Back to the Future
1900: Where is THE CAR?

Photo: Fifth Ave NYC on Easter Morning 1900

Source: US National Archives
1913: Where is THE HORSE?

Photo: Easter 1913, New York. Fifth Avenue looking north.
Technology-based Disruption
What is a Disruption?

A disruption happens when a new product or service helps

- **create a new market**
- **significantly weaken,**
- **transform,** or
- **destroy** an existing product / market category / industry.

- Ex: car -> horse, PC -> typewriter, iPod->Walkman
Fast Forward to 1985

1985

Image Source: GMAuthority.com
Mainstream Disruption Forecasts

• In the mid-1980s AT&T hired McKinsey & Co to forecast cell-phone adoption by the year 2000
• Their (15-year) prediction: 900,000 subscribers.
• The actual number was... 109 million
• They were off by a factor of 120x

Motorola DynaTAC 8000X from 1984. Source: Wikimedia
Source: Economist
AT&T Disrupted while $$ Trillions Created

- AT&T's landline telephony market was disrupted,
- It Missed out on a multi-trillion dollar opportunity!

$2.4 trillion - Market Cap Top 15 Global Internet Public Companies (2)

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Subscriber Data Source: CTIA—The Wireless Association
Internet Companies: Internet Report 2015 - Mary Meeker
It's usually the 'Experts' and 'Insiders' who dismiss disruptive opportunities.

"The Internet will catastrophically collapse in 1996."

"There is no reason anyone would want a computer in their home."
- Ken Olson, CEO, Digital Equipment Corp., 1977

"I do not believe the introduction of motor-cars will ever affect the riding of horses."
- Scott-Montague, United Kingdom MP, 1903
Why do smart people at smart organizations Consistently Fail to Anticipate or Lead Market Disruptions?
1. Disruption Models
2. Exponential Technologies
3. Business Model Innovation
4. Product Innovation

Created New Tech Disruption Framework to Anticipate & Lead Market Disruptions
Exponential Technologies

“If the rate of change on the outside is greater than the rate of change on the inside, the end is near.”

- Jack Welch

- # of transistors doubles (roughly) every two years.
- Tech Cost Curve (Annual Improvement Rate) ~ 41.4%
Technologies improving at exponential rates.

- **Data Storage** – Kryder’s Law
  - Hard Disk $ cost per bit down 50% every 18 months.

- **Digital Imaging** – Hendy's Law
  - Pixels per $ - 59% / year

- **Network Capacity**: Butter’s Law of Photonics
  - The $ cost of transmitting a bit decreases by 50% every 9 months.
Key Technologies Disrupting Transportation

1. Energy Storage
2. Electric Vehicles
3. Mobile Internet / Cloud
4. Sensors / IoT
5. Self-Driving Vehicles
6. Big Data
While there are many kinds of stories, there's only one plot: things are not as they seem.

- Jim Thompson, film-maker
Li-on Battery costs dropping exponentially

• Laptop Li-on battery costs dropped ~14% per year over 15 years. (1)

• Investments in battery tech increasing dramatically:
  • Now 3 multi-trillion $ industries investing:
    1. IT/Electronics
    2. Automotive &
    3. Energy

• Since 2010, battery costs have dropped at ~16%/year -> ACCELERATING

(1) Clean Disruption
Projected Cost of Li-On Battery $/kWh

Assumptions: **16%/year cost improvement**

Source: Clean Disruption
Tesla's Battery – Ahead of the Curve

- Tesla PowerWall Residential Battery:
  - $350/kWh (7kWh or 10kWh)
- Tesla Microgrid/Commercial Battery:
  - $250/kWh for commercial/microgrid (100kWh)

- Market reaction: Tesla received $800+ million in orders / reservations first week!

Sources: Tesla, Bloomberg

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Tesla's Battery GigaFactory

- $5 billion investment (6,500 jobs)
- Battery pack output: 50 GWh/year -> 500,000 cars/year
- Double world battery production
- Reduce battery pack costs by 30%+

- Tech: "Tesla expects to increase pack capacity by roughly 5% per year." (1)
Battery Megafactories are coming!

• **BYD** plans to add **6 GWh** every year.
  • Could ramp up to **34 GWh** by 2020 - matching Tesla's **35 GWh** (1)

• **Foxconn** and **LG Chem** could add combined **22 GWh** (2)
  • Plus **Samsung SDI**, Apple, Bosch, VW, etc.

