The Next Great Technology Surprise! *Surprise?*

White Paper

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Introduction

What is the next great technology breakthrough? How do we anticipate the next technological threat or, on the more positive side, opportunity? How can we stay ahead of the stampede so we avoid the consequences of being trampled or destroyed by new technology in the hands of our competitors or enemies?

How does a bottle of Dom Pérignon champagne offer a Science and Technology (S&T)[1] lesson?

It is tempting to think that "game-changing" or "disruptive" technology bursts upon the scene without warning. History yields the unexpected message that the influence and application of technology tends to be agonizingly slow and evolutionary. Technology is a catalyst, an enabler, not a direct cause of change. It is the way true leaders, those who take us "where no one has gone before," *think* about and *visualize* technology that drives change and opportunity.

What is sometimes a surprise is the magnitude and rate of success of an application. Apple's iPod®, clever and innovative, is not a technical surprise; the pervasiveness of its acceptance, especially at its initial price point, may be.

This paper explores ways to think about technology that may help identify and exploit the next great technology. It focuses on three ways to help understand what and how innovations succeed.

- Recognizing potentially high impact technology
- The time span from discovery to practical application
- Attitudes that block innovation or inhibit development.

The technology that will influence our lives, our security, and our businesses over the next 20–40 years already exists, if only in discovery or prototype form. Examples are described every day in popular and arcane professional magazines, on the Internet, and in the news; and explained and demonstrated on cable's technology-oriented television programs. It is easy to overlook the implications of those discoveries by focusing only on the dazzling technology.

The magnificent benefits to be derived from such technological wonders as anthropomorphic robots, e-media, multi-functional "sixth sense" personal electronics (implants?), renewable energy, electric vehicles, non-lethal weapons, cures for cancers, holographic conferencing, and hypersonic transportation are intriguing. It is also useful to remember that this is a world where well over half the population has never traveled farther than 20 miles from home nor gone faster than 20 miles per hour and lacks a reliable or safe source of potable water. 1.6 billion people have no access to electricity. In such an environment, the introduction and implementation of advanced technology may be measured in decades rather than years. The practical basics such as cheap, reliable water purification or desalinization may have the most profound impact.

[1] *S&T*, *Science and Technology*, is, for these purposes, synonymous with the term *R&D*, *Research and Development*.

The invention of the transistor in 1947 brought about radical possibilities. It was initially viewed as a mere substitute for a vacuum tube, an amplifier—something to do the same job, but smaller and using a fraction of the power. Less obvious at the time was the fact that it was also the essential stepping stone to integrated circuitry, economically viable computers, Sony Walkmans®, Apple's iPod®, "bag phones", then cell phones, and a long, long list of other applications. The small, solid-state transistor was enabling technology that has changed so much across so many consumer, industrial, and military venues.

To recognize and economically exploit technology, the focus has to shift quickly and creatively away from a technology itself and toward what that technology can attempt and accomplish.

Technology or Application?

There is value in anticipating the impact of technology. Identifying the technology is part of the process. Notionally, think in terms of the ubiquitous functional block diagram with an input and an output. *Technology by itself takes an input and transforms it without additional art or skill*. Any person or event initiating the transformative process of using pure technology will get precisely the same results as any other person. A transistor is pure technology by this definition. A smoke detector triggering an alarm is pure technology. A traditional metal lathe is pure technology, but skill is required to operate it successfully. The output of the lathe depends upon both technology and skill or art. An aircraft is technology. Landing a commercial aircraft in the Hudson River with no fatalities is far more. Sometimes in application, technology needs an assist from the artisan.

At first pass, often the underlying technology and the application are indistinguishable. That can be misleading. The iPod®, Facebook® and YouTube® are radical implementations of existing technology but were not new technology at the time of their introduction. The Segway Human Transporter®, both innovative and radical, is a sophisticated integration of existing technology. The transistor was new technology, initially applied as a mundane substitute for vacuum tubes, but ultimately pervasive in application and at the root of immeasurably extraordinary, though not immediate, change. These examples are all terrifically creative and impressive.

Sometimes technology is a building block. The transistor does nothing useful by itself. It is essentially useless until it is part of a system. This characteristic, too, is an important concept in thinking about the impact of technology.

The overnight air freight business is an example of something not thought of as "technology." It uses technology; e.g., airplanes and ground vehicles. It is also a business that is dependent upon proprietary algorithms. The algorithms are the technology. In fact, the large air freight businesses strive to eliminate from their processes the variability introduced by people and will probably be the first commercial organizations to fly unpiloted air vehicles.

To grasp and exploit the potential, think loosely and broadly about "technology".

Prediction or Anticipation?

Technologies that will be pervasive and influential a hundred years from now are easy to predict with remarkable accuracy. The linear and non-linear projections of life-altering technologies for the next 5, 10, 20, and 40 years are much more difficult to recognize. The technologies that will be economically viable over the next 20–40 years already exist in basic form. Think in terms of anticipating rather than predicting the application of technology in the future. The difference is important. *Prediction* implies something mystical, something ethereal; it carries the connotation of luck and low accountability. *Anticipation* is rooted in sensitivity, experience, logic, deliberate effort, and skill.

