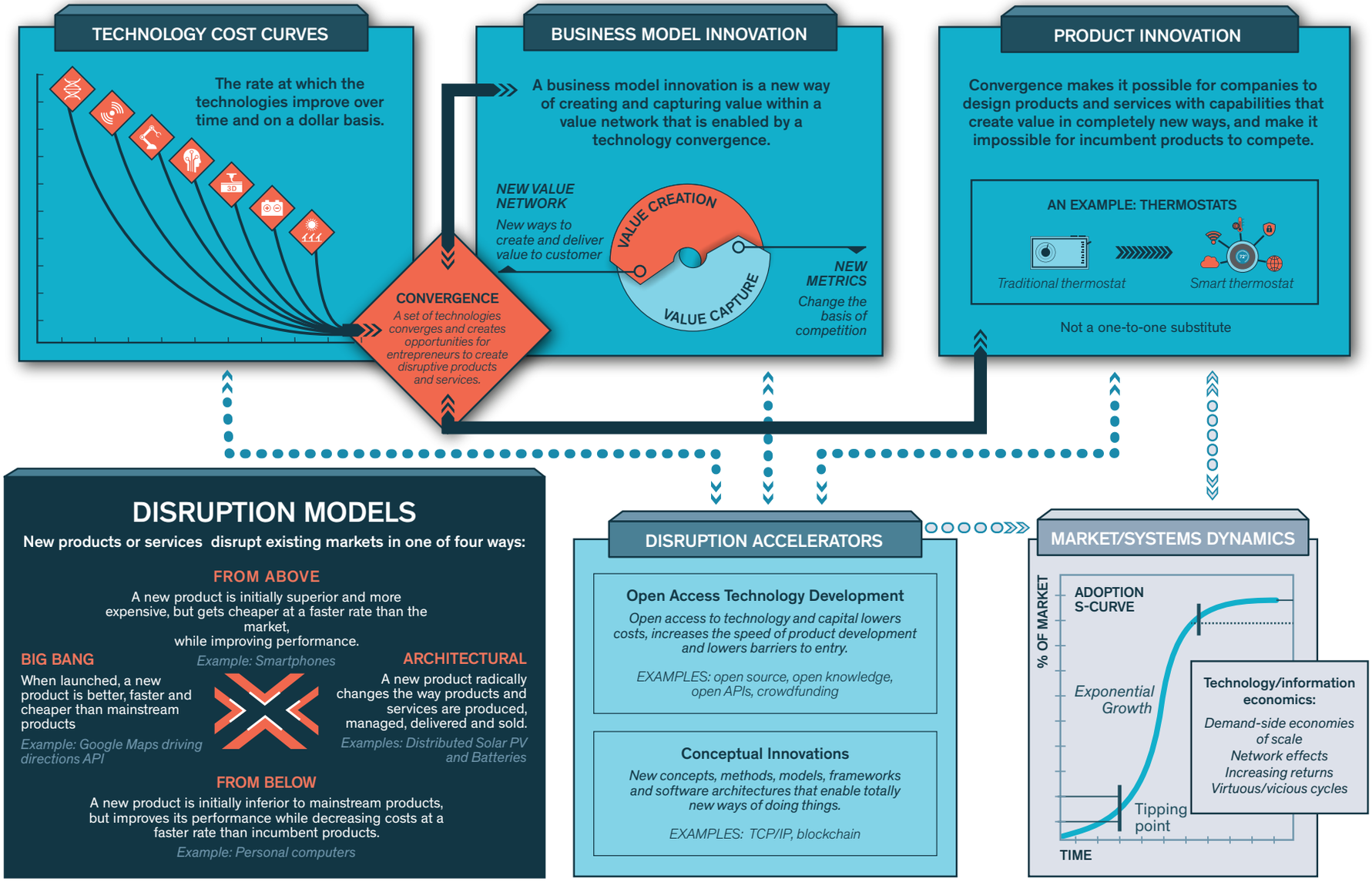
Seba Technology Disruption Framework™

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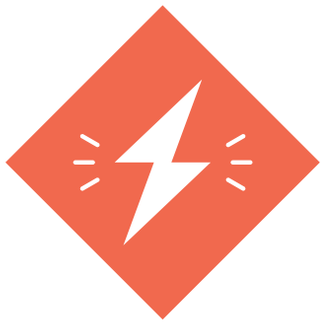
The Seba Technology Disruption Framework™

The Seba Technology Disruption Framework™ was created by Tony Seba. This framework is the result of more than a dozen years of research, publishing and teaching courses including “Strategic Marketing of High Tech Products and Innovation”, “Business and Revenue Model Innovation”, “Finance for Entrepreneurs” and “Anticipating and Leading Market Disruption.” Seba has taught thousands of entrepreneurs and corporate leaders at Stanford Continuing Studies.

