr>
<td>2016</td>
<td>$41,800</td>
<td>$23,100</td>
</tr>
<tr>
<td>2019</td>
<td>$31,000</td>
<td>$23,900</td>
</tr>
<tr>
<td>2022</td>
<td>$22,400</td>
<td>$24,700</td>
</tr>
</tbody>
</table>

Sources: ARK Investment Management LLC, 2017 | 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.
1. Mobility-as-a-Service

Based On ARK’s Research...

…the demand for EVs will be orders of magnitude higher than current forecasts.

### Annual EV Sales in 2022

(Forecasts as of 2017)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Sales</td>
<td>500,000</td>
<td>3,450,000</td>
<td>3,500,000</td>
<td>17,000,000</td>
</tr>
</tbody>
</table>

Sources: ARK Investment Management LLC, 2017; Bloomberg New Energy Finance, U.S. Energy Information Administration, EV-volumes.com
1. Mobility-as-a-Service

**MaaS Results In More Miles Traveled And Fewer Cars Sold**

While ARK expects global vehicle miles to increase two- to three-fold, auto sales should be flat to down, thanks to the higher utilization of taxi fleets.

Sources: ARK Investment Management LLC, 2017; IHS Markit, The Federal Highway Administration (FHWA), and the Research and Innovative Technology Administration (RITA)
1. Mobility-as-a-Service

Transportation By Air

By the early 2020s, electric drones should be able to transport a passenger to the airport for the same price as a taxi, but in a fraction of the time. Alternatively, autonomous electric taxis likely will be able to transport passengers for the price of a subway ride today.

Future Cost and Convenience of Travel Options
From Manhattan to JFK Airport

Cost

$- $50 $100 $150 $200 $250

Time (min)

0 10 20 30 40 50 60 70 80 90

Helicopter
Electric Passenger Drone
Subway
Personal Car*
Taxi*
Autonomous Electric Taxi

Sources: ARK Investment Management LLC, 2017 | *Includes parking for four days  †15% increase in traffic due to autonomous
Autonomous electric trucks should offer a shipping option less expensive than rail, on a cost per ton-mile basis.

**Cost Per Ton-Mile by Mode**

- **Air**: $1.36
- **Human Driven Diesel Truck**: $0.12
- **Rail**: $0.04
- **Autonomous EV Truck**: $0.03
- **Barge**: $0.01

**Cost Savings (Per Ton-Mile)**

- **Human Driven Diesel Truck**: $0.12
- **Savings from Electric**: $0.02
- **Savings from Autonomous**: $0.06
- **Autonomous Electric Combination Effects**: $0.01
- **Autonomous EV Truck**: $0.03

**Cost Savings Per Mile**

- **Human Driven Diesel Truck to Autonomous EV Truck**: $2.22
- **Savings from Electric**: $0.37
- **Savings from Autonomous**: $1.11
- **Autonomous Electric Combination Effects**: $0.19
- **Autonomous EV Truck**: $0.56

*Note: Cost per ton-mile for air and barge is using 2014 and 2011 data, respectively (latest available).
Sources: ARK Investment Management LLC, 2017; Research and Innovative Technology Administration (RITA), Association of American Railroads (AAR), and the National Transportation Library (NTL)
1. Mobility-as-a-Service

## Delivery By Air

Amazon drones should be able to deliver a 5 lb package in 30 minutes for $1.

### Amazon Drones vs. Current Delivery Options

<table>
<thead>
<tr>
<th>Delivery Window</th>
<th>Price</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Minutes</td>
<td>$1.00</td>
<td>Amazon Drone</td>
</tr>
<tr>
<td>1 - 2 Hours</td>
<td>$7.99 or free</td>
<td>Amazon Prime Now*</td>
</tr>
<tr>
<td>Same Day</td>
<td>$73.68</td>
<td>FedEx Same Day</td>
</tr>
<tr>
<td>Next Day</td>
<td>$38.48</td>
<td>FedEx Standard Overnight</td>
</tr>
</tbody>
</table>

*Prices given are for members with a subscription. An Amazon Prime subscription is $99 per year. One hour delivery is $7.99 and two hour delivery is free.