Anticipation in Action

Schlumberger Limited is a $20-plus billion international company and a leader in the technology of evaluating oil wells and oil fields. Founded in 1926 as Sociétè de Prospection Électrique by brothers Conrad and Marcel Schlumberger and based on emerging technology, the company has a long history of success. The Schlumbergers had a vision that was beyond the current technology; but they worked with what they had, invested in proprietary S&T, and watched for the advent of the microelectronics that would enable them to place the sensors they needed in locations otherwise inaccessible.

The first transistor patent was filed in 1925 in Canada (CA 272437), and the first one granted in the US was (#1,745,175) in early 1930. The holder of both patents was J. E. Lilienfeld, who had an extensive background in vacuum tubes. But it was more than another 20 years before the first transistors were actually manufactured, and it was not until 1958 that they became commercially viable. The June, 2010, issue of *Scientific American*, citing the March, 2010, issue of *Nature Nanotechnology*, describes the first junctionless transistor, produced by a team led by Jean-Pierre Colinge at Tyndall National Institute in Ireland. This device closely matches J. E. Lilenfeld's patent. So in this case, it was 85 years from a public, formal explanation of the technology to a technology demonstration.

In a world with an emerging understanding of quantum entanglement, even aliens showing up with warp drive, although disturbing, would not qualify as a surprise.

Recognizing High Impact Science and Technology

The questions to consider looking forward in time involve change. What will change? What will it mean to individuals? To families? To lifestyles? To professionals?

At the risk of oversimplification, only two things really change—values and technology. They change over time, across cultures, across geography, and from individual to individual. They are interdependent.

Consider working definitions of values and technology.

> **Values:** "Values represent basic convictions that 'a specific mode of conduct or end state of existence' is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence. Value Systems represent a prioritizing of individual values in relation to their relative importance."[2]

To put it more simply, values represent what we are willing to invest time and money in, and value systems represent a priority for investing time and money.

> **Technology:** Tools, including processes, procedures, and equipment, which produce identical results regardless of the individual employing them.

There is a continuous spectrum from pure technology to pure art.

Other things change, of course, but in many ways the changes are driven by, or measured by, changes in values or technology. As a child grows and matures, the child's values change. Political institutions change, but they change in response to a shift in values. Our collective attitude about protecting the environment demonstrates a change in values that is driving a significant amount of S&T investment. One of the major inhibitors to the development of military submarines in the US and the UK was the belief among key decision makers that submarine warfare was immoral. Others believed it was unnecessary. Germany shared neither of those inhibitions and those values quickly changed at the beginning of the World War I in 1914. Collateral damage in combat used to be a given; today it is unacceptable. The value of high-gas-mileage vehicles varies with the price of gasoline. The value of the US going to the moon changed when the Soviet Union launched Sputnik. The value of personal technology has changed dramatically.

Successful technology implementation projects and organizations that successfully exploit technology do not focus on the technology. They focus on what the technology does.

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[2] Milton Rokeach, *The Nature of Human Values*. New York: Free Press, 1973.

Technology has the highest probability of dramatic impact in the following areas:

- Energy conversion (e.g., explosives, HVAC, efficiency, fuels, photovoltaics, …)
- Communication (e.g., smart phones, language translation, wifi, video conferencing, legal processes such as voting and court appearances, encryption, photonics, …)
- Information organization and transfer (e.g., e-book, data fusion, sensor fusion, …)
- Transportation (e.g., robotic vehicles: personal and commercial,)
- Transformation (e.g., manufacturing processes, medical/biological processes, …)
- Distribution (e.g., wireless emedia, logistics algorithms, smart electrical grids, …)

Think broadly and, in a sense, negatively as well as positively. The technology for realistic video conferencing for up to a dozen people in each of two locations is in place today. It requires dedicated facilities and bandwidth. Culturally many value face-to-face meetings; so the facilities often go unused, despite the savings they could provide in time and direct costs associated with physical meetings. Now consider a scenario such as the recent air travel restrictions in Europe due to atmospheric volcanic ash. Video conferencing might suddenly be the most attractive alternative, and people might find that they value the benefits of video conferencing, including dependability, compared to those of air travel. Demand could push the growth of bandwidth. Software might change the environment so that a person in a track suit sitting in a sidewalk café in Paris could appear as though he were in a business suit in an office. Demand could soar. But while the demand for bandwidth would accelerate, the demand for airliners, associated fuel, hotels, taxis, restaurants, even luggage, might plummet.

Recognizing high impact technology requires three things:

- Awareness and understanding of the core technology. The transistor was of minor interest as an amplifier, but when the same device was understood as a switch, it became compelling technology.

OR

- Understanding the need and scanning for the technology to fill the need. Eniac worked but needed the transformation of solid state devices to become practical.

AND

- Imagining ways to apply the technology in high impact categories.
- Recognizing the values that shape or constrain the end use and what might change those values. If there really was no market for computers in its many forms, the transistor would be an asterisk in history.

The Time Span from Discovery to Practical Application

The history of technical innovation offers three relevant lessons:

Discovery/Invention: Over the next 20 years, there will be no fundamental, profound technological *surprises* that have impact. There *will* be surprises and advantages in the maturation and application of current technologies.

Vision: The creative contribution is in recognizing the practical value, economic or strategic, of the technology and in extending its value.

Application: The professional skill is in economically applying and delivering the value of the technology. This is the "game-changing" or "disruptive" activity and it may change dramatically near term as new skills evolve. The rapidly developing skills of systems thinking, systems engineering, and modeling and simulation may initiate a revolution in the speed of application.