The framework was the backbone of Seba’s book “Clean Disruption” (July 2014) which has accurately predicted the ongoing disruption of energy and transportation due to technologies such as batteries, electric vehicles, self-driving vehicles and solar PV and business models such as ride-hailing.

The framework is used by independent think tank RethinkX to analyze and forecast the scope, speed and scale of technology disruption and its implications across society. RethinkX published its first sector report “Rethinking Transportation 2020-2030" in May 2017. Co-authored by James Arbib and Tony Seba, the report concludes that we are on the cusp of the fastest, deepest, most consequential disruptions of transportation in history.

Here is a primer that summarizes the Seba Framework.

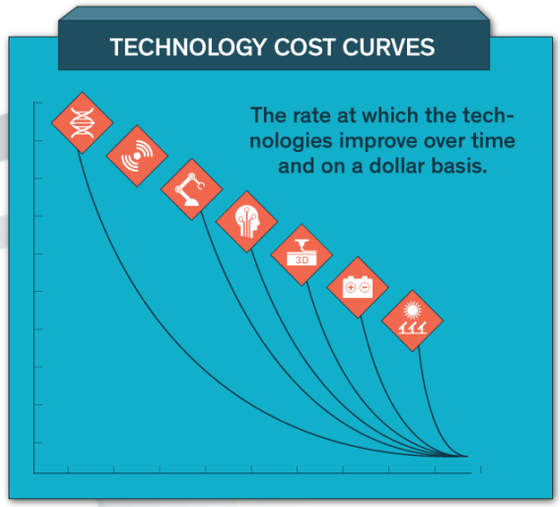


Disruption: A disruption happens when new products and services create a new market and, in the process, significantly weaken, transform or destroy existing product categories, markets or industries.

The digital camera disruption destroyed the film camera industry. However, disruption does not always imply the destruction of an existing market. For instance, the web significantly weakened but did not destroy the newspaper publishing industry. Ride hailing has radically transformed the taxi industry, but has not (yet) destroyed it.

Disruptions are made possible by the convergence of technologies and business-model innovations enabled by these technologies. Disruptions are also accelerated by open access technology development.

Convergence: Several technologies, each one improving at a different rate, converge at a certain point in time to make it possible for new products or services to be developed. Apple and Google launched the iPhone and Android products within months of each other in 2007. That's because the convergence of technologies that made the smartphone possible — in terms of bandwidth, digital imaging, touchscreen, computing, data storage, the cloud, lithium-ion batteries and sensors — all happened around 2007. By combining technology cost curves and business model innovations, the Seba Technology Disruption Framework can help anticipate when a given set of technologies will converge and create opportunities for entrepreneurs to create disruptive products and services. For example, Seba's book "Clean Disruption" (2014) accurately predicted that the market would commercialize electric vehicles with 200-mile range at a cost of $35,000 to $40,000 (unsubsidized) by 2018. The GM Bolt and the Tesla Model 3 — leading a wave of such EVs — are now being pre-sold by the hundreds of thousands.



Technology cost curves: Technologies have cost-improvement curves, which show the rate at which a given technology improves over time. The best known technology cost curve is Moore's Law, which postulates that computing power doubles every two years or so. The Seba Framework studies the economic side of these technology-improvement curves; that is, it looks at how a given unit improves on a per-dollar basis. For instance, when analyzing batteries, the metric we may look at is cost in dollars per kilowatt-hour.

For lithium-ion batteries, the cost per kilowatt-hour ($/kWh) improved at a 14% rate between 1995 and 2009.[1] Technology cost curves improve due to a combination of factors, including increased investments, research and development, manufacturing scale, experience and learning effects, openness, competition, standards, ecosystem integration, application across industries and the size of the market(s). Solar photovoltaic, when measured in dollars per watt ($/W) has improved from about $100 per watt in 1970 to about 33 cents per watt in 2017. This is an improvement rate of about 11.4% per year.

