

Using Technology and Business Trend Knowledge to Systematically Accelerate Innovation

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Abstract

2000 person-years of systematic research into the dynamics of system evolution – including analyses of technical and business systems across all fields of human endeavour – has revealed a number of highly repeatable innovation patterns. At the highest level, these patterns reveal a direction of evolution towards increased customer benefit, decreased cost, and decreased environmental and other ‘harm’s. Successful systems, in other words, will inherently, shift towards delivering higher ‘value. They will also eventually become more sustainable. Unfortunately, the large majority of customers will usually rank reduction of environmental harm as a poor third in relation to the benefit and cost elements of the value equation. The theme of the paper is that by systematically deploying the 35 discontinuous technical trends and 31 business trends that underpin the overall evolution findings, it is possible to accelerate the achievement of sustainable products and business models without expecting customers to compromise on either benefits or cost.

Introduction

Starting in 1946, researchers have been examining how different industries have evolved over time. One way of doing this is to take all of the solutions for a given industry, place them in date order, and then see if any patterns can be traced. Figure 1 illustrates such an example.



Figure 1: Evolution of ‘Body Protection’ Systems

Not that there was a patent database in the Middle Ages, but we can probably imagine that over time the shield was progressively enhanced and refined. There were, in other words, a series of incremental improvements in shield design. Ultimately, however, the shield suffers from some fundamental limitations. The first one is a conflict between a desire for it to cover as much of the person holding it as possible. The problem here is that the bigger it is the heavier and more unwieldy it will be. The second, probably bigger, conflict is that

we require one arm to hold it, and therefore only have one free arm to do other things. As shown in the second picture in the sequence, the suit of armour solved both of these problems; a person wearing the suit of armour now had two free arms with much less weight cantilevered from each arm. Alas, there were new problems that came with this new system – it was still heavy, the wearer wasn't particularly manoeuvrable, and visibility wasn't great. Again, these turned out to be fundamental limitations of the armour system. It wasn't until someone came along and invented chain-mail in fact that the state of the art was able to make another forwards jump. Chain-mail now gave far greater freedom of movement to the wearer, but with the best will in the world this protection system too hit a hard limit when the threat changed from swords and arrows to bullets. When the threat system changed, the protection system also needed to change. As shown in the fourth and final picture in the sequence, that change currently comprises a Kevlar-type vest.

Let's shift 'industry' now and look at how solutions for cutting things has evolved. Figure 2 illustrates a similar left-to-right time progression.



Figure 2: Evolution of 'Cutting' Systems

The first evolution stage in this progression is a simple hand tool. The main problem with this tool is its limited productivity. A desire to increase productivity ultimately meant that the world had to add power and more cutting surfaces. The new problem now became one of accuracy. This problem was eventually solved when machine tools arrived, and the world invented systems like the bandsaw. As always seems to be the case, even this system eventually hit some kind of fundamental limit. In this case, that limit relates to tool wear. In order to solve that problem, a new non-mechanical solution was required. We see such a solution arriving in the form of, first, water-jet based cutting tools, and, now more recently, laser-based systems. There is no tool-wear with a water jet. The potential for mess and difficulties of recycling and cleaning the water become the limitations of this system. The laser manages to eliminate both of these problems, as well as offering the potential for higher accuracy and an ability to form more intricate shapes.

Perhaps we can begin to see connections between Figure 1 and Figure 2. They are both completely different industries, but there does seem to be some similarity in how they have evolved. Let's try and see if a clearer pattern emerges as we shift our attention to a third industry. This time let's move to the automotive sector and the design of steering control systems. Figure 3 presents another left-to-right time progression for this sector:

