CLEAN DISRUPTION

TECHNOLOGY MEGATRENDS DISRUPTING PUBLIC & PRIVATE TRANSPORTATION

PRESENTATION TO

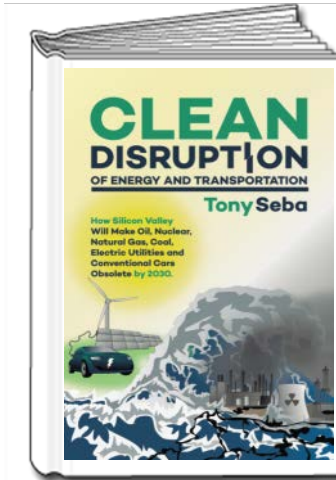
CA Transit Association

50th Annual Conference

19 Nov 2015

Tony Seba

www.tonyseba.com



Back to the Future

5th Ave New York City, April 15, 1900

1900: Where is THE CAR?

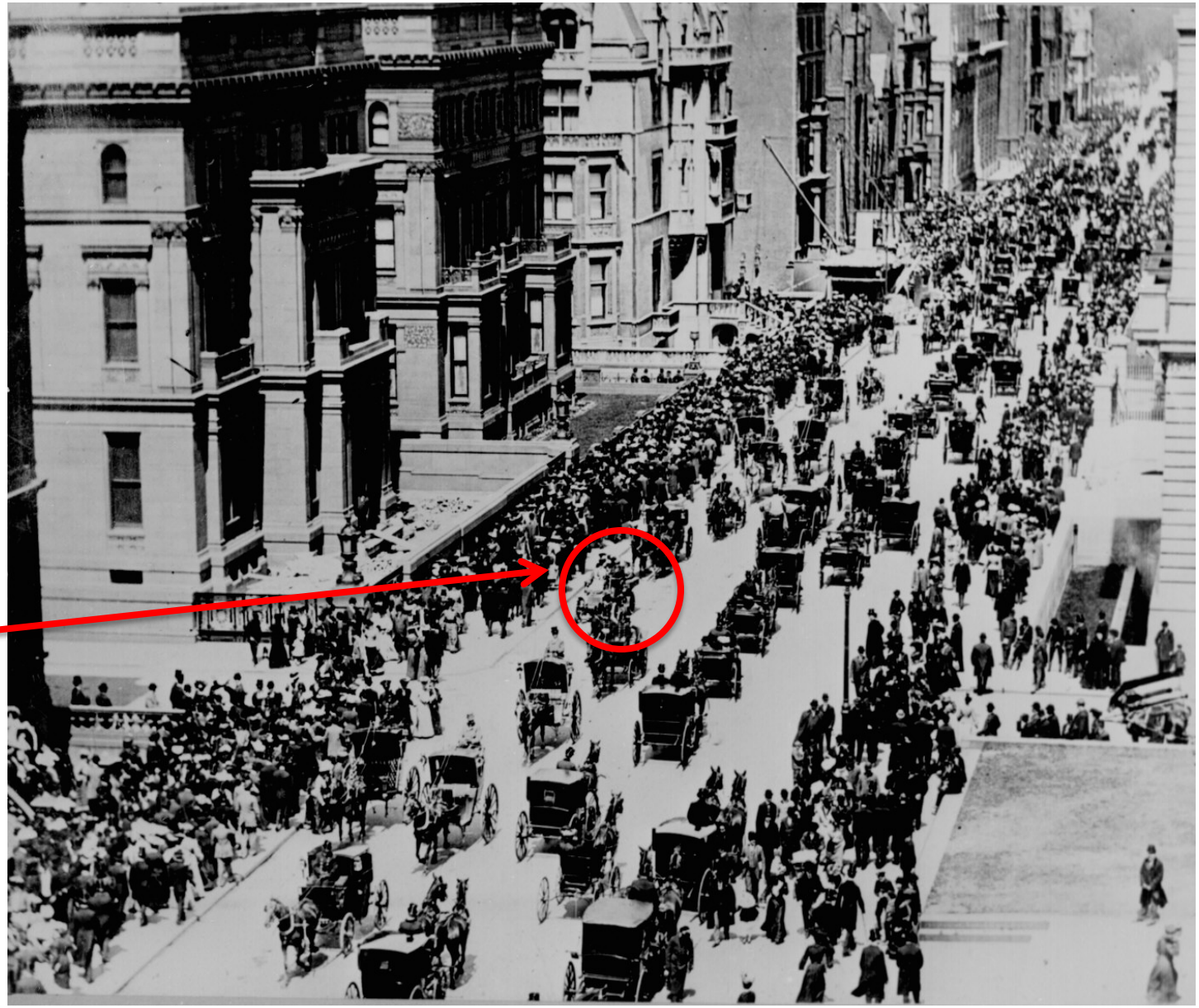


Photo: Fifth Ave NYC on Easter Morning 1900

Source: US National Archives

5th Ave New York City, March 23, 1913

1913: Where is THE HORSE?

Photo: Easter 1913, New York. Fifth Avenue looking north.

Source: George Grantham Bain Collection

Technology-based Disruption

Rodin – Thinker - Photo: Tony Seba

What is a Disruption?

A disruption happens when a new product or service helps

- **create a new market**

and

- **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…

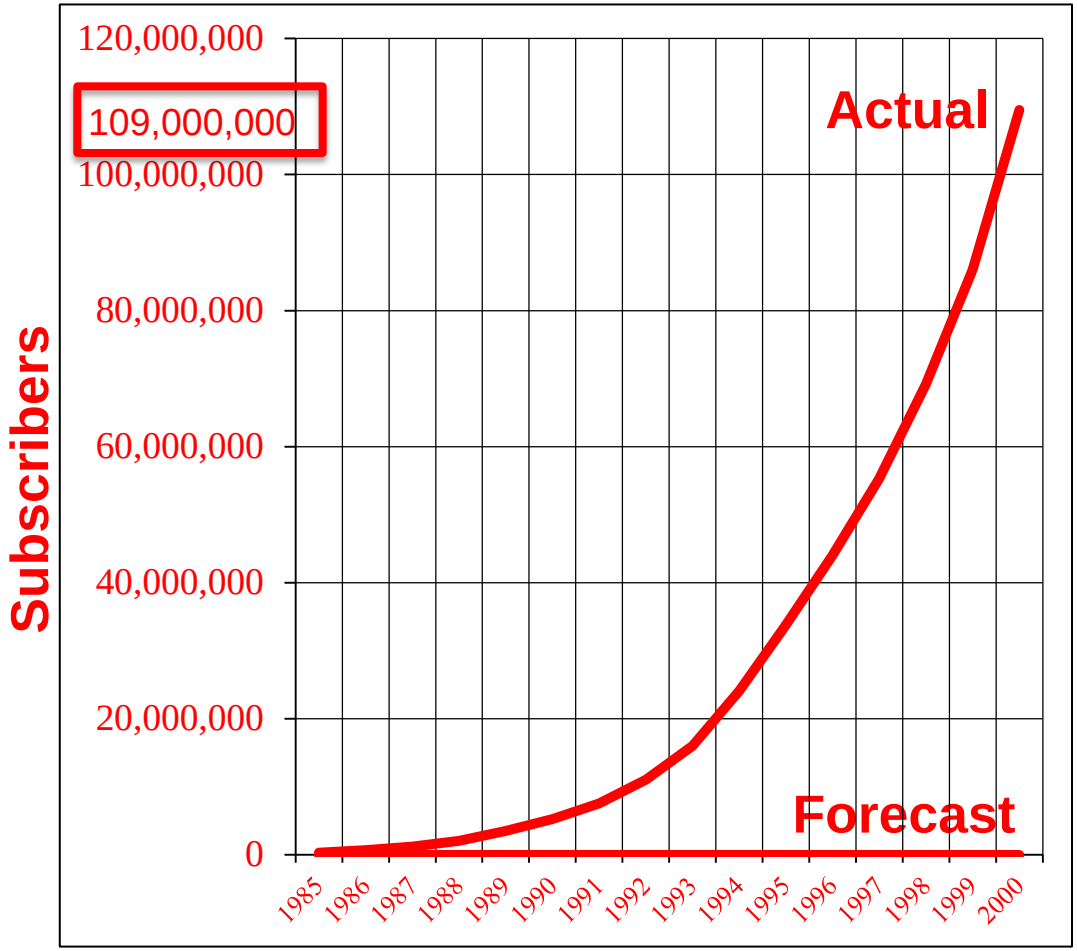
… **109 million**

- They were **off by a factor of 120x**

Motorola DynaTAC 8000X from 1984. Source: Wikimedia

Source: Economist

AT&T Disrupted while $$ Trillions Created



	Company	Home Country	Market Cap. ($MM)
1	Apple	USA	$763,567
2	Google	USA	373,437
3	Alibaba	China	232,755
4	Facebook	USA	226,009
5	Amazon.com	USA	199,139
6	Tencent	China	190,110
7	eBay	USA	72,549
8	Baidu	China	71,581
9	Priceline Group	USA	62,645
10	Salesforce.com	USA	49,173
11	JD.com	China	47,711
12	Yahoo!	USA	40,808
13	Netflix	USA	37,700
14	LinkedIn	USA	24,718
15	Twitter	USA	23,965
Total Market Cap of Top 15			$2,415,867

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

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

Subscriber Data *Source:* CTIA—The Wireless Association

Internet Companies: Internet Report 2015 - Mary Meeker

It's usually the '<u>Experts</u>' and '<u>Insiders</u>' who <u>dismiss</u> <u>disruptive</u> <u>opportunities</u>

"The Internet will catastrophically collapse in 1996." -Robert Metcalfe, 1995.

"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."

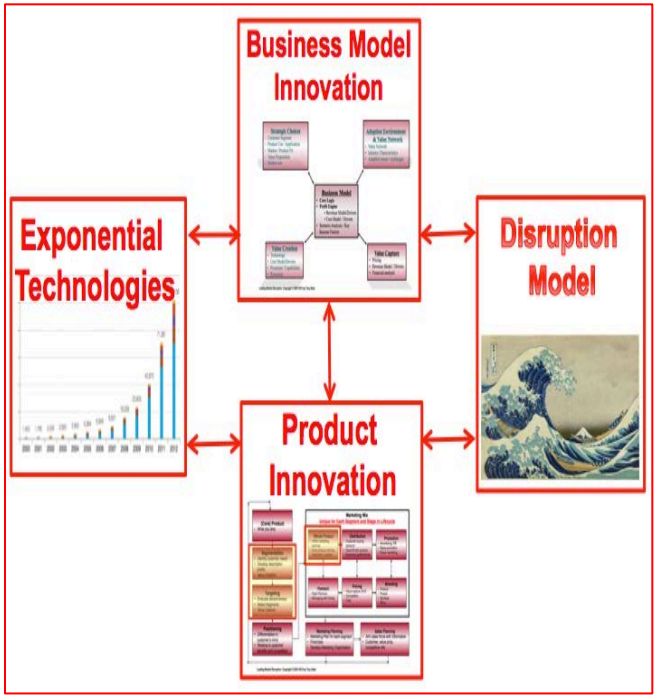
- Scott-Montague, United Kingdom MP, 1903

Why do smart people at smart organizations Consistently Fail to Anticipate or Lead Market Disruptions?