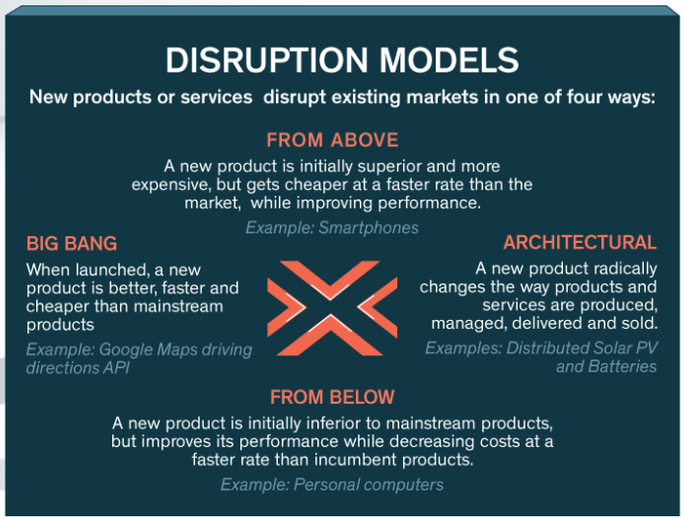
When we look at technology cost curves, it's important to know what the main driver of the improvement is. Swanson's Law postulates that solar PV costs tend to fall by about 20% for every doubling of cumulative shipped volume.[2] Therefore, in the case of solar PV, the technology cost curve is mainly driven by volume, not time. Seba predicted in his 2009 book "Solar Trillions" that the cost of unsubsidized solar energy would be as low as 3.5 cents per kilowatt-hour by 2020, thus beating oil, coal, and nuclear. This prediction has recently come true.[3] Demand for both coal and nuclear have peaked and declined, and market values of listed companies in both industries have collapsed as a result.

Exponential Technologies: Technology cost curves and their underlying performance improvement rates vary widely. Information and communication technologies have had high annual improvement rates (Moore's Law has been around 41% per year), while solar PV technology has improved comparatively slowly (11.4% per year). The concept of exponential technologies, coined by Ray Kurzweil, refers to very fast technological change.[4] While he didn't draw a clear line as to what improvement rate makes a technology exponential, his work has emphasized technologies that double their performance every year or two. Moore's Law points to a doubling of computing performance every two years, while wireless communication was improving even faster, doubling performance every 10 to 11 months. The power of exponential technologies is that their performance vastly exceeds the human brain's mostly linear comprehension of growth. For instance, Hendy's Law postulated in 1998 that digital imaging had been improving at about 59% per year (measured as pixels per dollar). A 59% cost curve implies that the technology would improve by about 100 times in ten years, 10,000 times in twenty years, and 1 million times in thirty years. Steve Sasson invented the first digital camera in 1975.[5] If Kodak had applied Hendy's Law to Sasson's invention, it would have predicted that in 2005 a $100 digital camera would perform at a level that would have cost $100 million to achieve in 1975. Kodak's profits peaked in 1999, and the company went bankrupt in 2012.[6] Both Hendy and Sasson worked at Kodak at the time of their discoveries. Other exponential technologies include sensors, artificial intelligence, 3D printing and DNA sequencing.

Technology cost curve improvement rates are not static. Sometimes they slow down temporarily or permanently. For instance, the internal combustion engine, which helped enable the car disruption of horse transportation a century ago, has not materially improved in decades. Small improvements in the cost-to-performance ratio of these technologies may require massive investments. Technology cost curves can also accelerate. Batteries improved by 14% annually for about 15 years. This improvement enabled computer laptop computers, and later, smartphones. From 2010 to 2016, lithium-ion batteries improved by about 20% per year.[7] As the cost per kilowatt-hour of lithium-ion decreases it helps to enable new markets, such as grid storage, residential electricity storage, unmanned aerial vehicles, and robots. The virtuous cycle continues to drive down costs where it can converge with other technologies to help enable disruptions of different markets at different points in the technology cost curve.

Disruption models

The Seba Technology Disruption Framework™ includes four key models that clarify how disruptions take place.



1. **Disruption from below:** *(Clayton Christensen)* A new product or service that is originally inferior compared to what the mainstream market offers improves its performance while decreasing costs at a faster rate than incumbent products.[8] This faster rate of improvement is due to cost curves of the key technologies used to develop the product. This product may initially serve the needs of niche markets, and as it improves its utility, it expands into new markets. Eventually it overtakes and disrupts incumbent products and markets. Examples include personal computers and solar power.

