Technology Management in Media and Information Firms

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4.1 Technology Drivers and Trends

The media sector consists of three broad segments: content creation, content distribution and media devices. This chapter focuses on the devices and their development, and, more generally, on the technology of media and communications that underlie distribution networks and content production. The key question of technology management is how to reconcile an unpredictable and disruptive process of innovation with organized business management.

The issues addressed are:

1. How does a media company organize its technology function?
2. How does technology innovation affect media industries?

Technology transforms our lives, our work, and the way we produce and consume media. For media firms, technology is destiny. Or, at least, it is a trajectory, a direction. Technology has always initiated big media innovations. The printing press created the publishing industry. The telegraph spawned global wireline networks. The phonograph created the music recording industry. Broadcast technology and TV screens shifted mass media to the home. More recently, personal computers, cellular mobile networks and the Internet have been rapidly transforming media.

As mentioned, in the Industrial Revolution, the main technology driver was the ability to create machine-based power as a substitute for human and animal muscle power. For the Information Revolution, the main technology driver is the increased ability to create machine-based information processing as a substitute and complement for human brainpower. This was achieved through the ability to manipulate sub-atomic particles (electrons and photons) through a variety of devices, followed by an ability to string these devices together to create systems and applications that could process all forms of information based on binary signals.

Not long ago, the various types of media employed specialized technology devices: text-based media such as newspapers used the printing press, audio-based media such as music used spinning vinyl records, film had its celluloid photographic technology, TV broadcasting transmitted various analog waveforms, while telephone networks enabled two-way audio signals over copper lines. Each of these media types was based on separate technologies, devices, suppliers, producers, industries and regulatory systems. But, more recently, all are increasingly based on common technical elements:

- Semiconductor electronic components;
- Software programs and modules;
- Radio-frequency transmission and receiving devices;
- Information processors;
- Display screens;
- Optical signal devices;
- Storage devices and components;
- Battery technology;
- Fiber transmission and distribution links;
- Signal switching and routing devices;
- Information coding methods.

Because these components are usable across most types of media devices, the expectation was that this would also lead to a convergence in the underlying media technologies in media industries and firms, and thus of media themselves.

"Media convergence" thus became a concept much bandied about, but was slower to emerge in reality. In the 1980s, the conventional wisdom was that the future electronic environment would be dominated by a titanic struggle between the giants AT&T and IBM, then dominant in their respective sectors of telecom and computers. Both were making big electronic boxes that were interconnected worldwide, and which generated and controlled flows of digital information. Inevitably, they would become each other's greatest rivals. Soon, however, business reality set in. IBM withdrew from the telecommunications sector, while AT&T abandoned its business in computers after incurring huge losses. There were other instances where successful companies moved beyond their core area and failed. Time Warner, in a major merger with AOL, wanted to enter the Internet; Microsoft made major investments in cable TV; the Japanese consumer electronics giant Matsushita (Panasonic) bought a Hollywood film studio; Bertelsmann moved into online activities. The outcomes were disastrous for the companies involved.

Will the same happen to a new set of media-tech companies, in particular Google, Apple, Amazon, Facebook and Samsung? Beyond company-specific issues, the more fundamental reason is that convergence is not the only business trend. A second powerful trend is the acceleration of innovation, and with it the incentives to specialization and differentiation in order to succeed in a highly competitive environment. While technology has been converging, few firms have succeeded in keeping up with the pace of change in multiple fields. Why this failure? To answer that question, we will discuss throughout this chapter a major "convergence firm"—the Japanese electronics and entertainment company Sony.

4.1.1 Case Discussion

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Sony

Is Sony the exception, or a confirmation to the frequent failure of "convergence" companies in the technology field? Sony has been active in many media and media technology sectors: TV sets, radios, audio players, computers, cameras, film production, TV shows, music, film production equipment, games and hardware/software, telecom handsets and financial services. The question is whether Sony can be a technology leader in all of these fields. Has Sony's technology strategy of convergence worked?

For 14 generations, the Morita family ran a sake brewery in Osaka. After Japan's defeat in World War II in 1945, Akio Morita broke away from family tradition and started, in a basement, the Tokyo Telecommunications Engineering Corporation, soon renamed Sony Electronics. In 1950, Sony came out with its first breakthrough product, an inexpensive transistor radio. By the late 1950s, Sony had become a major producer of radios, television sets and other home entertainment devices. In the 1970s, Sony changed its strategy from that of a low-cost producer to being a technology leader with a wide array of smartly designed products.

In 1975, Sony introduced the first consumer video cassette recorder, the Betamax. But the VHS technology of its rival, Matsushita, prevailed. In 1979, Sony introduced the Walkman as a portable cassette tape audio device and sparked a revolution in portable music and in music cassette sales.

Sony's strategist in the 1980s was Norio Ohga, who had had a career as an opera singer and symphony conductor, Ohga negotiated Sony's acquisition of CBS Records for $2 billion. This helped Sony to launch the compact disc (CD). Based on the success of the CD, Sony entered the film business as well. In 1989, Morita bought the film studio UA-Columbia from Coca-Cola for $3.4 billion. Nobuyuki Idei, who handled the home video division, succeeded Morita as Chief Executive Officer (CEO). Sony was nicely balanced across its business segments and geographic regions, deriving about a quarter of its sales each from Japan, Europe, the USS and the rest of the world. Sony became, according to annual Harris Polls, America's number one "best brand" for most of the years 1996–2007, ahead of Coca-Cola, Ford, or General Electric.

Since 2000, however, Sony has been under pressure. Worldwide prices for consumer electronics (CE) products fell. New competitors emerged. Sony's revenues declined, as did its profits and stock price. By 2005, Moody's lowered its long-term credit ratings for Sony from A1 to A2. In that year, Sony's most profitable business was not electronics or entertainment but, rather, financial services. Under fire, Idei's successor, Kunitake Ando, was forced to step down. Welsh-born Howard Stringer, a former news producer at CBS in New York, became Sony president. He spoke no Japanese, was no engineer and operated mostly from Sony's American base in New York.[1]

Sony began rebuilding. It sold its real estate assets and financial services, and dropped 6% of its workforce (16,000 employees). It eliminated about 600 products, closed four plants in Japan and another four overseas. Another round of job reductions was started in 2012, totaling over 10,000. But this did not end the problems. Sony's products did not sell as they used to. It lost a considerable amount of money on its TV sets, fell behind in flat screens, laptops and mobile phones, and was weak in MP3 players, despite the connection to its own huge music division (which also declined.) The questions are, therefore, whether Sony's technology efforts worked well, whether they were well-managed, or whether they contributed to the decline of the company.

4.2 Technology Management

4.2.1 The Technology Function

Research and development (R&D) is the creation of new knowledge by a firm, and the strengthening of its existing and future operations and products. "Research" expands the firm's scientific knowledge and engineering skills. "Development" applies this knowledge and makes it relevant to the firm's business through new products.

1 Schlender, Brent. "Inside the Shakeup at Sony." *Fortune Magazine*. April 4, 2005. Last accessed August 10, 2012. ► http://money.cnn.com/magazines/fortune/fortune_archive/2005/04/04/8255921/index.htm.

The image of innovation has been that of an individualistic endeavor. Indeed, lone (or duo) inventors abound—Gutenberg, Fulton, Watt, Marconi, Morse, Bell, Tesla, the Wright Brothers, the Lumière Brothers, Jobs and Wozniak, Gates and Allen, Brin and Page. But the reality of corporate R&D is less glamorous than such heroic images of invention. Thomas Edison's major innovation may not have been the real lightbulb but, rather, a figurative one: the organized process of invention.

Edison established a free-standing laboratory in 1876 in Orange, New Jersey. In that laboratory, one year later, the Edison team developed a rotating wax tin-foil cylinder with grooves, creating the first consumer electronics product. In 1891, Edison's lab came out with an early movie technology. In 1879, the lab developed the light bulb; this led to electric power generation and distribution which, in turn, enabled and powered numerous new devices.

Following this model, major companies established large organized R&D structures. They created sprawling research facilities such as Bell Labs, IBM Labs, RCA Laboratories and GE-Labs (Fig. 4.1).[2] Similar big corporate labs exist in other countries. This approach has not been the organizational path for start-ups, which are more inclined to follow the lone-inventor model. However, some of the most innovative technologies were initially spawned inside the large labs by researchers who then went out on their own.

4.2.2 Chief Technology Officer (CTO)

Inside a company, the technology function is often run by an executive with a title such as Chief Technology Officer (CTO) or Chief Scientist. The CTO is the link between business managers and technical personnel. The role of the CTO must be distinguished from that of the Chief Information Officer (CIO), who is responsible for internal IT adoption and support.

The CTO is not a lab director but, rather, a business person who is technical- and management-savvy (often with a tech background) who shapes part of the overall corporate strategy along the dimension of technology.[3] The CTO's role differs depending on the company, the industry and their personal qualifications. Generally, they oversee the process of technological innovation in products and operations. To do so, the CTO needs to be a change agent who can identify new technology and bring it into the company. Obviously, large companies are more likely to deploy a CTO than small ones but, conceptually, even a grocery store needs someone who takes the initiative to bring in new technology.

We will now review several of the functions of CTOs as a way to understand a company's management of technology, a critical task in the media and information sector.

4.2.3 Key Tasks for the CTO: Technology Assessment

The CTO identifies present and future technology options, and assesses their potential role for the company. Factors are technical viability and business potential.[4] A similar assessment effort must be conducted by investors when they evaluate a start-up firm that is based on new technology, or by a company when it tries to acquire another firm that holds special technologies and patents.[5]

However, assessing technology is difficult even for experts. One of the greatest scientists of all time, Ernest Rutherford of Cambridge University, dismissed nuclear energy in a presidential address to the Royal Physics Society in 1933: "Anyone who expects a source of power from the transformation of these atoms is talking moonshine."[6] At the opposite extreme, another famous scientist, John von Neumann, predicted in 1956 that "a few decades hence, energy may be free, just like unmetered air." If two such leading lights can be so wrong, and diametrically so, how can a lesser technology manager have a chance to be right? The answer is that a CTO need not deal

2 AT&T also operated a huge R&D facility at Murray Hill, NJ, and several other research centers. Photo used under Creative Commons. Beaumont, Lee. "Bell Labs Holmdel." ► https://commons.wikimedia.org/wiki/File:Bell_Labs_Holmdel.jpg.

3 Lewis, W. W. and H. L. Lawrence. "A new mission for corporate technology." *Sloan Management Review* 34, no. 3 (1990). Taken from Smith, Roger D. "The Role of the Chief Technology Officer in Strategic Innovation, Project Execution, and Mentoring." *Research Technology Management* 46, no. 4 (August 2002): 3.

4 Inside Jobs. "CTO." Last accessed July 11, 2011. ► http://www.insidejobs.com/jobs/cto.

5 Smith, Roger D. "The Role of the Chief Technology Officer in Strategic Innovation, Project Execution, and Mentoring." *Research Technology Management* 46, no. 4 (August 2002): 10.

6 Doyle, Jim. "Energy from Nuclear Fission". June 20, 2011. Last accessed July 12, 2011. ► http://www.btinternet.com/~j.doyle/SR/Emc2/Fission.htm.

Fig. 4.1 Bell Labs R&D Facilities in Holmdel and Murray Hill, NJ in their heyday

with the long-range future of science. Their role has to be to deal with the set of "plausible possibles," i.e. with scenarios and opportunities that are composed of building blocks that already exist.

How to go about looking forward in such a way? To stay close to the leading edge, information is key. This means close ties to academic laboratories and journals, attendance at trade shows, the reading of trade and technology magazines, checking out websites, and the creation of a personal network of respected innovators and business analysts.

Another way to review the state of and pace at which technology advances in a field is to look at published patents in one's sector.[7] Patent applications and grants are useful as a source of information about the "prior art" of technology innovations. Looking at patent applications, one can identify competitors, innovators, and potential partners and licensees, as well as the velocity of technology in a sub-area.[8]

Progress in the field of electronics has followed broad trends. A major way to assess a specific technology is to compare it with the more general rate of change in the electronics sector. Forty years ago, the computer electronics pioneer Gordon Moore observed that the power of semiconductors doubled every one to two years, predicting that this trend would continue. This rate of progress—about 40% a year—became famous as

7 US government's website for patent searches is ► https://www.uspto.gov. IBM's free site ► https://www.ibm.com/ibm/licensing/. In Europe, the European Patent Office is at ► http://www.epo.co.at:80/index.htm. And in Japan ► https://www.j-platpat.inpit.go.jp/web/all/top/BTmTopEnglishPage.

8 Department of Commerce. "US Patent Office." May 27, 2011. Last accessed June 12, 2011. ► http://patft.uspto.gov/netahtml/PTO/search-bool.html.

"Moore's Law." And, indeed, it described the progress over the subsequent decades pretty well. Computer components became smaller, or more powerful, or cheaper, at roughly the predicted rate. Whereas in 1970 a memory chip would store 1000 bits, it holds up to 8 trillion in 2017 (1 terabyte). Such progress enables marvels of technology, from computerized tomography (CAT) scans to video over cell phones.

Part of the secret for the resiliency of Moore's Law has been that it has moved from prediction to self-fulfilling prophecy. It establishes a time line for progress that everyone in this highly decentralized industry understands. When a company is engaged in developing the next generation of its components, software, or hardware, it knows that the overall pace of technology progresses at the rate of Moore's Law, and it must plan to match it. If it falls behind that pace, it must add engineers, money and partners to its development effort. If it is too far ahead, it could end up designing products that have no complementary devices or content and will not find buyers. If its production costs do not drop fast enough, it must compensate by gaining scale or moving to cheaper shores. Thus, like a giant bell tower, Moore's Law has helped to synchronize the development of global electronics.

Similar trends can be observed in the transmission throughput "speeds" achieved by engineers, which leads to ever-cheaper transmission "bandwidth."[9] Or, to the increased amount of information that can be stored and processed in progressively less space for progressively less money. It also translates to an exponential trend in the cost per unit of distribution of information over time.

A firm can look ahead, identify the trends in the underlying components in terms of performance and cost, and then analyze in what direction this is taking the industry. There is no need to resort to science fiction. One can observe the trends, what leading edge adopters are already doing, and what technology companies are offering by way of hardware and applications. Of course, details of developments are unfathomable in advance, but the broad trend is a different story.

4.2.3.1 Selection of R&D Projects for Funding

According to one analysis, it requires about 3000 raw ideas to produce one substantially new, commercially successful industrial product.[10] Of 3000 new ideas, 125 are narrowed down to small projects of which approximately nine evolve into significant projects for major development efforts and commercial launches (Fig. 4.2).[11] Of these, only one is commercially successful.

With these staggering odds, how is a firm to evaluate how to select among technology ideas?