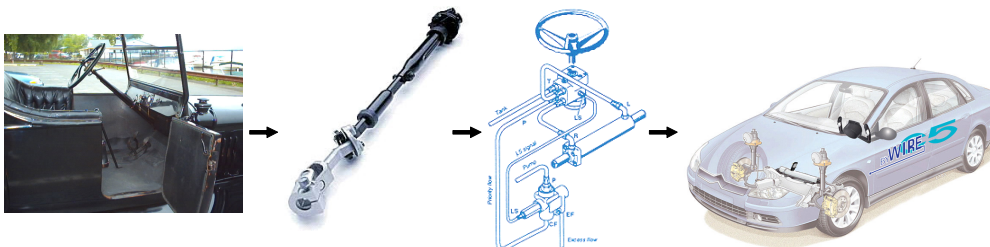


Figure 3: Evolution of 'Steering' Systems

The reasons for the jumps between stages are different again this time. The first picture illustrates the steering column of a Model T Ford. The column is a rigid shaft. The problem with this system is that there is an engine between where we want to put the steering wheel and the front axle we want to be able to steer. We can solve this problem by introducing an articulated shaft as illustrated in the second picture. This solution solves the location problem, but is still heavy. Evolution to hydraulic steering systems (third picture) helped solve this weight problem and gave the designer almost complete flexibility as far as positioning of components under the hood of the car. Effective as they are, hydraulic systems also hit fundamental limitations. This time these limitations include the weight of carrying around the hydraulic fluid, the reliability and safety problems that can result from high pressurisation of the fluid, inability to recover braking energy, and certain dynamic behaviour instabilities. In the latest 'drive by wire' design solutions – a jump that the aerospace industry made several years ago – we can see yet another step-change advance, one that solves many of these problems.

Can we see a pattern yet? How about another example. This time – Figure 4 – the 'measuring distance' industry:

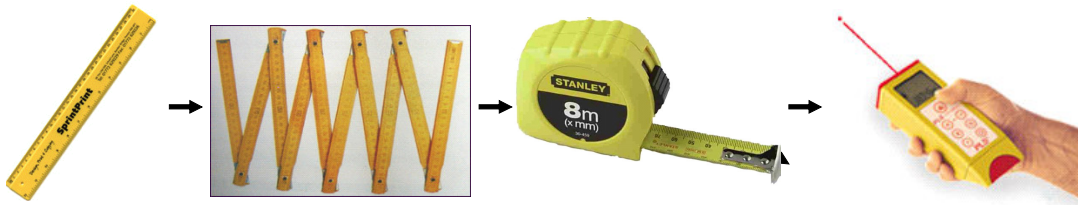


Figure 4: Evolution of 'Measuring Distance' Systems

Again we can reverse engineer and see different fundamental limits at each of the stages – inconvenience, inability to measure long distances, weight, accuracy, safety, etc – but again there appears to be some kind of underlying pattern in terms of what each of the evolution stages looks like.

One final example should serve to cement the pattern. This time the focus shifts to the much more rapid evolution of the computer keyboard. The progression looks something like the pictures shown in Figure 5.

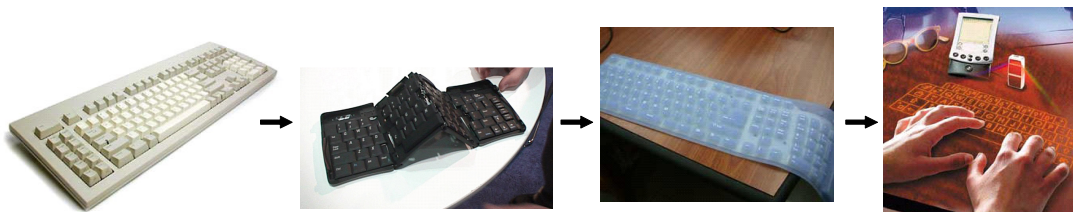


Figure 5: Evolution of Computer Keyboard Systems

The reasons why the system has jumped from one stage to the next this time are generally speaking the same – the increasing desire to make the keyboard more compact. A folding keyboard folds up to form a smaller package than a traditional keyboard; a roll-up one is even smaller; while a projected keyboard effectively delivers the desired function of the keyboard, but now the keyboard is virtual.