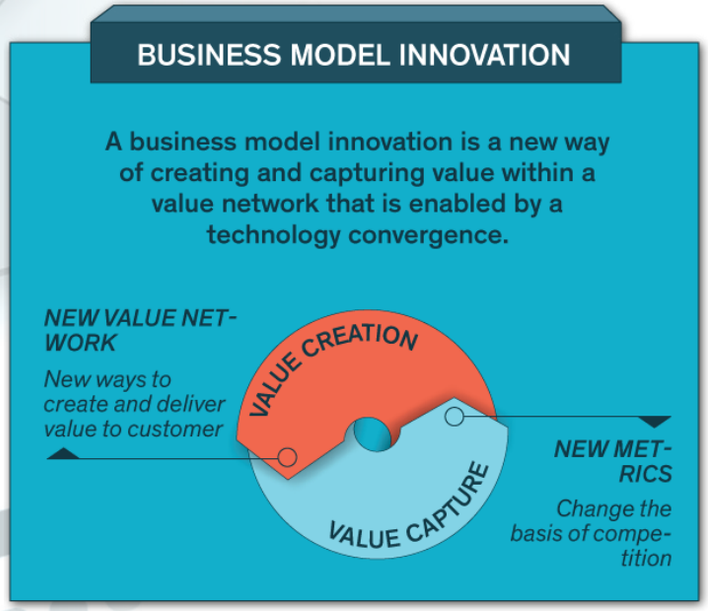
2. **Disruption from above:** *(Tony Seba)* A new product is superior but more expensive than competing products in the mainstream market. In time, however, the cost of the product is lowered until it becomes less expensive than incumbent products. By understanding the technology cost curves of the disrupting product, it is possible to predict when the disruption will take place. It is important to note that many times, these disruptive products are not just one-for-one substitutes, so analysts and industry experts don't understand the coming disruption. The smartphone is a recent example. When the Apple iPhone came out at about $600 in 2007,[9] experts said that it was not disruptive. Who would want to buy a $600 phone when they could buy a $100 Nokia cell phone?[10] What they did not understand is that a smartphone is not just a phone. An iPhone is a platform that allows us to do hundreds of things, including finding a date, getting driving directions, doing online banking, and, yes, making phone calls. The smartphone is not and never was a one-to-one substitute for the conventional cell phone. The electric vehicle (EV) is another example of a disruption from above. The EV is a superior product in a number of ways, not just an electric version of an ICE car.[11] "Clean Disruption" lists nine reasons why the EV is disruptive. For instance, the battery in an EV allows us to power an average American home for a day or two (and up to two weeks in India).

3. **Big bang disruption:** *(Larry Downes and Paul Nunes)* A new product is better, faster, and cheaper than mainstream products on the day it is launched.[12] Incumbent products have little or no time to react and are quickly disrupted. Examples include Google Maps with driving directions API, which disrupted the then growing GPS market served by companies like Tom Tom and Garmin. The Transportation as a Service (TaaS) disruption highlighted in this report is a Big Bang Disruption.

4. **Architectural disruption/Disruption from the edge:** *(Seba)* A new product radically changes the way products and services are produced, managed, delivered, and sold. The architecture of the conventional electric power industry is centralized: it generates electricity with a small number of large power plants and delivers the electricity to millions of customers downstream in real time. Solar energy and batteries flip the architecture of electricity: they enable millions of customers to generate, store, manage, and trade electricity. When the cost curves of solar and batteries (plus sensors, power electronics, software, and new business models) converge, the central generation model is disrupted. At that point, the architecture of energy flips from central generation to distributed generation. Architectural disruption is thus not just about technologies disrupting an existing market from below or above. Solar PV (plus storage) is disrupting every form of conventional power generation (coal, nuclear, natural gas, diesel). However, even solar (plus storage) generated in large power plants will not be able to compete with on-site (rooftop) solar (plus storage). This is an architectural disruption. The reason is that on-site generation and storage does not need the expensive transmission infrastructure needed to bring energy generated at large-scale centralized plants to where the demand is.

Other models

Systemic disruption: Disruptions can potentially have devastating effects far beyond a single market category, causing whole sectors of the economy to be disrupted as a result. TaaS using on-demand, electric autonomous vehicles is not just disruptive to the ICE car manufacturing industry. It also has devastating effects on the oil industry as well as parking, insurance, car leasing and car dealerships. Like dominoes falling, it may also trigger dramatic impacts on shipping, logistics, real estate, and infrastructure, and the bond and equity markets. Tens of trillions of dollars (beyond vehicles) may be at stake because of the TaaS disruption.



Business model innovation: Business model innovation is every bit as disruptive as technology innovation. A business model includes the core logic and strategic choices for creating and capturing value within a value network.[13] A business model innovation is a novel way of creating value and capturing value within a value network that is made possible by a technology convergence.

Disruptive business models may have a totally new logic and new set of metrics that change the basis of competition, and make it extremely difficult (or even impossible) for incumbents to adapt or to win.

