Managing Technology Discontinuities for Competitive Advantage

Chris Floyd

In this high-tech era, technology discontinuities occur in every industry sector. Digital mobile telephony, computer optical storage systems, high performance polymers, biotechnology, and genetic engineering are all examples of the technologies that are changing the world we live in, creating opportunities for some companies and putting others out of business. How can companies anticipate technology discontinuities so that they become opportunities for competitive advantage rather than threats to survival?

Quite likely your organization has a clearly articulated technology strategy for addressing weaknesses and building on opportunities. If it doesn't, the Third Generation R&D approach promoted by Arthur D. Little (outlined in earlier issues of *Prism)* provides a firm foundation. Most managers stop at this point, however, believing that their strategy is robust enough to cope with any new technology threats or opportunities. Do not be deceived. A good technology strategy will help you cope with predictable trends in technology, but it cannot lessen the impact of the unexpected. To expect the unexpected, you need to supplement the development of your incremental strategy by looking more widely at long-term trends, identifying where market conditions and technology capabilities create opportunities for new technologies to take hold. You also need to put in place business processes for anticipating technology discontinuities. And you need to agree on your strategy for action.

Assess Your Vulnerability

At any one time, some technologies are more vulnerable than others. To work out when it's going to be your turn, you need to ask yourself two questions. First, what is the market going to be looking for in the long term? If there is a rapidly growing demand for ever-greater performance, you can assess the targets your technologies will need to meet. Second, are your technologies running out of steam? If they are maturing, with diminishing improvements in performance, or, even worse, approaching a natural limit, you know that they will never be able to deliver more than incremental improvement. Compare this assessment with the market need and you will have a good idea of how vulnerable you are to a technology discontinuity. In particular, if a core technology appears to be running out of steam while market needs are growing inexorably, the conditions are right for a step change (See Exhibit 1).

What is the long-term market? Start by looking at your own business 20 years out. Will the world still want the products or services that you offer? If so, will the competitive drivers have changed?

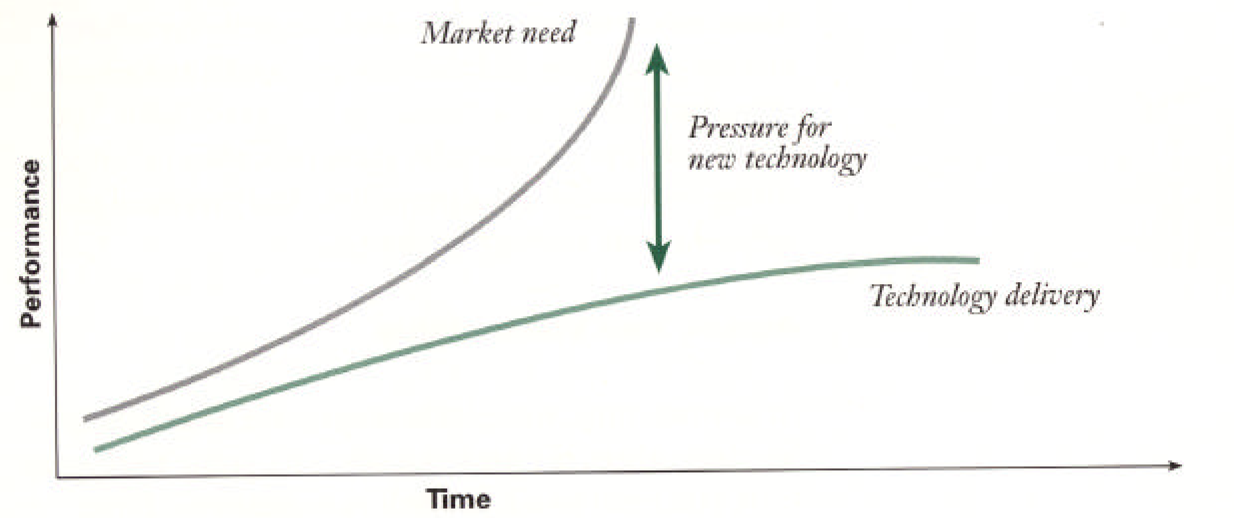
You need to look far into the future to explore how your markets might evolve and determine what technology pressures are likely to occur. Take the health care industry as an example. By talking to customers and suppliers, reviewing market trends, and using the scenario techniques described elsewhere in this journal, you can envision what the health care industry might look like in 20 years. Surely, the market will increase as a consequence of demographics and of increasing prosperity in the developing world. Just as surely, there will be pressure to contain costs, as the average age of the population increases and a relatively smaller proportion of society carries an ever-greater health care cost burden. Also, there may be changes in how health care is funded, with a growing move toward managed health care systems, in which total life cost is more significant than the cost of individual treatments. Taken together, these market pressures suggest a shift toward earlier, less-invasive treatments, such as pills rather than complex surgery. When surgery is unavoidable, it may mean simple keyhole surgery in outpatient clinics rather than major procedures in hospital operating theaters whenever possible. This is the positive scenario, in which technology is used to deliver better health care for all. Alternative scenarios could place greater emphasis on cost, arguing that demographics will increase health care needs faster than economic growth will generate the ability to pay for it.