**Most couriers do not travel more than 10 miles. This is an estimate for a 10 mile delivery.

Sources: ARK Investment Management LLC, 2017
ROBOTICS

Research by Sam Korus
2. Robotics

A Review

- Amazon Acquires Kiva Robotics
- Amazon Had 1,000 Robots in Its Warehouses at the End of 2013
- Teradyne Acquires Universal Robots, a Collaborative Industrial Robot Company
- Fanuc and Preferred Networks Train Robots in Parallel Using Deep Reinforcement Learning
- Amazon Has Over 100,000 Robots in Its Warehouses

SoftBank Acquires Boston Dynamics

Source: ARK Investment Management LLC, 2017 | A selection of events, achievements and innovation milestones.
Industrial robots are continuing to decline in cost, expanding the addressable market.

Industrial Robot Cost Decline (2015 Dollars)

Unit Cost

Cumulative Industrial Robots Produced

Sources: ARK Investment Management LLC, 2017
Data from: Sources: United Nations Economic Commission for Europe, International Federation of Robotics, Boston Consulting Group
2. Robotics

Robot Demand Is Responding To Lower Costs

Sources: ARK Investment Management LLC, 2017
Data from: Sources: United Nations Economic Commission for Europe, International Federation of Robotics, Boston Consulting Group
2. Robotics

Robot Growth Should Be Sustained By More Use Cases

Industrial Robot Sales Forecast
(Annual)

- BCG Low
- BCG High
- ARK Model Midpoint

Sources: ARK Investment Management LLC, 2017; Boston Consulting Group and International Federation of Robotics
2. Robotics

Collaborative Robots Should Gain Market Share

Sources: ARK Investment Management LLC, 2017; Teradyne

Collaborative Robots Relative to Total Industrial Robot Sales

- Industrial Robots
- Collaborative Robots

19% CAGR
50% CAGR

Robot Sales (Units)

200,000 400,000 600,000 800,000 1,000,000 1,200,000 1,400,000 1,600,000

ARL INVEST  |  BIG IDEAS 2018  |  22
3. Deep Learning

A Review

- LeCun Uses Backpropagation to Train Convolutional Neural Nets that Can Read Handwritten Digits with 99% Accuracy (Later Deployed in ATMs)
- Deep Neural Net Wins 2012 ImageNet Challenge, Reducing the Error Rate by 36%
- Microsoft’s ResNet Deep Neural Net Achieves 96% Accuracy in the ImageNet Challenge, Reaching Human Level Performance for the First Time
- DeepMind’s AlphaGo Defeats Global Champion Lee Sedol in the Game of Go. The AI Program Combined Deep Learning with Monte Carlo Tree Search and Reached a Major AI Milestone Ten Years Ahead of Schedule
- Companies Large and Small are Launching Deep Learning Products and Services. Among them are Apple, Alphabet, Amazon, Baidu, Deere, and Fanuc

Source: ARK Investment Management LLC, 2017 | A selection of events, achievements and innovation milestones.
3. Deep Learning

Deep Learning Is A Subset of Artificial Intelligence (AI)

- 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.

Source: ARK Investment Management LLC, 2017
3. Deep Learning

Deep Learning Is A Continuation Of “Software Eating The World”

Relative to the Internet, Deep Learning could impact more sectors, causing more profound disruptive innovation across different industries.

Source: ARK Investment Management LLC, 2017
3. Deep Learning

Many Deep Learning Products And Services Were Launched In 2017

<table>
<thead>
<tr>
<th>SMARTPHONES</th>
<th>AGRICULTURE</th>
<th>ROBOTICS</th>
<th>AI CLOUD</th>
<th>SOFTWARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>iPhone X uses AI powered facial recognition.</td>
<td>Deere acquired Blue River for precision agriculture.</td>
<td>Miso Robotics launched AI powered burger flipping robot.</td>
<td>Every cloud provider launched AI as a service.</td>
<td>Salesforce, Box, Nuance, Adobe</td>
</tr>
</tbody>
</table>

Software providers use AI for classification and tagging.

Source: ARK Investment Management LLC, 2017
Deep Learning Is Now Smarter And More Adaptive

DeepMind’s AlphaZero uses reinforcement learning, with no human training, to achieve world class performance across three games.

*Elo: A measure of relative skill between players
Deep learning can recognize and generate images. Early results were blurry and unconvincing, as seen on the left. The latest results approach photorealism, as seen on the right.

