Technology Innovations Driving Future Growth for the Semiconductor Industry

Brian Cotton, PhD | Senior Vice President & Partner
October, 2018
Today’s Growth Drivers for the Semiconductor Industry

<table>
<thead>
<tr>
<th>Technology We can See Today</th>
<th>What about Tomorrow?</th>
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<tbody>
<tr>
<td>RF GaN forecast to hit $750 million in 2022:</td>
<td></td>
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<tr>
<td>5G networks, data center applications</td>
<td></td>
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<tr>
<td>Semiconductor ATE forecast to hit $5.5 billion in 2022:</td>
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<tr>
<td>SoC products for smartphones, wireless/wired communications devices, consumer electronics</td>
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<tr>
<td>PMICs for wearable technology forecast to hit $1.8 billion in 2022:</td>
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<tr>
<td>Smart accessories, health technology, VR/AR sets applications</td>
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</tbody>
</table>
Agenda in Brief

- Digital Transformation is the Future of ICT
- Today’s Growth Drivers – The Engines of Digital Transformation
- Tomorrow’s Growth Drivers – The Engines of Digital Disruption
- The Big Picture of Growth – Big Challenges
Why all the Hype around Digital Transformation?
Digital Transformation is a Fundamental Driver of Growth

- A market worth hundreds of billions of dollars, but how do you really measure it?
- New products and processes
- Changing insights
- Cultural shifts

““I think that the most secular, deep trend that we’re seeing play out is the increasing digitization of everything...and the most important transformation, perhaps, is that business models themselves are being changed”

““At least 40% of all businesses will die in the next 10 years...if they don’t figure out how to change their entire company to accommodate new technologies”

Satya Nadella

John Chambers
Business Models for a Digital World

- Gig Economy (Uber)
- Crowdsourcing (Kickstarter)
- Freemium (Spotify)
- Mass Customization
- On-Demand (DoorDash)
- Sharing Economy
- XaaS (Salesforce)
Today’s Growth Drivers
### The Engines of Digital Transformation (1Q2015)

<table>
<thead>
<tr>
<th>Impact Timeframe</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
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<tbody>
<tr>
<td></td>
<td>Data Mining/Big Data Analytics</td>
<td>Cloud Platform</td>
<td>4D Printing</td>
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<td></td>
<td>Biometrics</td>
<td>Drones</td>
<td>Quantum Computing</td>
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<td></td>
<td>Cryptocurrencies</td>
<td>Holography</td>
<td>Quantum Computing</td>
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<tr>
<td></td>
<td>General-purpose Autonomous Robotics</td>
<td>The Blockchain</td>
<td>Neuromorphic Computing</td>
</tr>
<tr>
<td></td>
<td>Li-Fi Networks</td>
<td>Unmanned Ground Vehicles (UGVs)</td>
<td>Nano Solar Cell Coating</td>
</tr>
<tr>
<td></td>
<td>Neuromorphic Computing</td>
<td>Powered Exoskeletons</td>
<td>Smart Fabrics</td>
</tr>
<tr>
<td></td>
<td>Quantum Dot Charging</td>
<td>Pervasive Connectivity</td>
<td>4D Printing</td>
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<tr>
<td></td>
<td>Brain-computer Interface (BCI)</td>
<td>Digestible Computing / Nanobots</td>
<td>Graphene &amp; Carbon Nanotubes (CNTs)</td>
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<td></td>
<td>3D Printing</td>
<td>Flexible Electronic Devices</td>
<td>Energy Harvesting</td>
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<tr>
<td></td>
<td>The Internet of Things (IoT)</td>
<td>Artificial Intelligence (AI)</td>
<td>Virtual Reality (VR)</td>
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<td></td>
<td>Contextual Mobile Devices</td>
<td>Augmented Reality (AR)</td>
<td>Wireless Energy Transfer</td>
</tr>
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*Source: Frost & Sullivan*
Growth Driven by Data – Big Data Story in Numbers

What Makes a Smart City?
Multiple Applications Create Big Data

A city of one million will generate 200 million gigabytes of data per day by 2020