By coupling these market pressure scenarios with an understanding of underlying technology trends, including the biotechnology revolution and the sea change in our understanding of the fundamental biology of the human body, you can build a set of pictures of how technology discontinuities could occur. Targeted drug treatments, growth factors, and even tissue regeneration seem likely to displace the systemic drugs and inactive bandages and splints of today. With these pictures in mind, the major medical device companies are taking the first steps to embrace the new technologies and position themselves to ride the technology change. Johnson & Johnson has taken a stake in Lifecare Biomedical and other companies for this purpose, and Smith & Nephew, the global woundcare and orthopedics business, has formed a joint venture with Advanced Tissue Sciences in California to build a tissue regeneration capability to support its business in orthopedic implants.

Scenario development and market pressure forecasting are not exact sciences; they are useful but not infallible guides to what's ahead. On the plus side, these techniques get companies talking to their customers and listening to their needs. On the minus side, people always have their own mental models: for example, customers rationalize their product needs in terms of current priorities. If customers like driving fast automobiles today, they may claim that they will want fast automobiles in 20 years time, although they might adapt their mental model to fast automobiles that are small and recyclable, with low fuel consumption. However, in 20 years' time the roads may be so congested that the possibility of fast driving is limited, with the result that outright performance may no longer be an issue.

Exhibit 1

The Pressure for New Technology



To avoid too narrow a focus on today's needs, you can refine the market pressure forecasting technique to incorporate underlying changes in market structure. For example, demographic trends will predict the size and geographic distribution of the population, work patterns, and the family structures of potential automobile purchasers. Combining this information with knowledge of the road network and some intuitive assessment of experiments on road traffic pricing in cities, automotive manufacturers can forecast how people might live in 20 years' time and what sort of automobiles we are likely to need. Armed with this forecast, they can then focus their detailed customer research, assign priorities to product attributes, and set technological priorities.

As with all forecasting techniques, realism is important. It would be easy to take the Malthusian view: grid-locked cities with millions of people spending hours each day stuck in traffic jams. It would be just as easy to adopt Bill Gates's view: everyone working, shopping, and socializing from home, linked by computer and telecommunications networks, spending hardly any time traveling or meeting others face to face. The actual future will likely lie somewhere between the two.

Are your technologies running out of steam?

Once you have a view of where your markets are heading in the long term, you can turn your attention to the technologies you have and assess their vulnerability to technology substitution by extrapolating technology trends and tracking technology evolution.

The easiest way to forecast where a technology is heading is to review past development and extrapolate on the assumption that trends will continue ad infinitum. This approach is particularly valuable for aggregate technologies at the top of the technology tree, such as trends in power per unit weight of internal combustion engines or in memory density on silicon.