Rodin – Thinker - Photo: Tony Seba

Created New Tech Disruption Framework
to Anticipate & Lead Market Disruptions

1. Disruption Models
2. **Exponential Technologies**
3. **Business Model Innovation**
4. Product Innovation

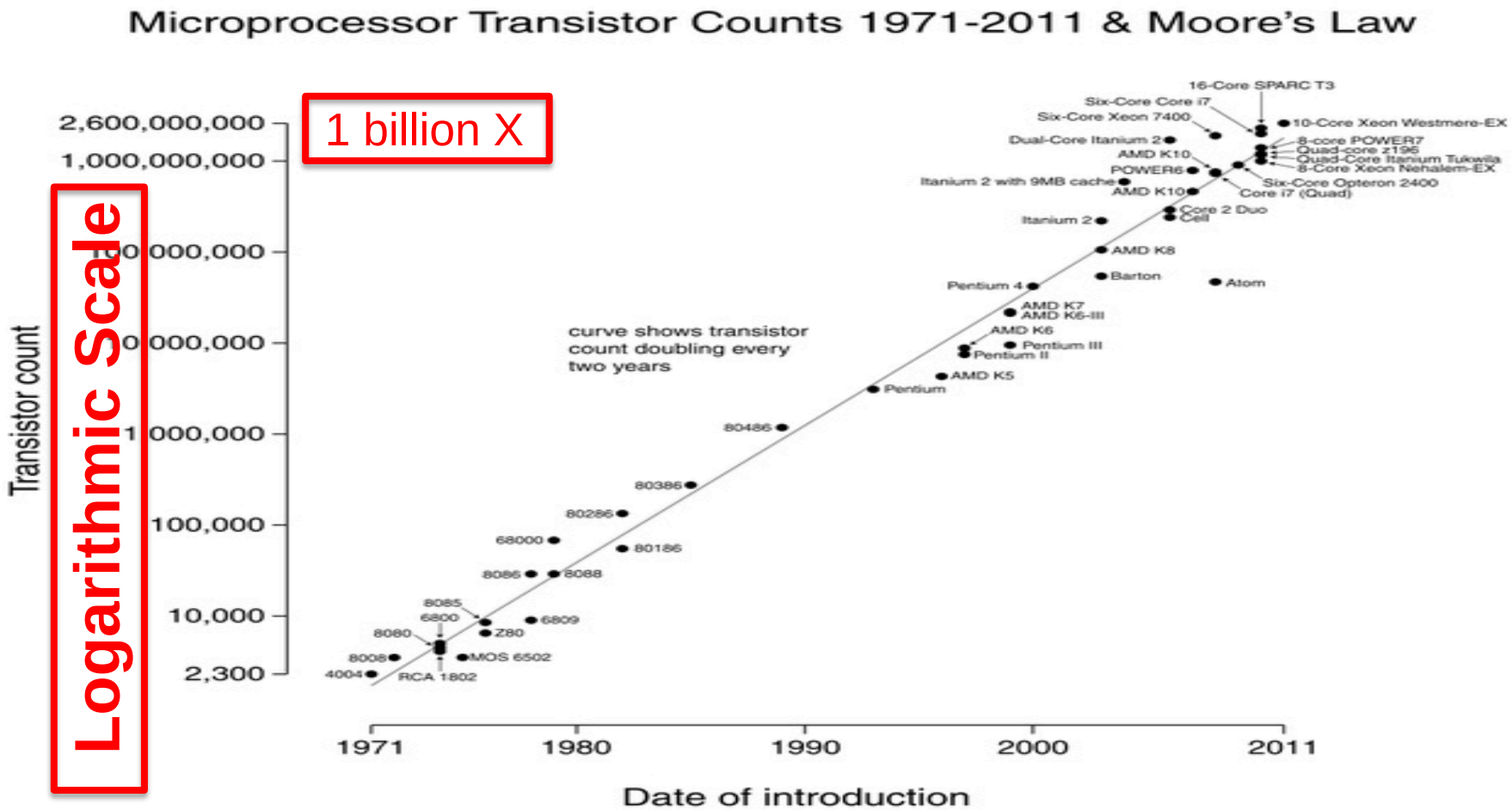


Exponential Technologies

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

- *Jack Welch*

Computing: Moore's Law (1971-2011)

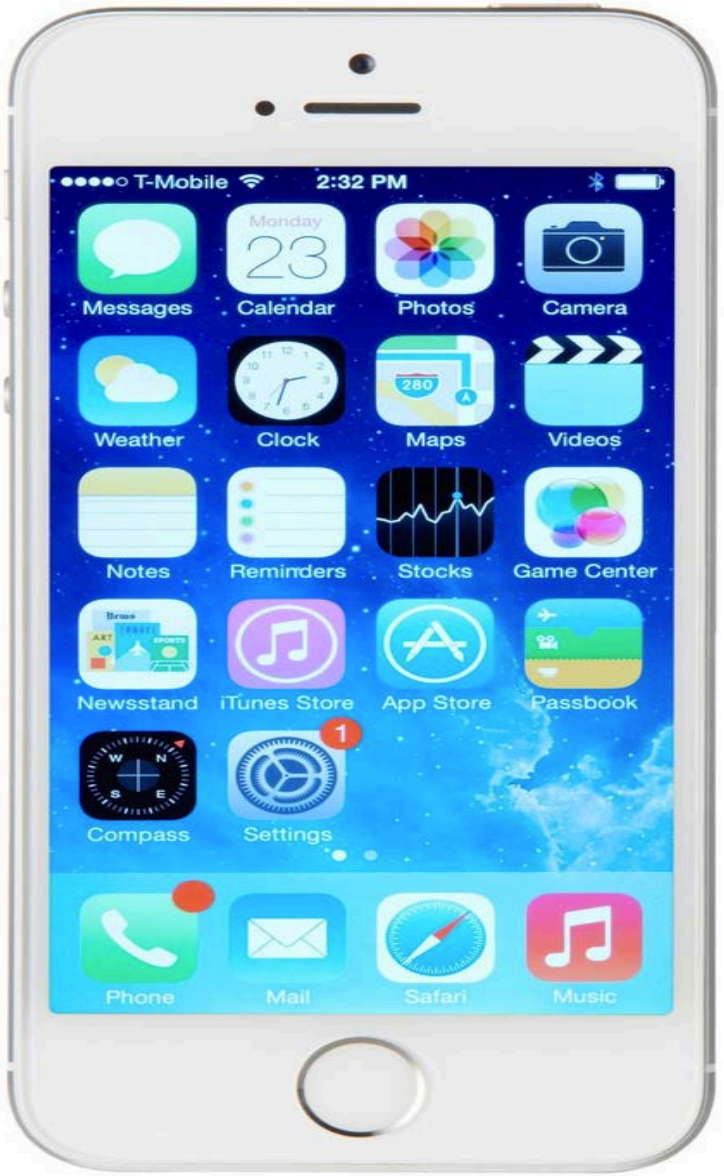


- # of transistors doubles (roughly) **every two years**.
- Tech Cost Curve (Annual Improvement Rate) **~ 41.4%**

Source: Wikipedia

PC / Internet / Mobile Phone disruptions: Convergence of Technologies

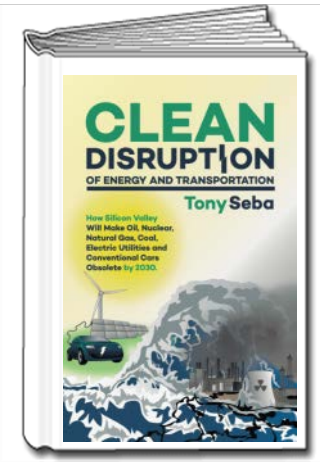
- **Technologies improving at exponential rates.**
- **Data Storage** – Kryder's Law
  - Hard Disk $ cost per bit down **50% every 18 months**.
- **Digital Imaging**– Hendy's Law
  - Pixels per $ - **59% / year**
- **Network Capacity**: Butter's Law of Photonics
  - The $ cost of transmitting a bit decreases by **50% every 9 months**.



Source: Wikipedia, iPhone image: Amazon.com

Key Technologies Disrupting Transportation

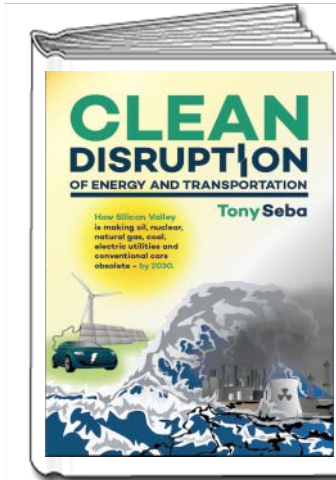
1. Energy Storage
2. Electric Vehicles
3. Mobile Internet / Cloud
4. Sensors / IoT
5. Self-Driving Vehicles
6. Big Data



1. Energy Storage

"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**

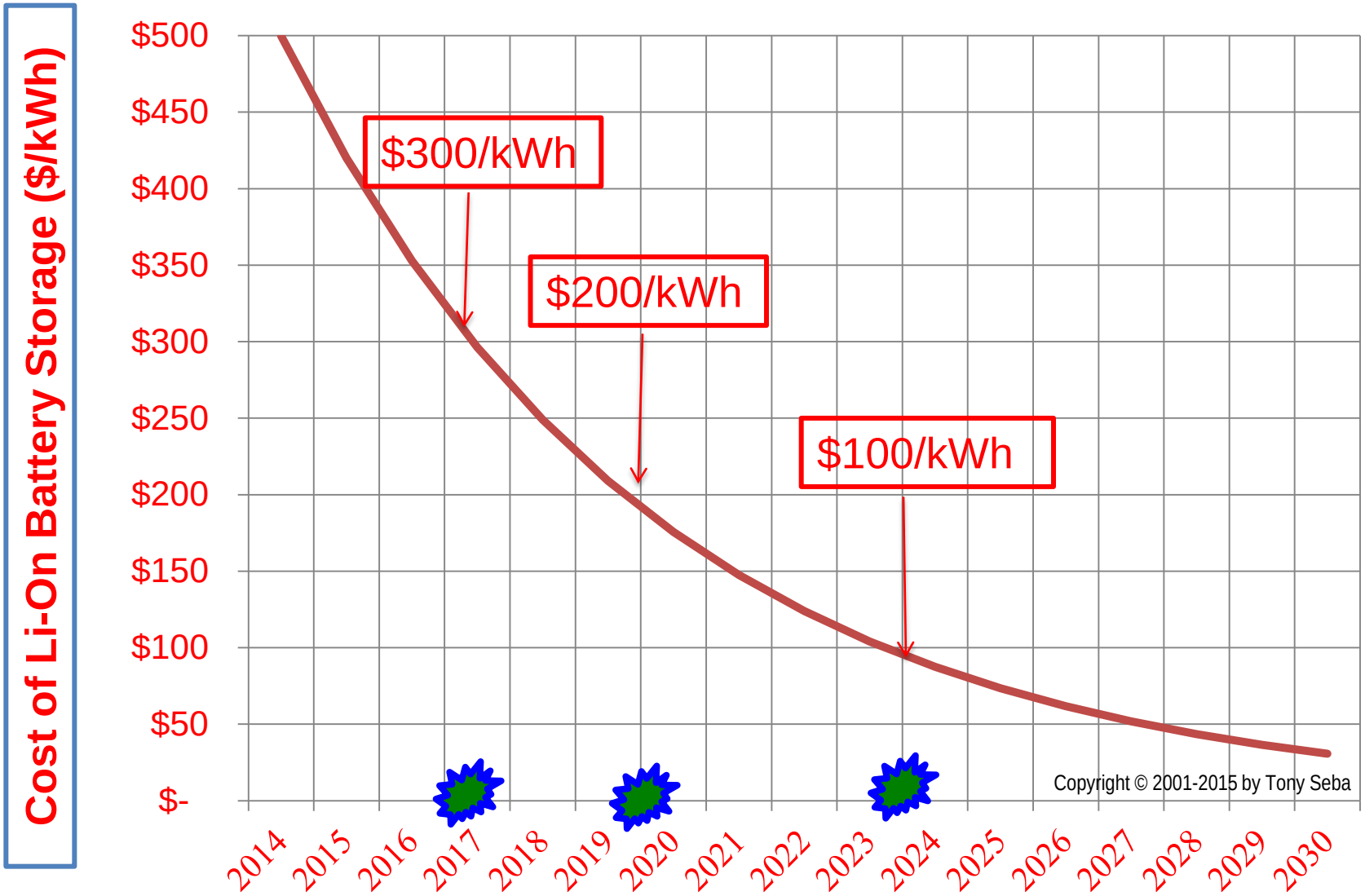
- **Laptop Li-on battery costs dropped ~14% per year over 15 years.** (1)
- Investments in battery tech increasing dramatically:
  - Now 3 multi-trillion $ industries investing:
    1. IT/Electronics
    2. Automotive &
    3. Energy

Photo: Telegraph.uk

- 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 <u>first week</u>**!

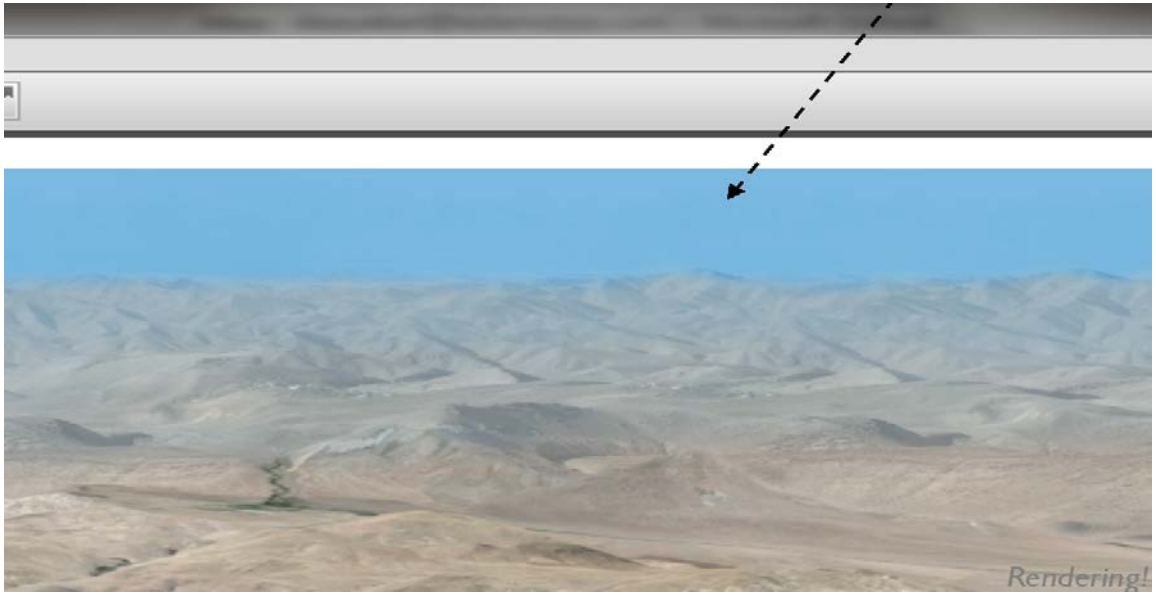
Image: Tesla,

Sources: Tesla, Bloomberg

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)



Source: Tesla
(1) ChargeDevs Mag

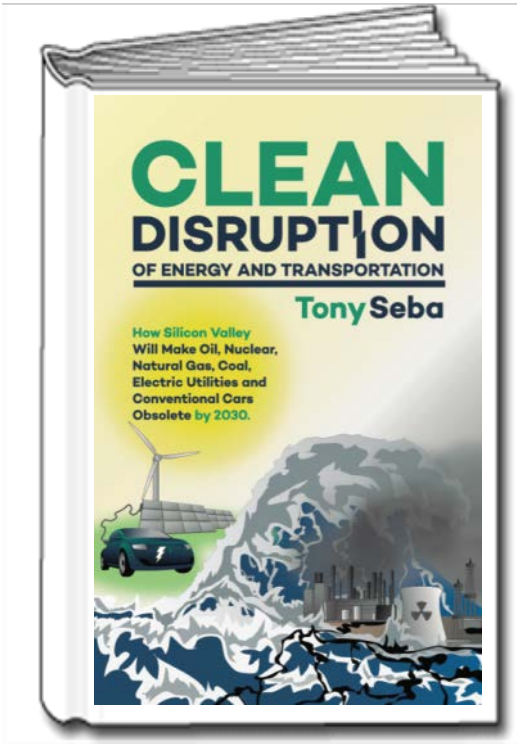
Battery Megafactories are coming!