Source: Alec Radford, NVIDIA
3. Deep Learning

Deep Learning Has Created A New Semiconductor Boom

Deep learning is the fastest growing workload in data centers.

NVIDIA currently has a near monopoly on this market, but a host of companies is vying for this opportunity, which we estimate will generate $9 billion in revenue.

### Companies Developing Deep Learning Chips

<table>
<thead>
<tr>
<th>Company</th>
<th>Ownership</th>
<th>HQ</th>
<th>Story</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nvidia</td>
<td>Public</td>
<td>United States</td>
<td>Current market leader using GPU based deep learning</td>
</tr>
<tr>
<td>Google</td>
<td>Public</td>
<td>United States</td>
<td>Custom designed TPU deployed in Google Cloud</td>
</tr>
<tr>
<td>Intel</td>
<td>Public</td>
<td>United States</td>
<td>Nervana based chip to be released mid 2018</td>
</tr>
<tr>
<td>AMD</td>
<td>Public</td>
<td>United States</td>
<td>GPU based deep learning</td>
</tr>
<tr>
<td>Qualcomm</td>
<td>Public</td>
<td>United States</td>
<td>Developing DL silicon for mobile</td>
</tr>
<tr>
<td>Cerebras</td>
<td>Private</td>
<td>United States</td>
<td>Ex-AMD team backed by Benchmark Capital</td>
</tr>
<tr>
<td>Groq</td>
<td>Private</td>
<td>United States</td>
<td>Ex-Google TPU team backed by Social Capital</td>
</tr>
<tr>
<td>KnuEdge</td>
<td>Private</td>
<td>United States</td>
<td>Headed by former NASA CTO</td>
</tr>
<tr>
<td>Mythic</td>
<td>Private</td>
<td>United States</td>
<td>In-memory inference for IoT backed by DFJ</td>
</tr>
<tr>
<td>Thinci</td>
<td>Private</td>
<td>United States</td>
<td>Computer vision / auto focus</td>
</tr>
<tr>
<td>Wave Computing</td>
<td>Private</td>
<td>United States</td>
<td>DL server with custom chip. In customer trials</td>
</tr>
<tr>
<td>GraphCore</td>
<td>Private</td>
<td>United Kingdom</td>
<td>UK startup backed by top AI researchers</td>
</tr>
<tr>
<td>Bitmain</td>
<td>Private</td>
<td>China</td>
<td>Top maker of Bitcoin mining chips</td>
</tr>
<tr>
<td>Cambricon</td>
<td>Private</td>
<td>China</td>
<td>China’s state-backed startup with a $1B valuation</td>
</tr>
<tr>
<td>DeePhi</td>
<td>Private</td>
<td>China</td>
<td>China based startup with a focus on video analysis</td>
</tr>
<tr>
<td>Horizon Robotics</td>
<td>Private</td>
<td>China</td>
<td>Ex-Baidu team. Embedded / computer vision focus</td>
</tr>
<tr>
<td>Tenstorrent</td>
<td>Private</td>
<td>Canada</td>
<td>Toronto based chip startup</td>
</tr>
</tbody>
</table>

Source: Alec Radford, NVIDIA
3. Deep Learning

Deep Learning Should Be An Internet Scale Opportunity

- In 1996, Internet companies made up 0% of the S&P 500
- In 2017, Internet companies made up 9.7% of the S&P 500

This foundational technology took about 10% share in roughly two decades.

Pure Internet Companies As A Percent of S&P 500

<table>
<thead>
<tr>
<th>Company</th>
<th>Market Cap ($B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alphabet</td>
<td>$727</td>
</tr>
<tr>
<td>Amazon</td>
<td>$563</td>
</tr>
<tr>
<td>Facebook</td>
<td>$513</td>
</tr>
<tr>
<td>Cisco</td>
<td>$189</td>
</tr>
<tr>
<td>PayPal</td>
<td>$88</td>
</tr>
<tr>
<td>Priceline</td>
<td>$85</td>
</tr>
<tr>
<td>Netflix</td>
<td>$83</td>
</tr>
<tr>
<td>Salesforce</td>
<td>$74</td>
</tr>
<tr>
<td>Ebay</td>
<td>$39</td>
</tr>
<tr>
<td>Expedia</td>
<td>$18</td>
</tr>
<tr>
<td>E*Trade</td>
<td>$13</td>
</tr>
<tr>
<td>Akamai</td>
<td>$11</td>
</tr>
<tr>
<td>Juniper Networks</td>
<td>$11</td>
</tr>
<tr>
<td>Verisign</td>
<td>$11</td>
</tr>
<tr>
<td>F5 Networks</td>
<td>$8</td>
</tr>
<tr>
<td>TripAdvisor</td>
<td>$5</td>
</tr>
<tr>
<td>Total</td>
<td>$2,425</td>
</tr>
</tbody>
</table>