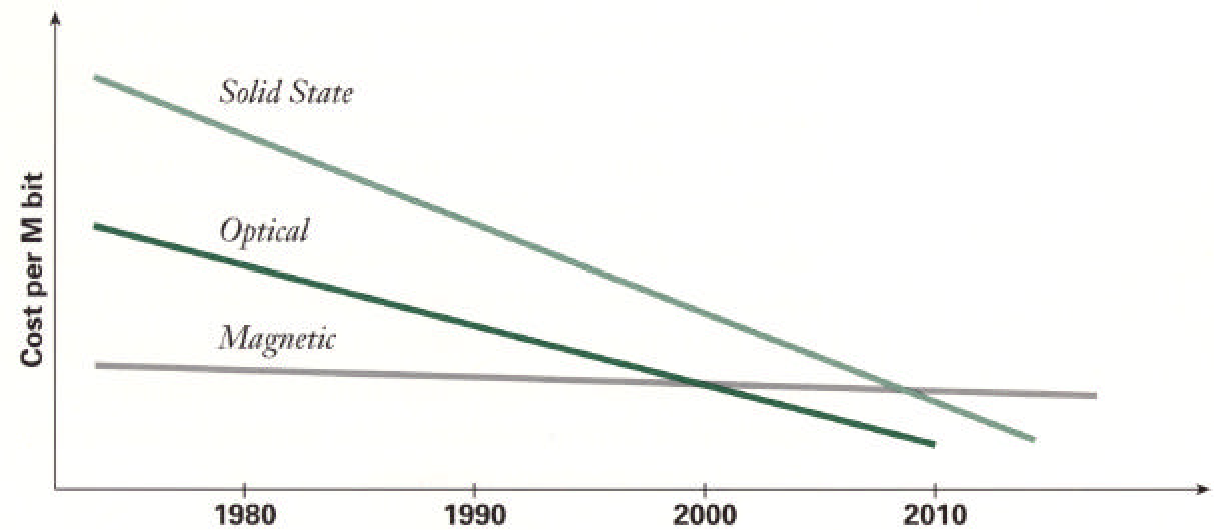
The advantage of this approach to forecasting is that, provided you can get hold of data on the past, predicting technology developments is straightforward. Particularly for overall performance trends, this approach can be very useful for deciding how far you will need to evolve the technology to stay ahead of alternative approaches, and hence for assessing whether your targets are realistic. In computer disc storage costs, for example, plotting magnetic technologies against optical technologies suggests that optical technologies are likely to capture the mass market within 10 to 15 years. As Exhibit 2 shows, however, solid state memory storage technologies are developing faster than optical technologies and are likely to be competitive within 20 years. This is of course bad news for the optical-technology-based companies, suggesting that the mass market potential of their products will be limited by the arrival of solid state memory products.

Do not, however, take this sort of analysis too literally. Remember that you are trying to predict the crossover points of three sloping lines 10 years out. Slight changes in the gradients of the lines can shift those crossover points dramatically, and shifts are not only possible but likely. Magnetic storage technologies are relatively mature and have been treated as such by magnetic storage businesses, which have scaled down R&D investment to the point that it covers only incremental development. With threats from optical and solid state technologies in sight, magnetic companies are stepping up their R&D, leading to a faster improvement in performance.

Limitations on individual technologies can also cause gradient shifts. Trend lines such as these assume that the cumulative effect of numerous incremental developments across many technologies will average out to give a steady overall trend. Although this assumption may be correct most of the time, at any one time the bulk of the improvement is likely to come from developments in only one or two of the technologies. As these fruitful seams diminish, development switches to new areas. The switch-over points cause hiccups in the overall trend. Over many years these hiccups go unnoticed, but if they happen in the next two or three years they can dramatically upset the expected trade-offs between competing technologies. In addition, perceptions of technology trends influence the setting and adoption of standards and tend to be self-fulfilling.