- **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



Motor Trend Nov 16, 2012

2013 Car of the Year: Tesla Model S

"**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)

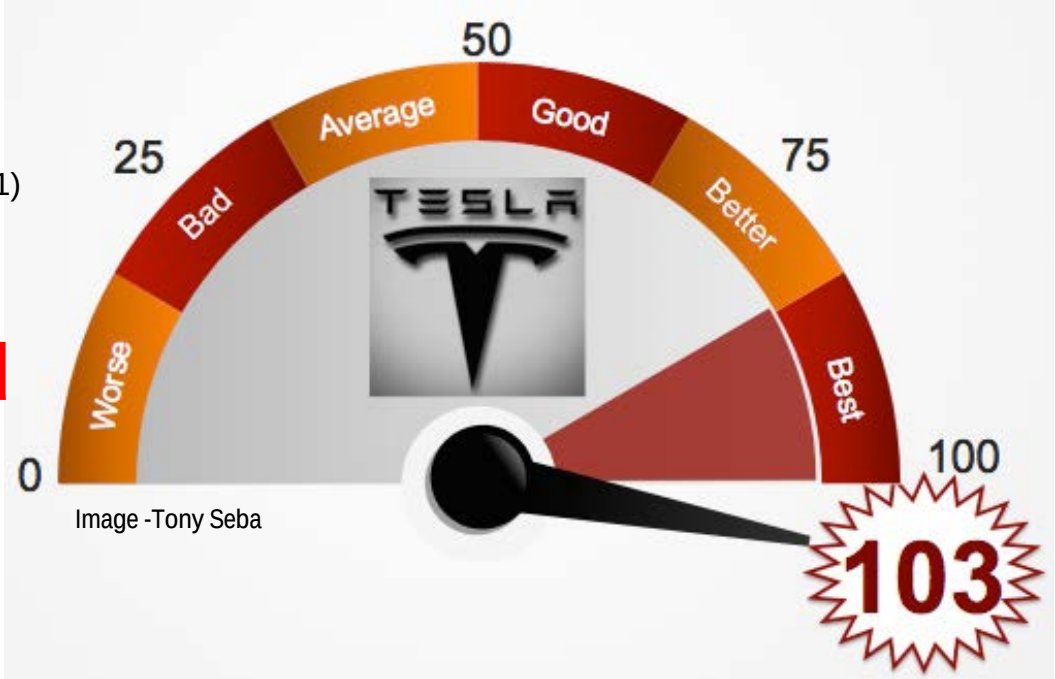


Image -Tony Seba

Sources: Motor Trends, (1) Consumer Reports, (2) Extremetech.com

But who can afford an Electric Vehicle?

Photo © Tony Seba

Is the Electric Vehicle Disruptive?

(You always need to ask)

Photo by Tony Seba

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**.

Image: Jeep.com

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)

Photo © Todd McLellan

(1) Baron Funds

3. EVs: 100X fewer Moving Parts

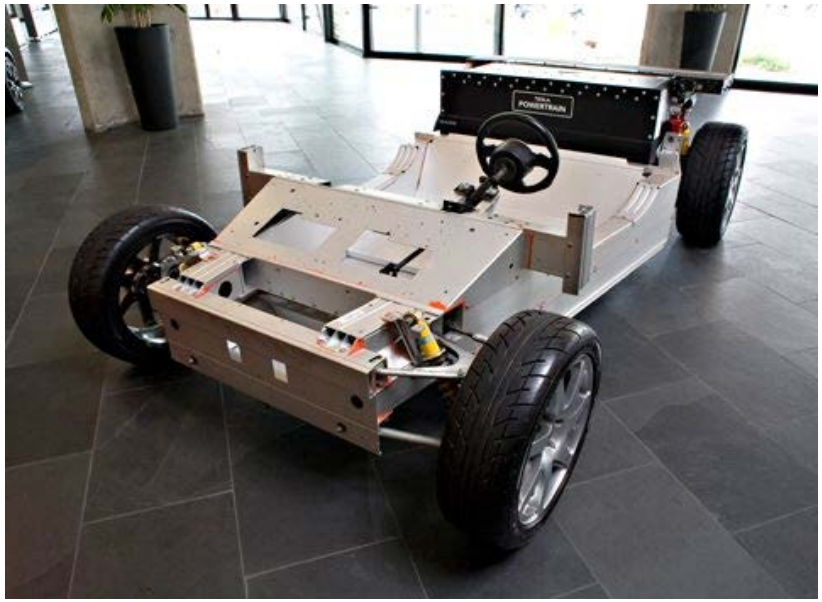
ICE (Gas) vehicle

2,000+ moving parts (1)

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

Electric Vehicle (EV)

18 moving parts (1)

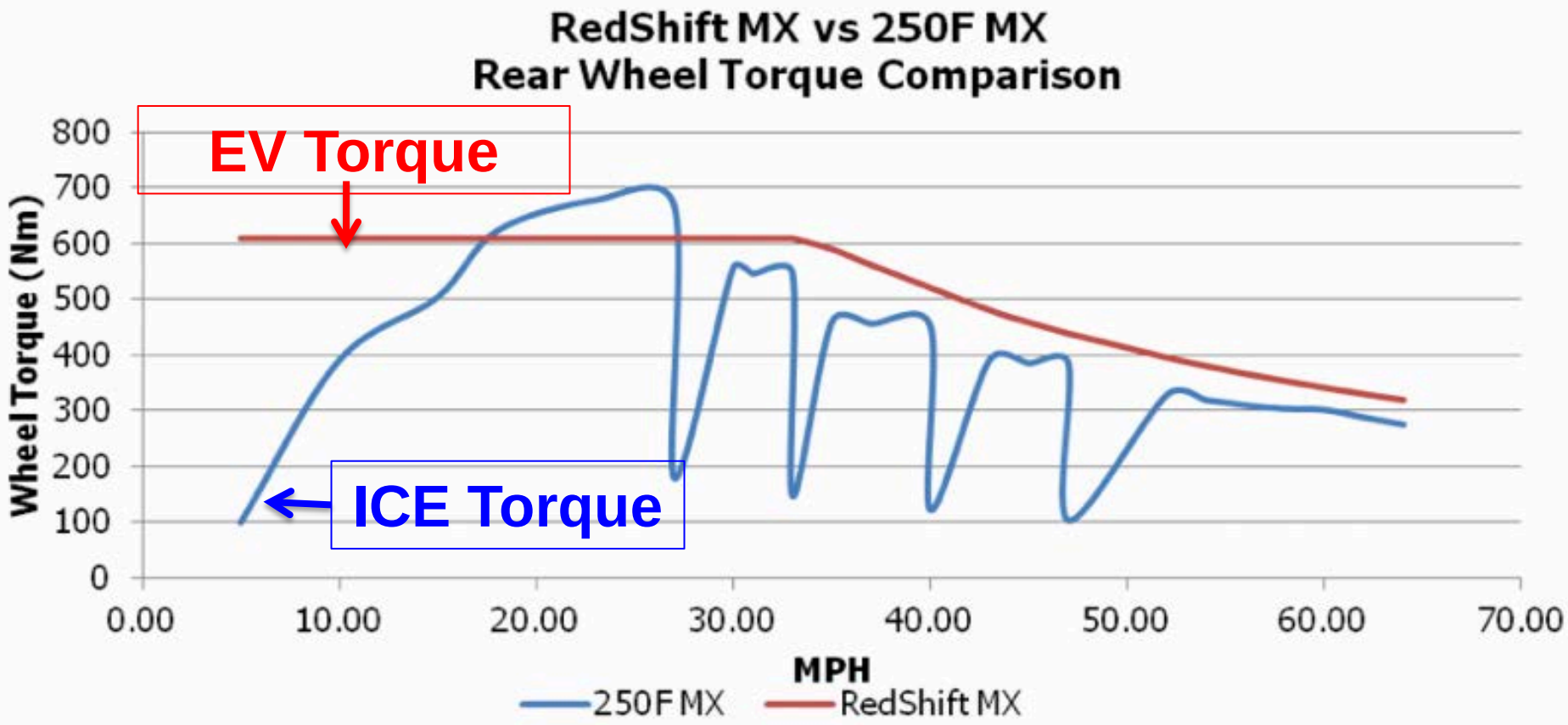


Photos: Tony Seba

- EVs **10X-100X** cheaper to maintain!
- Tesla: **Infinite Mile Warranty!**" (2)

(1) Baron Funds (2) Tesla blog

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)

(1) ChargeDevs Magazine, Image: BRD Motorcycles

5 - Wireless Charging

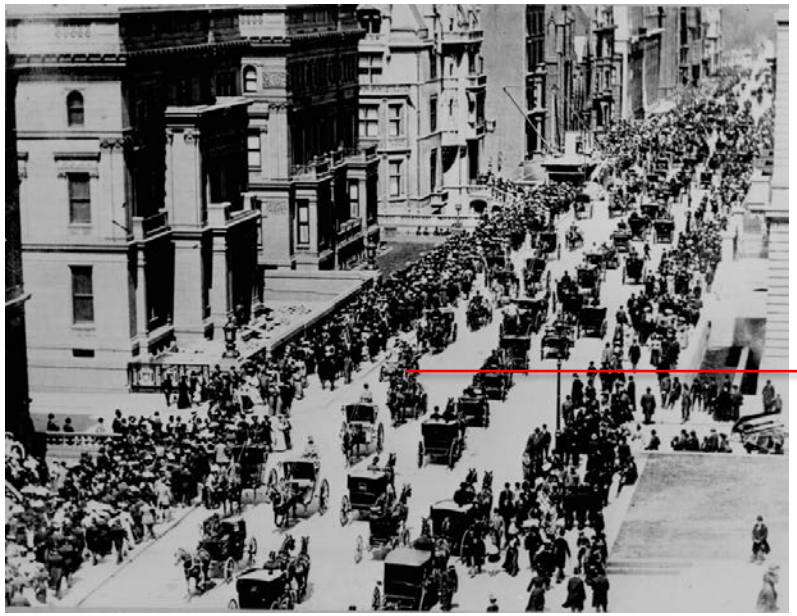
- **Inductive Power Transfer (IPT)** technology allows EVs (buses, cars, bikes, trains) to charge the battery wirelessly

- While EVs wait at the bus stop, traffic light, shopping, parking garage, etc.
- **EV vs ICE** is like **Mobile vs landline phone**!