S&P 500 Market Cap Created by The Internet

S&P 500 Market Cap $25,107
Share of Purebred Internet Companies 9.7%

Source: ARK investment Management LLC, as of December 2017

3. Deep Learning

Deep Learning Should Be An Internet Scale Opportunity

- In 1996, Internet companies made up 0% of the S&P 500
- In 2017, Internet companies made up 9.7% of the S&P 500

This foundational technology took about 10% share in roughly two decades.

Pure Internet Companies As A Percent of S&P 500

<table>
<thead>
<tr>
<th>Company</th>
<th>Market Cap ($B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alphabet</td>
<td>$727</td>
</tr>
<tr>
<td>Amazon</td>
<td>$563</td>
</tr>
<tr>
<td>Facebook</td>
<td>$513</td>
</tr>
<tr>
<td>Cisco</td>
<td>$189</td>
</tr>
<tr>
<td>PayPal</td>
<td>$88</td>
</tr>
<tr>
<td>Priceline</td>
<td>$85</td>
</tr>
<tr>
<td>Netflix</td>
<td>$83</td>
</tr>
<tr>
<td>Salesforce</td>
<td>$74</td>
</tr>
<tr>
<td>Ebay</td>
<td>$39</td>
</tr>
<tr>
<td>Expedia</td>
<td>$18</td>
</tr>
<tr>
<td>E*Trade</td>
<td>$13</td>
</tr>
<tr>
<td>Akamai</td>
<td>$11</td>
</tr>
<tr>
<td>Juniper Networks</td>
<td>$11</td>
</tr>
<tr>
<td>Verisign</td>
<td>$11</td>
</tr>
<tr>
<td>F5 Networks</td>
<td>$8</td>
</tr>
<tr>
<td>TripAdvisor</td>
<td>$5</td>
</tr>
<tr>
<td>Total</td>
<td>$2,425</td>
</tr>
</tbody>
</table>

S&P 500 Market Cap Created by The Internet

S&P 500 Market Cap $25,107
Share of Purebred Internet Companies 9.7%

Source: ARK investment Management LLC, as of December 2017
3. Deep Learning

Based on ARK’s research…

…deep learning could approach a global market cap of $17 trillion in 20 years.

Deep Learning Market Cap Creation

Source: ARK Investment Management LLC, 2017 | 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.
ARK INVEST | BIG IDEAS 2018

CRISPR GENOME-EDITING

Research by Manisha Samy
CRISPR-Based Genome-Editing Makes its Debut

The Cost to Sequence a Whole Human Genome Drops to $1,000

The U.S. Department of Agriculture (USDA) Rules That It Will Not Regulate a Non-Browning CRISPR-Modified Mushroom Variety, Freeing it Up For Human Consumption

The HGP Embarks on a Mission to Synthesize the First Human Genome

Study Finds That Cancer Fighting Cells Are More Powerful When Used With CRISPR

CRISPR Corrects Disease in Viable Human Embryos

China Treats its First Cancer Patient Using CRISPR

Scientists Use CRISPR to Build World’s Smallest Tape Recording Device

CRISPR Treatment Reverses Hearing Loss in Mice
ARK believes that CRISPR is a genome-editing platform that will address the world’s most salient health issues. It is like a “Molecular Swiss Army Knife” with a rapidly expanding number of tools that perform different functions:

- Cut DNA/RNA at a single point or in stretches
- Insert DNA/RNA and create novel gene sequences
- Activate and Silence genes without making permanent changes
- Regulate protein expression levels epigenetically
- Record and Timestamp biological events
- Track the movement of specific biological molecules
- Identify the presence of specific cancer mutations and bacteria
- Locate molecules without making changes
- Target and Destroy specific viral and bacterial DNA and RNA
- Interrogate gene function multiplexed
- Activate drug release at a specified trigger

**Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)**
4. CRISPR Genome-Editing

The Number Of Human Genomes Sequenced Should Soar

By 2022, the cost of sequencing or “reading” the DNA of a full human genome should drop below $100, creating an explosion in the number of whole human genomes sequenced.