Exhibit 2

Competing Data Storage Technologies



Extrapolation of trends tells you when you are running out of steam. It can also show you when you are about to hit immovable barriers. In the miniaturization in silicon, for example, components are heading toward tracks less than one molecule across. To produce something so small clearly contravenes the laws of science, showing that miniaturization cannot continue for much longer at the same rate. If you believe that performance needs will increase, you will have to look for technology substitutes that will give new ways of achieving that extra performance, such as operating systems that use less processing power, or alternative processor technologies. In a similar vein, optical components are limited by the properties of light, magnetic components by the size of the magnetic particles, and structural components by the theoretical limits on melting point and material strength.

Although useful, simple extrapolations do not tell the whole story, as they do not take into account deviations likely to occur because of changes in industry conditions. Particularly when you are looking at individual technologies rather than aggregate technologies, you need to adopt a more detailed approach, examining how each technology is evolving. When a new technology emerges, the market is uncertain of its potential and adoption is slow and haphazard. Once its worth has been proved, the rate of adoption increases rapidly, providing the market feedback and impetus for development. The technologies then evolve more rapidly, increasing market adoption. Ultimately, however, the process slows down. The technology approaches physical or practical economic barriers, the market becomes saturated, and the pressure for development disappears.

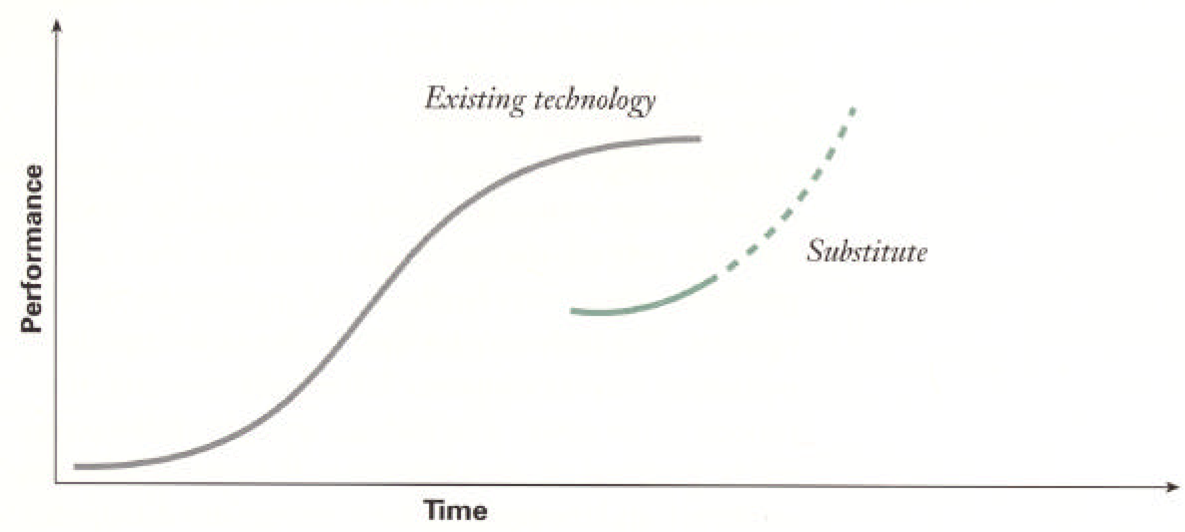
At this point, the technology can be classified as aging, and substitution threats become visible, with new technologies unconstrained by the same barriers offering novel market attributes.

Technology evolution, in other words, appears to follow an „S“ curve, with new technologies overtaking and replacing existing ones (Exhibit 3). The implication of this concept is that you can track what is happening to your technologies and anticipate when you need to move on. This is a big leap forward from conventional forecasting. The „S“ curve idea makes explicit the view that technologies will sooner or later be replaced. It also makes explicit the idea that the new technology can creep up unnoticed and ignored on incumbent technologies.

Even if you know what is happening to a technology now and what has happened in the past, you can seldom predict when evolution will level off. Technologies move in fits and starts, with a lot of scatter in real data points around the smoothed regression curve. Looking back at a long history with numerous data points presents no problems, as the regression curve can be fitted well to the data. But extrapolating from 10 percent of the final data is risky, since any scatter in the last few points is likely to distort the curve.