Innovation is a discovery process and may not necessarily have a sure destination.[12] But it helps to define the task for the R&D project clearly. When Steve Jobs envisioned the iPod, he defined the goal as "1000 songs in my pocket." Once a task is well-defined, it is easier to develop a focused and actionable strategy. (However, many of the most important innovations cannot be willed; rather, they emerge serendipitously.)

Ralph Waldo Emerson wrote, "If a man can write a better book, preach a better sermon, or make a better mousetrap than his neighbor, though he build his house in the woods, the world will make a beaten path to his door." But this is not necessarily true. Studies show that 40–90% of new products fail. Experts and early adopters loved TiVo's digital video recorder but consumers were reluctant to sign up; the company lost over $600 million by 2005 and, subsequently, was in the red in six out of eight years because of low demand.

Why do consumers fail to buy innovative products? An explanation is supplied by behavioral economists such as 2002 Nobel Prize

9 Magee, Christopher L. "A Quantitative Functional Approach to the Study of Technological Progress." Massachusetts Institute of Technology, April 30, 2007.

10 Stevens, Greg A. and James Burley. "3000 Raw Ideas = 1 Commercial Success!" *Research Technology Management* 40, no. 3 (May/June 1997): 1–12.

11 Graph based on Stevens, Greg A. and James Burley. "3,000 Raw Ideas = 1 Commercial Success!" *Research Technology Management* 40, no. 3 (May/June 1997): 1–12.

12 Satell, Greg. "How to Manage Innovation." *Forbes*. March 7, 2013. Last accessed May 2, 2017. ► http://www.forbes.com/sites/gregsatell/2013/03/07/how-to-manage-innovation-2/.

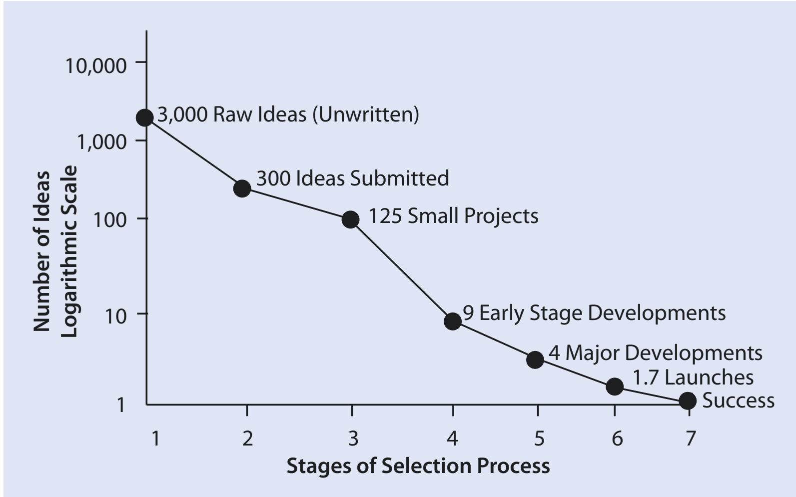

Fig. 4.2 R&D project selectivity and success rate

winner Daniel Kahneman, who showed, with Amos Tversky, that consumers have a "loss aversion," which means that they fear losses much more than gains of the same magnitude. The problem with introducing a new technology or application is that it forces consumers to change their behavior, which is never easy. Studies show that people tend to overvalue the benefits of the goods they own and know over new ones, by a factor of 3:1. Innovators, at the same time, overvalue their new products by a similar factor, 3:1. Having put their ideas, hopes, energy, money and time into a new product, some innovators tend to lose a sense of realism.[13] Taken together, there is a mismatch of 9:1 between what innovators think consumers want and what consumers truly desire. A new product must therefore not be better by a small measure; rather, its gains must far outweigh the potential losses, or consumers will not adopt it.

In every active company, plenty of ideas bubble up that could lead to promising products. But money, time, personnel and attention are scarcer than ideas. How, then, does a company select projects for R&D funding? Gut feeling and hunches are one way to go. Another is to formalize the process. There are several methods to do so.

Scoring methods rank potential R&D projects according to several performance dimensions.[14, 15] Such dimensions could be the completion probability of a project, its duration, its budget cost, the number of researchers needed to complete the project, the potential use for follow-up products and so on. As an example, assume that three projects are assessed (Table 4.1).[16]

Projects are scored along criteria 1–7, with a grade ranging from 1 to 10 (column 3), and the weighting of each criterion, according to its importance, from 1 to 10 (column 2). For example, Project A scores a high 10 on criterion 1, and a low 2 on criterion 2. These scores are then multiplied by their weight factor (7.5 and 6.9), resulting in scores of 75.0 and 13.8 (column 4). These criterion scores are then added up and result in an overall score of 313.4 for Project A, 286.6 for Project B, and 268.0 for Project C. The projects can be ranked from high to low. Project A scores highest and Project B is second-highest.

However, the scoring method has problems. The formula and its weights tend to be inflexible. Yet, if they were flexible and changeable they could be manipulated to get a desired result.

13 Gourville, John T. "Eager Sellers & Stony Buyers." *Harvard Business Review* 84, no. 6 (June 2006): 98–106.

14 Poh, K.L. B. W. Ang, and F. Bai. "A Comparative analysis of R&D project evaluation methods." *R&D Management* 31, no. 1 (January 2001): 63–75.

15 *The Economist*. "Out of the Dusty Labs – The Rise and Fall of Corporate R&D." March 1, 2007. Last accessed May 2, 2017. ► http://www.economist.com/node/8769863.

16 Rengarajan, S. and P. Jagannathan. "Project selection by scoring for a large R&D organization in a developing country." *R&D Management* 27, no. 2 (April 1997): 155–164.

Table 4.1 Ranking and scoring R&D projects

Criterion no.	Weightage factor (W.F)	Project A		Project B		Project C	
		Marks	Marks × W.F.	Marks	Marks × W.F.	Marks	Marks × W.F.
1	7.5	10	75.0	10	75.0	8	60.0
2	6.9	2	13.8	10	69.0	8	55.2
3	6.8	10	68.0	2	13.6	2	13.6
4	7.0	10	70.0	10	70.0	8	70.0
5	4.6	8	36.8	2	9.2	2	9.2
6	5.1	8	40.8	8	40.8	10	51.0
7	4.5	2	9.0	2	9.0	2	9.0
Total score			313.4		286.6		268.0

Table 4.2 ROI of projects

Year	0	1	2	3	4	Net profit	ROI	NPV	ROI_D
Project A	−9000	−1000	4000	6000	10,000	10,000	1.0	4304	0.43
Project B	−3000	0	0	3000	6000	6000	2.0	3047	1.01

The weakness of the scoring method is that a technology-based formula is not linked to a market-based *economic-financial analysis*. Such analysis is based on one of several interrelated methodologies: net present value (NPV), internal rate of return (IRR), return on investment (ROI), discounted cash flow (DCF), cost-benefit analysis (CBA), and the payback period.

Example: Project A contains a new technology development with high initial research expenditures of 9000 (Table 4.2). However, the project is expected to have high returns after year 2. In contrast, Project B is a project with modest research expenditures (3000). However, it will not generate revenue for two years due to authorization procedures. After the first two years, Project B is expected to produce significant returns in years 3 and 4.

If we compare net profits, Project A is superior (10,000 vs. 6000). But what about the return on investment? ROI is found by dividing net profit by the investment. For project A, this would be $\frac{10,000}{10,000} = 1.0$. For project B, it is $\frac{6000}{3000} = 2.0$. Now, project B seems superior.

But this does not take into account the time-value of money. Some of the revenues are realized in future years down the road. To take this into consideration, one discounts the future earnings by a discount rate of, say, 10% per year. Then, we obtain NPVs for A and B of 4304 and 3047. Now, Project A is the superior option. While the NPV of Project B is lower, its undiscounted ROI is higher. Lastly, if the ROI is used with the time-value of money considered (i.e. discounted), as would be the economically proper way, it would be, for project A, $\mathrm{ROI} = \frac{4304}{9000 + 900} = 0.4347$, and for project B, $\mathrm{ROI} = \frac{3047}{3000} = 1.0157$. Thus, Project B is the superior choice.

The chief problem with these financial methodologies is that it is difficult to forecast future net revenues. It involves subjective projections of sales, prices, the state of the economy and the effectiveness of competitors. Company projections of future market penetration are often overly optimistic. One must also pick the appropriate discount rate, and that rate varies with risk.

A final observation: these technological and financial analyses are not be quite sufficient for an optimal selection of projects. Timing, marketing efforts and market forces may greatly affect the success of a project. But this should not leave a company with pure intuition. A formal framework of analysis forces disciplined thinking as a complement, not a substitute, for good judgment and vision.

4.2.4 Integration of Technology with Firm Strategy

Beyond the technological and economic performance of R&D, there is also a question: is the R&D project aligned with the company's overall strategy?

R&D budgets are set for one or several years but, within the budget, decisions about projects are often left largely to R&D management. Normally, R&D should not drag the company into a strategy different than the one it planned.[17] But there must also be flexibility to capitalize on fortuitous discoveries that are outside the strategic focus of the firm. Usually, these should be sold or licensed to others,[18] but there can be exceptions. The Finnish company Nokia was mostly a paper product producer with a small electronics sideline before it seized on the newly opened Scandinavian cellular phone market, the world's first, and for several years became the leading global mobile handset manufacturer.

A major strategic decision for the firm is to select the scope of its activity. It could be a narrowly focused specialist or, alternatively, a broad-based diversified technology developer. Diversification has certain advantages in reducing risk. It allows for synergizing across several product lines and also what economists call "economies of scope"— cost saving in the development, production and marketing of multiple products.

But there are also disadvantages to diversification. In a fast-moving field, if a company is not fully focused on a particular product it may lose its competitive edge for that product. Diversification may also lead to a lower scale than for the specialist firms. Intel is a specialist focusing on microprocessors and all the company's R&D goes toward making that product line better, faster and cheaper. Andy Grove, famed former CEO of Intel, recalled, "The most significant thing was the transformation of the company from a broadly positioned, across-the-board semiconductor supplier that did OK to a highly focused, highly tuned producer of microprocessors, which did better than OK." Specialized firms may have competitive advantages in their narrow field, with resultant market power. But specialization means putting all one's eggs into one basket.[19] Demand could fizzle, or competitors may emerge. Staying specialized without the certainty of weak competition and ongoing demand is risky.[20] Intel, for example, missed out on components for the emerging portable computing devices of smartphones and tablets. Apple and Samsung, on the other hand, have multiple products to fall back on if their smartphones do not work out. But being a jack-of-all-trades has disadvantages, too, where competition is strong in each segment. In recent years, the debate between specialization and diversification has tended to go in favor specialization.[21]

One must also think about innovation across time.[22] The strategic question is how much of a firm's activity level should rely on improving already well-established products, and how much of it should be based on products that must be newly developed. Reliance on the former plays to a firm's current strength but leaves it vulnerable in the future. Conversely, reliance on future products leaves it vulnerable to risk if things do not work out.

A useful perspective is that of the "three horizons." One author, Tim Kastelle, suggests that a firm should create a balance between "improving existing products and processes," "searching out

17 Say, Terry, Alan Fusfeld, and Trueman Parish. "Is your firm's tech portfolio aligned with its business strategy?" *Research-Technology Management* 46, no. 1 (January/February 2003): 32–38.

18 Smith, Roger. "5 Patterns of the Chief Technology Officers." *Research-Technology Management*. Last accessed April 30, 2017. ► http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.158.1721&rep=rep1&type=pdf.

19 Hesseldahl, Arik. "Intel Fights Back as Chips Are Down." *Businessweek*. January 17, 2007. Last accessed June 1, 2011. ► http://www.businessweek.com/technology/content/jan2007/tc20070117_984122.htm.

20 Yager, Tom "What's a Monopoly to Do?" *InfoWorld* 27, no. 33 (August 2005): 52.

21 Ante, Spencer E. "The Info Tech 100; Constant reinvention of who you are, what you produce, and how you sell it is critical for any tech player." *BusinessWeek*. July 2, 2007. Last accessed May 3, 2017. ► https://www.bloomberg.com/news/articles/2007-07-01/the-info-tech-100.

22 Kastelle, Tim. "Innovation for Now and for the Future." *The Discipline of Innovation*. August 17, 2010. Last accessed May 5, 2017. ► http://timkastelle.org/blog/2010/08/innovation-for-now-and-for-the-future/; The concept goes back to Baghai, Mehrdad, Stephen Coley, and David White. *The Alchemy of Growth*. New York: Perseus Books, 1999.

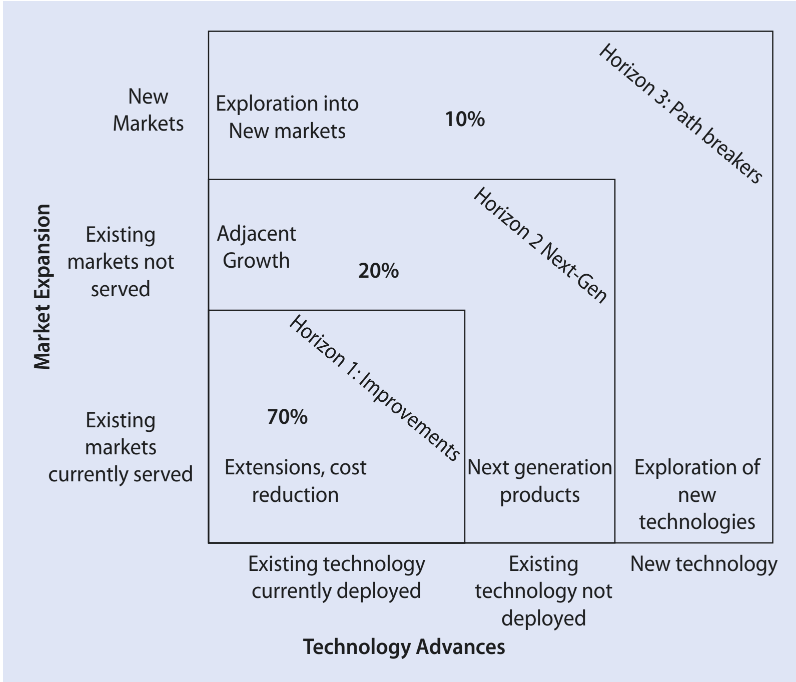

Fig. 4.3 Investment horizons in innovation

adjacencies" and "exploring completely new markets" (Fig. 4.3).[23]

The first horizon (H1) involves implementing innovations that improve current operations. Innovations related to the second horizon (H2) are those that extend current competencies into new but related markets. Innovations related to the third horizon (H3) are those that will change the nature of the industry. In general, H3 innovations tend to be radical rather than incremental. H1 innovations are low-risk, low-return, while H3 innovations are high-risk, high-return. H1 R&D projects, dealing with a firm's core technologies, are typically necessary but not sufficient to achieve competitive advantage. They have well-defined commercial objectives. The likelihood of technical success is relatively high, and the costs and benefits can be defined fairly well. In contrast, R&D in H3 projects is speculative and its budget requirements largely conjecture. The R&D projects of H2 are somewhere in between. They deal with key technologies. Thus, a firm should have a portfolio of three broad classes of technologies: the first to maintain its position in the market; the second to provide competitive advantage; and the third category, that of "pacing technologies," aims to advance the market significantly.[24] A firm should think of its innovation efforts as a portfolio, with innovation taking place across all three time horizons. The balance is based on the firm's risk tolerance and on industry volatility.