• **Tech Cost Curve** could accelerate!

---

(1) Reuters (2) Benchmark Minerals
2. The Electric Vehicle Disruption

Photo © Tesla Motors
“It drives like a sports car, eager and agile and instantly responsive. But it's also as smoothly effortless as a Rolls-Royce and carry almost as much stuff as a Chevy Equinox. Oh, and it'll sashay up to the valet at a luxury hotel like a supermodel working a Paris catwalk.”

**Consumer Reports:**
Best Car EVER! (1)

Best-selling high-end large luxury car in America! (2)

Sources: Motor Trends, (1) Consumer Reports, (2) Extremetech.com
But who can afford an Electric Vehicle?
Is the Electric Vehicle Disruptive?

(You always need to ask)
1. Electric Motor – 5X more Energy Efficient

Internal Combustion Engine

17%-21%
Energy Efficiency

Electric Motor

90%-95%
Energy Efficiency

Sources: ICE – DOE, EM Wikipedia
Images Source: ICE - Tony Seba, Electric: BradMerritt.com
2. EVs are **10X** cheaper to charge / fuel

- It costs **$15,000** to fill up a (gas) Jeep Liberty over **five years** (Consumer Reports).

- An **Electric** Jeep Liberty would cost **$1,565** in electricity.

- Improvements in power electronics will increase **10X**.

Assumptions:
- 12,000 miles/year
- Tesla Roadster: 4.6 miles per kWh.
- Ave retail electricity in the U.S.: 12 ¢/kWh
- 5 year-cost = (60,000 miles * 0.12 $/kWh) / 4.6 miles/kWh = $1,565.

Sources: Consumer Reports, DOE, Clean Disruption
3. Maintenance - Gasoline Car: 2,000+ moving parts (1)
3. EVs: 100X fewer Moving Parts

**ICE (Gas) vehicle**
2,000+ moving parts

**Electric Vehicle (EV)**
18 moving parts

Transmission, driveshaft, clutch, valves, differentials, pistons, gears, carburetors, crankshafts...

- EVs 10X-100X cheaper to maintain!
- Tesla: **Infinite Mile Warranty!**

Photos: Tony Seba
4 – EVs FAR MORE powerful than ICE

“The Tesla P90D accelerates faster than $1 million gas 'supercars' from Ferrari, McLaren, Lamborghini, Pagani and Porsche.”

(1) ChargeDevs Magazine, Image: BRD Motorcycles
5 - Wireless Charging

• Inductive Power Transfer (IPT) technology allows EVs (buses, cars, bikes, trains) to charge the battery wirelessly.

• While EVs wait at the bus stop, traffic light, shopping, parking garage, etc.

• EV vs ICE is like Mobile vs landline phone!

Photo Source: Conductix-Wampfler
Ok, so the EV is **DISRUPTIVE**.

How long will the transition take?
Disruption from Above:
Cost of EV with 200-mile (320 Km) range

Assumptions: 4 miles/kWh, 50kWh batteries, 16% yearly improvement in battery costs, EV Costs = 3X cost of battery

Source: Clean Disruption
"GM plans to launch a $30,000 EV by 2017 with 200-mile range."

"The Chevy Bolt will be aimed squarely at the $35,000 Tesla Model E slated to come out 2017."
Foxconn to make EV for $15,000

“Foxconn, the maker of the Apple iPhone to invest $811m to develop Electric Cars."

"Foxconn CEO Terry Gou said they are targeting EVs priced at less than $15,000. " (1)
EVs = Computer Tablets on Wheels
Amsterdam announced that all public buses will be electric by 2025.

"We decided to just do it. No experiments with five buses." (City Transport Alderman Choho)

First 40 buses will be delivered in two years. Transition complete by 2025.

- 6 buses on Schiermonnikoog Island are also electric.
- 300 buses in Linburg province to be electric.
3 - Mobile Internet & Cloud Transport

CaltrainMe
Embark iBART
Lyft
Uber
Zipcar
DriveNow
ChargePoint
NextBus
PayByPhone
My Smartphone — On-Demand Transportation

Plan & schedule ALL transportation needs with Apps

1. **Buses**: NextBus
2. **Trains**: CaltrainMe, iBART
3. **Car-Sharing**: Zipcar
4. **Ride-Sharing**: Uber, Lyft
5. **Parking**: PayByPhone
6. **EV Charging**: ChargePoint

Image © 2015 by Tony Seba

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TECHNOLOGY
ENABLING BUSINESS
MODEL INNOVATION
CAR- Sharing

Zipcar:
- On-demand individual transportation
  - By the hour, by the day
- 760k members and $270m in revenues (2012)
- Share-to-own ratio: 15
  - 1 shared zipcar replaces 15 cars on the road

On-Demand Mobility: changing the concept of Car Ownership
RIDE-Sharing

Companies disrupting private and public transportation.