Exhibit 3

The Technology „S“ Curve



Attempts to forecast the evolution of technologies present other problems too. The rate of evolution depends on numerous factors, including the macroeconomic climate, competitive intensity in the industry, and market pressures. Consequently, you cannot predict at the start of an S curve how long it will take to reach the end. Even worse, because S curves typically last for tens of years, small errors in predicting the slope of the curve or the level of evolution at a given time are likely to have a significant effect on the predicted date and level of achievement.

Substitution can take you by surprise, occurring through an offshoot of the original technology. For example, in hindsight, Dolby B was the obvious substitute for conventional audio cassette systems, and steel radials were the obvious substitute for rayon corded radial tires. At the time, however, they looked like little more than incremental improvements; no one could have identified them easily as full-blown substitutes.

The reasons are clear. Existing technologies have a critical mass of technology development and a large applications base to justify them commercially. New technologies lack both committed resources and commercial justification. Their development is therefore a result either of an act of faith by management or of a need for a niche application. Initial development and commercialization are inevitably slow until you reach a critical mass of resource and market need, at which point the new technology begins moving up the S curve.

Flat-screen displays for consumer television applications are an example of an emerging substitute technology that is still underperforming conventional CRT picture tube televisions. Flat-screen displays are more than twice as expensive as picture tubes, are limited to small screens, and give inferior color quality, resolution, and reliability. In short, they pose no serious threat to conventional picture tubes. So far the only applications for which they have found a market are miniature portable televisions, portable computer screens, and industrial displays, as used in process control systems.

Why then are the big electronics companies investing so heavily in developing flat-screen displays? Because the conventional technology is at the top of its S curve. As screen size increases and wide screen formats are adopted, conventional televisions become too large and too heavy for home use. High definition television will make the situation worse. The electronics companies recognize the trend and are searching for alternative screen technologies. If flat-screen technologies produce displays that cost less and perform better, their problem will be solved. Flat screens will then open up new potential for products as the technologies move up their S curve. At the moment, none of the companies concerned knows how to improve the performance of flat screens. Consequently, they are investing in a range of technologies. Canon is developing ferroelectric displays, Matsushita supertwist liquid crystals, Philips microtransistor network technologies. Choosing which of the various flat-screen technologies to invest in, however, is a matter of rational judgment based on knowledge of competitive position and perceptions of how the technologies are expected to evolve. The real challenge was to identify flat-screen technologies as a substitution threat before the competitors did.

Anticipating the Discontinuities

It should be clear from this discussion that forecasting is an imprecise science. You can have a good idea of how vulnerable you are to a technology discontinuity, and you can even begin to guess what form that discontinuity might take – but you are only guessing and you cannot make concrete plans. To cope with the lack of certainty you must organize yourself to manage discontinuities. Four key messages on how to do this stand out from our work with multinational clients:

• Maintain business as usual

• Look forward and outward

• Keep an open mind

• Place side bets

Maintain business as usual. Technology discontinuities can threaten the very existence of the firm, but they do not occur frequently and they cannot be scheduled into the business plan. Other things being equal, you need to run the existing business as if a discontinuity will never happen. So, for the existing business, plan for the future and invest in the R&D you need. The R&D plan should address the key technologies of today and the pacing technologies of tomorrow. It should also cover the emerging technologies that could be important in the future. As it can take many years to build a competence in a given technology, the planning needs to be long-term – a 10-year plan is perfectly reasonable for most industries.

Look forward and outward. There is a great danger in relying on an internal view of the future. The expert of today cannot be relied on to make valid judgments on the availability of and need for technology in the future. As we have said, people are constrained by their own interpretation of the world – their mental models. If you put a group of individuals from the same company together to discuss technology trends, you tend to get one of two extremes. Some groups become very cautious, making optimistic people feel that their views are outrageous. Other groups are carried along by shared enthusiasm, and end up forecasting imminent breakthroughs, sweeping rational objection aside. It is hard for people who are heavily involved in an industry to acknowledge that a new technology, currently underperforming the conventional technology, offers more long-term potential and poses a significant threat.