The three kinds of innovation need a different mix of input and skills. H1 innovations require mostly money and people. H2 innovations go deeper, and need a corporate culture of creativity and management that is willing to push forward and onward. H3 innovations require top management to make bets on careers and, even, the company. The major career risk is that of management, not of the researchers. The company must give its staff considerable leeway, lower controls and avoid negative feedback for the failure of crazy ideas.

A company such as 3M, which pioneered scotch tape and post-it notes, derives up to 30% of its revenue from products launched in the past five years. It emphasizes H2 and H3 strategies in its R&D. The company—and, similarly,

23 Kastelle, Tim. "Innovation for Now and for the Future." *The Discipline of Innovation*. August 17, 2010. Last accessed May 5, 2017. ► http://timkastelle.org/blog/2010/08/innovation-for-now-and-for-the-future/; The concept goes back to Baghai, Mehrdad, Stephen Coley, and David White. *The Alchemy of Growth*. New York: Perseus Books, 1999.

24 Erickson, Tamara J. et al. "Managing Technology as a Business Strategy." *MIT Sloan Management Review*. April 15, 1990. Last accessed May 3, 2017. ► http://sloanreview.mit.edu/article/managing-technology-as-a-business-strategy/.

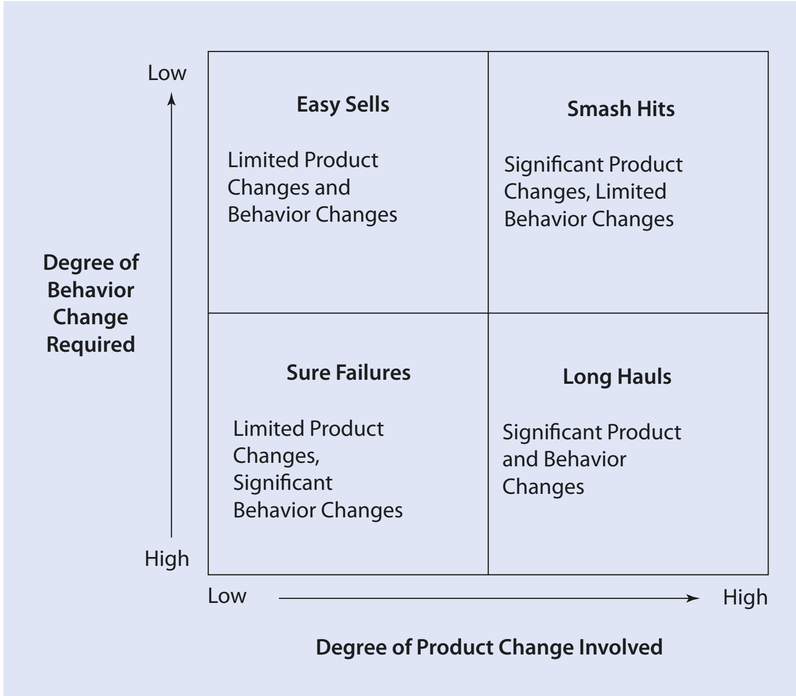

Fig. 4.4 Dimensions of consumer acceptance

Google—uses a 15% or 20% rule, where certain employees are expected to devote a fixed portion of their time to projects unrelated to their job, i.e. work associated with H2 and H3.[25] Even so, both companies' main R&D efforts deal with improving existing products (H1), not on as yet unborn technology generators. For Google, much of the R&D work is on innovations in its core products: the search engine, maps, online advertising and so on. The company's PR narrative—such as self-driving cars—tends to project a more ambitious agenda than warranted by reality. Google, too, uses a 70/20/10 split, with most innovation efforts going to improving existing activities.

The last type of innovation tends to differentiate leaders from followers. But they are gambles, and investments in potential breakthroughs are hard to justify in conventional business terms of ROI. One must think of them as buying options on future opportunities. Ideally, a relatively modest investment—and downside risk—creates the potential for a large upside. The problem with a breakthrough R&D strategy is that it could either fail to deliver, or actually succeed in technological terms and yet be too far ahead of market readiness in terms of complementary products and consumer demand.[26] The figure above is technological in nature (will it work?) and does not consider markets (will it sell and be profitable?).

How can a company analyze the market for its innovations? In the first instance, it helps to look at demand, and to organize innovations by consumer acceptance. Four such categories are "easy sells," "sure failures," "long hauls," and "smash hits" (see Fig. 4.4).[27] They are ordered in a matrix whose two dimensions are product improvement (the horizontal axis), and the change required from the consumer (the vertical axis). Some innovations require a major behavior change and the others less so, but they may offer major improvements that could conceivably overcome this.[28] Companies may create great new products, but this may not mean much if it requires major behavior change. It is easier to change technology than behavior.

25 Satell, Greg. "How to Manage Innovation." *Forbes*. March 7, 2013. Last accessed May 5, 2017. ▸ http://www.forbes.com/sites/greg-satell/2013/03/07/how-to-manage-innovation-2/.

26 Clayton, Christensen M. *The Innovator's Dilemma*. Boston: Harvard Business School Press, 1997, xv.

27 Graph based on Gourville, John T. "Eager Sellers & Stony Buyers." *Harvard Business Review*, 84, no. 6 (June 2006): 98–106.

28 Gourville, John T. "Eager Sellers & Stony Buyers." *Harvard Business Review*, 84, no. 6 (June 2006): 98–106.

Easy sells The product benefit improves modestly and requires only limited adjustments in behavior. Examples: a move from iPhone 7 to iPhone 8, or another James Bond movie.

Sure failures The innovation has only limited benefits in performance but requires a significant behavior change. Example: transitioning from the standard QWERTY keyboard configuration to the Dvorak keyboard, which is slightly faster but requires relearning the "muscle memory" of typing.

Long hauls These innovations provide a technological improvement, but require a significant behavior change. Initially, at least, adoption will be slow because consumers resist the switch. An example is satellite radio. Even the cellular telephone took a fairly long time to spread (25 years to reach an 80% adult subscribership). If the product does not sell itself, and a company business plan is over-optimistic about adoption rates of the new product, it will fail.

Smash hits The innovation generates major benefits with only slight behavior change. Example: the Google search engine.

An illustration of these categories is the TiVo DVR and the DVD player, both products of the late 1990s. By 2005, the USA had 20 times more DVD players than TiVo DVRs, even though the value of a TiVo player was much greater (recording TV shows, skipping advertisements and so on). Consumers were familiar with music CDs and needed no behavior change, in contrast with TiVo which required a new viewing behavior.

Yet, many companies do not have enough resources to wait patiently for demand to grow. The second option is to have innovations that offer a quantum leap in improvements (in the order of almost three times of previous performance, as we have discussed) to overcome consumer conservatism. But such innovations are rare. The third alternative is to target consumers who are either early adopter types, or who are not yet users of legacy products and thus have no commitment to them.[29]

29 Gourville, John T. "Eager Sellers & Stony Buyers." *Harvard Business Review* 84, no. 6 (June 2006): 98–106.

Market demand does not provide a full answer either. An innovation must also be profitable. Demand for the product helps, of course, but the cost side of investments and operating expenses is also a factor. This is dealt with graphically in ▫ Fig. 4.5,[30] which shows a "bubble diagram," where projects are mapped according to three dimensions: NPV (the horizontal axis), a measure for profitability; the probability of R&D success (the vertical axis); and the required investment (the size of each bubble).[31] The overall size of the bubbles adds up to 100%. The bubble diagram model helps management to make resource allocation decisions, given the finite resources of budget and people. The sum of the areas of the circles is a constant, zero-sum game. The model then forces management to consider tradeoffs. If one adds or enhances one bubble – one project – then some other projects must be reduced or dropped.

There are four different types of projects:

- *Pearls* (upper left quadrant): such projects have a high probability of success (low risk) and a high yield. In ▫ Fig. 4.5, the company is engaged in two pearl projects, one of them with a high investment need. But profitability is high, which justifies the project.
- *Oysters* (lower left). These are long-shot projects with a high expected payoff but low probability (high risk) of technical success. A technical breakthrough will generate strong payoffs. The company has three such projects but funds them at a low level, thus protecting its downside.
- *Bread and Butter Projects* (upper right). These are safe choices. The probability of success is high but the rewards are low. Examples would be improvements of existing products. As discussed, a firm may put 70% of its R&D budget into such projects. And, indeed, the company has several such projects, and more than half of its R&D investments are allocated to them.
- *White Elephants* (lower right): these are low-probability and low-reward projects. Nevertheless, the company has several of such projects. This seems to be a flawed allocation of scarce resources.

30 Based off of Cooper, Robert. *Winning at New Products*. New York: Basic Books, 2011.

31 Cooper, Robert G., Scott J. Edgett, and Elko J. Kleinschmidt. "Portfolio Management in New Product Development: Lessons from the Leaders – II." *Research-Technology Management* 40, no. 6 (1997): 43–52.

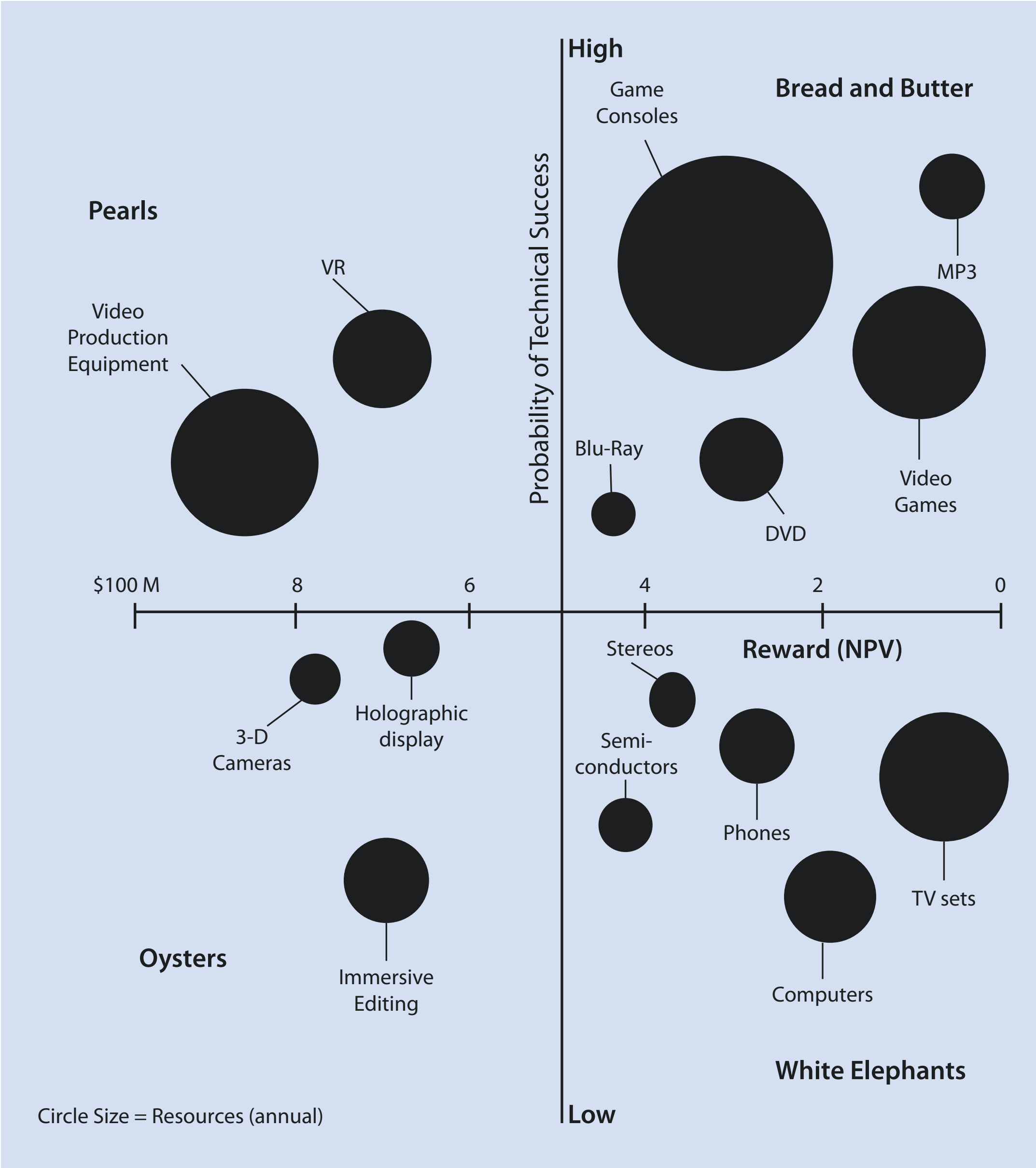

Fig. 4.5 Risk-reward diagram of projects

4.2.5 The Placement of R&D: In-House, Acquired, or Co-developed?

The question of in-house vs. outside innovation is not simply one of yes/no, but also one of "what" and "where." Rarely would a firm innovate, on its own all, of its components and all the elements of its value chain. It would, instead, focus on one or several aspects and leave the others for development by outside vendors. Why should it develop its own cameras or computers? The important R&D question for companies to consider is, then: where is the right "decoupling point" of its internal technology development? Which part of its value chain does it create and innovate on its own, and which does it acquire from others, either off-the-shelf or by special commission? Advantages of development inside the company include proximity of R&D to production and marketing, the protection of business secrets, a clear ownership of the intellectual property rights, better cost control of projects, and greater familiarity of the firm with the needs of customers and markets. But an outsourcing of R&D has advantages, too. Outsourcing allows firms to take advantage of specialists with experience and economies of scale. For example, for content-oriented media companies, technology R&D is not a core competency. Even for technology companies such as device manufacturers and network operators, the outsourcing of some or all R&D is part of a larger trend of separation of production and development. In some cases, production-oriented firms subcontract their R&D. In other cases, conversely, firms focused on R&D will outsource production. And, in some cases, "virtual companies" outsource both.