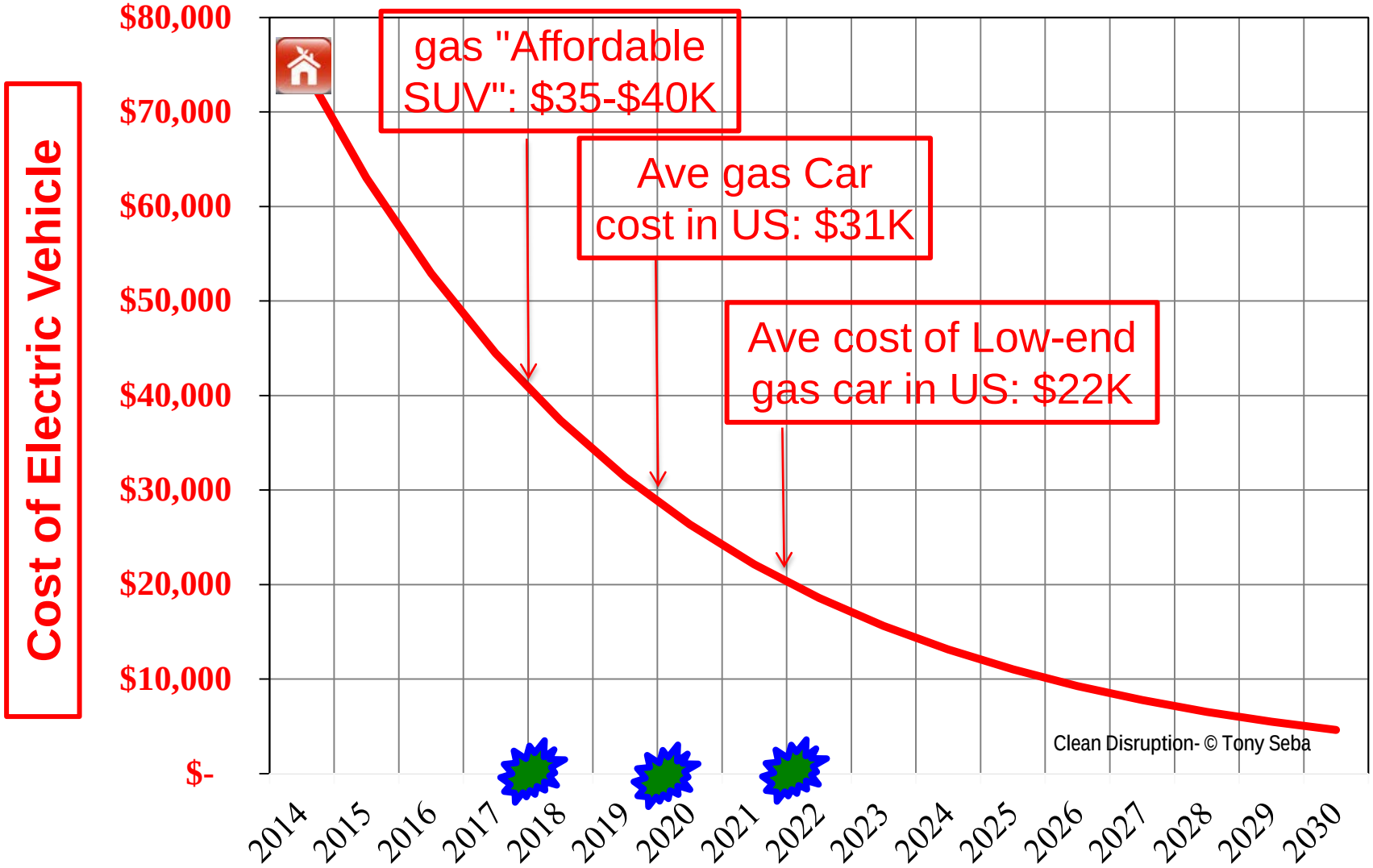
Photo Source: Conductix-Wampfler

Ok, so the EV is <u>DISRUPTIVE</u>.

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

THE WALL STREET JOURNAL

Jan 9, 2015

GM Readies Electric Rival to Tesla

"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." (1)

Image Source: Car and Driver

(1) Source: WSJ

ComputerWorld Sept 4, 2014

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

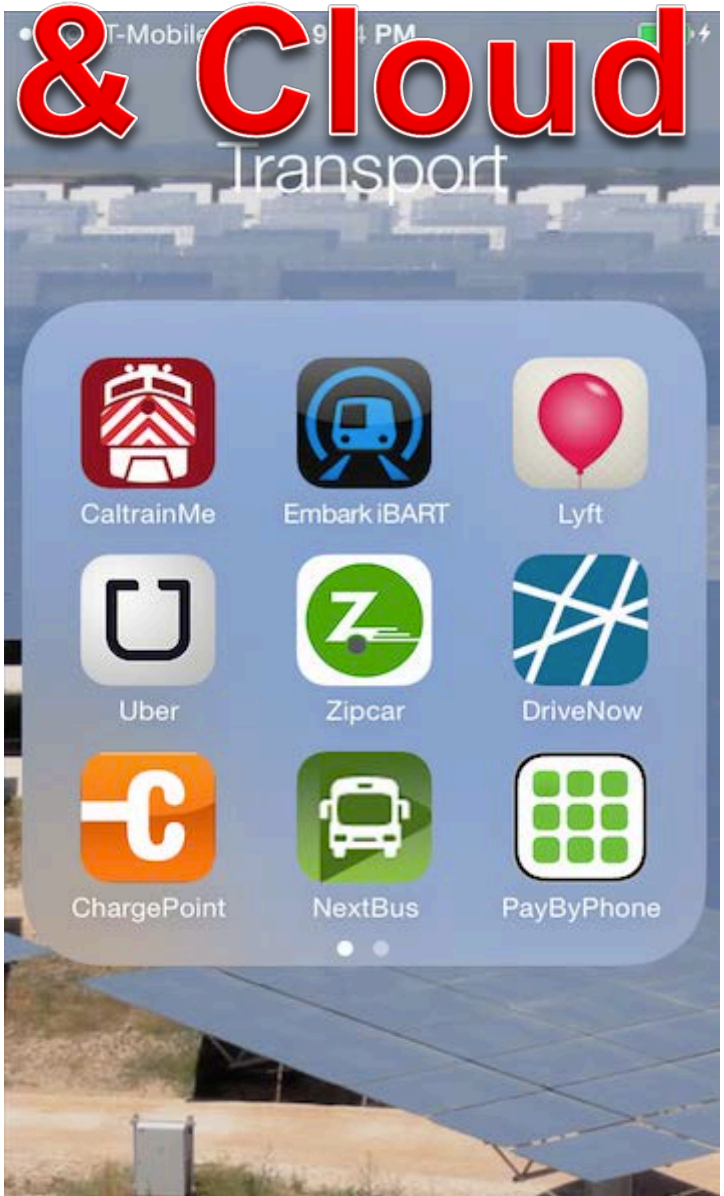
Amsterdam: All Electric Transport by 2025

- 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.

Photo ©2015 : Tony Seba

Source: CleanTechnica

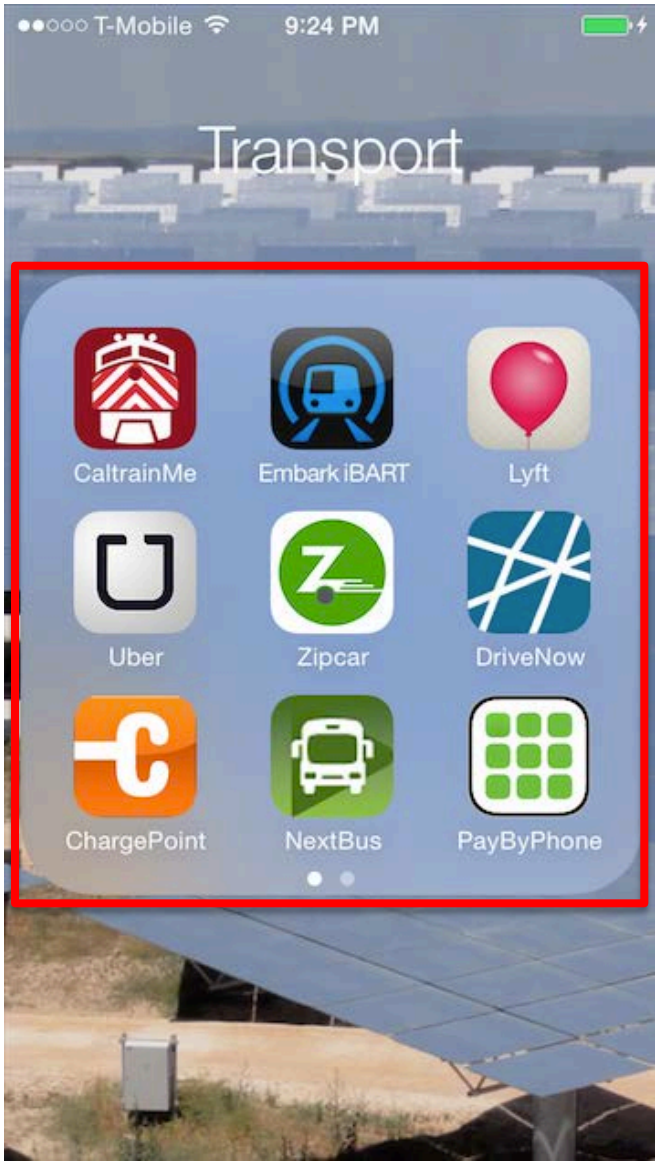
3 - Mobile Internet & Cloud



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

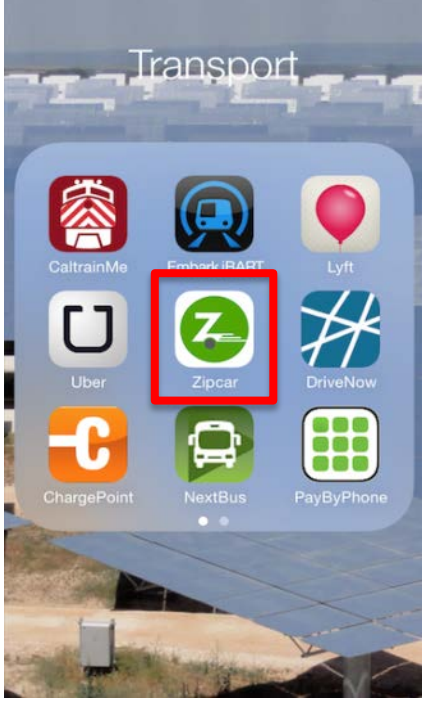


Technology enabling Business Model Innovation

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**



Images: Tony Seba

On-Demand Mobility: changing the concept of **Car Ownership**

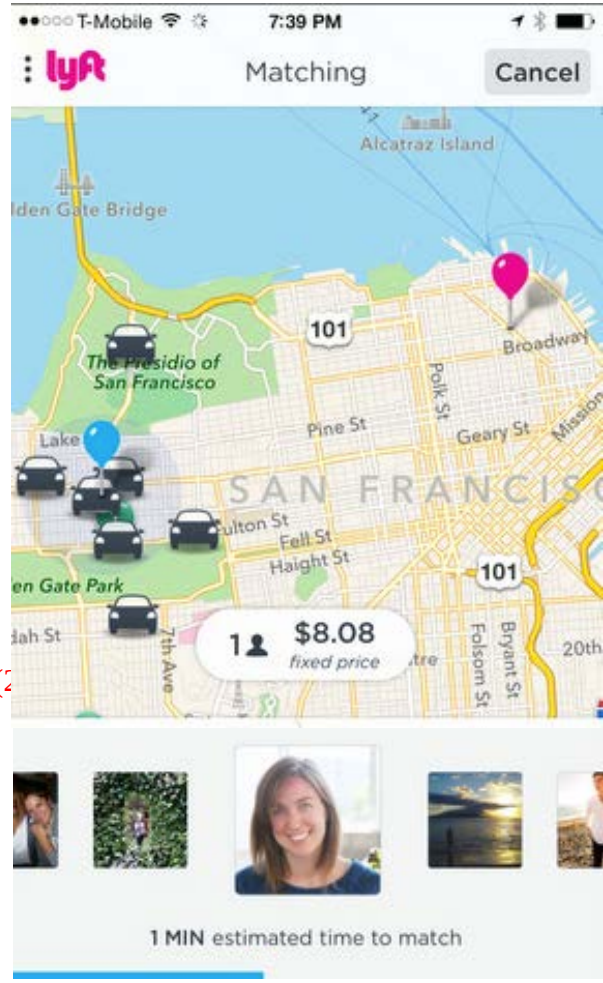
Source: "Clean Disruption"