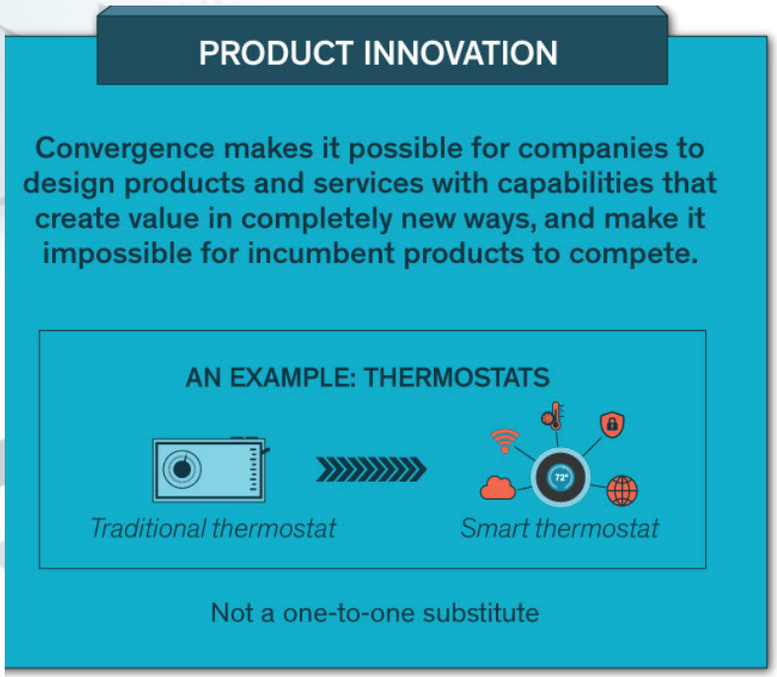
For example, ride-hailing (Uber, Lyft, Didi) is a business model innovation enabled by the convergence of smartphones and the Cloud. This convergence enabled instant connections and geographic matching between individual passengers and drivers with spare capacity in a highly efficient, convenient and cost-effective way. Ride-hailing (also called ride-sharing) companies applied a brokerage business model by taking a cut of every transaction.

Similarly, Airbnb is a business model disruption. Another example: the solar energy industry in U.S. residential and commercial markets grew exponentially after the introduction of a new business model called zero-money-down solar. In this model, the solar provider would finance, install and even own the solar panels. Traditionally, homeowners had to purchase the panels upfront. But the new business model allowed them to purchase or lease them like they did a car: with no or little money down, and agreeing to a set monthly payment for several years.

Note that the business models don't have to be entirely new. Uber and Airbnb use the age-old brokerage business model, while solar borrowed the car lease and car loan models that have been used in the auto industry for a century. These business models were used in new settings to solve different problems, and were made possible by technology convergences.

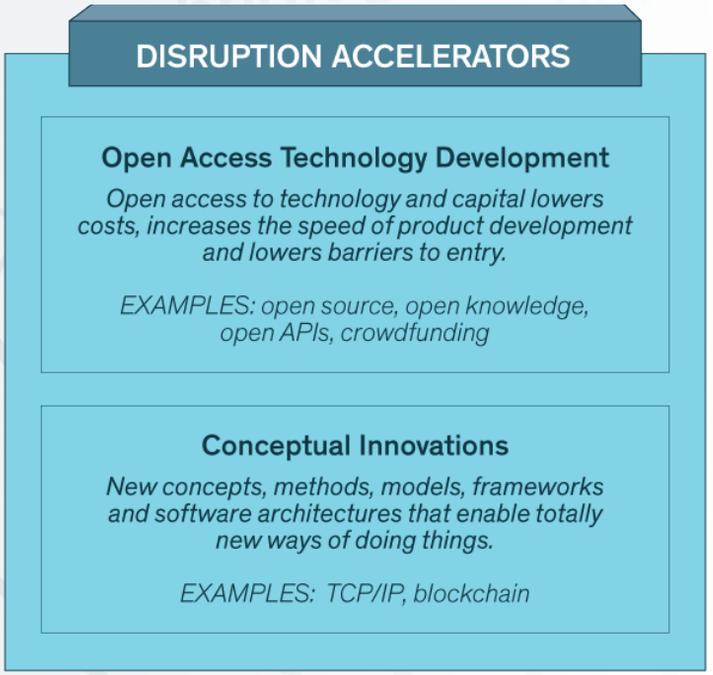
Value network: Disruptors may leverage portions of existing value networks — a connected series of organizations, resources and knowledge streams involved in the creation and delivery of value to end customers — within and outside the industry they are disrupting, and/or create totally new networks that bypass the incumbents and reach customers in new ways. For instance, Tesla used the value network of the consumer electronics industry to source its batteries, hired people from the computer and auto industries, and created its own stores to reach customers directly, bypassing the auto industry's dealer channel.