- Connecting users with drivers

- **Uber** (started 2009):
  - May '15 - 311 cities in 58 countries (1)
  - Est. 2015 Bookings = $10 billion (2)
  - 1 million drivers (global) (3)

San Francisco Figures

- # Uber Drivers (2015): 22,000
- # of Taxicabs (2012): 1,825 (4)

Carpooling \(\sim\) half of Uber Rides

(1) (2) (3) Business Insider
(4) Wikipedia
On-Demand Public Transportation

Santa Clara (Silicon Valley) VTA about to unveil an ON-DEMAND Transportation system pilot:

- Dynamic, on-demand service models
- Addressing first/last-mile connections needs
- Enhance ridership on core transit lines, and
- Learn about the varied existing and evolving travel needs within Santa Clara County

System is

- Mobile-First App
- Cloud-based
- On-demand
- Data-driven
- Small Trial (5 Vans)
4 - Sensors & The Internet of Things
## Sensors: 1,000X Changes in 7 Years (2007-2014)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Change</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Sensors</strong></td>
<td><strong>UP 1,000x</strong></td>
<td>From 10 million to 10 billion</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td><strong>DOWN 1,000x</strong></td>
<td>E.g., from $250/axis for gyros to $0.75 for three axis</td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td><strong>DOWN 1,000x</strong></td>
<td>From W to mW and mW to µW, depending on sensor</td>
</tr>
<tr>
<td><strong>Physical Size</strong></td>
<td><strong>DOWN 1,000x</strong></td>
<td>E.g., gyro from 2000 mm³ to 2 mm³,axis</td>
</tr>
<tr>
<td><strong>Number of Transistors</strong></td>
<td><strong>UP 1,000x</strong></td>
<td>From 1000s per sensor to 1,000,000s / sensor.</td>
</tr>
</tbody>
</table>

### On the road to trillions of Sensors: Exponential Unit Growth
$99 sensor-based auto accessory that talks to a car's onboard computer and uses the smartphone's GPS sensor to provide driver with real-time info:
1. "Check Engine" light codes
2. Trip Timeline
3. Driving information: acceleration, braking, speeding
4. Alerts your contacts after "Crash Incident"
Sensors + Mobile Internet = Big Data -> Disruption of Car Insurance

<table>
<thead>
<tr>
<th>Features</th>
<th>Device + App</th>
<th>Device + App + Insurance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine diagnostics</td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>MPG tracking</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Gas cost per trip</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Car locator</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Compare trips</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Automated street sweeping alerts (San Francisco only)</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Per-mile car insurance</td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>24/7 service</td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>Roadside assistance</td>
<td></td>
<td>✔️</td>
</tr>
</tbody>
</table>

Source: MetroMile.com
V-2-Vehicle & V-2-Infrastructure

- Sensors enable vehicles to broadcast data such as location, direction, and speed to nearby vehicles.
- Connected vehicles (bikes, cars, buses, trains, ferries) can also “talk” to traffic signals, toll booths, school zones, and roadway infrastructure.
SF Muni Sensors: The devices are designed to keep lights green when a Muni bus is approaching. (1)

The system also has the ability to make red lights shorter based on the presence of a bus.

The system is cutting about 10% off travel time from beginning to end of bus routes. (2)
Vehicles As WiFi Hotspots
Internet of Moving Things

- Porto, Portugal (pop. 230,000): turned 600+ vehicles inc. entire public bus fleet, taxis, and service vehicles into a V2V connected network that offers
  - WiFi to passengers and drivers,
  - Generates data on traffic, logistics, and vehicle operations

- Metrics (Launched in 2003)
  - 260,000 unique users
  - 26 million Internet sessions
  - 2.5 TB of traffic data/month
  - 450,000 hours of Internet traffic
  - Offloaded 70% of cellular traffic to fixed lines