People tend to think that the discovery is *the* important part of the triad, but all three are essential. Fusion is an example. The early history is difficult to pinpoint and label precisely, but Einstein's published work in 1905 was critical to postulating fission and fusion. By 1925 fusion was recognized as the nature of solar physics and nuclear fusion was first observed in the lab in 1932. The first fusion bomb exploded November 1, 1952. And "controlled" fusion as a source of massive amounts of non-polluting, cheap energy is still a concept. It was more than 40 years from concept to first application; then 60 years more, so far, to the next practical application. If fusion ever becomes a source of commercial energy it will not be a technological surprise.

Aircraft is another example. Arguably either Abbas Ibn Firnas around 877 or Leonardo DaVinci around 1485 conceived the first heavier-than-air flying machine. Ibn Firnas' machine was a glider and it flew. DaVinci's was an ornithopter that probably did not fly. In 1868, John Stringfellow designed a triplane. In 1871, the first wind tunnel to study aircraft design was built in the UK. In 1874, Frenchman Félix du Temple flew a monoplane a short distance. Frenchman Clément Ader flew about 200 feet in 1890, and crashed upon landing. Based upon their four flights on December 17^{th}, 1903, and, it is speculated, on the fact that the flights were photographed, the Wright brothers are often credited with inventing the airplane. The first regular commercial flights began in 1913 and by 1918 air mail was under way. A host of other examples around the world offer evidence that others flew in the late 1800s. The detailed history is not important for this analysis. More important is that for aircraft, it was 400 to 1000 years from concept to flight then around 40 years from the initiation of serious work on a self-powered aircraft to achieving a reasonably reliable aircraft with a functional purpose beyond the marvelous curiosity of flying.

The development of practical aircraft offers another important lesson in the development of technology: all the essential elements need to be in place and adequately understood. Ader crashed because he lacked a flight control mechanism. The aerodynamics alone were not enough. Aerodynamics and propulsion were not enough. Success came when the aerodynamics were understood, a viable propulsion system was available, and the flight controls were adequate. Today, it is clear that even the Wright brothers' 1903 aircraft was a *system*.

There is an old expression, "second place is first loser." Leadership in S&T in a competitive environment requires understanding both how the technology fits within a "system" and the system boundaries.

The advent of the US military's M-16 rifle and its AR-15 predecessor is a fascinating bit of history based upon misunderstanding how a rifle is used in practice rather than in theory. The rifle was considered a piece of stand-alone technology and the ammunition, although newly designed for the rifle, was considered a separate piece of technology. From 1961 demonstrations through 1964 applications in combat, the two versions of the rifle worked well using one brand and a consistent type of ammunition. In 1964, a different type of ammunition, with a different powder formulation, was added to the inventory. Although it clearly met specifications, the new ammunition led to corrosion and associated catastrophic weapon failure in combat. Modifications to the rifle eventually resolved the issues. The point is that the rifle and ammunition were in fact a system comprising interdependent technologies necessary for successful application.

The September 28, 2009, issue of *Aviation Week and Space Technology* describes research at China Lake: "A few years ago we had the problem of getting an effect that required a small kinetic warhead [to detonate] within a few feet [of the target] …. We had the platform, the delivery vehicle and a weapon with enough accuracy. What we did not have was the [communication] pipes to get information because nobody had thought through the end-to-end, system-of-systems acquisition piece."[3] All the pieces have to be in place.

All three elements—discovery/invention, vision, and application—are essential for technology to have any influence and impact. The convergence of these three elements happens over decades, not overnight. Technology does not "burst" upon the scene; it evolves into applications over decades. So the next great

[3] David A.Fulghum, "Missiles for Rucksacks," *Aviation Week & Space Technology Magazine*, September 28, 2009, 66.

technology is here today. Of course, there is always a miniscule probability of the totally unforeseeable; however, if it is indeed unforeseeable then it is by definition futile to try to anticipate it.

Technology: Discovery to Practical Innovation

The following tables describe a condensed development cycle for several high-impact technologies. In modern history, the time span for technological development follows a general, but very loose, pattern. It takes about 20 years from discovery to practical implementation and another 20 years from practical implementation to widespread use. This is a rule of thumb, a probability distribution, not a rigid timeline. Nevertheless, it is useful counter-evidence to the belief that technology evolves rapidly. The point is to show that technology evolves; it does not materialize. People with an interest can be aware.

Table 1. Discovery to Practical Innovation —Transistors

Discovery	Time Span	Practical Innovation
The first patent for a semiconductor amplifier was granted to J.E. Lilienfeld in 1925, although there is no evidence a working model ever existed.	17 to 20 years, concept to production.	First working transistor, December, 1947. Western Electric started commercial production of transistors in 1951.
William B. Shockley wrote in his Bell Labs notebook on December 29, 1939, that it should be possible to replace vacuum tubes with semiconductors.	7 years first production to commercial product.	Regency TR-1 transistor radio introduced October, 1954,
Transistors were initially viewed simply as energy efficient substitutes for triode vacuum tubes invented in 1907.	6 more years to corner half the consumer radio market.	Sony's TR-63 was introduced in 1957, and the Zenith Royal 50 was introduced in 1960.
	85 years from first patent to demonstration.	2010, Jean-Pierre Colinge at Tyndall National Institute in Ireland produces a junctionless transistor emulating Lilienfeld's original patent.