The manufacturing contractors are known as electronic manufacturing services (EMS) or original equipment manufacturers (OEM) firms. A major OEM, Flextronics, produces handsets for mobile device companies located in high-cost countries. The world's largest PC maker, largely unknown outside the industry, is Quanta, a Taiwanese company. It manufactures computers for most major brands around the world.[32] Apple outsources part of its manufacturing to Foxconn in China. One of Foxconn's plants employs 230,000 workers, 60,000 of whom live in factory dormitories. Outsource manufacturers such as Selectron, Flextronics, Celestica, SCI Systems, Foxconn, and Jabil Circuit increasingly do the design and R&D of various products, not just the manufacturing. Alternatively, specialty boutique design companies perform the R&D. In the extreme, only the marketing would still be done by the name-brand company, and even that could be contracted out.

4.2.6 The Organizational Structure of R&D Activities

Among the most important issues facing a large company is how to position its R&D within the larger multi-divisional corporate structure. The R&D will either be centralized, decentralized, or somewhere in between. Control and funding are the central issues.

In industrial firms, R&D was often a top-down structure. Major firms created sophisticated stand-alone laboratories. Bell Labs won six Nobel prizes, and IBM-Zurich earned two such prizes. Xerox's Palo Alto Research Centre (PARC) innovated PC elements such as the computer mouse, the Ethernet protocol for computer networking and the graphic user interface (GUI).[33] But a centralized research system creates a distance from the production and design activities of the firm. In contrast, a fully decentralized R&D structure permits various company units to pursue goals closer to the product lines. In such a system, the corporate-level R&D is limited in scope, and focuses on the identification and evaluation of emerging technologies which have no home yet in the company. Hitachi and Intel are examples, with little corporate-level R&D.

Intermediate arrangements are "centrally led" or "centrally supported" R&D. Typically, the corporate center handles the research part of R&D, covering more basic technology that might have applications across the company, while the refinements and applications into products—the development—is handled by divisional labs.

A related organizational question is how an R&D lab should be structured. They could be arranged according to research *disciplines* such as typically found in universities; e.g. chemistry, metallurgy, electronic engineering. This promotes specialization and makes it easier to hire promising young scientists. The disadvantages are an orientation to "science," rather than commercial innovation; a work-pace under less time-pressure; and greater difficulty in the conducting of cross-disciplinary R&D. In contrast, R&D activity can also be organized by type of *activity*, such as basic research, applied research, development, design, engineering, prototyping, testing. This is a more ad hoc structure, the staffing of which could fluctuate greatly.

A third approach is to organize an R&D department by *product line*, such as storage devices, TV sets and tablets. Advantages are a stronger customer focus, easier coordination and smoother integration with business activities. A fourth option is to organize the R&D department by project, such as a new type of flat screen. Such a system frequently operates on a matrix basis, drawing experts from different parts of the company, labs and scientific specialties.

32 Funding Universe. "Quanta Computer Inc." Last accessed July 11, 2011. ► http://www.fundinguniverse.com/company-histories/Quanta-Computer-Inc-Company-History.html.

33 The Economist. "Out of the Dusty Labs – The Rise and Fall of Corporate R&D; Technology R&D." March 1, 2007. Last accessed August 10, 2012. ► http://www.economist.com/node/8769863.

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Another dimension for the organization of R&D is its geographical location. Global companies conduct R&D globally. Technology has few frontiers, though some countries have tried to erect protectionist barriers around "their" companies and "their" technologies. Pioneers of R&D internationalization have been high-tech companies with global markets, headquartered in a relatively small home country with finite technology resources. Examples are Philips in the Netherlands, Ericsson in Sweden and Nokia in Finland. European companies perform about one-third of their R&D outside their home countries. Another reason for an international distribution of production facilities are the politics of trade, since the location of an R&D facility may be part of a company's efforts to gain market access. A third reason is the relative cost, which favors low-cost R&D in India or China. Other locational factors are governmental subsidies, strong universities with a large pool of graduates, harmonious labor relations, and a favorable regulatory and tax system.[34] Some tech companies from around the world have created small innovation labs in Silicon Valley as footholds in order to remain up-to-date on emerging technologies and to develop deeper relationships with start-ups.

There are, however, also reasons against international R&D. These include an immobility of top research personnel and a lack of critical mass when R&D is dispersed, plus language and cultural problems, political instability, the diffusion and potential loss of company know-how, and significant coordination and transaction costs.

4.2.6.1 Case Discussion

How Sony's R&D Is Organized

Sony's R&D outlays were considerable. In 2008, they were $5 billion and, in 2013, $5.7 billion[35] Its R&D priorities were in its digital image sensor business (supplying camera components to smartphone makers),[36] the 4K Playstation and artificial intelligence.[37] Samsung's R&D expenses were about $14 billion, higher than any other ICT company. Microsoft expenses were $10 billion, Google $8 billion, and IBM's and Cisco's $6 billion each. R&D as a percentage of revenue was 7% for Sony, slightly higher than for Samsung and IBM, much higher than for Apple (2.5%) but lower than for Microsoft, Google and Cisco, all with about 12–13%.

Thus, Sony did spend a great deal on R&D and also achieved much innovation, if patents are a measure. In 2013, Sony filed 2241 US patent applications; Samsung, 4945; and Panasonic, 2232. In 2015, Sony had 2448 US patent applications; Samsung, 5059; and Panasonic, 1474.[38]

But Sony's R&D system was not well-coordinated. It was spread out across divisions and countries. Its R&D strategy was to give its various labs a pretty much free hand. At times, different divisions developed incompatible products.

Sony's R&D is based on a corporate (central) research lab with six separate sub-labs. The corporate lab is used for the development of next-generation products with wide applications, such as OLED video display screens. Additionally, there are R&D labs at network level, as well as division level and regional zone level.[39] The zones are Asia, the USA and Europe. The aim was to better coordinate R&D activities not only within each region, but also among regions. CTOs were appointed for each zone and given considerable authority. A relatively informal and non-bureaucratic cooperation between them was encouraged. The idea was to establish personal relationships and teamwork in order to achieve global synergy. An example is Sony America's zone R&D, which

34 For example, IBM had 12 corporate research centers worldwide in 2017, with over 3000 employees in R&D centers in the USA (Hawthorne, Yorktown Heights, Almaden and Austin), Australia (Melbourne), Brazil (São Paulo and Rio de Janeiro), China (Beijing), Kenya (Nairobi), South Africa (Johannesburg), Israel (Haifa), India (Delhi and Bengaluru), Ireland (Dublin), Japan (Tokyo) and Switzerland (Zurich). (Last accessed May 9, 2017 at ► http://www.research.ibm.com/labs/).

35 PwC. "2013: Top 20 R&D spenders." Last accessed on June 21, 2016 at ► http://www.strategyand.pwc.com/global/home/what-we-think/innovation1000/top-innovators-spenders#/tab-2013.

36 Kennedy, Joshua. "3 Changes to Watch at Sony (SNE)." *Investopedia*. January 26, 2016. Last accessed June 21, 2016. ► http://www.investopedia.com/articles/markets/012616/3-changes-watch-sony-sne.asp.

37 Davies, Jamie. "Sony leans on AI to give technological advantage." *Business Cloud News*. May 18, 2016. Last accessed June 21, 2016. ► http://www.businesscloudnews.com/2016/05/18/sony-leans-on-ai-to-give-technological-advantage/.

38 USPTO. "Ranked List of Organizations with 40 or More Patents, as Distributed by the Year of Patent Grant and/or the Year of Patent Application Filing, Granted: 01/01/2015–12/31/2015." Last accessed June 21, 2016. ► http://www.uspto.gov/web/offices/ac/ido/oeip/taf/data/topo_15.htm#PartB.

39 All R&D labs are assigned fairly generic "3 Missions" and "6 Goals". The "3 Missions" were: Strengthen R&D employee's abilities and knowledgebase; Globalize domestic R&D efforts; Establish a "global human information network." The "6 Goals" were: Clear vision and policy; Clear target and differentiation of R&D strategy from rivals; Strategic selection and precise focus of R&D themes through fair evaluations; Highly skilled ("best of the best") staff for R&D; Mobility of technology and R&D staff within a global Sony; Export of Sony's R&D function and strengthen overseas labs.

spearheaded the development of the cell processor (jointly with IBM and Toshiba). (This example also illustrates that, rather than outsourcing its R&D, Sony's R&D has increasingly become a collaboration with major partners.)

Sony has international R&D facilities in Asia, the USA and Europe, each specializing in one or more fields of technology. For example, the Sony China Research Lab in Beijing (2005) focuses on security technology, intelligent media, solar cells and wireless networks. Sony opened seven R&D labs in the USA since 1987. The research focus in the USA includes the Advanced Video Technology Center (AVTC) in San Jose, California (1994), which focuses on HDTV, and the Open 3D Research Center in Las Vegas (2010), specializing in 3D TV and film, in collaboration with CBS. Research in Europe is done in Brussels, Alsace, Paris, Stuttgart, Barcelona, Lund (Sweden), Basingstoke (UK) and Pencoed (UK). The Sony Computer Science Lab in Paris focuses on the personal music experience, computational neuroscience, developmental cognitive robots and self-organizing communication. The European Technology Center in Stuttgart focuses on sensing systems, material science and automotive entertainment.

4.2.7 Open Innovation – Community-Based R&D

Another way to organize R&D is to link it with developers and with users. The two are overlapping. A structured and company-led approach is where the company builds basic platforms (hardware, software, or both), and aims to create uses and users. To do so, it provides specifications of the product to developers to induce them to create applications. This creates a symbiotic relationship, where both the platform company and the applications firms benefit from the creation of synergies and network effects. An example is Apple with its iPhone apps.

For some companies, a major management strategy is therefore to encourage developer-based innovation. They may provide independent developers access to their software or platforms. They do so by granting interoperability arrangements via application program interfaces (APIs) that enable the outside programs to link up and thereby make the device more versatile and powerful.[40] Developers then compete with each other's applications software. The credit card company Visa, for example, gives developers access to hundreds of its financial payment APIs.[41] The social media company Facebook offers a Games Developer Center that features a variety of interoperability arrangements, monetization tools and services for game developers.[42] The goal is to drive traffic to the Facebook site. Amazon and Microsoft provide developers with the Internet of things (IoT) software development kits so that they can build IoT apps and products.

Going one step further is *user-generated innovation*.[43] Advantages are not only reductions in a company's development time and cost, but even more so a potentially better match of product with customer needs, given that the latter are directly involved. It also raises user loyalty because they are more involved. The company can import low cost, high-quality ideas from a wide array of experts[44] and test these ideas, as well as its own, by a "peer-review" process of a "smart crowd." An example is the car maker BMW, which set up a "Customer Innovation Lab," which is an online tool kit to help customers develop ideas and innovations for automobile telematics and driver assistance systems. BMW chooses the best ideas, which are then implemented by its engineers.

Taking still another step is "open innovation," where there is no longer a company in charge, only a community of users, developers and volunteers

40 In some cases, such access to the APIs has been mandated by governmental regulators in order to enable competition in the applications.

41 Thurai, Andy. "How APIs Fuel Innovation." *Wired*. Last accessed June 21, 2016. ► http://www.wired.com/insights/2013/12/how-apis-fuel-innovation/; PYMNTS. "Visa's Developer Platform Begins With and 'I'." February 5, 2016. Last accessed May 9, 2017. ► http://www.pymnts.com/news/payments-innovation/2016/visas-developer-platform-begins-with-an-i/; Tibco Mashery. "Driving Innovation and Revenue with Partners and Developers." September 22, 2015. Last accessed May 9, 2017. ► https://www.mashery.com/sites/default/files/Edmunds-Case-Study.pdf.

42 These tools include Achievements API, Scores API, App Notifications, Requests, Feed Gaming and Facebook SDK for Unity. The Facebook Games Developer Center offers information such as games overview, API migration guide, tutorials, production and checklists, game monetization and more.

43 Von Hippel, Eric. "Horizontal innovation networks – by and for users." *Industrial and Corporate Change* 16, no. 2 (2007): 293–315.

44 Rigby, Darrell K. and Barbara Bilodeau. "Management Tools & Trends 2013." *Bain & Company*. 2013. Last accessed May 9, 2017. ► http://www.bain.com/Images/BAIN_BRIEF_Management_Tools_%26_Trends_2013.pdf.

who come together in a loose and decentralized collaboration to create an innovative product or service. In computer software, there has been community development in the form of "open source" software such as Apache and Linux,[45] to which numerous people contribute. It is an important challenge for company R&D leadership to find ways to integrate such largely uncontrolled and dynamic innovation with proprietary corporate R&D.

4.2.8 Budgeting for Innovation

The cost of R&D has been climbing. This is not surprising, since the "easy innovations" are done first and the cost of subsequent innovation increases. A second reason is that the average economic lifespan of innovation has shortened due to increasing competition, globalization and convergence. Costs are also going up due to the acceleration of the process. Often, company managers, under competitive pressure, demand that technology developers speed up their activity. They need to understand the cost implications. Compressing R&D project time may greatly raise its cost relative to speed-up gains. The reason is that each R&D step builds upon results of previous tasks. To accelerate a project, then, requires some of the steps to overlap and to start with less information. Several approaches may have to be tried concurrently, rather than sequentially. A study shows that a 1% squeeze in the duration of a project can increase costs at double that rate.[46]

The broader question is how much money a firm should put into R&D. The largest technology firms in electronics spend billions of dollars annually on R&D. Microsoft, IBM, Intel, Google, Nokia, Panasonic, HP and Sony all devote well over $5 billion per year to R&D. In 2013, Samsung spent $14 billion in R&D, over about 6% of its revenues. Qualcomm spent 20% of its sales revenues on R&D, about $150,000 per employee. But how much should a company spend? Often, there is no shortage of good ideas and worthy projects; however, their aggregate will be unaffordable.

Of course, the firm's financial condition is relevant. When things are tough, R&D is often one of the first things to be cut from corporate budgets. The famed AT&T Bell Labs shrank from 25,000 in the 1970s to just 1000 researchers in 2003. Its 1975 budget, which, in 2003 dollars, had been $3.24 billion,[47] had dropped to $115 million in that year.[48] While cutting out R&D may make sense in the short term, from a long-term perspective it is like eating one's seed corn.

One way to estimate a target R&D budget is to compare the firm's R&D to that of competitors, either in absolute terms or by the ratio to sales. A second way is to adjust one's R&D spending to that of rival companies' flow of new products, so as to match or surpass it.

A third method, which is finance and economics oriented, would be to determine the incremental profit from incremental R&D spending. But that is easier said than done. One would need to have an idea of the productivity of R&D spending. Productivity can be measured by an output—for example, by the number of patents. (While each patent tends to be distinct in terms of effort required or its value, when the number is large the differences tend to average out.) On average, Sony spent $2.0 million on a patent in R&D expenses, Samsung spent $2.7 million and Google spent $4.3 million.

Several R&D performance measurement techniques have been developed. According to one study, US industrial firms use more than 50 metrics to monitor their R&D function.[49] They come in several categories.