<table>
<thead>
<tr>
<th>Application</th>
<th>Data Generation (PB per day)</th>
<th>Transmission (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected Plane</td>
<td>40 TB</td>
<td>0.1%</td>
</tr>
<tr>
<td>Connected Factory</td>
<td>1 PB</td>
<td>0.2%</td>
</tr>
<tr>
<td>Public Safety</td>
<td>50 PB</td>
<td>&lt;0.1%</td>
</tr>
<tr>
<td>Weather Sensors</td>
<td>10 MB</td>
<td>5%</td>
</tr>
<tr>
<td>Intelligent Building</td>
<td>275 GB</td>
<td>1%</td>
</tr>
<tr>
<td>Smart Hospital</td>
<td>5 TB</td>
<td>0.1%</td>
</tr>
<tr>
<td>Smart Car</td>
<td>70 GB</td>
<td>0.1%</td>
</tr>
<tr>
<td>Smart Grid</td>
<td>5 GB</td>
<td>1%</td>
</tr>
</tbody>
</table>

Source: Cisco Global Cloud Index, 2015–2020
IoT Device Market Size and Forecast (Global), 2014-2024

Source: Frost & Sullivan; all figures rounded; values in millions; Total devices = all types of connectivity.
Smart Countertop calculates nutrient values in the food.

Smart Fork monitors how much and how long it takes to eat.

The connected kitchen links kitchen gadgets to information on the Internet, contributing at least 15% savings in the food and beverage industry by 2020.

Consumer Adoption Rates of Smart Technology, US, 2016 and 2020

<table>
<thead>
<tr>
<th>Technology</th>
<th>2016</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Refrigerator</td>
<td>4%</td>
<td>23%</td>
</tr>
<tr>
<td>Smart Vacuum</td>
<td>9%</td>
<td>22%</td>
</tr>
<tr>
<td>Smart Watch</td>
<td>8%</td>
<td>25%</td>
</tr>
<tr>
<td>Wearable Fitness Device</td>
<td>13%</td>
<td>33%</td>
</tr>
<tr>
<td>Connected Security System</td>
<td>7%</td>
<td>25%</td>
</tr>
<tr>
<td>Smart Thermostat</td>
<td>9%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Smart Thermostat offers product-regulated heat and timer monitoring.

Smart Scale links quantity values to a cellphone via Bluetooth.

Connected Security System

Companies, such as Google, use machine learning algorithms to refine the operation of data systems, improving efficiency by 15 to 25%.

Source: Harvard Business Review; Acquit Group; Frost & Sullivan.

The Connected Kitchen
5G: Going Far Beyond Cellphones to Enable Massive IoT

Almost $620 billion in applications revenues by 2026

- Smart meters, grid management
- Supply chain monitoring
- Telemedicine, remote diagnostics, health telemetry
- Traffic monitoring, enhanced navigation systems

Source: Ericsson, Arthur D Little, Frost & Sullivan
Digital Reality Enables Immersive Experiences

A 12X REVENUE GROWTH FROM 2017 TO 2021

The Big Winners for A/R: Defense, Automotive, Manufacturing

The Big Winners for V/R: Entertainment and Gaming

Source: Frost & Sullivan
AI Disrupts the Economy to Boost the Knowledge GDP

“AI could potentially create $3.5 trillion to $5.8 trillion in annual value in the global economy.”
McKinsey Global Institute (2018), Notes from the AI frontier: Insights from hundreds of use cases
Tomorrow’s Growth Drivers
Q: Please estimate for the following technologies [you previously indicated as most disruptive in your industry] their current adoption and expected adoption in 2027 in your industry N = 105

Source: Frost & Sullivan
OK Computer: The Rise of Conversational Computing

Global Conversational Computing (2017-2022)


NLP and AI-Enabled Voice Assistants

APPLICATION AREAS
Taking it all in: Biology Meets Computing


- **Portable Headsets**
  - Concentration based Gaming
  - Non-invasive brainwave monitoring
  - Neuromarketing

- **Games and Apps**
  - Home Appliances Control
  - Training for ADHD patients

- **Thought Controlled Devices**
  - Dlexia or Dementia Assessment
  - Wheelchair Control

- **Machine Controlled Thoughts**
  - Thought to speech conversion
  - Restoration of Communication

- **Brain to Brain Communication**
  - BMI Augmented & Virtual Reality
  - Mobile Device Control
  - Military Drone Control

- **Consumer Electronics**
  - Mobile Device Apps
  - Mobile Device Control

- **Healthcare**
  - Neuromarketing
  - Restoration of Communication

- **Others**
  - Robotics Control
  - Mind Controlled automotive functions

Source: Neuralink, Frost & Sullivan
The Hopes and Promises of Quantum Computing

### Implications for Enterprise
- Reimagine analytic workloads
- Hybrid HPC-quantum computing architectures
- Revenue forecasts range from a few billions to tens of billions by 2025.