Table 2. Discovery to Practical Innovation—Radar

Discovery	Time Span	Practical Innovation
In 1887, German Heinrich Hertz demonstrated that radio waves are reflected from metallic objects. Guglielmo Marconi may have described radar concepts in a paper delivered to the Institute of Electrical Engineers in London in 1899.	17 years from the discovery that metallic objects reflect electromagnetic radiation to the first practical demonstration.	In 1904, German Christian Huelsmeyer applied for a patent and demonstrated his "Telemobiloscope" the first practical "radar" intended to help prevent ship collisions.
Nikola Tesla suggested radio waves could be used to detect moving objects.	30 years from the first practical demonstration to renewed interest (WWII approaching) and demonstration of true radar including both detection and ranging.	In 1934, the US Naval Research Laboratory demonstrated pulsed radar over the short distance of one mile.
In 1935, a British team demonstrated their ability to identify the altitude of an aircraft at 15 miles.	(From the late 1920s and early 1930s, radar development work was going on in many nations including the US, Great Britain, Germany, Japan, Russia, France, Italy, Netherlands, Canada, Australia, and perhaps others.)	In 1937, Britain built 20 radar stations along its east coast. In 1939 Britons Randall and Boot developed the first magnetron, essential to modern radar.
	53 years to commercialization.	Practical deployment of military radar began in 1937 in Great Britain. In 1940 RCA delivered the first commercial radar.

Table 3. Discovery to Practical Innovation—Lasers

Discovery	Time Span	Practical Innovation
In 1912 and 1917 papers, Einstein describes the interaction of electrons and light.	48 years theory to first demonstration.	First ruby laser demonstrated in 1960. First CO_2 industrial cutting laser introduced in 1970.
Simultaneously with work at Bell Labs, Columbia grad student Gordon Gould conceives the modern laser November, 1957, delivers a paper and applies for a patent in 1959 that is finally granted in 1986.	13 years practical concept to first industrial application (1970–1982).	First commercial fiber optic telephone traffic in 1977. (Required room temperature continuous wave diode laser and low loss fiber.)
First ruby laser demonstrated in 1960. First laser diode 1962.	16 years first demonstration to first commercial application.	First public demonstration of optical audio disk by Sony September, 1976. Modern CD introduced 1982.

Table 4. Discovery to Practical Innovation—Digital Computers

Discovery	Time Span	Practical Innovation
Computer histories invariably start with England's Charles Babbage's work in 1821.	10 to 15 years from digital concepts to first demonstration.	Multiple devices produced in the mid to late 1940s including the famous ENIAC and Colossus Mk 1 & 2.
The history is sketchy. In France, Louis Couffignal described, but did not build, a binary computer controlled by electromagnets and punched tape, probably in the mid 1920s.	20 to 25 years from concepts to commercial application.	UNIVAC delivered to the US Census Bureau in 1951. IBM 360-series introduced in 1964. DEC introduced PDP-8 in 1965.
In 1937, George Stibitz at Bell Labs demonstrated "Model K" a relay based calculator. Unrelated, Vannevar Bush at MIT began work on digital concepts that became part of the Rapid Arithmetic Machine Project.	50 years from concept to the first practical personal computer.	The Altair "minicomputer" was introduced in 1975, arguably the first practical personal computer.
Transistors began replacing vacuum tubes, first demonstrated in 1953.		Apple I introduced in 1976, followed by the Commodore PET and Radio Shack TRS-80 in 1977.

Table 5. Discovery to Practical Innovation—Internet

Discovery	Time Span	Practical Innovation
1960 concept paper, Man-Computer Symbiosis, by JCR Licklider.	29 years from concept to implementation.	CompuServe offered the first Internet connectivity in 1989.
First public "concept" demonstration, December, 1968 in San Francisco.		ARPANET live in 1970, restricted access, non-commercial uses.
		The "Gore Bill" (High Performance Computing and Communication Act of 1991) provided $600 million to promote networking.

Table 6. Discovery to Practical Innovation—GPS

Discovery	Time Span	Practical Innovation
In 1951, Dr. Ivan Getting at Raytheon proposed GPS in response to an Air Force request.	27 years from concept to initial implementation	First satellite launched in 1978. Opened to non-military use in 1983, with limitations.
First satellite system completed in 1995.		1997 first commercial automotive products introduced
	Nearly 50 years to unrestricted availability.	Military limitations removed in 2000.

Table 7. Discovery to Practical Innovation—Internal Combustion Engine (Piston in Cylinder)

Discovery	Time Span	Practical Innovation
1823, English engineer Samuel Brown developed an 8,800 cc, 4 hp, hydrogen powered, internal combustion engine installed it on a cart, and drove up a hill.	33 years from both practical demonstration and theoretical understanding to the first commercial applications.	1856, Italian Peitro Benini demonstrated a 5 hp engine and went on to commercialize stationary engines.
1824, Carnot described the Carnot cycle (diesel).		1885, Benz Patent Motorwagen went into production. Daimler installed an engine on a bicycle.
1879, Karl Benz was granted a patent for a two-stroke engine.	42–49 years from initial demonstration and theory to broad commercial use. Availability of suitable fuel contributed to the delay. (Gasoline was a waste byproduct of kerosene production.)	
1876, Otto, Daimler and Maybach (automotive giants) had their patent for a 4 cycle engine rejected, opening the door for general use.		1892, England, Hornsby Company sold a stationary engine for water pumping.