The problem is compounded by two other barriers to the acceptance of the threats. First, new technologies are often developed in industries other than those in which they achieve their commercial potential, so they tend to emerge unnoticed. Because new technologies are often driven by special performance needs, many such technologies are developed in the defense and aerospace industry, before being transferred to civilian commercial applications. Technologies can also transfer from one industry sector to another. For example, many metal extrusion and forming processes are now used in food processing. Consumer electronics display technologies are used in automobiles, and plastics processing technologies have been transferred to the ceramics industry.

Even when a technology in another industrial sector is identified as a threat, its significance may be under-estimated as the difficulties inherent in transferring technologies between sectors become apparent. These difficulties are often perceived as insurmountable, whereas in reality their impact is more likely to be just one of delay.

Keep an open mind. Organizations often suffer from the „not invented here“ syndrome. If an electric valve company has been successful for decades, senior managers who have grown with it and nurtured that success may refuse to accept that a transistor technology from the telecommunications industry could ever be a credible threat. Consequently, substitute technologies, if they are identified at all, tend to be dismissed at first as being appropriate solely for niche applications. Only later, as the limitations of current technologies and the potential of the substitution become more apparent, is the threat taken seriously. But by then it may be too late.

There are exceptions to this myopia. In the development of fast computers, the limits of silicon technologies are well understood, and rapid evolution is accepted as normal. Consequently, the industry is working hard to develop substitute optical computing technologies and has begun to explore biological techniques. In most industries, however, the pace of change is slower and the limitations of conventional technologies are tolerated rather than treated as barriers to be overcome.

To identify possible new technologies and overcome barriers to accepting technology change, you need to give someone responsibility. Some organizations set up technology listening posts, designed to capture and evaluate new technologies as they occur in other industries or in academia. Other firms build the role into the corporate

R&D program. Still others view it as a part-time activity for everyone involved in technology development. The mechanism you choose should be the one that best fits your culture, provided you can ensure that this activity is taken seriously and not treated as a trivial staff function.

Place side bets. If new technologies are emerging, invest in some of them, so that you can build your own technology base and learn how they might affect your business. If your business is in coal- and gas-fired power generation equipment, think what fuel cells might do for you and seize a piece of the action so that you can get beneath the hype to understand where and when they might pose a threat. If you are in automotive engine components, indulge in some future scenario work to explore what might happen and what your role might be. Then invest to spread the risk should a major discontinuity occur. Remember, it can happen very fast. Experience suggests that when a new technology has a demonstrable benefit over existing technology and when there are no regulatory barriers, 80 percent of the market can switch in five years. Five years is not a long time in business, particularly if the existence of one of your divisions is under threat. Investing to keep tabs on the future is money well spent.

What to Do When Discontinuity Occurs

Finally, it has happened. Your worst fears are realized, and you are faced with a substitution that looks as if it could displace a large proportion of your business. What should you do? You face a choice of four actions: exit, defend, build, or buy.

Exit. Abandoning your current business and allowing the substitution technology and the competitors who are promoting it to take over may not be as defeatist as it seems. If the substitution technology meets customer needs better than yours by a wide margin, if technology is a key purchase criterion, and if you are poorly placed to make the switch, you need to face up to the need to withdraw. For example, business commentators criticized slide rule manufacturers for failing to spot the threat from calculators. But what could they have done to embrace a new technology so far removed from their knowledge base? More positively, companies in precision engineering are always redefining their markets to capture segments in which their production technologies have a current competitive advantage. For example, electric discharge machining (EDM) is the current preferred technology for manufacturing many miniature complex-shaped steel components. As the substitution technologies of metal injection molding and powder metal sintering evolve, they will become the preferred technologies. In such a situation, the EDM business should move on to new products and markets rather than invest heavily in new production technologies. The decision depends on the degree to which technology – rather than access to and understanding of market – is the key success factor.