**Source:** ARK Investment Management LLC, 2017

**KEY EXPECTATIONS**

- **2018-2021:** NovaSeq instruments and chemistries should drive sequencing costs down by ~40% per year
- **2021:** Cost/Genome ~$100
- **2022:** ~170 million human genomes should be sequenced
The cost of CRISPR, or “editing” DNA, is dropping, as is its time-to-manufacture, accelerating the pace of innovation.

### Newer Genome-Editing Techniques

**THE CRISPR ADVANTAGE**

- Increases research thanks to lower costs and ease of use
- Reduces manufacturing time thanks to operational efficiencies
- Re-invigorates opportunities in regenerative medicine, such as stem cell research

<table>
<thead>
<tr>
<th></th>
<th>ZFNs*</th>
<th>TALENs**</th>
<th>CRISPR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year of First Human Cell Modification</strong></td>
<td>2003</td>
<td>2009</td>
<td>2012</td>
</tr>
<tr>
<td><strong>Time to Manufacture (days)</strong></td>
<td>22</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td><strong>Cost (per pair of nuclease)</strong></td>
<td>~$5,500</td>
<td>~$360 per pair</td>
<td>~$30 per pair</td>
</tr>
</tbody>
</table>

*ZFNs: Zinc Finger Nucleases  **TALENs: Transcription activator-like effector nuclease
Source: ARK Investment Management LLC, 2017
4. CRISPR Genome-Editing

Use Case: Agriculture

CRISPR should increase the yields of livestock, crops, and aquaculture in different ways:

• Breed TB- and other disease-resistant cattle
• Shift breeding practices from random to more scientific techniques
• Raise pigs with lower fat content
• Increase the milk yield of cows

• Yield more productive, pesticide-free, and weather/bug resistant crops
• Enhance taste and nutritional value
• Surface new seed variants for hard-to-modify crops like wheat and rice

• Cut gestation periods in half
• Increase the conversion of feed into weight
• Sterilize farmed fish to protect wildlife
• Breed disease-resistant fish to avoid food poisoning

Source: ARK Investment Management LLC, 2017
4. CRISPR Genome-Editing

**Use Case: Agriculture**

By 2025, CRISPR could expand the agricultural market by an estimated $170 billion, sustaining projected growth in the global population.

CRISPR should have the first commercial impact in Agriculture:

- **2020**: CRISPR could enable the first commercial waxy corn variety
- **2025**: CRISPR may increase food yield by an estimated 585 trillion calories
- **2025**: CRISPR may increase agricultural productivity enough to feed an additional 800 million people

Source: ARK Investment Management LLC, 2017
4. CRISPR Genome-Editing

Use Case: CAR-T

Globally, CAR-T cancer therapy could generate $250 billion per year in revenues, with royalties payable to CRISPR companies.

- Chimeric Antigen Receptor T-cell (CAR-T) therapy is a novel immunotherapy that modifies a patient’s own T-cells to target and kill malignant cells while keeping healthy cells intact.

- CAR-T therapy is in its infancy: CRISPR could enhance the safety and efficacy of next generation CAR-T therapies.

*Autologous: involves one individual as both donor and recipient. **Allogeneic: involves different individuals of the same species

Source: ARK Investment Management LLC, 2017
4. CRISPR Genome-Editing

Use Case: Monogenic Disease

CRISPR should dominate the $75 billion annual addressable monogenic disease market. Only 5% of diseases caused by a single gene have any available treatment today.

- CRISPR can address 10,000 monogenic diseases, of which only 5% have any treatments today
- 1 in 100 live human births results in a monogenic disease
- CRISPR will enter human trials in 2018

4. CRISPR Genome-Editing

Based On ARK's Research...

CRISPR’s toolbox should disrupt more than therapeutics and agriculture.