Metrics: Disruptive business models may create a totally new set of metrics that change the basis of competition and make it extremely difficult (or even impossible) for incumbents to adapt or to win. New industries create new metrics for success. Companies measure themselves and organize their resources around those metrics, and the market rewards companies that are best at optimizing those metrics. As an example, the music industry traditionally measured success as a function of album or CD units sold. These metrics dominated over other indicators (e.g., number of songs per album or number of times songs were played). Industry awards were created to reward those who maximized those metrics: Gold Records (500,000 sold) or Platinum Records (1 million sold) were designed to reward recording artists who maximized those metrics. The advent of Internet streaming (or music as a service) disrupted this metric, ushering in a new key metric: number of plays per song. This new metric changed the basis of competition, bringing with it a totally new set of industry dynamics. Music-industry CD revenues plunged 84% in one decade, from $9.4 billion in 2006 to $1.5 billion in 2015, driven by on-demand streaming music.[14] Streaming came "out of nowhere" to generate $2.4 billion. Streaming companies are software companies with zero marginal costs that generate revenues with a number of business models. By one measurement, it takes 1,500 streams to equal the revenues of one album sale.[15] Traditional companies pushing CDs cannot possibly compete with streaming. Companies that organize themselves around pushing CDs cannot possibly compete in the new business environment. Similarly, Software as a Service (SaaS) companies (like Salesforce.com) ushered in new metrics that traditional software companies (like Oracle and SAP) could not compete with. They had to adapt or die.



Product innovation: Technology convergence makes it possible for companies to design products and services that solve customer problems in new ways. These products may have capabilities that create value in completely and heretofore unimaginable new ways, and they may make it impossible for incumbent products to compete.

The NEST Learning thermostat is an example. The convergence of sensors, mobile communications, computing, artificial intelligence, and the cloud made the product possible. The NEST learns users' patterns and behaviors and adjusts temperatures automatically to match their comfort levels. To minimize energy usage, the thermostat adjusts the temperature when the user leaves for work. An app that runs on smartphones makes it possible for the user to tell the thermostat to turn the heater or air conditioner on or off remotely. Using sensors, the NEST knows when a user is home, and uses artificial intelligence to adjust temperatures accordingly. It also has the capability to communicate with the utility to learn electricity prices, and to switch the heater and air conditioner on and off to save money while keeping temperatures within user comfort ranges. For instance, in the summer, it can "pre-cool" a home before the daily peak pricing period starts, and then turn the air conditioner on and off to maintain a comfortable temperature range while saving the owner money. Traditional thermostats could not possibly do this. Additionally, the thermostat communicates with the NEST Protect smoke and carbon monoxide detector. For example, upon learning from Protect that there is a carbon monoxide leak, the thermostat can shut down the furnace, a potential cause of the leak.[16]



Disruption Accelerators

Open access technology development (OATD): Open access allows knowledge, skills, data, technologies, inventions and products to be developed at an increasingly faster and potentially disruptive pace. Open access to capital enables entrepreneurs to create products that would otherwise not have been funded by traditional investors.

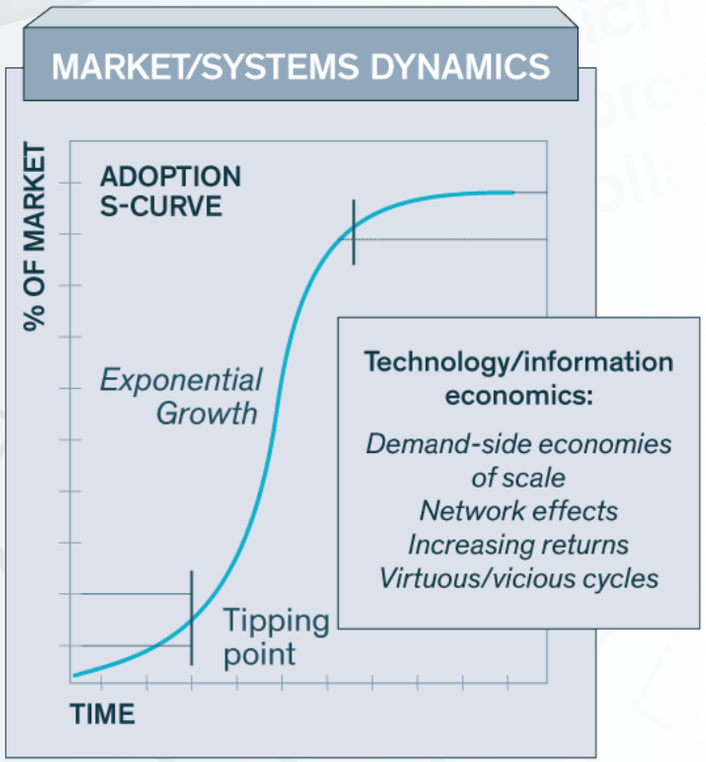
The following are dimensions of an open access technology development ecosystem that can contribute to the acceleration of disruptions:

- Open **data** (Example: Climate.com)
- Open **content** (Wikipedia, Safecast)
- Open **knowledge** (Udacity, Coursera, Kahn)
- Open-source **software** (Android, Linux)
- Open-source **development/collaboration** (GitHub)
- Open-crowd **product development** (Quirky)
- Open **innovation** (Innocentive)
- Open **research** (Materials Project)
- Open **business models** (MySQL, RedHat)
- Open **APIs** (Google Maps, OpenAI)
- Open **funding**/crowd funding (Kickstarter, Indiegogo)

Open access lowers barriers to entry and lowers the cost and increases the speed of product development. It also reduces the ability of established companies to defend market positions, pricing power, and longevity of cash flows from existing products and services. Open access reduces advantages of scale, and reduces the need for corporations to build technology in-house. It allows anyone, anywhere to compete, leading to a dramatic increase in the number of competitors – and potential disruptors.