45 Von Hippel, Eric. "Horizontal innovation networks – by and for users." *Industrial and Corporate Change* 16, no. 2 (2007): 293–315.

46 Graves, Samuel B. "Why Costs Increase When Projects Accelerate." In *Measuring And Improving The Performance And Return On R&D*. Arlington, VA: Industrial Research Institute, 316–318.

47 Noll, A. Michael. "Telecommunication Basic Research: An Uncertain Future for the Bell Legacy." *Prometheus* 21, no. 2 (June 2003): 177–193.

48 The Economist. "Out of the Dusty Labs – The Rise and Fall of Corporate R&D." March 1, 2007. Last accessed May 2, 2017. ► http://www.economist.com/node/8769863.

49 Werner, Bjorn M. and William E. Souder. "Measuring R&D Performance—State of the Art." *Research Technology Management* 40, no. 2 (March–April 1997): 38–46.

- **Quantitative Metrics**
  - *Input measures* include the number of scientists employed, or total R&D expenditures.
  - *Output measures* include the number of patents filed, costs reductions and the number of new products released.
  - With economic values assigned to such measures, one can calculate the ROI attributable to an investment in R&D.

Qualitative Metrics Qualitative metrics rely on expert judgments on the performance of individual scientists, teams, groups, or departments. They are similar to evaluations of academic departments or researchers by peer reviewers. These evaluations can be transformed into numeric scores and related to R&D spending. Both quantitative and qualitative metrics have advantages as well drawbacks, and they can be combined into a single and integrated metric.

4.2.9 Implementing R&D Alliances

Companies may acquire and create new technology through R&D alliances with other firms. The advantages are numerous: the pooling of talent, economies of scale and scope, risk-sharing, leveraging comparative advantages, attracting talent, stimulating internal innovation, increasing overall technological innovation capabilities, increased speed, reducing costs through sharing and rapid access to new or proven technologies.

There are also disadvantages to such collaboration. They include transfer of know-how to rival firms, the transaction cost of coordination and contracting, loss of control, lower ability to profit from the innovation and potential conflicts. In order for R&D alliances to succeed, there must be technological and strategic compatibility, a more efficient innovation process and improved market access. These factors are hard to coordinate effectively and a majority of R&D alliances fail.

An important part of alliances is with universities. Private capital plays a role in the commercialization of innovations, but not directly in the funding of basic research, the results of which are distant and speculative. Thus, basic research is mostly conducted in government labs and universities.[50] Many research ideas are created inside the universities and they flow through them from multiple directions.[51] Companies benefit from collaborations with leading research universities, which gives them early access to basic research and researchers. Examples are the symbiotic relations of Silicon Valley companies with Stanford and Berkeley, of Route 128 corridor businesses in Boston with Harvard and MIT, and of the North Carolina Research Triangle firms with Duke, the University of North Carolina, and North Carolina State.

A firm may use universities as suppliers of useful research. Intel, for example, selects academic scientists and teams to develop technology that results in patents. Both company and university research benefit. Research funding from a corporation allows universities to conduct more advanced and expensive research.[52]

4.2.10 Knowledge Management

In far-flung organizations, knowledge of the flow of R&D and its absorption between various levels is important.[53] As the past CEO of Hewlett-Packard, Lew Platt exclaimed with exasperation: "If HP knew what HP knows, we would be three times as profitable." Knowledge management (KM) is the organization and distribution of information, experience, "tacit knowledge" and wisdom inside the company. It aims at sharing knowledge while also protecting it. It is crucial for any company to ensure the effective management of the flow of internal and external technical information.

50 Waites, Robert. "Reinventing Corporate Research." *Research-Technology Management* 45, no. 4 (2002): 15–22.

51 Tennenhouse, David. "Intel's Open Collaborative Model of Industry-University Research." *Research-Technology Management* 47, no. 4 (2004): 19–26.

52 The Economist. "Out of the Dusty Labs – The Rise and Fall of Corporate R&D." March 1, 2007. Last accessed May 2, 2017. ► http://www.economist.com/node/8769863.

53 McCormick, John. "5 Big Companies That Got Knowledge Management Right." *CIO Insight*. October 5, 2007. Last accessed June 14, 2012. ► http://www.cioinsight.com/c/a/Case-Studies/5-Big-Companies-That-Got-Knowledge-Management-Right/.

There are a variety of knowledge management tools. Documents can be tagged with metadata, which makes them searchable. This avoids having to replicate information that has already been created and to put together pieces into a greater whole, which is often a foundation of innovation. Software can also be used to limit who has access to what material. Other tools are knowledge mapping of resources, creation of communities of practice and social software for interaction.

At its most fundamental, knowledge management is like creating an internal search engine that makes company-generated information accessible throughout the organization, and even to customers and vendors. It reduces duplication and assists coordination.

4.2.11 Standards Strategy

CTOs are often a company's liaisons on technology matters to the outside research community — universities, government labs, professional associations and other companies. In particular, companies need to deal with standards bodies and standardization efforts. Standards are quite prevalent in most parts of media technology. Examples are the times a DVD spins per second or the number of scan lines or the ratio of width to height of a TV picture. A standard tries to create common parameters. In some cases, such as driving on the left side of the road or the right, the substance of the standard is less important than its existence. This example also shows that standards can coexist, with different regions, car manufacturers and car owners going their own way (though, one hopes, not on the same road). In media technology, standards are widespread; almost as widespread are the struggles over them. Behind many standards is a saga of rivalry, conflict, intrigue and diplomacy. Examples are the original analog color TV broadcast protocols (NTSC in the US vs. PAL in some parts of Europe and SECAM in others), video cassette recorders (Sony's Beta vs. Panasonic's VHS), for mobile wireless (GS vs. CDMA), or for high-definition DVDs (Blu-ray vs. HD-DVD).

The alternative to standards is a proprietary technology. In some cases, it becomes so prevalent as to constitute a de facto standard for most market participants. An example is Microsoft's DOS and then Windows operating system, which was not "standardized" with other companies or countries, but which emerged as the de facto way in which much of the microcomputer industry functioned.

The benefits of standards include expanded network effects.[54] Standards enhance compatibility. But proprietary technology may fail if other competitors have a similar product which is non-proprietary or easy to license. Examples are the failure of Sony's Beta VCR system vs. the open VHS. Deciding between openness or control is never easy, but it typically depends on a company's ability to create alliances with others.

There are also disadvantages to formal standardization. To reach an agreement on a standard can be costly and time-consuming. Lagging companies may try to slow down the process in order to catch up. There is often politicization and companies try to enlist their governments as being a "national champion" that benefits the country.

In the media field, standards tend to be set either by various international or domestic industry organizations, or by governmental, inter-governmental and semi-governmental organizations.[55] It is important for a company to play the standards game well. Standards can determine company success, as well as market structure. Yet, generally speaking, start-up companies and their investors are unfamiliar with the role standards play, and ignore the standards process until they are forced to follow it.

A big standards battle, such as Sony Blu-ray vs. Matsushita's HD-DVD, costs many millions just in the standards body process. A mid-size tech company with a more modest budget could easily spend $100,000 a year just on monitoring the standards process affecting it.

Digital technology does not require uniformity in the same way that analog technology does. It is more flexible. Smart TV sets can process multiple standards. Different video providers will

54 Shapiro, Carl and Hal Varian. "Waging a Standards War." *Information Rules*. Boston: Harvard Business School Press, 1999, 228–233, 238–242, 273–276.

55 Standards bodies include the International Telecommunication Union (ITU), the International Standards Organization (ISO), the European Telecommunications Standards Institute (ETSI), the American National Standards Institute (ANSI), as well, in the USA, as the Institute of Electrical and Electronics Engineers (IEEE). There is the CEA (Consumer Electronics Association) and SMPTE (Society of Motion Picture and Television Engineers). DVB sets TV and video standards for Europe and elsewhere. Internet standards are set by bodies such as the Internet Engineering Task Force (IETF) as well as the W3C (www consortium).

choose different standards and compete with them. This permits rapid entry of new technologies and innovation. In consequence, it is unlikely that uniform standards will be as important to the future of media as they have been in the past.

Beyond those specific tasks, one of the CTO's major responsibilities is to help foster a climate of innovation in the organization. This is further discussed in ▶ Chap. 5 Human Resource Management for Media and Information Firms.

4.2.11.1 Case Discussion

Sony's Standards Efforts

Sony had mixed results from its standards efforts. It scored a great success when it developed the CD player technology jointly with Philips of the Netherlands as its European ally, and this then became the worldwide standard.

On the other hand, Sony's go-it-alone approach did not work for Betamax at all. Many years later, Sony's Blu-ray DVD standard prevailed after a major struggle, but it took much coalition-building to achieve it; also, the process retarded consumer acceptance of high-definition DVDs by several years. Partly in consequence, Blu-ray penetration rates were much lower than those of the previous generation, that of DVD players.

4.3 The Six Stages of Media and Communications Technology Digital Convergence: "The 6 C's"

The next major section of this chapter is a discussion and overview of the significant trends in technology as they affect media and communications. Due to the breadth of the subject, it can serve only as an introduction. But such an introduction is important for those engaged in or contemplating a career in this sector.

Traditional media were separated by delivery technology—printed paper, film on celluloid, broadcast amplitudes, telephone wires, vinyl discs, computer discs and so forth. Similar specializations separated the provision of content from conduit. Within these separate markets, a firm could achieve market power. In the 1980s and accelerating in the 1990s, however, a technical convergence of media gradually began to blur the clear lines between segments, thereby creating potentially more rivalry. This fundamentally affects media, the borders between them and the market structures in which they operate.

The "convergence" of technology has been a broad and long process. It can be decomposed into several distinct convergences, some sequential, some marching in parallel. This will be the subject of the segments that follow.

4.3.1 Convergence #1: Computers

Several major technologies have come together to make computers possible. In particular, they are calculating devices, electronic components and control codes.

4.3.1.1 Calculating Devices

Calculators started as mechanical devices such as the abacus, created to assist people in arithmetic. In 1642, when he was 19, Blaise Pascal, a French mathematical genius and entrepreneur, invented a mechanical calculator. In the nineteenth century, Charles Babbage, a British scientist, inventor, traveler, economist, politician and author, designed a complex "difference engine" and a still more elaborate "analytical engine." His work was supported by Ada Byron (the Countess of Lovelace and the daughter of Lord Byron).

4.3.1.2 Components

Babbage's machines and similar calculators that followed had to rely on mechanical wheels, gears and so on. As soon as calculations became more complex, mechanical devices were not up to the task. To overcome this required the use of electrical signals. A major breakthrough was the electric vacuum tube, which goes back to 1906 and the AT&T engineer Lee de Forest. This made it possible to mirror and amplify weak signals, as well as to open and close an electric circuit. The vacuum tubes were bulky, fragile and energy hogs. They were replaced in the 1950s by "solid-state" transistors based on silicon.

Transistors were invented in 1947 by William Shockley and his AT&T Bell Labs team, for which they received a Nobel Prize in 1955. Shockley started his own company. In turn, two of Shockley's best engineers, Robert Noyce and Gordon Moore, left him to start their own firm, Fairchild Semiconductors, which subsequently split off to form Intel, the perennial leader in microprocessors.

Transistors are the key element of all microelectronics. They are similar in concept to an electronic tube: a weak signal controls a stronger one and is thus amplified. Transistors consist of three terminals: the source, the drain and, between them, the gate. When a positive charge is applied to the gate, the electrons are pulled from the source to the drain, meaning that the transistor is "on." But when the positive charge at the gate is removed, electrons do not flow and the transistor is turned "off." The on/off functionality of the transistor is what enables it to code and process information as binary 0s ("off") and 1s ("on").

Transistors proliferated, as did the other solid-state components that are part of electronic circuits, such as resistors and capacitors. In the third generation of components, these elements were put together in a single "integrated circuit" (IC) on a silicon chip. The first such integrated circuits were produced in 1959 by Texas Instruments and Fairchild Semiconductors. Each IC contained an increasingly large number of transistors on a single semiconductor chip. Such a chip was dedicated to a particular function, such as math calculations, or thermostat control. This changed with the fourth generation of components, *microprocessors*, which were programmable, i.e. they could be instructed to do many different things. (There are also many types of specialized chips, e.g. for image processing.)

In order to boost performance, semiconductor manufacturers now combine multiple processor "cores" on a single chip. In 2018, Intel's I9-7980XE Processor had eighteen cores, and operated at a 4.20 GHz clockspeed.

The next generation of chips moved miniaturization and integration to yet another level, that of a "computer-on-a-chip" or a "system-on-a-chip" (SOC). They contain many components of a single chip: a processor (CPU), non-volatile memory (ROM or flash), volatile memory (RAM), a clock, an input/output control unit and more. This is ideal for compact products such smart phones.

4.3.1.3 Control Code and Devices

As machines began to develop power and speed, it became evident that they required control by human operators who were often too slow, expensive, and unreliable. Mechanical control devices were therefore developed. In 1805, punch cards were used in France to control a weaving loom. In 1896, Herman Hollerith introduced a tabulating machine for use by the U.S. Census Bureau.

Central to the ability of electronic machines to process and store information is "binary" coding, in which information is expressed as a string of 0s and 1s. These sequences and patterns of 0s and 1s can represent not only decimal numbers, but also letters, numbers, colors and graphics. They can be manipulated through the mathematics of "Boolean" algebra, developed by George Boole in the nineteenth century, establishing the mathematical foundation of what became "computer science." The mathematics of controlling electronic calculating devices were advanced by Alan Turing of the UK along with John von Neumann, who had left Hungary for the USA. During World War II, they conceptualized how a machine could manage computational tasks.

Instructions that controlled the functioning of computer hardware became known as "software." Its "programs" or "languages" have progressed from the earlier specialized, expensive science of mathematicians to a craft by skilled programmers and technicians, and to a stage where machines are able to write programs for other machines. The software has moved from an arcane and specialized craft product that only specialized engineers could interpret to a thriving, industrialized and often consumer-oriented industry producing a mass-product—and from products of low volume and high price to those of high volume and low price.[56]

In the late 1990s, there were new developments in software. The first and most potentially challenging development was the growth of the Internet. As transmission bandwidth grew cheap and plentiful, many observers expected that users would only need a so-called "thin client" with which to access the Internet, with the intensive

56 Noam, Eli. *Media Ownership and Concentration in America*. New York: Oxford University Press, 2009.

computing done at a distance by more powerful servers. By reducing the need for a standardized operating system and for most applications programs, software providers would compete based only upon their price and performance criteria such as speed, reliability and ease of use. The thin-client network computer concept failed to live up to expectations, but the emergence of cloud-based computing may bring a revival.