- **Manufacturing and Materials**: Hack living organisms to produce synthetic proteins and enzymes at scale.
- **Diagnostics**: Enable cheap, rapid point-of-care diagnostics.
- **Microbiome and Population Health**: Induce superbugs to “self-combust,” addressing antibiotic resistance issues.
- **Biodefense and Surveillance**: Track infectious diseases and bio-attack threats.
- **Biofuels and Sustainability**: Increase the efficiency of ethanol production by 2-fold.
- **DNA Storage**: Archive massive amounts of data in a nanogram of DNA.

Source: ARK Investment Management LLC, 2017
ARK INVEST | BIG IDEAS 2018

CRYPTOASSETS

Research by Bhavana Yarasuri and Julia Hemmendinger
5. Cryptoassets
A Review

- **2009**: Bitcoin Network Launch
- **2010**: Mt Gox Launches; Bitcoin Tops $1000 for the First Time
- **2013**: Mt Gox Hack Causes Collapse
- **2014**: Bitcoin Network Launches; PayPal Announces Bitcoin Integration; Ethereum Crowd Sale Takes Place
- **2015**: Ethereum Network Launches; ARK Publishes Its First White Paper on Cryptoassets
- **2016**: Bitcoin Transaction Volume Crosses $100 Billion for the Year
- **2017**: Japan Deems Bitcoin a Legal Means of Payment; The Number of Cryptoassets Tops 1200; Bitcoin Surpasses $10,000 for the First Time, Closing in on $20,000; Bitcoin Futures Launch at CBOE and CME; ICO Funding Surpasses $4.2 Billion

Source: ARK Investment Management LLC, 2017 | A selection of events, achievements and innovation milestones.
5. Cryptoassets

Bitcoin Can Play The Roles Of Currency And Store of Value

\[ \text{bitcoin} = \text{Money over IP} + \text{Digital Gold} \]
5. Cryptoassets

Bitcoin As Money Over IP

In the 1980s, communicating across the world was expensive.

Voice over IP (VoIP)

Instant communication everywhere without relying on expensive telecom providers

The Internet enabled “free voice”

Today, transferring funds across the world is expensive.

Money over IP (MoIP)

Instant value transfer of any amount to any person anywhere at almost no cost

ARK believes blockchain technology will enable fee-less transfers

Source: ARK Investment Management LLC
Increasingly, bitcoin is serving as a “store of value”, especially in countries plagued with hyperinflation, like Zimbabwe and Venezuela.
ARK believes that bitcoin and other cryptoassets are not just “currencies”, but part of a new asset class.* Asset classes differ in three ways: politico-economic features, correlation of price movements, and risk-reward profiles.

**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, filecoin

- **Cryptotokens**
  - **Uses:** consumer facing distributed applications
  - **Examples:** augur, gnosis, aragon, 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
Cryptoassets are still small compared to other asset classes.

<table>
<thead>
<tr>
<th>Asset Classes</th>
<th>Global Market Capitalization USD Trillions (as of Dec 31, 2017)</th>
<th>Total Cryptoasset Network Value as a % of each asset class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cryptoassets</td>
<td>$0.6</td>
<td>100%</td>
</tr>
<tr>
<td>Gold Outstanding</td>
<td>$8.6</td>
<td>7%</td>
</tr>
<tr>
<td>Money Supply (Narrow)</td>
<td>$37</td>
<td>1.7%</td>
</tr>
<tr>
<td>Equities Outstanding</td>
<td>$80</td>
<td>0.8%</td>
</tr>
<tr>
<td>Money Supply (Broad)</td>
<td>$90</td>
<td>0.7%</td>
</tr>
<tr>
<td>Bonds Outstanding</td>
<td>$94</td>
<td>0.7%</td>
</tr>
<tr>
<td>Real Estate</td>
<td>$217</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

Sources: ARK Investment Management LLC, 2017 | Data: Coinmarketcap.com, World Gold Council, SIFMA Fact Book & CIA Fact Book
5. Cryptoassets

Cryptoassets Have Appreciated Rapidly

After being recognized as a new asset class it typically takes decades before values rise sustainably above 1% of global GDP. Cryptoassets hit 0.8% of global GDP in less than a decade.