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 ~= half** of Uber Rides

(1) (2) (3) Business Insider

(4) Wikipedia

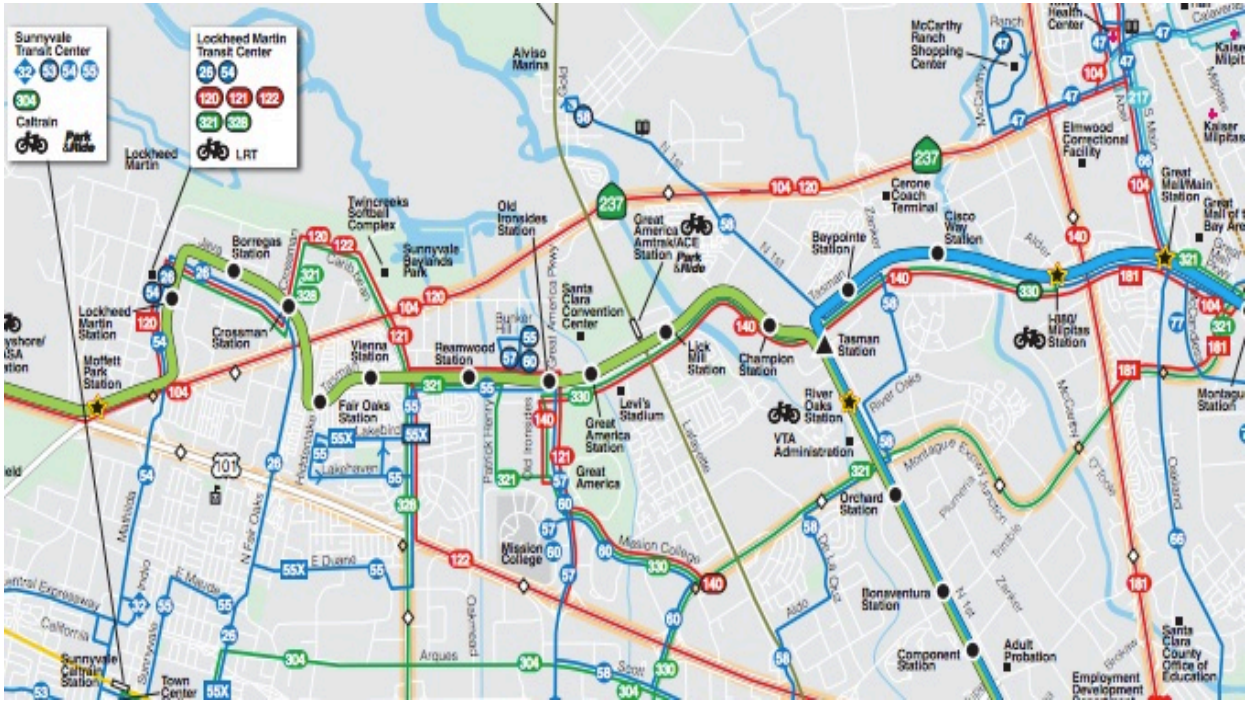
On-Demand Public Tranportation

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

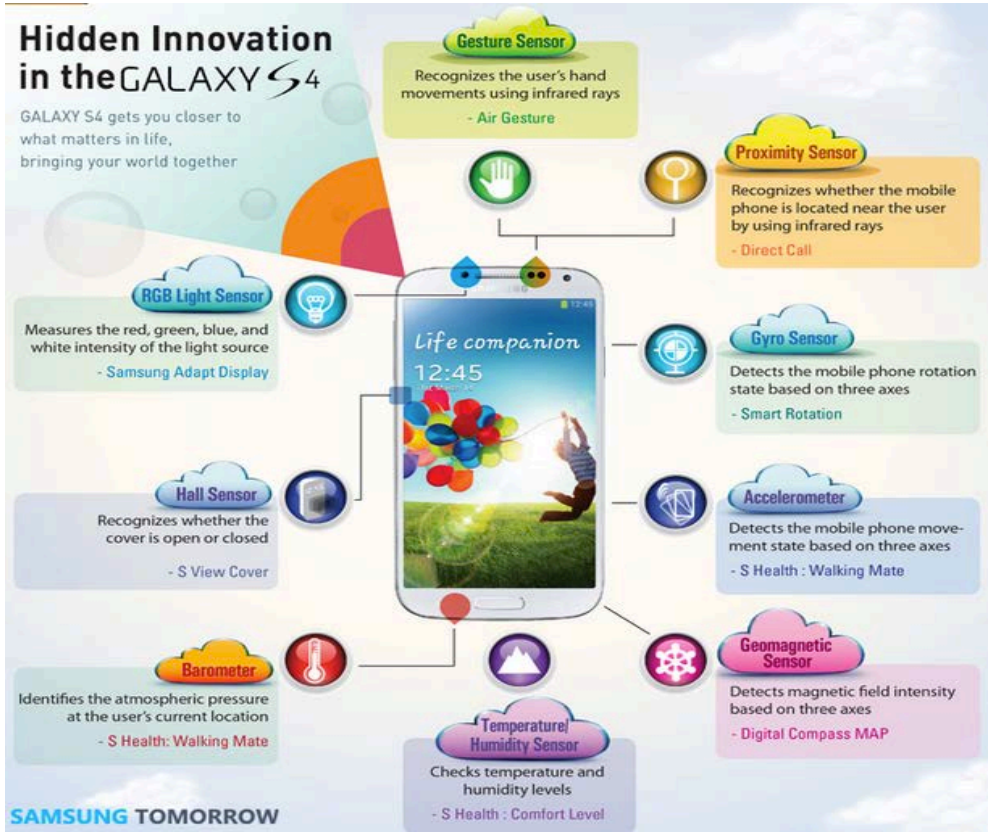
System is

- Mobile-First App
- Cloud-based
- On-demand
- Data-driven
- Small Trial (5 Vans)



Images: Stanta Clara VTA

4 - Sensors & The Internet of Things



Sensors: 1,000X Changes in 7 Years (2007-2014)

Unit	Change	Comments
Number of Sensors	UP **1,000x**	From 10 million to 10 billion
Cost	DOWN **1,000x**	E.g., from $250/axis for gyros to $0.75 for three axis
Power consumption	DOWN **1,000x**	From W to mW and mW to µW, depending on sensor
Physical **Size**	DOWN **1,000x**	E.g., gyro from 2000 mm^3 to 2 mm^3/axis
Number of **Transistors**	UP **1,000x**	From 1000s per sensor to 1,000,000s / sensor.

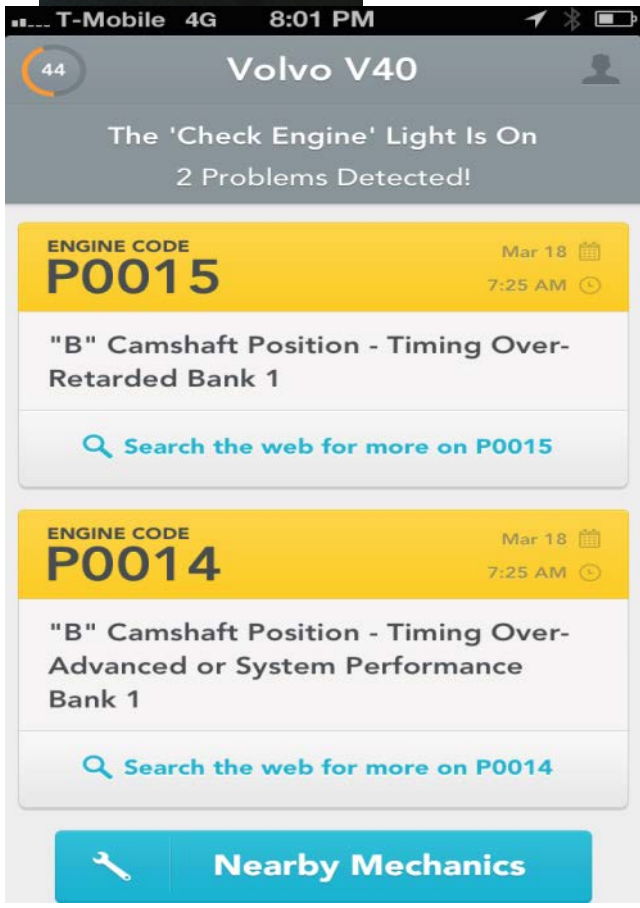
- On the road to trillions of Sensors: Exponential Unit Growth

Source: Janusz Bryzek, TSensors

Car Sensor Tech

$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"



Photos: Tony Seba

Sensors + Mobile Internet = Big Data -> Disruption of Car Insurance

METROMILE

iPhone App | Per-Mile Insurance | Login

Features	FREE Device + App	Device + App + Insurance
Engine diagnostics	✓	✓
MPG tracking	✓	✓
Gas cost per trip	✓	✓
Car locator	✓	✓
Compare trips	✓	✓
Automated street sweeping alerts (San Francisco only)	✓	✓
Per-mile car insurance	-	✓
24/7 service	-	✓
Roadside assistance	-	✓
	Sign up free	Get Insurance Today

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.

(1) Computerworld

Image: DOT NHTSA

Vehicle-2-Infrastructure SF: Transit Signal Priority

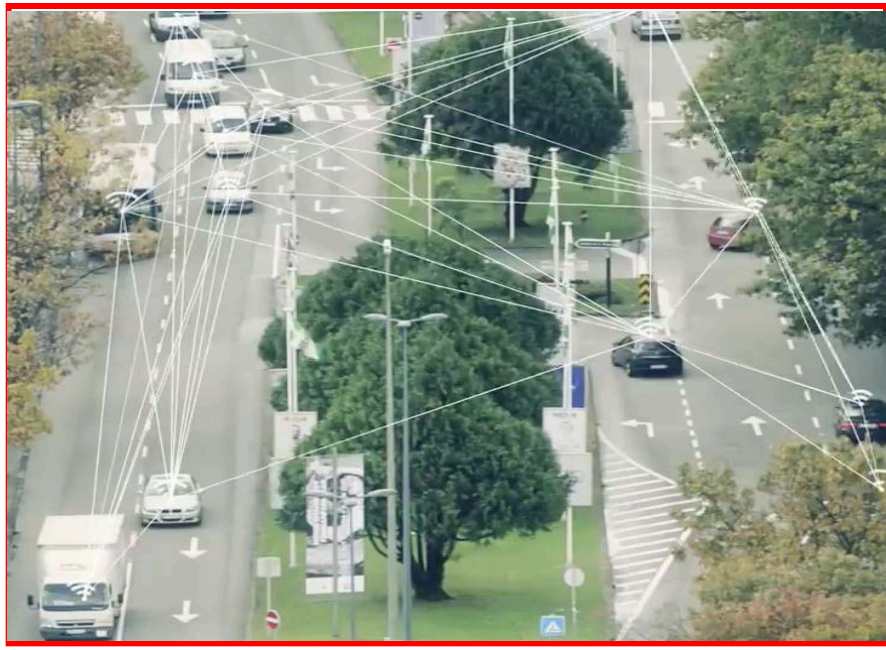
- SF Muni Sensors: The devices are designed to **keep lights green when a Muni bus is approaching**. (1)
- The system also has the ability to make red lights shorter based on the presence of a bus.
- The system is **cutting about 10% off travel time** from beginning to end of bus routes. (2)

(1) SFMTA (2) RichmondBlog

Photos: Tony Seba

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



(1) Source Veniam

Photos: Veniam.com

5 - The Autonomous Vehicle Disruption

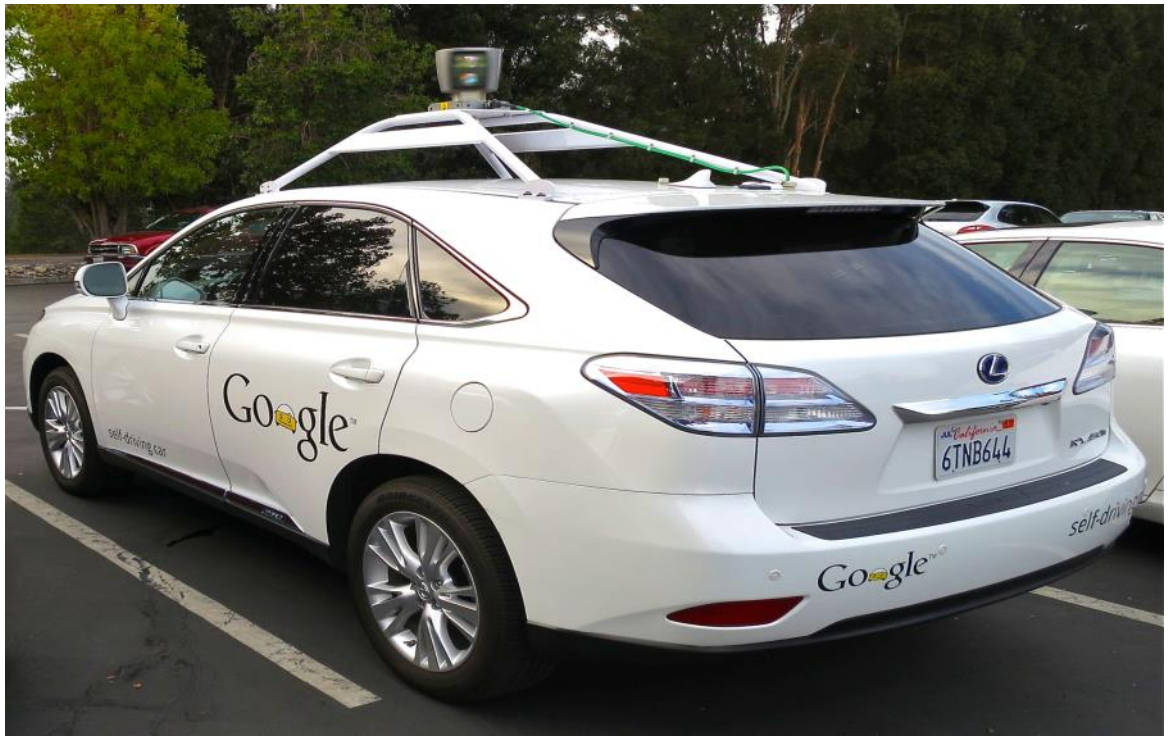
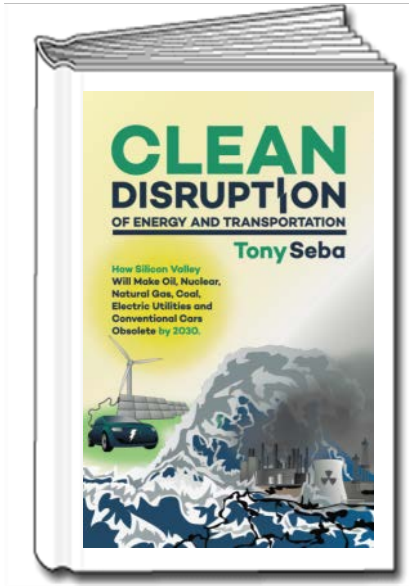