What has happened in this industry is exactly what has happened in the previous four. We could find exactly the same evolution pattern if we chose to examine many thousands of other systems. From cameras to cell-phones, chairs to satellites, evolution has followed the same basic pattern. The pattern is reproduced in Figure 6. In the Systematic

Innovation methodology (Reference 1) that brings this and other trends together, this pattern is called 'Dynamization'. It is all about how systems evolve in terms of how they achieve movement. The basic progression suggests that systems evolve from being static or immobile structures, to structures featuring one or more joints, to completely flexible systems to fluids or gases and then finally 'fields'.

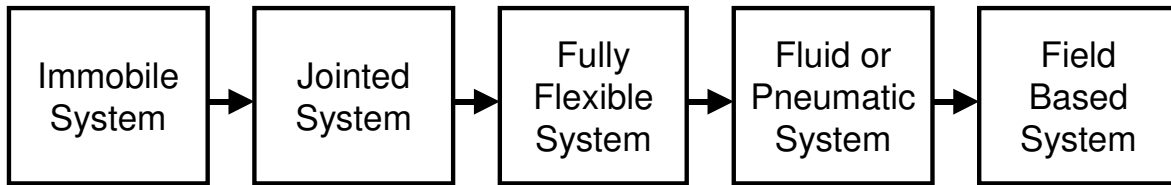


Figure 6: 'Dynamization' Evolution Trend

Referring back to the earlier figures, it is possible to see that sometimes a system has leap-frogged a stage. In some cases – surgical cutting instruments for example – the system has jumped directly from scalpels to laser or ultrasound cutting devices (both of which immediately cauterise arteries and so the loss of blood following incision is close to zero). Sometimes the 'field' is different things – it may be a laser or ultrasound or magnetic, etc – all we can say in general is that it will be some kind of field at this final stage. Sometimes – as in the case of the Kevlar vest – the system hasn't reached the end of the trend yet. This is where the trend becomes very interesting from the accelerated evolution perspective, since we can now examine the jumps that have occurred in other sectors that have not yet occurred with our product. Admittedly in this case, the idea of stopping a bullet using a fluid or, particularly, a field is difficult to imagine, but, if the trend is correct, then these would be good places to direct R&D efforts. More practically, we can see an evolution jump that is far more likely to occur in the near term when we look at the grass-cutting system evolution shown in Figure 7.



Figure 7: Evolution of Grass/Weed Cutting Systems

Where do we think this system might evolve in the future? Based on the Dynamization trend, it seems a fairly safe bet that the system will eventually become some kind of a 'field' (laser?), possibly via an intermediate (fluid?) stage. Other parts of TRIZ will tell us that in the final situation, the need for a grass/weed-cutting device will disappear altogether (Reference 1). In the meantime, we have a good idea where to direct our R&D efforts if we were looking to get into this industry.

Yes, But...

Perhaps as you see this example, your brain is thinking ‘yes, but...’. Yes, but a laser system will be too expensive; Yes, but it might be unsafe. Undoubtedly in any innovation these ‘yes, but’s...’ will almost always be present. The big difference between Systematic Innovation and what normally happens when someone says those words, is that in Systematic Innovation ‘yes, but’ is a start point rather than an end. A ‘yes, but...’ means we have found a contradiction. Besides the future prediction part of the overall method, the next biggest part is a toolkit to assist in the process of eliminating trade-offs and contradictions. That subject is too big for this paper, and so we will simply refer readers to References 2 or 3 if they wish to find out more about the Contradiction elimination toolkit. The main thing we need to keep in mind is that whenever a Trend direction delivers us a ‘yes, but’, someone somewhere has already solved that problem. In actual fact, we may be able to find the answer to our ‘yes, but’ problem by examining some of the other trends of evolution uncovered by the Systematic Innovation researchers. Note here that in the terms of the method, whenever we use the word ‘trend’ we are specifically thinking about the discontinuous jumps that occur when a system overcomes a fundamental contradiction and jumps to another way of doing things and not the usual gradual directional shift we normally think of when we see the word ‘trend’. Now would be a good time to examine one or two of these other discontinuous system-jump trends:

Rhythm Co-ordination

In all, depending on how the overall total is segmented, the Systematic Innovation researchers have uncovered 35 different discontinuous trends (Reference 1). These trends fit into three broad categories; trends related to the physical evolution of a system, trends related to temporal evolution and trends relating to the way in which the interfaces between systems evolve. The Dynamization trend is primarily focused on physical system evolution. The Rhythm Co-ordination trend – Figure 7 – is far more closely related to temporal evolution of systems.