4.3.1.4 The Computer

We have briefly explained the emergence of calculating machines, electronic components and software control languages. By the 1940s, these elements were put together into the first computers.

During World War II, British and Polish decryption of the German secret military "Enigma" codes led to advanced mechanical calculation machines, which soon became electronics-based devices that could quickly go over millions of permutations. The Harvard Mark I (1943) was the first program-controlled calculator. It weighed five tons, had 750,000 parts and 3304 relays. The US Navy utilized it for ballistic tables. The chief programmer was Grace Hopper, who later became the first woman US Admiral. But it was still a specialized machine for specialized purposes, rather than a universal multi-task computer. In Germany, similarly, Konrad Zuse in 1941 developed the Z3 as a programmable computing machine. The first general purpose computer was the ENIAC (1946). It was designed by John Mauchly and J. Presper Eckert of the University of Pennsylvania to break codes, calculate artillery flight and assist in nuclear development. It was 100 feet long, weighed 30 tons and cost $500,000. The ENIAC's inventors commercialized the technology into the Universal Automatic Computer (Univac) and soon sold their company to Remington Rand. This was the beginning of the computer industry.

IBM, a major office machine supplier of typewriters and desktop calculators, entered the market in 1953. It was able to leverage its dominant position in the tabulator punch card market and soon dominated the business market. When such "mainframe" computers were not powerful enough to meet specialized demand for high performance, "supercomputers". In 2011, the IBM Sequoia could run at the speed of 20 PetaFLOPs. In 2017, the top performer was the Chinese Sunway Taihulight with 93 PetaFLOPs. By 2018, the Oak Ridge National Laboratory in Tennessee took the lead with its 200 PetaFLOP Summit computer. Exascale computers were being developed, the equivalent of about a trillion regular laptops.

These supercomputers—whose performance rises roughly a thousand-fold each decade—consist of massive, parallel processors and are used for large-scale scientific calculations, simulations, code-breaking algorithms and so on.

A different approach to high processing requirements is taken by Google and cloud providers. They run "server farms" of hundreds of servers. These servers are not supercomputers but, rather, commodity-class PCs running a customized version of Linux operating software. They aim to achieve best performance per dollar, instead of being the fastest machines. With upward of 450,000 servers, each with over 80 gigabytes of hard drive space and 2–4 gigabytes of RAM, Google's processing capacity reached about 143 PetaFLOPs in 2018, with over one million servers in operation, mostly of the inexpensive commodity type.[57]

Massive computing is used in the film industry for producing special effects and animation. Animated objects such as talking cars or animals are relatively straightforward to generate by computer. It is harder to create the believable animation of regular people, since humans are pretty experienced in the subtle reading of other human faces and motions, and computerized recreations would have to be near-flawless in order to be believable, rather than seen as cartoons. To do so requires animation computers with a huge combined processing capacity. In 1977, computer processing was still so prohibitively expensive that, when George Lucas made the original *Star Wars* film, he could afford to use computer graphics for only a single 90-second sequence.[58] The Death Star sequence took several computers three months to complete. The trend in the film industry shifted from a single supercomputer doing animation and special effects, to several mainframes and, eventually, to a network of medium-sized workstations known as "render farms." DreamWorks' render farm had about 30,000 "cores." Pixar had 24,000.

57 Pern, James. "What is Google's Total Computational Capacity" *Google+*. ► https://plus.google.com/+JamesPearn/posts/gTFgij36o6u. Halfacree, Gareth. "Google announces 100 petaflop TPU 3.0 pod" *bit-tech* ► https://www.bit-tech.net/news/google-announces-100-petaflop-tpu-30-pod/1/

58 Epstein, Edward Jay, *The Big Picture, The New Logic of Money and Power in Hollywood*. New York: E.J.E. Publications, Ltd., Inc., 2005.

Once it becomes technically and economically feasible to create believable human characters, the next step will be for studios to create entirely artificial actors by computer technology. They would own the characters—like they own Mickey Mouse—pay them no salaries, subject them to amazing stunts, fine-tune their physical features, and let them live happily forever, with no profit participation or residual rights to royalties. At a foreseeable point in the future, this will become an economically viable proposition.

Consumer Computers

The 1960s, 1970s and 1980s saw a number of governments around the world supporting "national champion" electronics firms in order to keep up with IBM in building computers. None was successful in challenging IBM. Yet, upstarts in the emerging Silicon Valley of California succeeded without government backing where the big firms had failed. They brought microcomputers to the consumer markets. Intel's 8080 microprocessor chip, introduced in 1974, enabled many computer processes. It could be combined with off-the-shelf components to build small computers, but large firms ignored this potential. Amateur computer builders therefore emerged to take advantage of this new market. In 1976, Steve Wozniak and Steve Jobs introduced the Apple I computer, which used a Motorola microprocessor and an operating system written in the BASIC computer language.[59] The microcomputers required software development machines. Focusing on the operating software for such small computers, Paul Allen and Bill Gates created Microsoft MS-DOS, which was adopted by IBM when it introduced its highly successful Personal Computer (PC) and laid the groundwork for Microsoft's and Intel's market dominance.[60] With the development of computer networks, the PC soon moved from being a standalone processor and storage device to an inter-networked device. The Internet became the major platform for such interconnection.

4.3.2 Convergence #2: Computers with Communications Hardware

The second convergence is that of computers with telecom communications. Electronic communications technology has been around since the mid-nineteenth century. Telecommunications—two-way individualized electronic communication—are now used more than ever before: at home, in the office, on the road, at the beach, when web surfing, chatting with friends, e-mailing, streaming music, watching video, holding a meeting, or running a company.

Telecom networks used to consist, at their user end, of lines known as "twisted pairs" of copper wires. For a higher capacity of signals, and for transmission under the oceans, copper co-axial (coax) lines were used. Optical fibers became a hugely powerful alternative means of transmission. They consist of very clear glass strands which can transmit the pulses emitted by light-emitting devices such as lasers. Not only do these fiber strands have a huge capacity, but they can also transmit signals for thousands of miles before they need to be regenerated and amplified. The trend of technological progress in wire-based communications, in terms of transmission rate ("speed"), has progressed at a compounded annual growth rate of about 44%, and that rate has been accelerating.[61]

The alternative to wired networks are wireless ones. In the 1840s, the English physicist James Clark Maxwell came up with the theory of electromagnetism. In 1888, Heinrich Hertz (Germany) demonstrated electromagnetic waves. In 1895, Gugliemo Marconi (Italy) applied these waves to transmitting telegraph-type signals to ships. Broadcasting soon followed. In time, technologists mastered increasingly high frequencies of electromagnetic waves. This made it possible to focus the radio beams narrowly, which enabled microwave transmission via one hilltop tower to the next, and later via satellites that seem to be hovering in a stationary orbit.

59 Smith, Roger. "5 Patterns of the Chief Technology Officers." *Research-Technology Management*. Last accessed April 30, 2017. ► http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.158.1721&rep=rep1&type=pdf.

60 Ohebsion, Rodney. "A Biography of Bill Gates and History of Microsoft." Last accessed May 9, 2017. ► http://www.rodneyohebsion.com/bill-gates.htm.

61 Koh, H. and C. L. Magee. "A functional approach for studying technological progress: Application to information technology." *Technological Forecasting and Social Change* 73, no. 9 (2006): 1061–1083.

The development of cellular wireless increased the utilization of the electro-magnetic spectrum by dividing a coverage area into small sections or "cells." Each cell uses a low-power transmitter. The same frequency can be reused in multiple cells in nearby (through non-adjoining) areas, and this greatly increases system capacity. This is only possible with the use of computer technology that can identify a calling party's location as they are moving, and is able to establish connections. It also benefited from increasing computing power in handsets—leading to "smartphones," which are small handheld computers that are network connected.

Manufacturing cell phones was initially a booming business with many vendors, but for a long time the average price for a cellular handset declined steadily while the products increased in complexity. Only a few manufacturers with very deep pockets were able to keep up.

4.3.2.1 Case Discussion

Should Sony Be in Telecom?

Today, billions of people around the world are walking around connected to each other through telecom networks and small computers in their pockets, made by a variety of manufacturers. Is Sony one of them? Sony was an active supplier of consumer telecom equipment. Initially it focused on well-designed devices such as answering machines and cordless telephones. Sony had a recognizable brand and achieved a strong and profitable market role. However, commodification in the low-end products and low-priced imitators caused Sony to lose its share. At the same time, Sony, as a consumer-oriented firm, had no success entering the business telecom market.

For more advanced telecom products such as mobile phones, an increasing resource commitment was required. At first, Sony followed a go-at-it-alone strategy; however, this was unsuccessful even in Japan, mostly because Sony was never a member of the "NTT family" of suppliers to the national telecom incumbent NTT.

By 1999, the state of Sony's wireless position looked dismal. Its global market share of the handsets market was less than 1% and it was losing money. In 2000, Sony entered into a joint venture with Sweden's Ericsson, the third largest vendor of handsets in the world but facing its own difficulties of plummeting market shares and record losses. The joint venture's headquarters were in the UK, with R&D labs in Sweden, Japan, China, the USA, Canada, Netherlands, India and the UK. The company relied heavily on the West European market, which was Ericsson's main turf.

Sony brought its strength in music to help stimulate its phone sales. The joint venture was, at first, able to increase its market share by two percentage points to 4.9% in 2009, which was in fourth place worldwide, but far behind the then market leaders Nokia (37.8%), Samsung (21%) and LG (11%). Worse was to come: Sony Ericsson was soon overtaken by Apple and its innovative smartphone. Sales shrank from 103 million units in 2007 to 57 million units in 2009, leading to the layoff of 2000 jobs, nearly 25% of the total number.

In 2008, Sony Ericsson came out with its smartphone Xperia. It outsourced the manufacturing of half of its Xperia line to the low-cost Taiwanese contract manufacturer Foxconn, many of whose operations are in mainland China. Xperia moved its operating system from Windows to Android (earlier, it had still used a third operating system, Symbian.) Xperia was well-designed and had useful features such as water resistance, but it did not make a big dent in the market. In 2011, Ericsson was bought out of its partnership by Sony for $1.47 billion. By 2013, Sony's world market share was about 2.1%.

Sony's initial role in to the first and second generations of mobile was due to the company's reputation as a consumer electronics giant, and due to its marketing prowess. But Sony did not succeed in entering the next level of mobile handsets on its own. The R&D here required a major commitment and investment. Instead, Sony had to rely heavily on Ericsson's R&D ability. When Sony and Ericsson parted company again, Sony could not stay technologically in the leading group, in contrast to its Korean rivals Samsung and LG.

4.3.2.2 The Internet

The Internet was initiated by the United States Department of Defense as a system of linking smaller networks. The Pentagon's Defense Advanced Research Projects Agency (DARPA) funded a project based on this concept, linking several defense technology R&D centers in government, private industry and academia. It could interconnect local computer networks provided the individual machine could speak a common digital language known as TCP/IP (Transmission Control Protocol/Internet Protocol). The resultant ARPANET grew rapidly after 1969. In 1995, the governmental system was replaced by a collection of commercial Internet backbones and Internet service providers (ISPs). ISPs link computer users to the Internet, and may provide additional services such as email. Small users typically connect to an ISP by using always-on high-throughput connectivity ("broadband") through various forms of transmission, such as a digital subscriber phone line (DSL), a fiber line, cable coax connection, mobile wireless network, or satellite. The ISP connects to the rest of the Internet by high-capacity links as directed by "routers," and reaches the main backbones which, in turn, connect directly or over still other backbones to other Internet nodes or ISPs.

The original Internet grew by leaps and bounds, but was initially confined to relatively sophisticated users. It was complex to use and its content was essentially geeky text. This changed dramatically with the introduction of the World Wide Web (the "web"). The web's key ease-of-use feature is hypertext, developed at Geneva's CERN laboratory in 1989 to allow researchers to reference other documents available on the Internet. This means that data need only be stored on one server to be accessible by any computer connected to the web. The number of host networks and domains increased exponentially. In 1995, 50 million people were online, primarily in the United States, Canada and Europe. By 2006, that number had increased to 694 million and, by 2013, to 2.71 billion, including by mobile devices. Plummeting computer and Internet access prices coupled with growing access, increased transmission and faster processing speeds drove Internet usage. Applications such as email portals, interactive gaming, online banking, e-auctions, e-tailing, online advertising, and social networks, and streaming music and video made the Internet increasingly popular.

For a period, the Internet was celebrated as open, free and competitive. Entrepreneurialism was high, financing easy and entry barriers were low. But, in time, it became dominated by large firms with market power, whether ISPs or large application providers. The common elements are high economies of scale (scalability), based on high fixed costs and low marginal costs, and often complemented by network effects (positive externalities) on the demand side.

4.3.3 Convergence #3: Integration with Consumer Electronics

The convergence of consumer electronics (CE) with computing and telecom devices has two dimensions:

1. Integrated multi-purpose devices;
2. Communications capabilities.

Devices combine a platform (typically, a CE device such as a music player or game console) with processing (calculators, computers and so on), data storage, software for operating systems and applications, and communications capabilities through connectivity technologies such as telecom, cable, Ethernet, mobile wireless, Wi-Fi, Bluetooth and the like.

Some such integration goes back a long time. Originally, consumer electronics devices were not connected to each other or to a central node. Example are phonographs (1870s) and cameras.[62] However, key devices of consumer electronics became connected by communications networks, though initially of the one-way variety. Milestones were:

- Radio sets (1920s);
- Television sets (1940s);
- Cable TV and satellite TV connected TV sets (1960s);
- MP3 players (1990s);
- Smartphones (2000s);
- Tablets (2010s).

CE became a global business, centered in Asia. For CE companies, the best business model has been to build up scale and experience behind early protectionist walls, then move into exports on a value-pricing basis; to build a strong, global brand with a few impressive products, and then expand into multiple products while commanding a premium price. The emergence of contract outsourcing manufactur-

62 Originally, cameras were based on optical and chemical processes, rather than electronics. They gradually incorporated electronics in light sensors and other control functions, and then became fully electronic by way of digital recording. We therefore include camera devices under consumer electronics.

ers (OEMs) such as Flextronics and Solectron lowers entry barriers on the design stage by giving smaller CE firms access to large, flexible manufacturing facilities with economies of scale. For example, an entrepreneurial upstart in TV sets, Vizio, entered successfully with a low pricing model and offshore manufacturing. In time, even established CE giants such as Sony, Philips and Motorola outsourced the manufacturing of products to the OEM firms.

More recently, TV sets also became "connected" by two-way access to the Internet, and supported links to content providers such as Netflix, as well as to each other. They incorporated electronic storage, switching, modems and home networking, and thus became, in effect, display and control terminals of home-based computer-style networks.