Photo Wikipedia



Financial Times

May 5, 2015

Nevada approves Autonomous Trucks

Video: WSJ

Self-driving cars may hit roads in 2018: Renault-Nissan CEO

PARIS Tue Jun 3, 2014 1:03pm EDT

TheVerge

Oct 2, 2014

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)

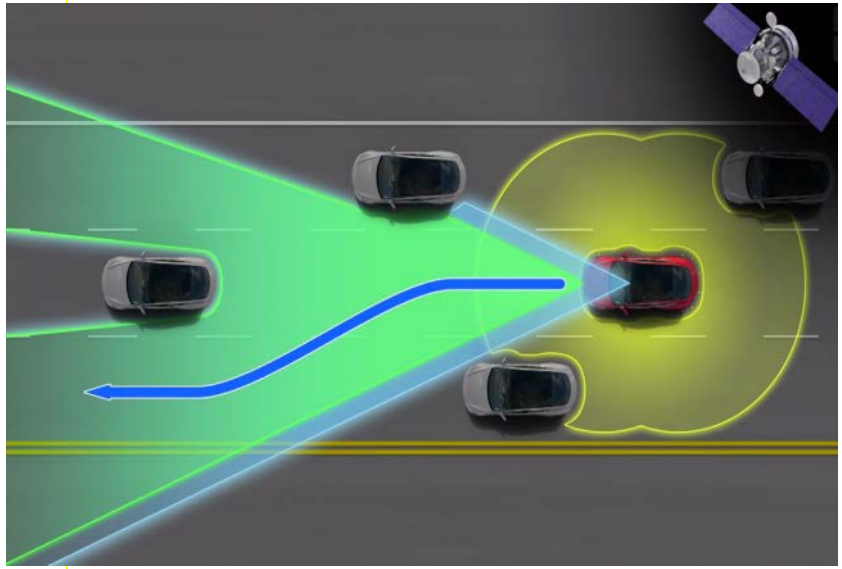
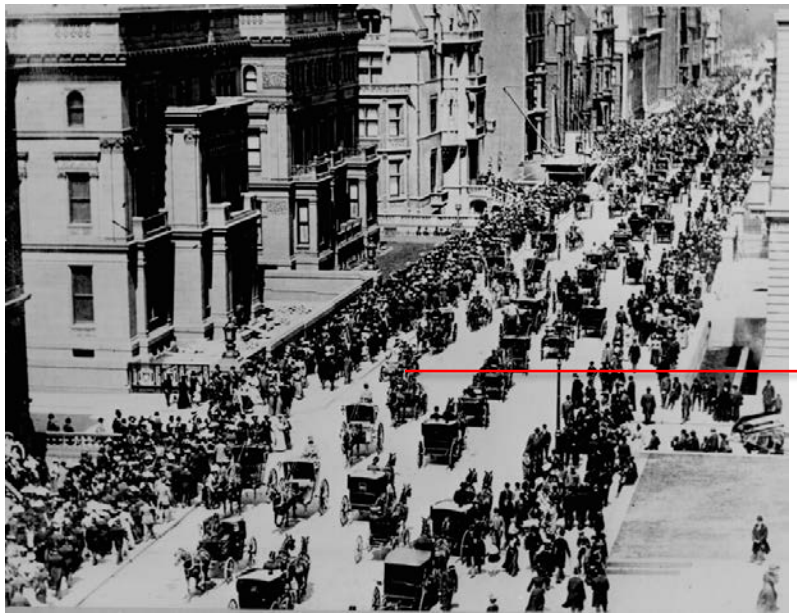


Photo: Tesla

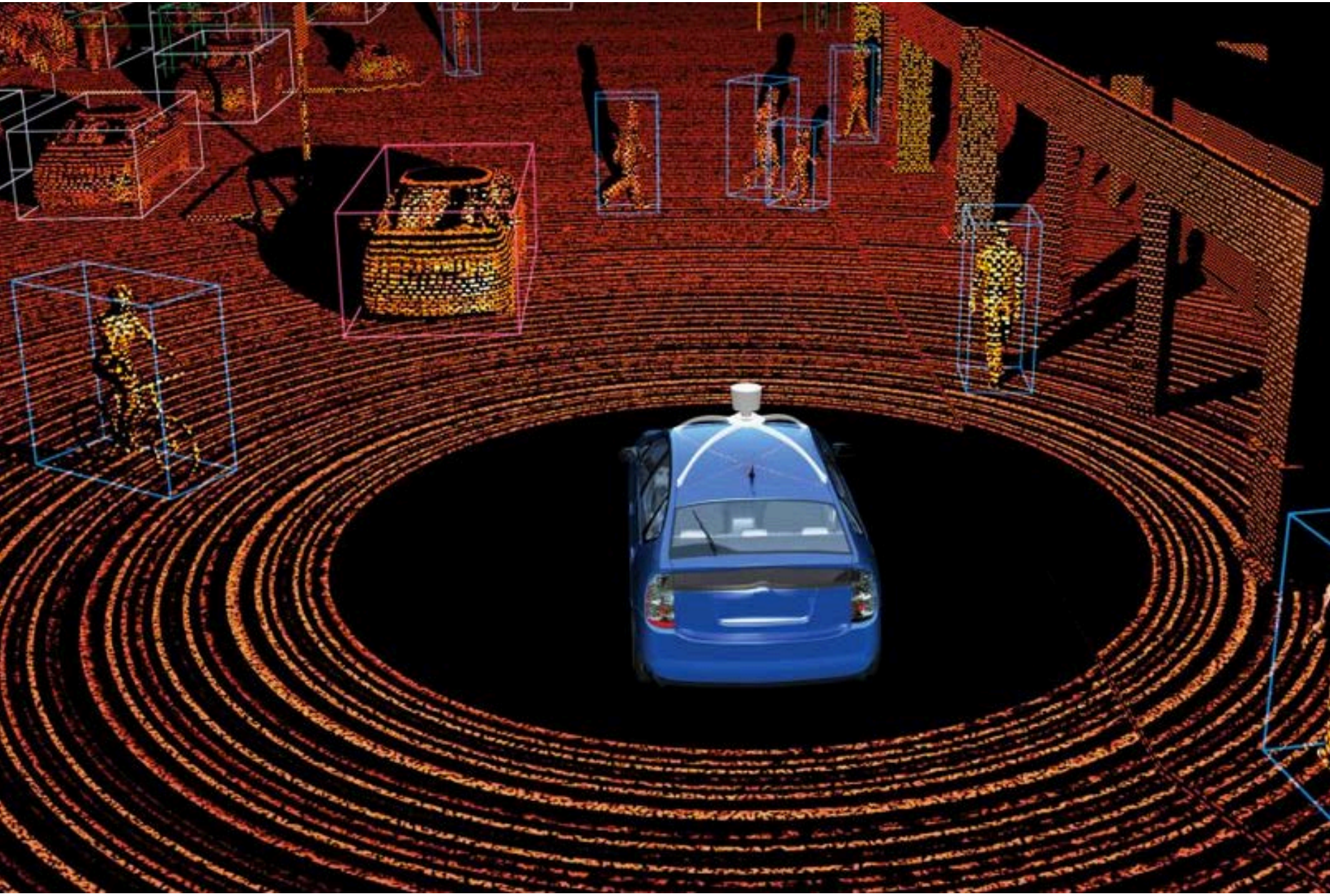
- Lane keeping, active emergency braking, cruise control, self-parking, summon the car ("meet me at work")... (2)

(1) UK Daily Mail (2) Elon Musk, Tesla

What about the COST of Autonomous Vehicles?



What an Autonomous Car Sees

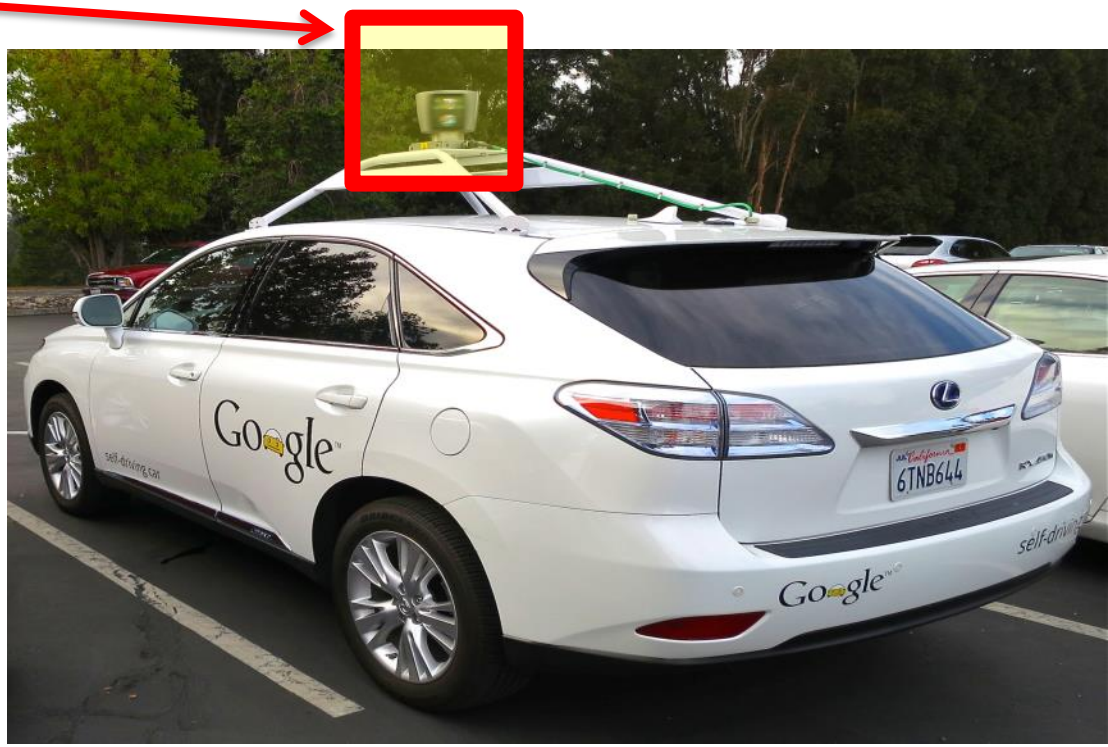


GraphicPopular Science

Exponential Technologies: Machine Vision – LIDAR Sensors

- 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**



Graphic Source Wikipedia

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:

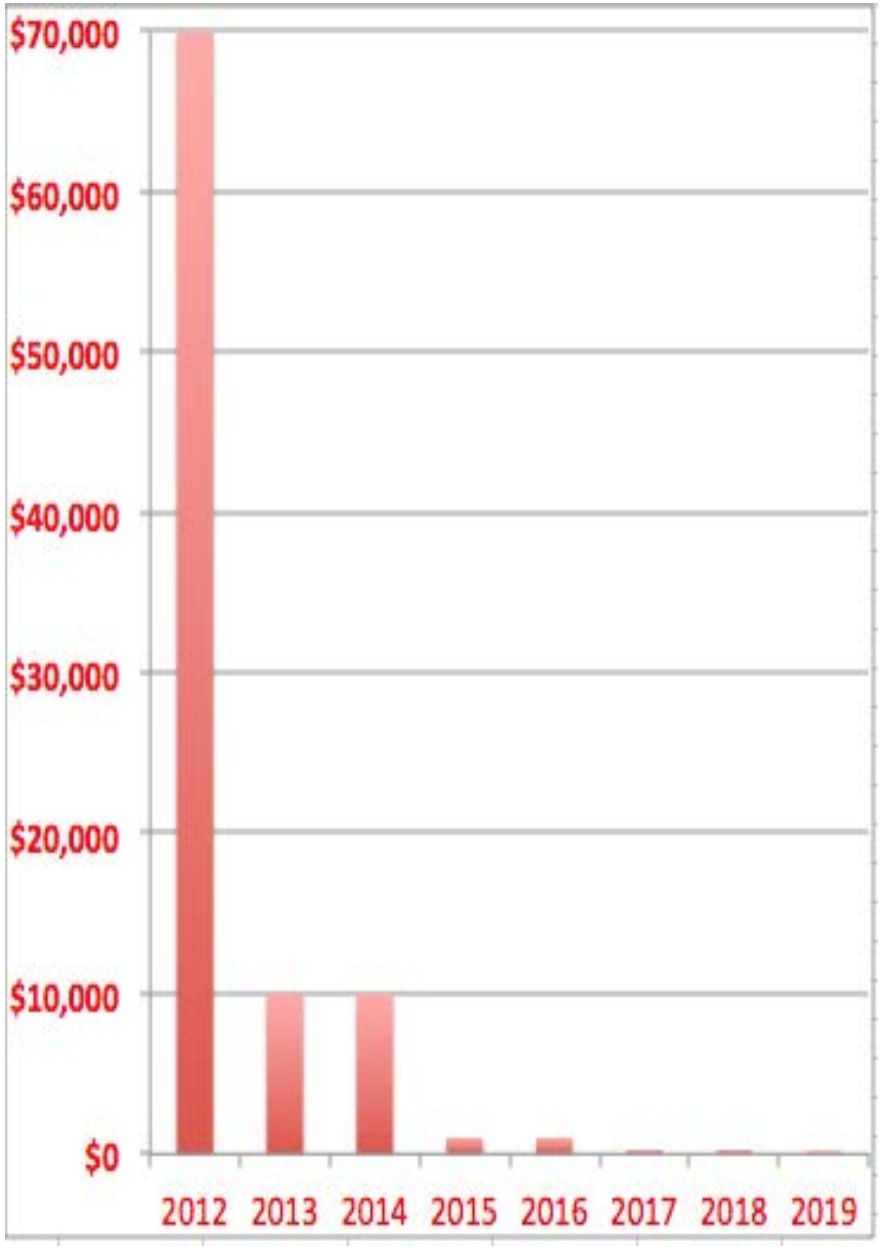
Gen 1: <$1,000

Gen 2: <$250

Gen 3: <$100

QUANERGY™

- 2015 LIDAR: ~**$1,000**
- Gen 2 (solid state): $250
- Gen 3 (postage stamp): **$90**