Copyright © 2001-2015 by Tony Seba
(1) Source Veniam
Photos: Veniam.com
5 - The Autonomous Vehicle Disruption
Nevada approves Autonomous Trucks

Voice of Wolfgang Bernhard
Head of Daimler Truckers & Buses

Leading Market Disruption- Copyright © 2001-2015 by Tony Seba

Video: WSJ
Self-driving cars may hit roads in 2018: Renault-Nissan CEO
Tesla capable of Self-Driving 90% of the time by 2015

“90% of your miles to be autonomous. For sure on highways.”(1)

• "Do almost anything... from 0 to 155 mph."(2)

• Lane keeping, active emergency braking, cruise control, self-parking, summon the car ("meet me at work")... (2)

(1) UK Daily Mail (2) Elon Musk, Tesla
What about the COST of Autonomous Vehicles?
What an Autonomous Car Sees

Google Car: 3D Machine Vision uses LIDAR
In 2012 Google announced that the cost of technology in its self-driving car was $150k.

LIDAR Sensor (for Machine Vision) was $70k in 2012

By the end of 2013, the next-gen LIDAR was $10k

By Oct 2014, a SV startup company announced LIDAR for $1k
LIDAR: From $70,000 to $1,000 to $90

- Designs focus simultaneously on cost, performance, size and reliability
- Gen 1: mechanical LiDAR (M8)
- Gen 2 & 3: solid state LiDAR (S3)

**Disruptive Pricing:**
- Gen 1: <$1,000
- Gen 2: <$250
- Gen 3: <$100

- 2015 LIDAR: ~$1,000
- Gen 2 (solid state): $250
- Gen 3 (postage stamp): $90
What is the **Cost Curve of Computing Power?**

- to process sensor input?
Year 2000: World's 1st 1-TeraFlops Computer
ASCI RED – Sandia National Labs

- Space = 1,600 sq ft (150 m²)
- Power Consumption = 850 kW
- Cost = $46 million
Exponential Technologies: GPU: NVIDIA Drive™ PX

- Dual Tegra® X1 GPU Processor
- 2.3 TeraFlops
- Power Consumption = 15 W
  - 56,666X improvement
- Cost = $59
  - ~1 million X improvement

✓ Built for Self-Driving Cars
  - Surround Computer Vision (CV) with Advanced Rendering
  - Deep Learning S/W, and
  - Over-the-air updates
Ok, cost is not an issue...but

Is the Market Ready for Self-Driving Cars?
Are consumers ready for Autonomous cars?

Consumers Desire More Automated Automobiles
Consumers Trust Driverless Cars

57% of consumers, globally, trust driverless cars—even more so in emerging markets.

<table>
<thead>
<tr>
<th>Country</th>
<th>Trust Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>95%</td>
</tr>
<tr>
<td>India</td>
<td>86%</td>
</tr>
<tr>
<td>China</td>
<td>70%</td>
</tr>
<tr>
<td>USA</td>
<td>60%</td>
</tr>
<tr>
<td>Russia</td>
<td>57%</td>
</tr>
<tr>
<td>Canada</td>
<td>52%</td>
</tr>
<tr>
<td>France</td>
<td>45%</td>
</tr>
<tr>
<td>UK</td>
<td>45%</td>
</tr>
<tr>
<td>Germany</td>
<td>37%</td>
</tr>
<tr>
<td>Japan</td>
<td>28%</td>
</tr>
</tbody>
</table>

Source: Cisco Customer Experience Report for Automobile Industry, May 2013 survey of 1,511 consumers in 10 countries.

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Are consumers ready for Autonomous cars?

Brazil: 95%
India: 86%
China: 70%
Cool! I can and also while **NOT** driving!

But what's the disruptive impact?
Cars: Hugely Inefficient Use of Assets

- Cars are our 2nd largest Capital Expense.
- Ave. car costs = $31k
- Plus OpEx: gasoline, insurance, maintenance, etc

- But cars are parked 96% of the time! (1)
SELF-DRIVING + CARSHARING:
CONVERGENCE OF TECHNOLOGY & BUSINESS MODEL INNOVATION
UBER announced Self-Driving Car Project

“Uber announced plans with Carnegie Mellon University to create the Uber Advanced Technologies Center: R&D of autonomous vehicles.”