*Cryptoassets formally recognized as a new asset class in 2015 in ARK’s whitepaper, “Bitcoin: Ringing The Bell For A New Asset Class”

5. Cryptoassets

Are Cryptoassets In A Bubble?

Many thought that cryptoassets were in a bubble in 2013 when bitcoin peaked around $1,000. Financial “booms and busts” are normal in technological revolutions. ARK believes the value proposition of blockchain technology is profound.

5. Cryptoassets

What We Expect In The Future For Cryptoassets

As the cryptoasset market evolves, each category will have a unique utility and value proposition.

01 A Store of value, particularly in emerging markets.
02 A means of payment, particularly in emerging markets.
03 A reserve currency for all other crypto-assets.

04 Computing power, storage, bandwidth, and other digital commodities will become securitized products that trade on financial exchanges.

05 Just as bonds are claims on fixed assets and equities are claims on excess cash flows, tokens will be claims on the utilization of assets and could become a part of corporate capital structures.

Sources: ARK Investment Management LLC, 2017
ARK INVEST | BIG IDEAS 2018

FRICTIONLESS VALUE TRANSFERS

Research by Bhavana Yarasuri and Julia Hemmendinger
6. Frictionless Value Transfers

A Review

- Alipay Launches
- Bitcoin Network Launches
- Apple Pay Launches
- WeChat Pay Reaches 1 Billion Active Users

Mobile Payments Hit $8.6 Trillion in 2016

- Square Cash App Launches Bitcoin Purchasing Function

Over the 3 Months Ended December 6th, Bitcoin’s Blockchain Facilitated More Than $1.5 Billion Worth of Value Transfer on Average Per Day

Source: ARK Investment Management LLC, 2017 | A selection of events, achievements and innovation milestones.
6. Frictionless Value Transfers

China Points To The Potential Of Mobile Payments

In China, mobile value transfers jumped 5-fold in two years, reaching $5.5 trillion in 2016.

Sources: ARK Investment Management LLC, 2017; Data: http://www.analysyschina.com/
6. Frictionless Value Transfers

**China Points To The Potential Of Mobile Payments**

Mobile enables 65% of the consumption in China as well as other financial transfers like gifts and B2B transactions.

**Mobile as a % of Total Value Transfers in 2016**

- Card Based Consumption 7%
- Cash Based Consumption 14%
- Mobile Based Consumption 41%
- Mobile transfers into savings products, B2B transactions, P2P payments and gifting 38%

*Sources: ARK Investment Management LLC, 2017 | Data: http://www.analysyschina.com/*
6. Frictionless Value Transfers

China Points To The Potential Of Mobile Payments

**ON-DEMAND BIKE SHARING**
- 25 Billion Transactions in 2017
- Average Value of $0.15

**TIPPING FOR CONTENT**
- 1.2 Trillion Transactions in 2016
- Average value of $0.01

**RED ENVELOPES & GIFT GIVING**
- 290 Billion Transactions in 2017
- Average Value of $1.50

6. Frictionless Value Transfers

China Points To The Potential Of Mobile Payments

Globally, mobile value transfers are expected to grow 5-fold and to reach $30 trillion by 2022.

China accounted for 94% of mobile transactions in 2016 and is expected to comprise 65% in 2022.

Sources: ARK Investment Management LLC, 2017
6. Frictionless Value Transfers

The Evolution Of Frictionless Value Transfers Has Accelerated

The number of transactions should increase significantly as technology enables programmatic value transfers.

<table>
<thead>
<tr>
<th>Cash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank Notes</td>
</tr>
<tr>
<td>Demand Drafts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Credit &amp; Debit Cards</th>
</tr>
</thead>
<tbody>
<tr>
<td>VISA, MASTERCARD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wire Transfers</th>
</tr>
</thead>
<tbody>
<tr>
<td>WESTERN UNION</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ATMs</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Mobile Payments</th>
</tr>
</thead>
<tbody>
<tr>
<td>WECHAT PAY, ALIPAY</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Social Payments</th>
</tr>
</thead>
<tbody>
<tr>
<td>VENMO, SQUARE CASH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digital Wallets</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPLE PAY, PAYPAL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Embedded Payments</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMAZON ONE CLICK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Machine to Machine Programmatic Value Transfers</th>
</tr>
</thead>
<tbody>
<tr>
<td>BITCOIN, LITECOIN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digital Commodities</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Real Time Insurance Contracts</th>
</tr>
</thead>
</table>
7. 3D Printing