Source Quanergy

Autonomous Vehicles = Computers on Wheels

- 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

Image: ExtremeTech

- Space = 1,600 sq ft **(150 m^2)**
- Power Consumption = 850 kW
- **Cost = $46 million**

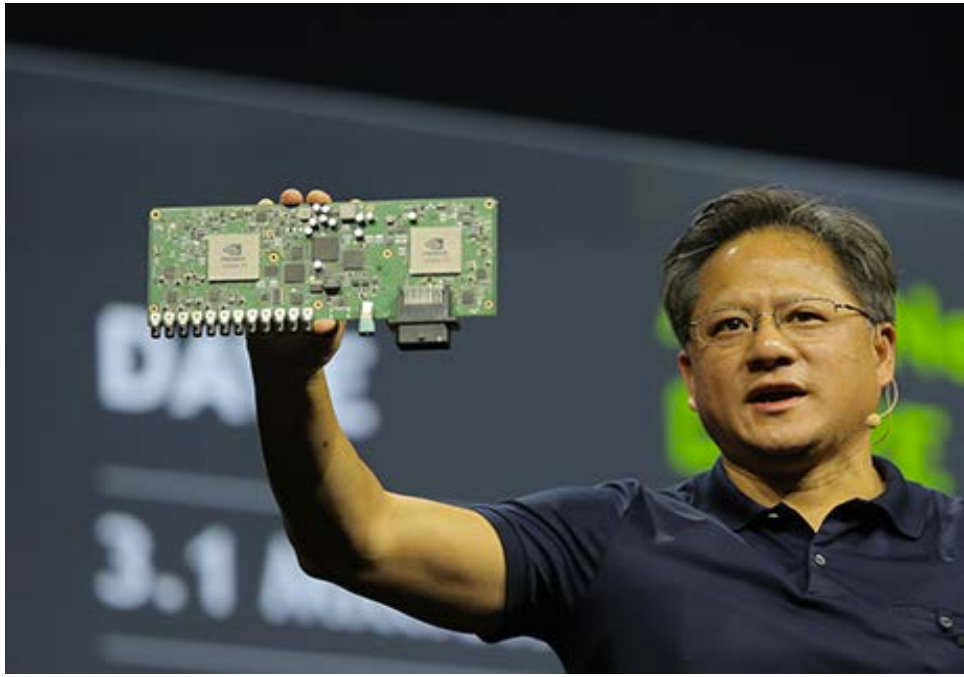
Source Wikipedia

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

Image & Data Source: NVIDIA

Ok, cost is not an issue…but

Is the <u>Market</u> Ready for Self-Driving Cars?

Rodin – Thinker - Photo: Tony Seba

Are consumers ready for Autonomous cars?

Consumers Desire More Automated Automobiles

Consumers Trust Driverless Cars

2.8b people

57%

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

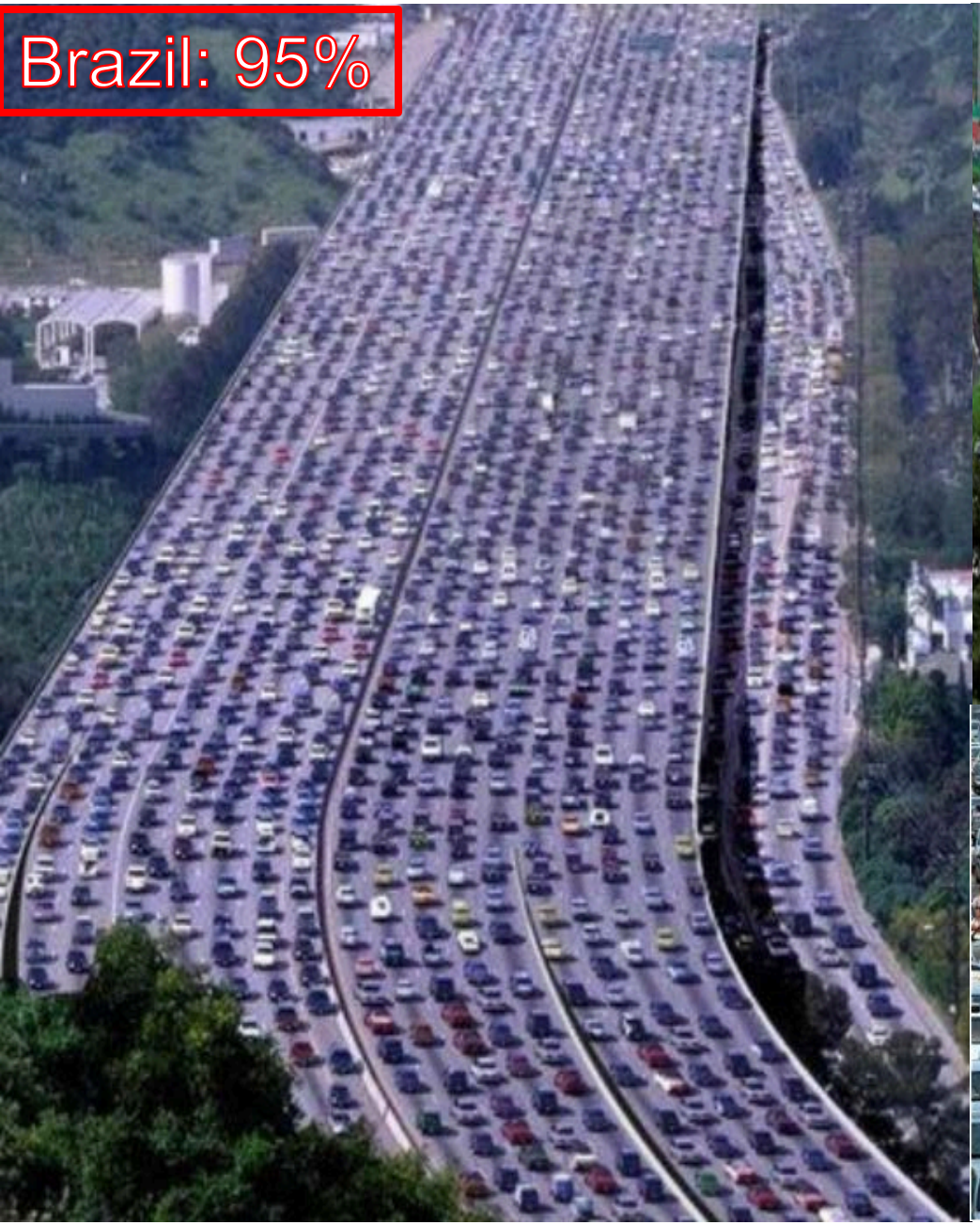
Brazil	95%
India	86%
China	70%
USA	60%
Russia	57%
Canada	52%
France	45%
UK	45%
Germany	37%
Japan	28%

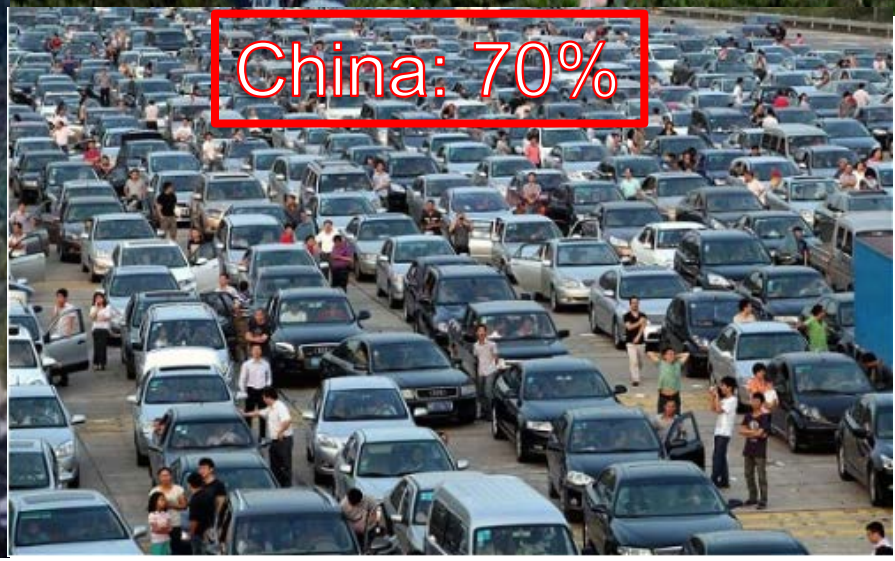
cisco

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

Source: Cisco Systems

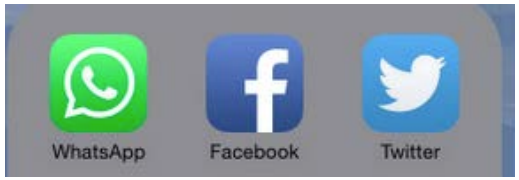
Are consumers ready for Autonomous cars?





Images Source: chinawshisper.com, inrix.com, ryot.org

Cool! I can



and also

while NOT driving!

But what's the disruptive impact?

Rodin – Thinker - Photo: Tony Seba

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)

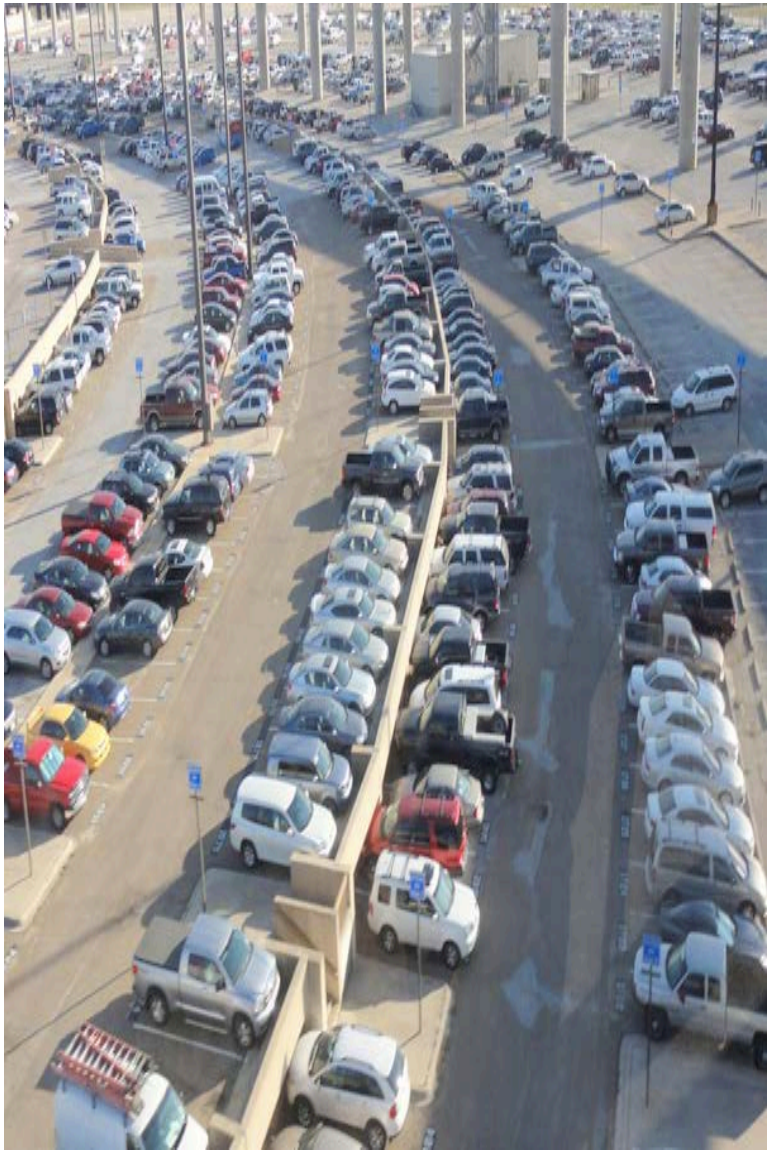
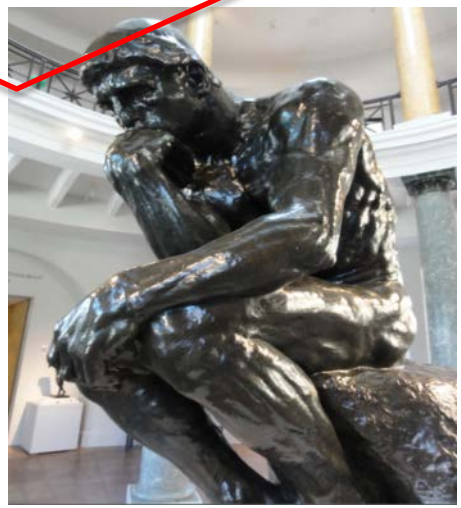