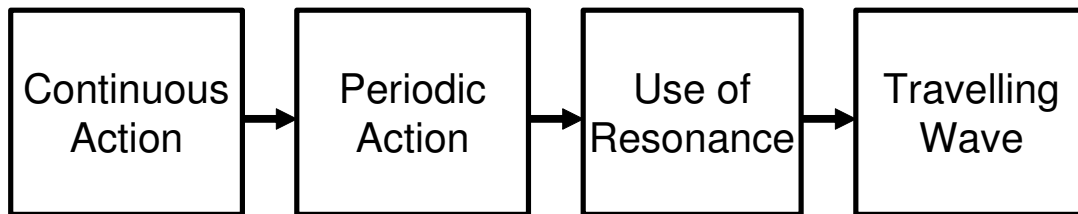


Figure 7: ‘Rhythm Co-ordination’ Evolution Trend

Should we have the inclination, we could do for the Rhythm Co-ordination trend exactly what we have just done for the Dynamization trend. As with all of the trends, the pattern emerges from the analysis of many thousands of systems. A single example should suffice to describe how and why systems might evolve through the first three stages of this trend. Figure 8 illustrates the evolution of a bottle cleaning process:

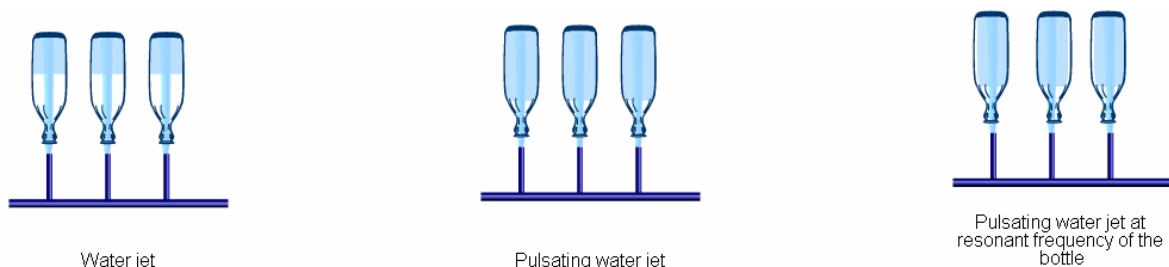


Figure 8: Bottle Cleaning Example Of ‘Rhythm Co-ordination’ Evolution Trend

In the first stage of the trend, water is pumped continuously into the upturned bottle. Such a system makes good use of gravity to empty the bottle ('the bottle empties itself'), but uses a considerable amount of water. Process engineers later discovered that if they switched from a continuous to a pulsed water jet it was possible to get the same cleaning action with around 50% less water. Later on, the third stage of the trend – 'resonance' – gave the idea of pulsing the water jet at the resonant frequency of the bottle. Now not only did the pulsed hammer effect do a good job of cleaning the bottles, but the fact that the bottles were now also resonating meant that the cleaning effect was magnified. In fact the water consumption for the same cleaning action could now be reduced by over 75% relative to the original water-jet system.

Increasing Ideality

Both the trends described here, the other 33 technical trends, and the 31 thus far uncovered discontinuous business evolution trends are all consistent with an overall trend direction. This higher level trend involves the progressive evolution of systems to a state of higher ideality. Ideality is defined in various ways in and around the Systematic Innovation community. The most frequently used definition is:

$$\text{Ideality} = \text{Perceived(Benefits)} / (\text{Cost} + \text{Harm})$$

The perhaps unsurprising finding from the near 3 million examples studied is that successful systems evolve in a direction where the customer receives higher levels of benefit, lower cost and lower 'harm' (where harm is defined as anything the customer perceives to be a negative aspect of a system – whether it be waiting time, or an environmental impact or social negative). We can see that this 'ideality' term is very closely related to typical definitions of 'value'. There is no coincidence in this similarity. As when thinking about value, not every one of the three constituent parts of the equation need all be moving in the right direction, but the overall ideality/value should be increasing for any new idea that is going to be successful.