“When there's no [driver], the cost of taking an Uber anywhere becomes cheaper than owning a vehicle...and then car ownership goes away.” said Uber's CEO
Mobility-As-A-Service: End of Car Ownership

- Mobility on Demand / Car-as-a-service:
  - Combine
  - Self-Driving Cars tech with
  - Car/Ride Sharing biz model
  - Cars available on-demand anytime anywhere to take you anywhere
- Cars will go from parking ~90+% of time to driving ~90+% of time.
- Cost / mile ~10X cheaper than car ownership
- We'll need ~80% fewer cars
- 80+% fewer parking spots (1)

(1) Clean Disruption
Helsinki, Finland: Clean Disruption by 2025

- Helsinki announced intention to build 'mobility on demand' platform based on self-driving cars by 2025.

- Mobile platform / app would knit together:
  - Driverless cars,
  - Little buses,
  - Shared bikes and
  - Ferries

- into a seemless "mobility on demand" service.

- Objective: make car ownership (in the city) obsolete
6 - Big Data
/
Open Data
All the technologies that I have talked about today are massive data generators:

1. Electric Vehicles
2. Mobile Internet / Smartphones
3. Sensors & IoT
4. Self-Driving Vehicles

They all generate huge amounts of real-time data

The LIDAR sensor alone (in autonomous cars) generates 1 GB/sec
BRONTO-DATA: the Internet of Things

- The number of sensor-based devices is increasing exponentially.
- The number of sensors within each device is increasing exponentially.
- The amount of data that each sensor generates is increasing exponentially.
- The number of connections between those devices is increasing exponentially.
- The result is a COMBINATORIAL EXPLOSION of data.
- This is not BIG DATA, this is BRONTO-DATA or EPTO-DATA
Open Data: Santa Clara VTA

Open Data: engage private sector to add value to public transport

Transit Operations

Highways & Roads

Finance

Active Transportation

Intersection Congestion

VTA does more than transit. As Santa Clara County's congestion management agency, we monitor and report about congestion levels in the county.

Bike Routes

VTA provides the most comprehensive source of bike lanes, trails and routes in Santa Clara County.

Bus Routes

VTA operates 70 bus routes that run more than 1,200 miles throughout Santa Clara County. This dataset shows them all.

Bus Stops

VTA maintains and provides service to 3,805 bus stops and 62 light rail stations throughout Santa Clara County. This dataset shows them all.
Big Data -> Redesigning Transportation

- MIT looked at NYC taxicabs data for one year (2011)
- 13,500 taxis made 150 million trips that started or ended in Manhattan
- **73,000** trips from Grand Central Station to Union Sq.
- **94,000** trips from Union Sq. to Grand Central Station
- That's **1.4 miles**: 4 min taxi, 7 min subway, or 20-25 min walk

✅ **Insights** like these can help city & transportation authorities design **efficient, cost-effective, sustainable transportation.**
Dynamic Design of Public Transportation: Self-Driving Shuttle (1)

- For instance: according to MIT study, carsharing could reduce 40% savings in number of taxi rides (less traffic, less gasoline waste, etc.)

- Also, what if the city decided to have an open, automated shuttle?

Navia City Shuttle Video Link:

Video: Consumer Reports
Battery Electric Bus/Tram Technology that allows transportation authorities to design new routes based on real-time data insights dynamically, efficiently, and cost-effectively.
SUMMARY
2015: we are HERE

Summary: Disruption of Transportation
The technologies, skills, organizations, and culture of the industrial revolution have run out of steam. They are being replaced by the technologies, skills, organizations, and culture of the information technology revolution.

1. Electric Vehicles
2. Self-Driving Cars
3. Sensors & IoT
4. Mobile Internet & Cloud
5. Big Data / Open Data...
6. ...and more... Artificial Intelligence...

We will see more changes in transportation over the next 5-10 years than we have seen since the invention of the gasoline ICE vehicle and the electric streetcar.
From Parking to Parks

Amsterdam for Cars

Amsterdam for Humans

The Clean Disruption of Transportation will also provide the best opportunity to redesign our urban landscape in a century!

Photos: Tony Seba
The Future is NOW

This Disruption is not in the future. It is NOW!
THANKS!

Q&A

www.tonyseba.com
CLEAN DISRUPTION
TECHNOLOGY MEGATRENDS DISRUPTING
PUBLIC & PRIVATE TRANSPORTATION

PRESENTATION TO
CA Transit Association
50th Annual Conference

19 Nov 2015

Tony Seba
www.tonyseba.com