A Review

- Invention of First 3D Printing Methods
- First Patent for 3D Printed Human Cells
- Consumer 3D Printing Hype
- 3D Printing Companies Restructure, Placing Less Emphasis on the Consumer Market
- GE Acquires Metal 3D Printing Companies, Arcam and Concept Laser
- HP Begins Selling Multijet Fusion Printer
- Adidas and Carbon 3D Partner on 3D Printing Shoe Midsoles
- FAA Drafts Guidance on Additive Manufacturing in Aerospace
- FDA Provides Guidance on Additive Manufacturing for Medical Devices

Source: ARK Investment Management LLC, 2017 | A selection of events, achievements and innovation milestones.
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**

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.

7. 3D Printing

**Use Case: Aerospace & Aviation**

General Electric expects its additive manufacturing efforts to generate $1 billion in revenues and save $3-5 billion in costs by 2020.

Thanks to 3D printing, GE is reducing costs and producing better performing parts for jet engines.

**PROOF OF CONCEPT:**
**ADVANCED TURBOPROP ENGINE (ATP)**

- Number of parts dropped from 855 to just 12
- Fuel burn lowered by 20%
- Weight reduced 5%
- Test schedule dropped from 12 to 6 months
- Structural casting eliminated

https://www.geglobalresearch.com/blog/3d-printing-creates-new-parts-aircraft-engines
ARK’s research shows that 3D printing for end use parts is the next frontier.

<table>
<thead>
<tr>
<th>Prototypes</th>
<th>Molds &amp; Tools</th>
<th>Consumer Products</th>
<th>Non-Consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market size: $12.5B</td>
<td>$30B</td>
<td>$260B</td>
<td>$230B</td>
</tr>
<tr>
<td>1st Applications: 1980’s</td>
<td>1990’s</td>
<td>Early 2000’s</td>
<td></td>
</tr>
<tr>
<td>Current Penetration: 30-40%</td>
<td>5%</td>
<td>&lt;1%</td>
<td></td>
</tr>
</tbody>
</table>

Sources: ARK Investment Management LLC, 2017; McKinsey; Stratasys; http://www.avplastics.co.uk/3d-printing-history.
7. 3D Printing

The 3D Printing Market Could Increase Nearly Ten-Fold By 2022

ARK’s research predicts the 3D printing market could grow to $65 billion by 2022.

Global Estimates for 3D Printing Market 2020 to 2025

Sources: ARK Investment Management LLC, 2017
©2018, ARK Investment Management LLC. No part of this material may be reproduced in any form, or referred to in any other publication, without the express written permission of ARK Investment Management LLC (“ARK”).

The content of this presentation is for informational purposes only and is subject to change without notice. This presentation does not constitute, either explicitly or implicitly, any provision of services or products by ARK and investors are encouraged to consult counsel and/or other investment professionals as to whether a particular investment management service is suitable for their investment needs. All statements made regarding companies or securities are strictly beliefs and points of view held by ARK and are not endorsements by ARK of any company or security or recommendations by ARK to buy, sell or hold any security. Historical results are not indications of future results. Certain of the statements contained in this presentation may be statements of future expectations and other forward-looking statements that are based on ARK’s current views and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in such statements. The matters discussed in this presentation may also involve risks and uncertainties described from time to time in ARK’s filings with the U.S. Securities and Exchange Commission. ARK assumes no obligation to update any forward-looking information contained in this presentation. Certain information was obtained from sources that ARK believes to be reliable; however, ARK does not guarantee the accuracy or completeness of any information obtained from any third party. ARK and its clients as well as its related persons may (but do not necessarily) have financial interests in securities or issuers that are discussed.

ARK’s statements are not an endorsement of any company or a recommendation to buy, sell or hold any security. For a list of all purchases and sales made by ARK for client accounts during the past year that could be considered by the SEC as recommendations go to http://ark-invest.com/wp-content/trades/ARK_Trades.pdf.

It should not be assumed that recommendations made in the future will be profitable or will equal the performance of the securities in this list. For full disclosures http://ark-invest.com/terms-of-use.