Table 8. Discovery to Practical Innovation —Submarine

Discovery	Time Span	Practical Innovation
1580, submarine described by England's William Bourne.	Over 200 years from practical concepts to a working prototype.	1776, American David Bushnell designed and built the infamous Turtle. Operated by Ezra Lee, it unsuccessfully attacked a British ship in New York Harbor.
1800, Robert Fulton built the Nautilus, which achieved a speed of 4 knots, submerged to 25 ft and remained submerged with a snorkel for up to 6 hours.	100 years from a working prototype to production.	1900, The US took delivery of two Holland VI submarines and ordered six more. The UK ordered five.
	Over 300 years from concept to production.	1901, the French submarine Gustav Zede was built.
	Note: many of the delays in submarine development were attributable to politics and tradition, not technology.	1911, US Navy Lt Chester Nimitz replaced gasoline engines with safer diesels.
		1914, World War I, UK had 74 submarines with 31 under construction, Germany had 28 operational and 17 under construction.

Table 9. Discovery to Practical Innovation—Cathode Ray Tube

Discovery	Time Span	Practical Innovation
1838, discovered, but not understood, by Michael Faraday.	59 years from discovery of the fluorescing phenomena to initial application as an oscilloscope.	1897, first description of using the CRT as a display for waveforms.
Philipp Lenard in 1905 and JJ Thomson in 1906 won Nobel prizes for their work with cathode rays.	96 years from discovery to the first public demonstration of an image.	1934, Philo Farnsworth demonstrated the first working all-electronic television receiver in Philadelphia.
1908, England's Alan A Campbell-Swinton proposed the use of a CRT for television.		1941, the US adopted the 525-line television standard, and commercial broadcasting began in the US.

Table 10. Discovery to Practical Innovation—Jet Engine

Discovery	Time Span	Practical Innovation
1680, Isaac Newton proposed that a carriage could be powered by a jet of steam.	Over 200 years from the "thrust" concepts to prototypes.	1903, Norwegian Jens Ǽgidius Elling demonstrated an in-line gas turbine that produced a net power.
1791, patent granted to England's John Barber for a stationary gas turbine. Never produced.	Over 100 years from a design concept to a prototype.	1910, Romanian Henre Coandă flew the first jet-propelled aircraft. It used an external piston engine to compress the air.
	29 years from the first flying prototype to an advanced flying prototype.	In 1939, Heinekl He flew 178 flights.
	34 years from the first flying prototype to full production.	1944, German ME 262 was the first operational jet fighter and went into mass production.
1928, Britain's Frank Whittle submitted concepts for a turbojet for aircraft; applied for a patent in 1930, granted in 1932.	24 years from Whittle's advanced practical concepts to commercial operation.	1952, BOAC offered the first commercial jet service with a de Haviland Comet.

Once in place, technology can be incredibly slow to evolve. There is an operating plant in New England, located next to a stream which provided the original power in the 1700's. That plant, with a widely recognized name, is still grinding its product on equipment that was originally manufactured in the early 1800s. It is still powered by leather belts off a line shaft. Industrial hardware suppliers still do a steady business in 4" leather belting for machine drives[4].

In the late 1700s, Eli Whitney tried to secure a government contract to produce muskets with interchangeable parts. The government decided that his unsolicited proposal was not technically feasible; so he did not get the award. Today's small arms still do not have interchangeable parts. If you buy a replacement part for a handgun or a long gun, commercial or military, the odds are that it will have to be fitted by a gunsmith in

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[4] Icon Group Int. Inc., *The 2009 Report on Industrial Leather Belting and Other Industrial Leather Products Made Wholly or Mostly of Leather*: *World Market Segmentation by City*, May, 2009.

order to work, notwithstanding the fact that interchangeable parts are both technically and economically feasible.

Three other points are worth making about evolving technology:

- Development often takes place simultaneously in different venues. Developers may be aware of the work of others; often they are not, or at least not the specifics.
- Innovation is often elemental, like the transistor, or an integration of existing technology into a new application.
- Increasingly, technology does not or cannot stand alone; it is part of a larger system. That has often been the case over the last 200 years.

Innovation Versus Commercialization

The people who commercialize technology are often perceived as the inventors. Sometimes that is true; more often it is not. Today it is more likely that commercialization will be done by a company with the names of the technology creators hidden behind the corporate veil. Certainly there are exceptions, yet how many people could name Dean Kamen as the man behind the Segway Personal Transporter®? More perhaps could name Steve Jobs as a force behind iPods®. How many people can name the inventors of the modern transistor?

Historically, most inventors seem to be more interested in the S&T than in end applications or finances. Serbian Nikola Tesla, for example, made significant contributions in electricity generation, radio, induction motors, air liquefaction, radiography, and television. He died destitute.

From the early days of personal computers, there was competition between Apple and the *IBM* PC. The IBM PC was the non-Apple benchmark. The term “PC” by itself was rarely used. Today, “PC” by itself means effectively “Windows® PC” and any connection with IBM has been relegated to a historical footnote.