As consumer electronics firms moved into networked devices, IT companies moved in the opposite direction and eyed the large consumer market. Most successful was Apple, which did well with its iPod, a music device based on computer-based data compression (MP3) and laptop-style memory (at first, magnetic hard drive; later, solid-state semiconductor). This was followed by the iPad, a light handheld and Wi-Fi-networked consumer computer in the tablet format which became a successful device for media consumption. There were also small innovator startups from the Internet and IT sector. TiVo, Roku, and Sling are examples, with products that extended the range of video options open to the user in terms of time and location. Virtual and augmented reality devices and applications (apps) emerged, with products by Samsung, Sony, Facebook, HTC and Google, as well as several Microsoft Windows-based vendors.

Thus, by the early twenty-first century, consumer electronics had transitioned from standalone devices lacking logical processing and produced by sprawling multi-product firms to an industry of inter-networked and "smart" products produced by a wider set of companies hailing also from other industries and from the startup sector. In the aggregate, this trend accelerated the pace of innovation in the consumer electronics industry and, in some cases, changed the scale economies. CE markets became global, manufacturing split off from product design and marketing, and the market power of large retail intermediaries rose enormously. The industry destabilized. Some CE firms weathered this challenge better than others.

4.3.4 Convergence #4: Integration with Content

The fourth type of convergence is that of media hardware with media content—with text, music, pictures, videos and games. This goes beyond one hardware device connecting to others. Such connectivity enables links to content, but they are not the content integration itself. An example is an interactive game console. These have built-in modems which can provide access to Internet content such as software, web browsing, social media and email. But, in particular, they offer content, i.e. games. Electronic books are another type of device, as are audio players. Apple's iPod and iPad were successful because Apple was able to integrate hardware and content through the creation of its online digital media retail site iStore.[63] By 2017, the Apple iTunes store had sold over 50 billion songs. It offered 45 million songs, 90,000 movies, 2.5 million iBooks and 2 million apps. Its annual revenue was almost $10 billion. This made Apple the leading music retailer in the world.

4.3.4.1 Video Game Hardware

Video games have become a new mass media—increasingly sophisticated, interactive, feature-rich and popular. Video game hardware was pioneered in the United States in the mid-1970s by Nolan Bushnell, who invented Pong (an early arcade video game machine) and founded Atari.[64] However, by 1984, consumers grew bored with Atari's products. A new entrant from Japan, Nintendo, became dominant in 1985. The higher quality of Nintendo games and 8-bit CPUs and, later, 16-bit machines reinvigorated the industry. In 1990, Nintendo machines accounted for 90% of the $4 billion global hardware and software markets. But, by 1993, Nintendo lost its leadership to Sega and its machine, which was based on a 32-bit microprocessor. Sega, in turn, lost out to Sony, which enjoyed quick success with its own 32-bit PlayStation machine released in 1995. Sony's PlayStation combined superior hardware with access to content, and a $40 million marketing campaign that focused on celebrities and

63 MacNN Staff. "Apple calls iPod nano demand 'staggering.'" *MacNN*. October 11, 2005. Last accessed May 9, 2017. ► http://www.macnn.com/articlesloaddetails/05/10/11/aapl.q4.conference.call/.

64 Earlier projects were those of Steve Russel and Ralph Baer ("Game Room," "Space War," and "Magnavox Odyssey").

trendsetters. In time, Sega withdrew from the video console business altogether, leaving Nintendo and Sony to duke it out with newcomer Microsoft, which entered the market in 2001 with its Xbox console.

As can be seen from its history, this market is unforgiving. New technology, expressed in processor complexity, drives console adoption. The first to market with the latest processor technology will sell many consoles in its first year, but sales will quickly fall in succeeding years as the novelty declines and rivals catch up.

Gaming consoles became more than just gaming machines. Machines function as DVD players and enable users to access the Internet, especially for online games. The intense competition in gaming consoles and the high demand for the latest game releases led industry participants to adopt a razor-and-blades business model. Manufacturers are willing to make little or no money on video game hardware sales to quickly build a large installed hardware base, thereby boosting profitable game or cartridge (software) sales.

The video game hardware industry is deeply competitive but sustains only three globally operated firms. These tent-pole companies are surrounded by small game developers, which jointly create the network effects and scale necessary for success with a very finicky and volatile user base. Entry barriers are high for the hardware consoles but much lower for the game applications.

4.3.4.2 Case Discussion

How Sony Achieved Content-Hardware Convergence

Sony's content-hardware strategy is probably stronger than that of any other company in the world. This strategy goes back to its Betamax defeat by the technologically inferior Matsushita's (Panasonic) VHS. The debacle led Sony's CEO, Morita, to conclude that hardware superiority was not enough and had to be supported by control over some content software to assure a format's success. Morita's content strategist was Norio Ohga. Ohga had had a career as an opera singer and symphony conductor. In 1986, Norio Ohga got Sony to buy the music division of CBS for $2 billion. This acquisition helped the success of the CD launch.[65]

In 1983, Sony and Philips jointly introduced the compact disc (CD) for high-fidelity, noise-free digital audio storage. The CD revitalized the recorded music and audio electronics industries. Sony also pioneered the portable audio tape player with the release of its popular Walkman in 1979. But the market as a whole declined with the advent of portable alternatives with better sound quality. New products emerged, most notably the portable MP3 player, introduced by the tiny computer equipment company Rio. Sony and Thomson followed with their own products. Sony, however, was hampered by the demands of its own music division for strong security against piracy. In 2001, Apple entered the market with the iPod, coupled with the music store i-Tunes, and quickly became the dominant force in the market with a share of 73.8% in 2005. Through innovations such as the iPod Mini and Nano, Apple was able to keep charging a premium price. In contrast, Sony's market presence in portable music declined.

In 2004, Sony added to its music content strength by joining up with Bertelsmann, another of the five music majors, and merging their music operations to create Sony BMG, the world's second largest music group. In 2008, Sony raised the stakes further and bought out Bertelsmann's half share of the company.

Sony Music Entertainment incorporates several subsidiaries including Columbia Records, Epic, Legacy, RCA, Jive, Kinetic, Arista, Sony Music Japan, Sony Music UK and Sony Music Germany. Sony also distributes many independent labels.

Sony tried to integrate this content into its mobile phone venture Sony Ericsson. In order to compete with Apple's iTunes and Nokia's Comes With Music services, Sony Ericsson launched its own mobile phone service: PlayNow Plus. However, this did not make much of a dent.

Also without success was Sony's MP3 player. Sony's music division, instead of helping the hardware to achieve leadership, worried greatly about piracy. This held Sony back from taking the lead in the MP3 market, which should have been Sony's stronghold given its dominance with its Walkman and Discman player generations. Yet, Sony's MP3 player was a distant runner up.

65 Epstein, Edward Jay. *The Big Picture, The New Logic of Money and Power in Hollywood*. New York: E.J.E. Publications, Ltd., Inc., 2005.

Music was only the first step for Sony's entry into the content business. Film followed. In 1989, Morita bought the film studio UA-Columbia for 3.4 billion dollars from Coca-Cola. Sony Pictures was able to produce big hits at the box office such as *The Da Vinci Code*, *Casino Royale*, and *Spider-Man 3*.

Sony used its content strategy to drive the transition to HDTV and high-definition DVD film format. By owning film content, Sony strengthened its hand in the battle over the standards. For example, Sony collaborated with the Discovery Network and with IMAX to launch a 3D network called "3Net," with Sony being the primary sponsor for the ESPN network. Sony used its game console PS3 to drive consumers to its Blu-ray videodisc standard, and prevailed over its rival Panasonic.

The success of the PS3 console was partly driven by publishing games such as EverQuest, Star Wars Galaxies, The Matrix Online, Gran Turismo, Warhawk and Formula One, which created a user base with Blu-ray, which in the end tipped the scale.

Thus, there have been several examples of success for Sony's content integration strategy. The Sony Reader was the first tablet to use an e-paper screen, but it had no Wi-Fi or wireless connections. It failed to make a splash while Amazon's Kindle got 85% of the market share. Kindle had the advantage of Amazon's book store, while Apple's iPad had the advantage of its iStore when it took off in 2010. Sony's online content store which offers a broad selection of fiction and non-fiction manga comics and graphic novels, did not take off, just as its music store had also failed. In 2014, Sony closed the North America operations of its Sony Reader due to lack of success against Amazon and others.

Other Sony efforts included a wireless broadband TV, enabling the first Dual-Band Wireless AV transmission, with web browsing, e-mail photos and access to personal contents while traveling. Sony's Cocoon (released 2003) was a Linux-based set-top box, with broadband Internet connectivity. Cocoon a aimed to become an alternative to the PC for accessing Internet content. It could also analyze previous choices and items stored to identify a user's preferences, and automatically record programs that fit that profile.

So, the question is whether Sony's content strategy has benefited the company, or slowed it down. Has Sony achieved an advantage from its content, or should it simply concentrate on offering a better hardware device platform? Sony's PS3 had the Blu-ray player and, with it and its Hollywood studio position, Sony was able to win against HD-DVD. On the other hand, Sony's music division opposed aggressive moves in MP3 players due to fears of piracy. And Sony's TV set business? Its film *Hancock* was made available via Internet download only for its Bravia premium brand TVs for just $9.99 prior to the DVD release.[66] Did that measurably increase Sony's sales? Probably not, but it generated some buzz. Despite these efforts, Sony's TV set sales were in serious trouble.

Symmetrically, one should also ask whether Sony's *content* benefited from Sony's hardware connection. Has Sony created new "convergence" types of content, or promoted its content better through its hardware? So far, there have been no examples.

4.3.5 Convergence #5: The Media Cloud

Today, the next generation of technology integration is emerging—that of connecting consumer hardware devices with computing services. The World Wide Web, with its numerous websites for information and transactions, was a major step. Today, we are moving to data processing itself, by way of "clouds," which is the current term for server-based services to end users. The basic idea has been around for decades, to move data and operations to big central servers, and to leave the periphery of end user "clients" to be relatively slim terminals. In that way, the device can be small, relatively simple and parsimonious with battery power.

Some companies, such as Amazon or Apple, have created huge facilities for their services. Apple spent about $1 billion on a new data center in Maiden, North Carolina. What are the implications? First, the consumer electronics business is being changed. If all devices in the home are interconnected, then we move from consumer electronics as hardware devices to consumer electronics as services. A familiar example is the voicemail service that is now being provided by a phone company as a service that replaces an answering machine—a hardware device. Services are paid according to usage, or by subscription, or by some sponsorship.

The necessary hardware will mostly be bought by service providers, rather than the consumers. In this market space, IT companies have more credibility than CE companies. More powerful but fewer hardware boxes will be sold. This is even worse news for retailers.

66 Nakashima, Ryan. "Sony free to mix music, electronics." *Los Angeles Times*. October 14, 2008. Last accessed June 1, 2011. ► http://articles.latimes.com/2008/oct/14/business/fi-sony14.

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4.3.6 The Next Convergence: Bio-electronics and Human Cognition

The next convergence (6C), clearly ahead of us, is that of IT technology with bio-technology: "bio-electronics." Already, cochlear implants, which directly stimulate the auditory nerve, have enabled thousands of deaf people to hear sound. Similarly, a retinal implantable chip for prosthetic vision may restore vision to the blind.[67] Another type of technology, aimed at creating a "touch and feel" sensation, is the TactaPad, where a pad is touched directly with the hands, providing dynamic "force feedback." The pad has a unique feel that corresponds to the object being touched.

But the applications will go deeper, rather than overcome sensory handicaps. We may be able to integrate a computer's speed and accuracy, as well as its ability to transfer knowledge easily, into our own sensory systems. Similarly, sensory signals picked up by humans may be processed by technical devices rather than the human brain, and human responses or emotions could be detected and interpreted directly in a kind of "brain-modem."

Futurist Ray Kurzweil, extrapolating current exponential trends in computation power, predicts that the capability of a human brain will be available electronically around 2023 for a price of 1000 dollars and, in 2037, for only 1 cent. Eventually, the capability of the entire human race can be reached in 2049 for 1000 dollars and, in 2059, for 1 penny.[68] While such extrapolations often reflect a technologist's narrow perspective of human capability, the broader point is valid: a good number of our mental processes could be done more powerfully by machines. And this includes the control of media-created sensory experiences.

Such technologies emerge first for medical and military use. They have a great potential for good, but have also implications for altering or controlling behavior. They are fraught with perilous implications and will lead to much societal debate. And they create enormous challenges to the next generation of technologists and media managers.

4.4 The Next Act for Sony

4.4.1 Case Discussion

Where Does This Leave Sony?

Sony is a brilliant technology and marketing firm but has difficulties in keeping up with specialized firms. Increasingly, it leaves R&D in those areas to partners or vendors. Sony's strengths are its integrator role, its strengths in design and its prowess in global marketing. The aim is a streamlined Sony. As Sony's past CEO Howard Stringer stated, "in terms of the variety of products, Sony is still unbeatable. The question is how much variety is too much variety."[69] Specialization is not just a matter of technology. Sony is spread thin not only in R&D, but also in the marketing of its products.

Aware that it may be too diversified, Sony gradually and reluctantly abandoned its "scatter-gun" approach to customer electronics in favor of focusing on the "champion products."[70] But internal stakeholder constituencies of product fiefdoms make such a prioritization difficult.

Internal communications in the sprawling company were often flawed. In one instance, Sony's marketing people did not alert the R&D managers of the impending demand for large flat screen TVs, leaving the company to fall behind Samsung and Sharp, and, embarrassingly, requiring it to buy those screens from its other competitors.

In the field of computers, PCs became a commodity, with Intel and Microsoft taking most of the profit. Sony's Vaio did not create a

67 McGee, Ellen M. and G. Q. Maguire, Jr. "20th WCP: Ethical Assessment of Implantable Brain Chips." Proceedings of the Twentieth World Congress of Philosophy, August 1998. Last accessed August 10, 2012. ► http://www.bu.edu/wcp/Papers/Bioe/BioeMcGe.htm.

68 Kurzweil, Ray. "The Law of Accelerating Returns." *KurzweilAI.net*. March 7, 2001. Last accessed August 10, 2012. ► http://www.kurzweilai.net/the-law-of-accelerating-returns.

69 Schlender, Brent. "If you don't act, you will kill the company." *Fortune Magazine*. April, 4, 2005. Last accessed May 11, 2017. ► http://archive.fortune.com/magazines/fortune/fortune_archive/2005/04/04/8255922/index.htm.

70 Nakamoto, Michiyo and Paul Taylor. "From push to pull – Sony's digital vision." *Financial Times*. January 6, 2006. Last accessed June 1, 2011. ► http://www.ft.com/cms/s/2/381891be-7f09-11da-a6a2-0000779e2340.html#axzz1O3C6NQw3.

strong multiplier for the company's overall products.