### Computational Power

<table>
<thead>
<tr>
<th></th>
<th>Quantum Annealer</th>
<th>Analog Quantum</th>
<th>Universal Quantum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Computational Power</strong></td>
<td>About the same as classical computers</td>
<td>Higher than classical computers</td>
<td>Much higher than classical computers</td>
</tr>
</tbody>
</table>

### The Pace of Development is Accelerating
- From 2007-2013, an average of 387 patents were published annually.
- From 2014-2016, this pace almost doubled to an average of 734 patents published annually.

### Top 7 Patent Holders (as of 09/2017)
1. D-Wave Systems (406)
2. Toshiba Corp. (258)
3. IBM Corp. (179)
4. Northrop Grumman Corp. (177)
5. Microsoft Corp. (161)
6. NTT (154)
7. Mitsubishi Electric Corp. (96)

### Sources:
IBM Research, Deloitte, Frost & Sullivan

“...quantum computing pans out, we’ll be able to control the very building blocks of the universe.” Peter Diamandis, 2016
The Big Picture of Growth
Precision Medicine for Anyone

Data Sources (%) by Factors to Practice Precision Medicine

Advisory Support
- mHealth
- Telehealth

Chronic Disease
- Pain
- Cardiac Disease
- Insulin
- Mental

Remote Care Data
- Sensors/Wearables
  - Clinical
  - Consumer

Socio-Economics
- Educational
- Insurance
- Community Support
- Ethnic & Racial

Environmental
- CO2/Air
- Water
- Soil
- Temperature
- Radiation

Exogenous Factors
- Personal
- Vocational
- Financial/ Family Obligation
- Personal Goals

Lifestyle
- Diet
- Activity
- Mental Well-being

Consultation
- Qualitative Patient Feedback

Clinical Data
- Screening
  - Point-of-care Tests
  - Lab tests

Omics/Dx Data
- Omics
  - Genomics
  - Proteomics
  - Glycomics
  - Metabolomics
  - Transcriptomics
  - Epigenomics
  - Phonomics

Imaging
- MDx
- CDx
- Biobanks
- MRI/CT Scan
- X-rays
- Molecular Imaging
- Ultrasound

Note: Data sources not mutually exclusive to individual factors and not exhaustive in nature

Source: Frost & Sullivan
Feeding a World of Eight Billion

The cost of food production and distribution needs to be substantially reduced.

- **Drones** in crop monitoring and management, water management and pest control. Developing areas can skip mechanization, fresh food can be produced quickly and cheaply in urban areas.
- **Unmanned agriculture equipment** for planting, fertilization and harvesting.
- **Hydroponic farms** can be show higher yields than traditional farms, reduce distribution and storage costs in urban centers.
- **Agile agricultural robots** in hydroponic farms to reduce labor costs and raise productivity.
- **3D printing** for meat and other foodstuffs used for emergency and remote applications.
- **AI** will be used to coordinate production (drones, robots) and distribution (drones, unmanned trucks) across all types of farms to avoid local shortages or gluts. Geological and historical data used to improve yields.
Easing the Congestion of Commuting

Transportation is already starting to be disrupted by robotic vehicles, AI-controlled systems and a shift toward transportation as a service.

- **Self-Driving Cars** will see a steady adoption, first in commercial settings to lower labor costs and make long haul transport safer, then in consumer settings as regulatory and insurance pressures seek to lower accidents and costs.
- **Access wins out over ownership** means fewer people will buy their own cars, opting to take advantage of on-demand access to transportation (TaaS).
- **AI** will form a single network of transportation. The AI will provide better-than-human route optimization and will actively route, and reroute, vehicles in real-time. AI-controlled transportation systems will reduce traffic congestion while increasing average road speeds.
- **Connected homes and wearable sensors** will collect data to be analyzed by the AI for predicting transportation demand, and will update demand in real-time for morning and evening commutes.
What’s Restraining Growth Driven by Digital Transformation?

My experience with emerging and disruptive technologies tells me that we all tend to think they will be adopted more quickly than they end up being adopted... these three (most game changing technologies) have some serious hurdles to get over before they become adopted.... most of which are people/cultural related hurdles.

Sales & Marketing Executive, USA

Source: Frost & Sullivan
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