Table 11. Innovation Versus Commercialization

Inventor/Discoverer	Commercial Development
Steamboat	
First steamboat in America demonstrated by John Fitch, 1787; this follows Jacques-Constantin Perier’s similar feat in Paris, 1783.	Robert Fulton, often cited as the inventor of steamboats, starts the first commercially successful steamboat service from Manhattan to Clermont, NY starting in 1807 and renaming his North River Steam Boat, The Clermont.
Radio	
Probably invented by Brazilian Padre Roberto Landell de Moura and privately demonstrated voice transmission and reception by radio in 1894, publicly in 1900, years ahead of the rest of the world. De Moura was granted a Brazilian patent in 1901, but outside the Roman Catholic church he and his work remained unknown. American Dentist Mahlon Loomis claims to have first demonstrated radiotelegraphy in 1866 and was granted a US patent #129,971 in 1872. There is no record of a public demonstration. Contemporaries of Marconi, including Nikola Tesla, Britain’s Oliver Lodge and Edouard Branly, Russian Alexander Popov and others did early work developing radio telegraphy.	Guglielmo Marconi clearly did major early work in the development of radio and had the first commercial company, the Wireless Telegraph and Signal Company. Marconi received the Nobel prize in 1909. In 1922 Marconi’s research center began commercial radio broadcasts in the UK.

Table 11. Innovation Versus Commercialization (Continued)

Personal Computer

Several people and companies are credited with developing the first personal computer beginning in 1970. Datapoint 2200, France's Micral N, Xerox Alto (with GUI), IBM 5100 and the Altair 8800 usually lead the list.

Apple's Steven Jobs and Steve Wozniak are the surviving commercial leaders following the Apple II's introduction in 1976. The Commodore PET and Radio Shack TRS-80 were probably commercial successes upon introduction.
The IBM PC was first introduced in 1981.

Airplane

Who "invented" the airplane is arguable, Ibn Firnas, DaVinci, John Stringfellow, Frenchmen Félix du Temple, or Clément Ader are legitimate candidates.

Orville and Wilbur Wright, in 1903 flew, were photographed, and continued with commercial development of aviation eventually with the Curtis-Wright Company ultimately part of Rockwell Aviation.

Champagne

Invented by Dom Pierre Pérignon or Christopher Merret, depending upon whether you prefer the French or English version of history.
Literature published since 2000 challenges the traditional view that Pérignon "invented" sparkling wines. Perhaps true, but up to that point refermentation was an undesirable accident and at the least, Pérignon exploited and controlled it.

Dom Pierre Pérignon commercialized the product and his name is still associated with fine (expensive) champagne.

Television

The term "television" was coined by Russian Constantin Perskyi in 1900.
The list of technical contributors is long, international and starts in the 1880s and the "Who invented television?" question is probably best answered by "no one person." RCA paid American Philo Farnsworth for the rights to his patents.

In the United States, RCA commercialized the hardware and NBC took the lead with programming.

Fuel Cell

Englishman William Robert Grove invented and demonstrated the first fuel cell in 1839.

To be determined. Industrial, commercial and residential fuel cells are available but they're a tiny fraction of the energy market and leadership recognition is elusive. In a sense, this is technology evolving in real time.

Explosives

Black powder first documented in 1200 AD
German Joseph Wilbrand invented TNT in 1863.
Sweden's Alfred Nobel invented Dynamite in 1866 and received a patent in 1867. (Nobel also invented the blasting cap in 1863).

Alfred Nobel developed and commercialized the product for industrial use through The Nobel Company in Germany, the United States Blasting Oil Company and in France, the Société Général Pour la Fabrication de la Dynamite.

Refrigeration

Ireland's William Thomson (better known as Lord Kelvin) described "heat pumps" in 1851.
The first practical refrigeration/freezer using ammonia gas was demonstrated in 1857 by either France's Ferdinand Carrè or Australia's James Harrison, depending upon the source.
In 1923 Frigidaire introduced the first single assembly refrigerator suitable for home use. Earlier home units were modified industrial units with compressor located remote from the "cold box."

General Electric, General Motor's Fridgidare and Sweden's Electrolux.

Table 11. Innovation Versus Commercialization (Concluded)

Guillotine	
Invented by French Physician Joseph Ignace Guillotin in 1792.	Popularized by the French Revolution, 1789-1802, last used in 1977.
Razor	
The modern straight razor is probably the result of England's Benjamin Huntsman's steel making process introduced in 1740. The "safety razor" with an enclosed, but not disposable, blade appeared on the market around 1850. King Gillette received his patent for the disposable blade safety razor in 1904 (#775134).	American King Camp Gillette. The Gillette Company was sold to Procter & Gamble in 2005 for $57 billion.

Obstacles to Innovation—Attitudes

Technical innovation is inherently difficult. It is also often a battle, sometimes figuratively, sometimes literally. In today's competitive and threatening environment unjustified attitudes can inhibit innovation to the point that it can place enterprises, even governments at risk. Sometimes it is the "abominable no man" attitude and other times it can be misguided exuberance that misdirects resources and leaves a trail of disappointment.

Resistance to change is natural. A business owner succinctly captured the thought when he said:

> *"I'm all in favor of progress as long as it doesn't require change."*

Unjustified, misguided or irrational resistance to change is a disaster when the team responsible for progress fundamentally rejects it. The following quotes are in some cases merely amusing opinions, but in others they represent a critical decision or were important influences on either government or corporate policy. Thomas Watson, Chairman of IBM is famous for his 1943 statement, "*I think there is a world market for about five computers*." But Watson recognized he could not afford to be wrong and although that thought may have led to caution, it didn't drive corporate strategy. In 1901, Wilbur told Orville Wright, "Man will not fly for fifty years." Again, it was an opinion, not a decision.