Defend the established technology. Substitutes don't always win. The incumbent technology has some immense advantages: customers know and understand it, the process and manufacturing equipment are already installed, and the infrastructure is already in place, with suppliers and customers down the value chain working together in mutually beneficial relationships. By contrast, new technologies are often expensive and poorly understood coming into their own only as suppliers move up the learning curve. The internal combustion engine makes the point well. As a basic engineering concept, it is well past its sell-by date. *Yet* it remains firmly entrenched as new alternatives – from gas turbines to batteries to hybrids – come and go.

The incumbent technology may also have untapped potential. Take the use of magnetic media for computer data storage. At first, magnetic storage appeared to be maturing fast and was written off as yesterday's technology. However, the threat of optical and solid state storage has prompted the magnetic media companies to renew their technology efforts, moving rapidly from 5-1/4" discs to 3-1/2" and on to ever smaller and higher-capacity products.

Another way to defend your business is by acquiring the substitute technology and burying it. In most cases, that strategy won't work. The driving force for the new technology will not go away just because you have stifled the new entrant. Furthermore, other new technologies are almost certain to follow, and you can't buy them all. However, buying and burying can gain you time, and that may be critical if you have your own technology under development. This approach has helped many companies survive when competing with new technologies; flat-screen displays and bioengineering are typical examples.

A defensive strategy cannot succeed in the long run, if current technologies are running out of potential while the market continues to grow. Sooner or later a technology discontinuity will occur. As a short-term strategy, however, defense can buy you time by delaying the arrival of a substitute or killing off a particular substitute by making market entry too difficult.

Build. The third option is to develop the substitute technology yourself, if the technical entry barriers are not too high. The Swatch is a good example. Again, the incumbent business starts with many advantages. If the incumbent understands customer needs well and has existing channels to market, it should be able to tune the substitute technology faster and more closely to customer needs than a new entrant can. This option is not always open to you, however, if the new technology requires special skills or disproportionate capital investment. The manufacturers of traditional domestic cooker elements could not have resisted the introduction of glass ceramic range tops, partly because the material has unique properties, is heavily patented, and requires capital-intensive processing.

Buy. The fourth option is to buy the substitute technology, either to use it or to bury it. In many cases, purchase is a logical option. It can take several forms: negotiate a license, acquire a company, or purchase components or equipment. If the technology is not strategically critical, purchasing components or equipment is often a viable route. An automotive subassembly business can buy-in plastic injection-molded parts to replace in-house machining of metal components. The same company could also buy-in a new adhesive jointing machine to replace its old spot-welding equipment.

If the technology is more strategically valuable, but not a primary basis of competition, licensing may be the best route. Licenses give access to new technologies at lower cost than outright purchase, but still keep the time and risk benefits lower than in-house development. If you compete primarily on nontechnology factors – such as applications knowledge, delivery response, and after-sales service – licensing upstream product and process technologies can be very cost-effective. For example, local packaging machinery companies that supply custom-designed equipment often license key aspects of the process technology as the most cost-effective way of competing.

For technologies that are fundamental to the success of the business, acquiring a company is likely to be the most appropriate route to acquiring the technology. If you are in the water business, for example, producing chlorine-dosing machinery for municipal and industrial water treatment, you face a threat from UV and ozone technologies. Internal development is not possible because none of the competitors has the skills required, and licensing is difficult, as most potential licensers want to go it alone; acquisition is the only viable option.

While you can't predict discontinuities, you can form an intelligent view on what is likely and what is not. You may not get it right all the time, but provided you have a better picture of the future than your competitors, you can choose the right direction and gain an immense competitive advantage over them.

Chris Floyd is a Director of Arthur D. Little, Inc., based in Harrogate, U.K. A leading member of the firm's Technology and Innovation Management Practice, he specializes in technology management. This article draws on material in a forthcoming book he has written on this subject.