Being pummeled financially, in 2009 Sony announced layoffs of 8000 permanent and 8000 contract workers, most of them in America. In 2010, there were 450 layoffs at Sony Pictures. In 2010, it reduced its capital investments in electronics by 30% and reduced manufacturing prices by 10%. It continued to shift R&D and manufacturing to be done outside the firm. Even so, it lost $5.5 billion in 2011. In 2013, sales declined and the loss was over $1 billion. TV shipment declined from 40 million to 20 million. According to its then- CEO Howard Stringer, every TV set built by Sony creates losses for the company.[71] Outside analysts recommended that Sony abandon product categories where it could no longer compete, such as televisions sets, and focus on its strengths such as entertainment and video games.

Kazuo Hirai, a lifelong Sony technologist, credited for making the PlayStation business profitable, was appointed as the new CEO.[72] Hirai aimed to turn the business around with cost cuts, layoffs, new products and a breakdown of internal barriers. His priorities were five initiatives:

1. Focus on the core businesses: digital imaging, games and mobile;
2. Turn-around of the TV business;
3. Expansion of business in emerging markets;
4. Creation of new businesses and acceleration of innovation;
5. Realignment of the business portfolio and optimization of resources, i.e. bring its content units to be more closely coordinated with its technology devices.

These were broad goals, hardly focused targets and action strategies. Concrete actions taken were a new top management structure ("One Sony, One Management"), which means a unification of all electronics business units, but, at the same time, the divisions would have more independence to accelerate decision making; one goal was cost reduction in the TV set business, cutting fixed costs by 60% and operating costs by 30%. In 2014, and again in 2015, CEO Hirai took several steps: Sony spun off the audio and TV set manufacturing operations into a wholly owned subsidiary to speed up processes; and its computer division, Vaio, was sold to an investment consortium, Japan Industrial Partners, for about $500 million plus a 5% stake in the new company. Another 5000 jobs (approximately 3% of global staff) were cut.

Within the constraints of legacy, Sony's strategy was to focus on its most profitable and high-margin businesses. It aimed to increase operating profit 25-fold within three years by growing its camera and game divisions, and give up on raising its sales in smartphones or computers. It then proceeded to cut 2000 jobs of the 7000 in its smartphone division.

The major building block for Sony was its strength as one of the largest camera manufacturers in the world. Sony is number one in 4K quality video, production cameras and projectors. The entire market, however, has greatly declined due to a migration to smartphone cameras. The emerging Sony strategy has been "From the Lens to the Living Room," meaning the value chain from professional content production hardware to consumer media devices. Profitability of Sony's camera business rose 73% in 2015/2016.

Another strategy was to differentiate Sony by connecting its entertainment properties—such as the music, movie and video game section—more closely with its electronic devices. This concept, of course, had been promoted for over two decades and it was not clear why it would be more successful now.

Sony also aimed to increase capital investments by generating significantly funds—$3.6 billion—in its first outside capital raising in 25 years. Partly based on these measures, operating profit rose in 2015/2016 by 330% (from $655 million to $2.81 billion). Losses in its mobile communications business dropped 72%, to $590 million from $2.08 billion.[73] Its gaming division's profits rose 84% to $850 million, with PS4 sales rising significantly to 35 million. On the other hand, it lost $270 million in its semiconductor and component division. That segment had recorded a profit of $850 million in the preceding year.

But the trends are still running strongly against it. Does this mean that, within the next few years, Sony will continue to break itself up? It will remain a strong brand—but with most of the R&D and manufacturing done outside, and with major product lines being spun off. Rather than a technology R&D developer, Sony will be a technology aggregator, and a technology/content integrator.

71 What Hi-Fi? "Sony Admits Losing Money On Every Kind of TV It Makes; Plans "different kind of TV." November 11, 2011. Last accessed June 14, 2012. ► http://www.whathifi.com/news/sony-admits-losing-money-on-every-tv-it-makes-plans-different-kind-of-tv.

72 Yasu, Mariko. "Sony's Hirai Stakes Reputation on Restoring TVs to Profit". March 27, 2012. ► http://www.bloomberg.com/news/2012-03-27/sony-s-incoming-president-hirai-to-run-home-entertainment-unit.html.

73 Kharpal, Arjun. "Sony just posted a 666% rise in profit as its turnaround plan takes hold." *CNBC*. April 28, 2016. Last accessed June 22, 2016. ► http://www.cnbc.com/2016/04/28/Sony-just-posted-a-666-rise-in-profit-as-its-turnaround-plan-takes-hold.html.

4.5 Outlook

We have discussed in this chapter a dozen tools and tasks for media and digital companies to manage their technology functions. Even all the enormous changes in media technology, we are most likely only at the early stages of the evolution. Coming down the road are many technologies with a media impact, some of which are listed below:

- Intelligent interfaces that make human-machine interaction more convenient;
- Bio-electronics that directly link physiological sensations with machines;
- Machine-to-machine intelligent communication;
- Semantic networks which can interpret and understand meaning;
- Intelligent screeners of information;
- Cognitive radio that can roam and can use bits and pieces of spectrum;
- Large, thin and flexible screens that are integrated into walls and various products;
- Ubiquitous non-stop connectivity;
- Gigabit-rate networks in the home;
- Megabit mobile wireless;
- Smartphones with visual projection;
- Miniaturization and systems-on-a-chip;
- Sensor networks that can provide feedback, monitoring and controls;
- Holographic and glasses-free 3D;
- Real-time rendering that enables true customization and interactivity of content.

People tend to over-estimate the short term but underestimate the long term. In technology devices, it is quite common to encounter a "hype cycle," in which new or anticipated products raise expectations that are far out of line with reality. Eventually, inflated expectations reach their peak and disillusionment sets in, a dark counter-reaction to the previous rosy scenario. But, in time, reality returns, and a cooler assessment emerges. And then, gradually, the impact of the new technology gathers momentum and its accumulated impact is often much larger than anticipated.

The preceding discussion has shown the many dimensions and tasks of technology management faced by a media or digital company or organization. They are issues that require an understanding of the underlying trends, of competitors' initiatives, production planning, market forces, the fostering of innovation, and government actions. They require savvy in tech, strategy, marketing, operations, HR and public policy. This is not an easy set of skills to combine, but it is an essential one for a media company. The aggregate impact is fundamental. Media technology affects media content and societal interaction. In that sense, R&D technologists are also the engineers of our culture and of our politics.[74]

4.6 Review Materials

Issues Covered

We have covered the following issues in this chapter:

- The technological trends that drive the media industry'
- The functions and responsibilities of the Chief Technical Officer;
- How to select R&D projects for funding;
- Whether to specialize or diversify in R&D;
- A tech company's R&D horizons for short-term and long-term projects;
- How to position and organize R&D within the firm;
- When to outplace R&D;
- How to involve developers and users in the R&D process;
- How to determine R&D budgets;
- How companies (and universities) benefit from R&D alliances;
- How companies manage their internal knowledge;
- How to play the standards setting game well;
- How semiconductors transformed IT and CE

74 Example: A study shows that, over time, films have shifted toward movie types that are most amenable to special effects, such as action films and sci-fi, while romance and drama have declined. "Movie characters can now be transported, transfigured, or killed in an incredible number of ways, but what can digital effects do for a kiss?" Ji, Sung Wook and David Waterman. "Production Technology and Trends in Movie Content: An Empirical Study." Working Paper, Indiana University, December 2010. Last accessed May 11, 2017. ► https://www.researchgate.net/profile/Sung_Wook_Ji/publication/228448250_Production_Technology_and_Trends_in_Movie_Content_An_Empirical_Study/links/55196ea60cf23c470a5c7a23.pdf.

- How personal computers and smart-phones evolved;
- How the Internet emerged and evolved;
- The future of the consumer electronics industry;
- How the integration of media hardware and content-generated new media types;
- The implications of the convergence of consumer hardware and computing devices;
- What the potential of a convergence of bio-electronics and bio-technology might be.

Tools Covered

We used these tools to discuss Technology Management issues:

- Moore's Law;
- R&D project selectivity and success rate;
- Scoring method for projects;
- Economic-financial analysis of project prioritization;
- A tech company's R&D categories for short-term and long-term projects;
- Dimensions of consumer acceptance;
- Risk-reward diagram;
- Network effects;
- R&D effectiveness index;
- Standards process participation;
- Knowledge management (KM);
- Media cloud.

4.6.1 Questions for Discussion

1. What are key technology innovations from the 1990s that will affect media by 2020? Explain. And what are technology innovations of the 2000 that will affect media in 20 years' time?
2. A consumer electronics manufacturer has hired your consulting services to forecast trends in CE. What do you foresee and how should this CE manufacturer adapt to the future?
3. When it comes to patents, is R&D management moving in an identifiable direction? If so, what is it, and does it make sense?
4. Is there a relationship between market volatility and technological progress in a field? How do these relationships play out in major media sectors?
5. You are the CTO for a network equipment firm. Researchers from the University of Wallalia have just reported discovering a new principle of particle physics that could lead to hyper-broadband that leaves all current transmission technology in the dust. How should R&D management address this opportunity and threat?
6. Does the current patent system retard technology innovation? Explain why, or why not.
7. Contrast the responsibilities of the CIO and the CTO at a typical media company.
8. How does the CTO evaluate the viability of R&D projects? What advance information from the R&D department would they require?
9. How does Moore's Law affect R&D planning?
10. How can a media company take advantage of user communities that would like to converge with the company, and provide innovation? What are possible disadvantages?

4.6.2 Quiz

1. Which of the following products is a part of the convergence of devices and content?
   A. Sony's multi-media platform Vaio computer.
   B. Amazon's e-book reader Kindle.
   C. Sony's mobile media player LocationFree TV.
   D. None of the above.

2. Which is not likely to be an impact of the ultra-broadband networks?
   A. Higher prices for devices as they become more powerful.
   B. More subsystems (software and hardware) are built into the devices.
   C. Transitions from device-based features to online-based services.

3. Which of the following best represents the organizational structure of R&D activities?
   A. In the centrally-support model, most research is done at the division level, while most development is done at the corporate level.
   B. As R&D becomes more complex, the R&D organizational structure becomes more decentralized.
   C. Companies can be successful in R&D even without any corporate level R&D.

4. Which of the following will ensure a standardization war victory over a rival?
   A. Control over a large part of the installed base.
   B. Perfect compatibility with former standards.
   C. Exceptional quality of new standards.
   D. None of the above.

5. Which of the following is the worst reason to join a R&D alliance?
   A. Members can share the cost for developing new technology.
   B. Members have highly complementary technology skills and experiences.
   C. The culture and structure of the alliance will reduce the development time significantly.

6. Which of the following is correct about the impact of home networks?
   A. Shifting actual functions to remote locations is not practical, because it overloads bandwidth requirements.
   B. It will become even more complex for the users to handle the functions of devices, because of the complexity of the network.
   C. Standardization will become more important because of various systems provided by various service providers.
   D. None of the above.

7. Which of the following is not a necessary criterion of good balance between the centralization and decentralization of R&D activities?
   A. The corporate level has the ability to conduct research and acquire knowledge to enable future profitable innovations.
   B. The company has the ability to synthesize the knowledge of different divisions.
   C. The responsibilities of R&D are split clearly between the corporate and division levels.
   D. None of the above.

8. Which of the following can be considered the first general purpose electronic computer?
   A. The Electronic Numerical Integrator and Computer (ENIAC), invented in 1946.
   B. The "difference engine," invented in 1839 by Charles Babbage and Ada, Countess Lovelace.
   C. The Atanasoff-Berry computer, developed by Iowa State College professor John Atanasoff and Clifford Berry in 1941.

9. The impetus for the development of the ENIAC was the need to:
   A. Compute enormous amounts of statistical data for meteorological research.
   B. Perform ballistics computations for firing tables during World War II.

C. Calculate studies of thermonuclear chain reactions, i.e. the hydrogen bomb.
D. All of the above.

10. In 1975, Intel CEO Gordon Moore predicted that the power of a computer chip would:
A. Progress arithmetically.
B. Progress exponentially, doubling every 18–24 months.
C. Double every four years due to exhaustion of early gains.

11. When IBM entered the computer industry in 1953, its business strategy did *not* include:
A. Leasing, rather than selling, equipment.
B. Leveraging its dominant position in the tabulator punch-card market by bundling equipment.
C. Making it cheap for competing manufacturers to connect peripheral equipment to create network effects.

12. The future trend in computing is:
A. Mainframes becoming insignificant.
B. Computer devices accelerating performance at the rate of Moore's Law.
C. Computer devices for every person on the planet.
D. All of the above.

13. With client-server computing, corporate growth is expensive because:
A. PCs take up a great deal of footprint.
B. The complexity of PCs makes maintenance difficult.
C. If companies decide to upgrade software, they must do so on every PC.
D. All of the above.

14. During what phase of tech product development, should a company more effectively analyze market potential?
A. Testing.
B. Product selection.
C. Prototype construction.
D. None of the above.

15. What is the trend of the video game market?
A. Reaching out to younger consumers.
B. Increased video game console sales.
C. Increased competition in portable consoles.
D. Online gaming sales are increasing mainly due to the popularity of high-tech games.

16. Which sales have decreased?
A. Gaming hardware sales.
B. Electronic game sales.
C. Electronic gaming software sales.

17. Which type of R&D model emphasizes the least importance on research?
A. Technology-driven.
B. National treasure.
C. Market-driven.
D. Global.

18. Which officer of a company is most responsible for the corporate R&D organizational structure?
A. Chief Information Officer.
B. Chief Technology Officer.
C. Chief Executive Officer.
D. All of the above.

19. What has the convergence of consumer electronics with telecom devices led to?
A. Integrated multi-purpose devices with communications capabilities.
B. Faster mobile Internet speed.
C. Telecom law regulation extended to consumer electronics devices.
D. Data caps.

20. What is not a key task or function of a CTO?
A. The CTO identifies present and future technology options.
B. The CTO contributes to published scientific research.

C. The CTO has to deal with scenarios and opportunities that are composed of building blocks that already exist.
D. The CTO shapes part of the overall corporate strategy along the dimension of technology

21. Which statement about the purchasing behavior of consumers is incorrect with regards to innovative products?
A. Consumers fear losses much more than gains of the same magnitude.
B. Behavioral change is not easy for consumers.
C. People tend to overvalue the benefits of new goods over the goods they own.
D. There is a mismatch between what innovators think consumers want and what consumers truly desire.

22. What is especially important for the innovation stage "Horizon 1: Improvements"?
A. Mostly money and people.
B. Corporate culture of creativity.
C. Making bets.
D. Exploration into new markets.

Quiz Answers

1. B
2. A
3. C
4. D
5. A
6. D
7. C
8. A
9. D
10. B
11. C
12. C
13. D
14. B
15. C
16. A
17. C
18. B
19. A
20. B
21. C
22. A