> *"Everything that can be invented has been invented."*
> Charles H. Duell, Commissioner of the US Patent Office urging President McKinley to abolish the office in 1899

> *"When the Paris Exhibition closes electric light will close with it and no more will be heard of it."*
> Erasmus Wilson, Professor at Oxford University, 1878

> *"The phonograph is not of any commercial value."*
> Thomas Alva Edison, 1880

> *"I do not look upon any system of wireless telegraphy as a serious competitor with our cables."*
> CEO of Western Telegraph Company, 1907

> *"Well informed people know it is impossible to transmit the voice over wires and that were it possible to do so, the thing would be of no practical value."*
> The Boston Post editorial, 1865, when Joshua Coopersmith was arrested for fraud for trying to raise money to invest in developing the telephone.

> *"[The telephone's] an amazing invention, but who would ever want to use one of them."*
> President Rutherford B. Hayes, 1876, after participating in a Washington-Philadelphia phone conversation.

"Radio has no future."
Lord Kelvin, 1897, former President of the Royal Society

"DeForest has said in many newspapers and over his signature that it would be possible to transmit the human voice across the Atlantic before many years. Based on these absurd and deliberately misleading statements, the misguided public... has been persuaded to purchase stock in his company."
US District Attorney prosecuting Lee DeForest for fraud, 1913

"The radio craze will die out in time."
Thomas Alva Edison, 1922

"While theorectically and technically television may be feasible, commercially and financially I consider it an impossibility, a develpment of which we need waste little time dreaming."
Lee De Forest, the inventor of audio radio

Where a calculator on the ENIAC is equipped with 18,000 vacuum tubes and weighs 30 tons, computers in the future may have only 1,000 vacuum tubes and perhaps only weigh 1 1/2 tons.
Popular Mechanics, March 1949

"I have traveled the length and breadth of this country, and have talked with the best people in business administration. I can assure you on the highest authority that data processing is a fad and won't last out the year."
Editor-in-charge of business books, Prentice Hall, 1957

"There is no reason for any individual to have a computer in their home."
Ken Olson, President of DEC, 1977

"There is not the slightest indication that [nuclear] energy will ever be obtaineable. It would mean that the atom would have to be shattered at will."
Albert Einstein, 1932

"I do not hesitate to forecast that atomic batteries will be common place long before 1980 It can be taken for granted that before 1980 ships, aircraft, locomotives and even automobiles will be automically fueled."
David Sarnoff (Chairman of the Board of the Radio Corporation of America), *The Fabulous Future: America in 1980*,1955

Foods will, by 1976, be sterilized by split-second exposures to atomic radiation, thus extending the shelf life of fresh foods practically indefinitely. Fission rays will immunize seeds, oats and other grains against desease.
Morris Ernst, Author of Utopia 1976, in 1955

"The horse is here to stay, but the automobile is only a novelty, a fad."
President of Michigan Savings Bank advising Henry Ford's Lawyer not to invest in the Ford Motor Company, 1903

"The nickle-iron battery will put the gasoline buggies out of existence in no time."
Thomas Alva Edison, 1910

"In 15 years, more electricity will be sold for electric vehicles than for light."
Thomas Alva Edison, 1910

In less than 25 years the motor-car will be obsolete, because the aeorplane will run along the ground as well as fly over it.
Sir Philip Gibbs, British author in 1928 in a book *The Day After Tomorrow, What is Going To Happen to the World*

That the automobile has practically reached the limit of its development is suggested by the fact that during the past year no improvements of a radical nature have been introduced.

Scientific American, January 2, 1909

Next year's cars should be rolling out of Detroit with plastic bodies.

Yale Magazine, 1941

"The Wankel will dwarf such major post-war technological developments as zerography, the Polaroid Camera and color television."

General Motors Corp announcing its commitment to the Wankel in 1969

What can be more palpably absurd than the prospect held out of locomotive travelling twice as fast as stagecoaches?

The Quarterly Review, England, March 1825

"Men might as well project a voyage to the Moon as attempt to employ steam navigation against the stormy North Atlantic Ocean."

Dr. Dionysus Lardner, Professor of Natural Philosophy and Astronomy at University College in London in 1938, the same year the British Ship the Great Western crossed the Atlantic entirely under steam power.

"Rail travel at high speed is not possible because passengers, unable to breathe, would die of asphyxia."

Dr. Dionysus Lardner, Professor of Natural Philosophy and Astronomy at University College, London

"Man will not fly for fifty years."

Wilbur to Orville Wright, 1901

The aeroplane is not capable of unlimited magnification. It is not likely that it will ever carry more than five or seven passengers. High-speed monoplanes will carry even less.

Walderaar Kaempfert, Manageing Editor of Scientific American and author of The New Art of Flying, June 28, 1913

Gliders will be the freight trains of the air. We can visualize a locomotive plane leaving LaGuardia Field towing a train of six gliders in the very near future. By having the load thus divided it would be practical to unhitch the glider that must come down in Philadelphia as the train flys over that place...

Grover Loening, consulting engieer to Grumman, 1944

"There is no basis for the ardent hopes and positive statements made as to the safe and successful use of the dirigible balloon or flying machine, or both, for commercial transportation or as weapons of war."

Rear-Admiral George Melville (Engineer-in-Chief of the US Navy), North American Review, December 1901

The idea that cavalry will be replaced by these iron coaches [tanks] is absurd. It is little short of treasonous.