Silicon Valley is an example of an **open access technology development ecosystem** (OATDE) that combines the above dimensions within one geography. But the benefits and disruptive power of OATDE are spread around the world. For instance, the exponential growth in robotics development over the last decade has been enabled by an open-source operating system called ROS or Robot Operating System. ROS was initially developed at Stanford University and is now managed by the Open Source Robotics Foundation.[19] Anybody anywhere around the world can download ROS for free and use it to create a new robot. Companies from MIT spinoff startup RethinkRobotics to French humanoid robot developer Aldebaran have used ROS to develop robots for different uses and industries. If an engineer needs to learn artificial intelligence for robotics, she can go online to a website such as Udacity and take a free course offered by Georgia Tech.[20] And while she's at it, she can learn how to program a self-driving car, and maybe win $100,000 in the process.[21] There are almost no barriers to a smart, committed engineer learning artificial intelligence and robotics to develop an autonomous vehicle. After doing that, it is possible to raise funds on a site like Kickstarter to take the product to the next level. If the entrepreneur wants to develop the whole vehicle, she can go to OSVehicle.com and use its open-source electric vehicle hardware platform.[22] One hour of assembly required. A small team of engineers based purely on OATDE can disrupt a billion-dollar car company in Detroit, Toyoda, or Wolfsburg. This team can learn artificial intelligence for free, use free operating systems that they learned to program for free, access open-source electric vehicle hardware platforms, and raise money openly on a crowdfunding site.

Conceptual innovation: New concepts, methods, models, frameworks and software architectures enable totally new ways of doing things. Packet switching led to the development of the Internet Protocol Suite (commonly known as TCP/IP or Transmission Control Protocol / Internet Protocol), a new conceptual model of communications that led to the development of the internet.[17] Blockchain is an open, shared, immutable, distributed ledger for recording the history of transactions (blocks).[18] Like the internet, Blockchain is a conceptual innovation that can enable a wide range of new uses that were not possible before. For instance, when Blockchain converges with technologies such as distributed solar PV, batteries, sensors, mobile communications and artificial intelligence, it could enable new forms of transactions between devices within the home and between neighbors, and cities — where the metric of value is a kilowatt-hour, rather than a dollar or a Euro – while bypassing the utility (or the government) as the centralized trusted payment intermediary. Conceptually, this could never have been done before, but now trust can be distributed and transaction sizes can be dramatically smaller and cheaper when using Blockchain.



Market and systems dynamics: Markets are complex adaptive systems. In complex systems, causal relationships are seldom (if ever) linear, and changes in single variables can trigger quick, exponential and massive effects. Technology markets are made even more complex as many technologies changing at different rates converge, enabling products and business models that were once impossible to develop or even conceive. Open technology development accelerates these converging interrelationships even further. Additionally, technology markets have characteristics such as increasing returns, network effects, and adoption characteristics that enable disruptions to happen at increasingly faster rates and in ways that industrial-era resource-based industries cannot comprehend, let alone compete with. That's because mainstream analysts tend to see markets as stable, linear, and relatively simple systems.

A reason for linear thinking is that the industrial era relied on supply-side economies of scale. Known simply as "economies of scale," this norm posited that companies (and industries) gain cost advantage based on increased output, size, or scale of production.[23] The larger you are, the more you produce, the less the unit of output costs. This in turn gives the company an advantage in the marketplace. Industrial-era businesses such as car companies, steel manufacturers, and conventional power-plant operators run by this principle: bigger is better.

Technology markets flip that equation because of information economics. Demand-side economies of scale are a function of the number of users, rather than the number of units of production. The more users a product or company has, the more utility it generates, both for other users and for the company that offers the product. Google search is an example: the more users use its search engine, the more data it generates, the more it learns, the more knowledge it generates, and the better its products get for all users, which leads more users to use it, and so on. That is, Google's search engine exhibits increasing returns: each additional unit of output is cheaper to produce than the previous one. Google's value does not derive from the company's massive data centers, but from the users of its search engine.

In his 2006 book "Winners Take All," Seba described many characteristics of technology markets that created winners such as Apple, Google, Netflix, and Salesforce.com that have created platforms that exhibit increasing returns. There are no limits to the growth of knowledge, which makes these companies extremely valuable, especially when compared with traditional industrial and extractive industries. These four companies alone have created more than $1 trillion in wealth since Seba published "Winners Take All." Not coincidentally, several of these companies are also developing some of the key technologies that are enabling the disruption of transportation described in this report.