Photo: Tony Seba

(1) Donald Shoup

Self-Driving + CarSharing: Convergence of Technology & Business Model Innovation



The Verge **Feb 2, 2015**

UBER ANNOUNCED SELF-DRIVING CAR PROJECT

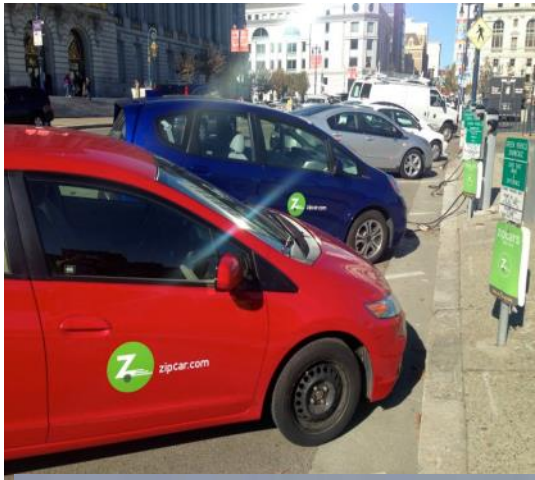
"Uber announced plans with Carnegie Mellon University to create the Uber Advanced Technologies Center: R&D of autonomous vehicles."

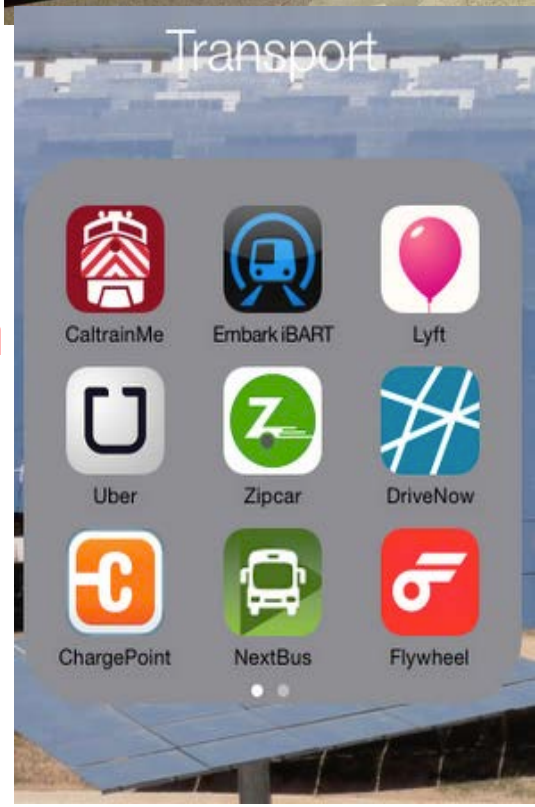
"When there's no [driver], the cost of taking an Uber anywhere becomes cheaper than owning a vehicle...and then car ownership goes away." said Uber's CEO

Image: Tony Seba

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**

theguardian

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Helsinki's ambitious plan to make car ownership pointless in 10 years

Finland's capital hopes a 'mobility on demand' system that integrates all forms of shared and public transport in a single payment network could essentially render private cars obsolete

• Live Q&A: Should we ban cars? From midday on Friday

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Adam Greenfield

theguardian.com, Thursday 10 July 2014 10.20 EDT

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(1) Guardian

6 - Big Data

/ Open Data

Big Data & Clean Disruption of Transportation

- 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**

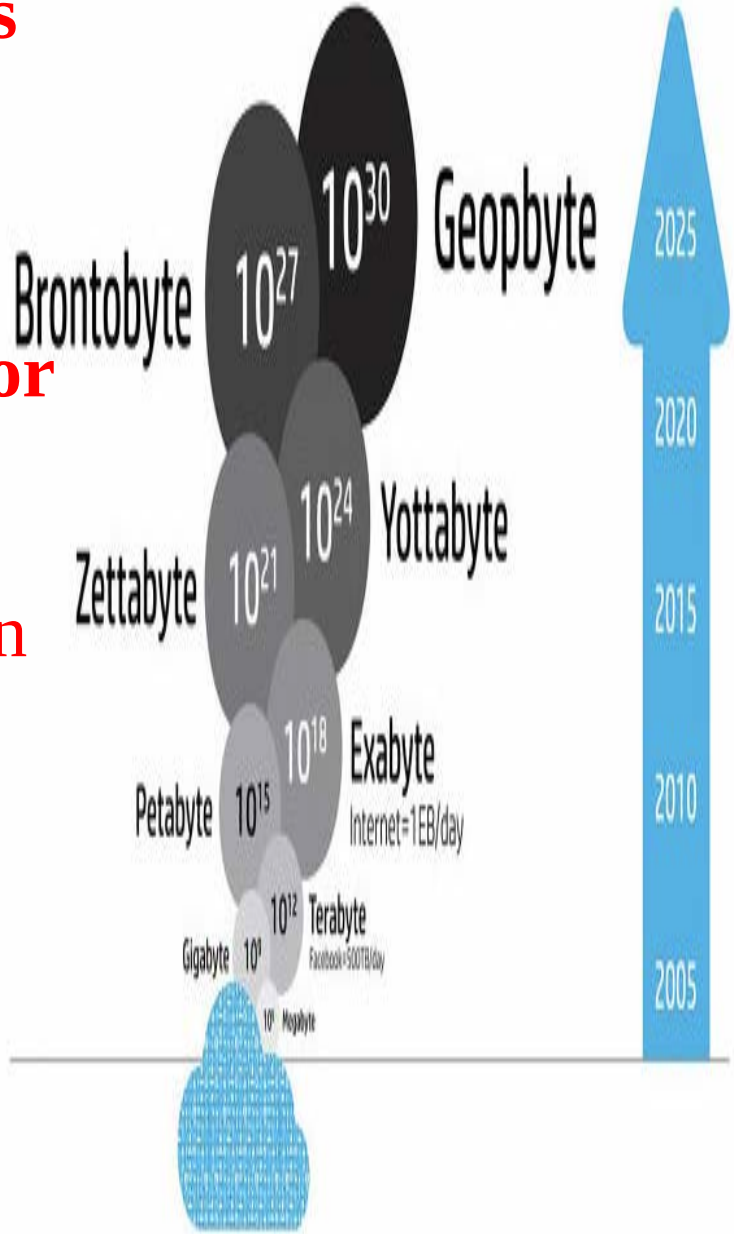

Image: DOT NHTSA

Open Data: Santa Clara VTA

https://data.vta.org

Sign Up Sign In

VTA OPEN DATA

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Transit Operations

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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.

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

Image: Santa Clara VTA

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

✓ **<u>Insights</u> like these can help city & tranportation authorities design <u>efficient</u>, <u>cost-effective</u>, <u>sustainable</u> <u>transportation</u>.**

Image: HubCap

Dynamic Design of Public Transportation: Self-Driving Shuttle (1)

Video: Consumer Reports

Dynamic Design of Public Transportation: Electric Bus/Tram Systems (2)

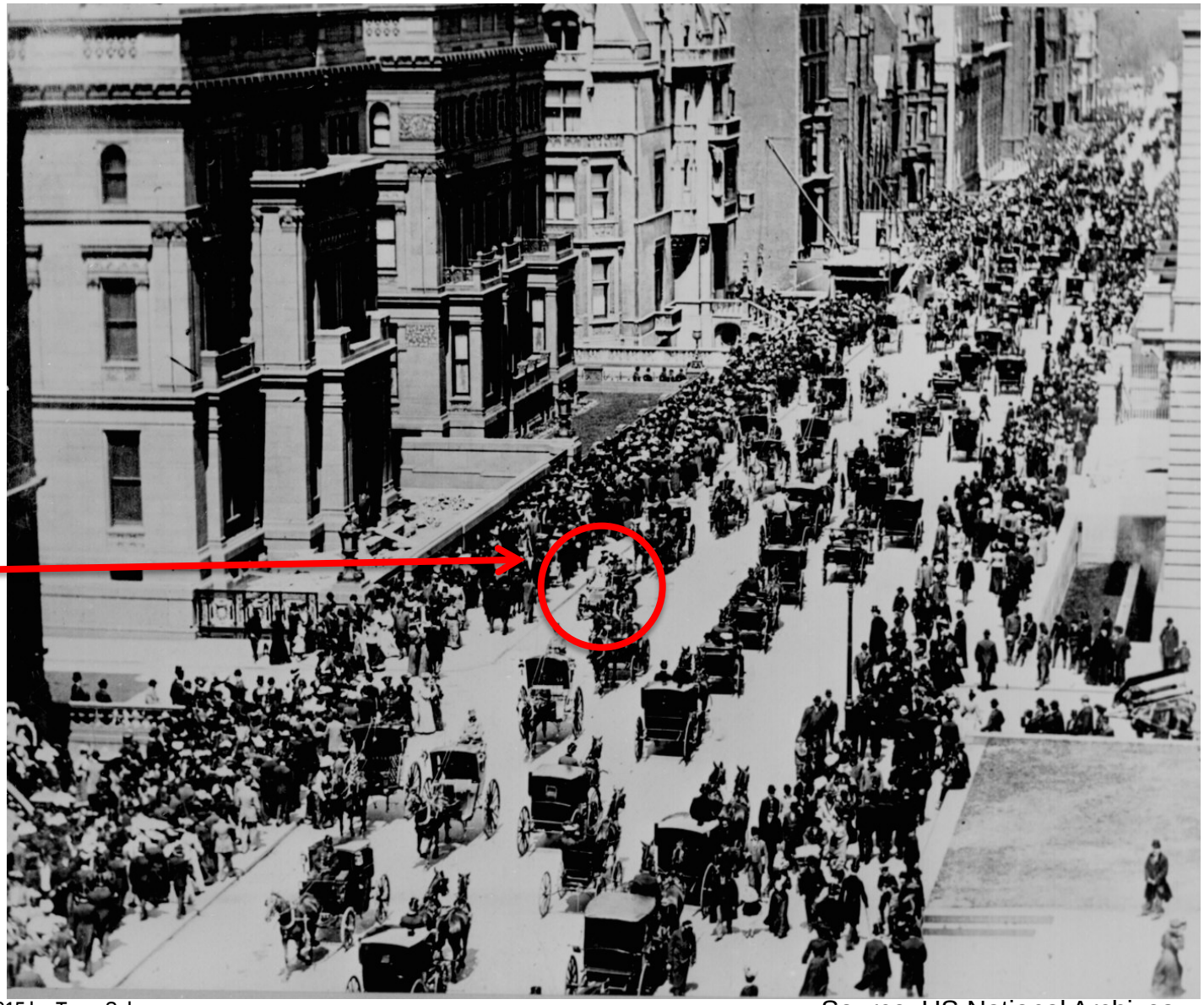
- ✓ **<u>Battery Electric Bus/Tram</u> Technology that allows transportation authorities to design new routes based on real-time data insights**
  - ➢ **dynamically, efficiently, and cost-effectively**

Image: Bombardier

SUMMARY

Summary: Disruption of Transportation

2015: we are HERE



Source: US National Archives

2015 – Clean Disruption of Energy & 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**.

Image: © Tony Seba

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!

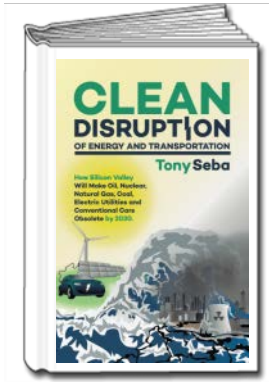
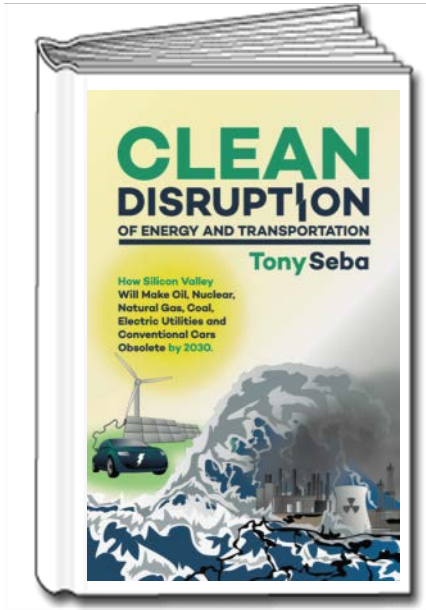


Photo:Tony Seba

THANKS!

Q&A



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CA Transit Association

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