Aide to British Field Marshall Douglas Haig after observing a tank demonstration in 1916

"Pershing won the war [World War I] without even looking into an airplane, let alone going up in one. If they had been of such importance he'd have tried at least one ride.... We'll stick to the army on the ground and the battle ships at sea."

John Wingate Weeks (US Secretary of War), 1921

"It is not possible ... to concentrate enough military planes with military loads over a modern city to destroy that city."

Colonel John W Thomason, Jr. (American author and Marine Corps officer), November 1937

"It is highly unlikely that an airplane, or fleet of them, could ever sink a fleet of Navy vessels under battle conditions."

Franklin D. Roosevelt, former assistant secretary of the Navy, in 1922

"The Air Corps does not at this time feel justified in obligating funds for basic jet propulsion research and experimentation."
Brigadier General George H. Brett to Robert Goddard, 1941

"That idea is so damned nonsensical and impossible that I'm willing to stand on the bridge of a battleship while that nitwit tries to hit it from the air."
Newton D. Baker (US. Secretary of War), 1921

"Good God! This man [Billy Mitchell] should be writing dime novels."
JosephusDaniels (US Secretary of the Navy), 1921

(On July 21, 1921 former German WWI battleship, Ostfriesland was sunk in 22 minutes, and similar demonstrations followed in September, 1921 and September, 1923. Mitchell was court-martialed in 1925)

"Before man reaches the moon your mail will be delivered within hours from New York to California to England, to India, or to Australia by guided missiles. We stand on the treshold of Rocket Mail."
US. Postmaster General, January 23, 1959

"This is the biggest fool thing we have ever done.... The bomb will never go off, and I speak as an expert in explosives."
Admiral William Daniel Leahy, advising President Harry S. Truman on the impracticahty of the US atomic bomb project, 1945

"By 1980 we will be self-sufficient and will not need to rely on foreign enemies ... uh, energy."
Richard M. Nixon (President of the United States), responding to the then gas shortage by proclaiming an initiative dubbed "Project Independence, "1973

"The Con Ed system is in the best shape in fifteen years, and there's no problem about the summer."
Charles Franklin Luce (Chairman of the Board of Consolidated Edison), New York television interview, July 10,1977 (on July 13, the Con Ed system failed and metropolitan New York was without electricity for more than 24 hours[5]

Summary

Predictions are difficult, suggesting the need of a crystal ball and some mystical abilities. *Anticipation*, however, is well-grounded in historical background and the logical extension of current knowledge. Anticipating the technologies that will come to fruition and change our lives over the next 20 to 40 years can illuminate and focus our attention and inform our investment strategies with intelligent reasoning.

Values and technology change. Those changes affect the speed, acceptance, and distribution of practical innovation. Technology evolves from innovation to innovation over a period of time. Contributing to that evolution are factors that can speed or slow the timeline, including attitudes about the current values and combinations of new technologies that contribute to creating a workable system.

Small technical innovations may have a large and pervasive impact on the adoption of new technologies. When visionaries understand and implement the technology's uses, an innovation can permeate the fabric of society. For example, the transistor, once thought to be a mere replacement for vacuum tubes, has come to provide uses throughout the world and enabled myriad development in electrical and miniature advances.

Technology rarely stands alone. Its development needs a context, an environment in which to work to provide new uses and adaptations. Inventors are remembered for a technological innovation only when they had a hand in commercializing that technology or applying it to a practical system.

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[5] Note: These quotes are taken from Christopher Cerf and Victor Navasky. *The Experts Speak: The Definitive Compendium of Authoritative Misinformatio*n. Villard, New York, 1998.

Values can be the impetus or the impediment to technology's adoption. Even when a technology has evolved to provide a system, both naysayers and irrational proponents can contribute to stalling or stagnation of what seemed a promising development. Because of these factors, it is difficult to predict the likelilikelihood of life-changing technologies becoming everyday or commonplace. However, over the next 20 years, five technologies offer promise, assuming their encouragement and commercialization.

The Author "Anticipates"

These are the five game changing science and technology innovations—or rather, evolutions—anticipated over the next 20 years:

1. The growth of video conferencing, one-on-one, groups of all sizes and the accompanying reduction of travel-related needs. Today's young people are growing up in a culture that prefers *texting*, including broadcast texting (one way) to conversation. The technology is evolving and travel is increasingly expensive, unpredictable, irritating, and discomforting.
2. The continuing evolution of systems engineering disciplines and particularly their associated technologies, including modeling and simulation, will change the quality and speed of innovation to the point that more new science and technology will be disruptive to the status quo.
3. Sensors are evolving rapidly. Video, audio, chemical, biological, visible and invisible-spectrum, passive, active sensor technologies are all rapidly evolving.
4. Fusion of data. This covers a broad spectrum. A telescope no longer needs to be built from a massive piece of thermally stable glass. It can be made of thousands of individual elements and their data streams integrated. Multiple and disparate data bases will be integrated. Hundreds or thousands of dispersed small sensors or data sources can be integrated or *fused*.
5. The evolution of data transformation and the fusion of sensors are the enabling science and technology for applications like "sixth sense" and sophisticated robotics in unending applications with potentially massive social and political disruptions. Not a new thought, but newly practical and increasingly economically viable.

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SynGenics specializes in bringing the power of mathematics to complex decisions and in transitioning products and processes from concepts to production, helping industry and government programs to develop their own next great technologies. Author Thomas Archer is Vice President of SynGenics. For more information, visit www.SynGenics.com.