Network effects: Demand-side economies of scale become powerful when users are inter-connected in networks. The value of the underlying network can grow exponentially with the number of users and connections that they have with one another. Think of the original telephone, or email network, or Facebook. If one person has a telephone or email or Facebook, it's useless. When a second person joins the network, then you can connect with one person. Once a third user adopts, then each existing user can connect with two people. By the time a tenth user joins the network, each user can connect with nine other people, and the total combination of possible calls, emails, or connections is about 90. Once the millionth person joins, there are just under one trillion possible connections. Note two things: the first is that each time a new user adopts the technology, the value of the network increases for existing users. They get more value at no cost to them. Secondly, the value of the network increases exponentially; i.e., the formula is calculated to be around N ^ 2 - N, where N is the number of users (this is called Metcalfe's Law).

Network effects virtually guarantee winner-take-all markets. There's no number-two network to Facebook. Operating systems like Microsoft Windows, Apple iOS, and Google Android have network effects. The value of the operating system increases with the number of users, which attracts software developers who create apps, which attract even more users, and so on, driving exponential growth in value. This virtuous cycle of value creation is the reason Apple, Google, Facebook and Microsoft have market valuations of hundreds of billions of dollars. In fact, these four companies plus Amazon are the five most valuable companies in the world, with a combined $2.6 trillion in market valuation (as of March 27, 2017).[24]

Technology adoption lifecycle S-curve: When Steve Jobs launched the Apple iPhone in 2007, mainstream experts and analysts from Bloomberg BusinessWeek to the Capital Group didn't give it a chance. Bloomberg's analyst wrote: "The iPhone's impact will be minimal. It will only appeal to a few gadget freaks. Nokia and Motorola haven't a care in the world."[25] Ten years later, there are 2.6 billion smartphones globally.[26] Whole industries have been launched because of the smartphone, and we could not imagine life without it.

Mainstream experts fail to appreciate that the technology adoption lifecycle is exponential, not linear. Adoption proceeds along an S-curve, where the early adopters who represent a small percent of the market set the stage for massive exponential growth as soon as the early mainstream users adopt a product or service.

Now that the smartphone has become a mainstream product, the expectation is that 6.1 billion users will have one by 2020.[27] The total world population is expected to be 7.6 billion by 2020.[28] That is, nearly every woman, man, and child on earth will use a smartphone just 13 years after its introduction. Not bad for a product whose impact was expected to be "minimal" by mainstream analysts.

S-curve acceleration: The adoption S-curve has accelerated over time. It took the telephone 75 years to reach 50 million users. Radio reached 50 million in about half the time: 38 years. The television did it in a third of the time it took the radio -- 13 years -- while the computer tablet reached 50 million in about a sixth of the time it took the radio: two years.[29] The rate of acceleration has itself accelerated.

End Notes

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TONY SEBA

Tony Seba is a world-renowned author, thought leader, speaker, educator and entrepreneur. Seba is the author of the #1 Amazon best-selling book "Clean Disruption of Energy and Transportation - How Silicon Valley Will Make Oil, Nuclear, Natural Gas, Coal, Electric Utilities and Conventional Cars Obsolete by 2030", "Solar Trillions" and "Winners Take All".

Seba is a co-founder of RethinkX, a think tank that analyzes and forecasts the scope, speed and scale of technology disruption and its implications for society and co-author of "Rethinking Transportation 2020-2030".

Seba is the award-winning creator of the Seba Technology Disruption Framework™. His work focuses on technology disruption, the convergence of technologies, business model innovation and product innovation that is leading to the disruption of some of the world's major industries, such as energy, transportation, infrastructure, food, real estate, health care, and services. He has taught thousands of entrepreneurs and corporate leaders at Stanford University's Continuing Studies.

A serial Silicon Valley entrepreneur and angel investor, Seba was an early employee at Internet powerhouse Cisco Systems and RSA Data Security and the co-founder and CEO of PrintNation.com, a venture-funded company that disrupted the commercial printing industry.

Seba has been featured in leading global media, including BBC, NBC, The Wall Street Journal, the Washington Post, Bloomberg, CNBC, ARD TV, and TV Chosun. Seba has been a keynote speaker at hundreds of global events and organizations including Google, the European Commission, CLSA, J.P. Morgan, Nomura, Davos, COP21 World Climate Summit, Intersolar and Global Leaders Forum. His speaking engagements have included investors with more than $30 trillion in Assets Under Management.

Seba has a Stanford MBA and a B.S. in Computer Science and Engineering from Massachusetts Institute of Technology.

www.tonyseba.com

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