One of the gratifying aspects of this equation is that over time 'harm' aspects will decrease. This is good news from an environmental and social perspective. The good news needs to be tempered slightly, however, with the knowledge that in the vast majority of systems, the customer will tend to opt for increased benefits (basically the useful functions delivered by the system that allow the customer to get done the job that they want done) or lower cost before they will go for lower harm (Reference 4).

The news gets slightly worse when we consider the other Systematic Innovation trends that underpin the increasing ideality trend. What many of these more detailed trends tell us – and the two selected for special consideration earlier both fall into the category – is that things often get worse before they get better:

Systems Become More Complex Then Less Complex

A close examination of the Dynamization trend illustrated in Figure 6 reveals this 'systems get more complex before they get less complex' trend quite vividly. A system containing one or many joints is a system that is very definitely more complicated than a simple immobile system. It is only when we reach the 'field' stage in fact that we have the potential to create a system that uses less material resources than the earlier mechanical and fluidic systems. Likewise, in the Rhythm Co-ordination trend, creating the ability to turn a continuous action into one with pulsations almost invariably necessitates the addition of something to the system to create the desired pulsation. Once we have such a

mechanism, the resonance stage comes somewhat more readily, and can often be achieved by simplifying the system (this is because 'resonant frequency' is a resource present in every system and so we don't have to add anything new). The general characteristic that may be observed in both of these trends is reproduced in Figure 9. The characteristic shows that allowing systems to evolve 'naturally' produces a period of increasing complexity – during which time, although customer benefits are increasing, costs and harms *may* be getting worse – followed by a period of decreasing complexity, when, having delivered all the possible or required benefits, the only remaining strategies for increasing net value are to reduce cost and eventually harm.

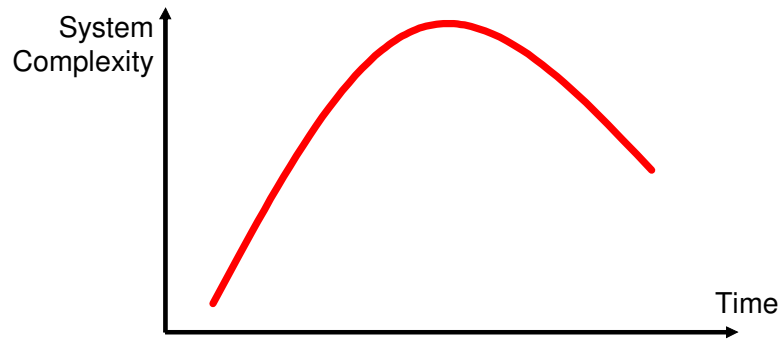


Figure 9: Systems Become More Complex Then Less Complex Evolution Pattern

Any given technical system may be at any given point in this increasing-decreasing cycle. Environmentalists may take some comfort, however, in the knowledge that as engineers make greater and greater use of 'fields' and less and less of mechanical solutions, that overall the world today appears to be in the 'complexity decreases' part of the trend. Think about the enormous increases in efficiency of jet engines or the extra-ordinary dematerialisation that has taken place in many construction materials to get a feel for why this might be so.

It is perhaps dangerous to speculate, but it would appear that increased knowledge of the Trends is offering to accelerate the evolution of systems. The Trends in effect act as a signpost that says 'head in this direction in order to create a more ideal solution'. Such a signpost, allows users to potentially 'force' the evolution of a system such that systems can evolve from start to end without having to take the traditional detour via increased complexity. In some cases – using a 'field' to stop a bullet – the world isn't yet smart enough to know how to engineer such a solution. But in other sectors – and grass-cutting would appear to be one – the fruit hangs considerably lower.

The intellectual property generating possibilities once we are aware of the trends are considerable. So much so in fact that Systematic Innovation has been advertised as a 'secret weapon' in certain parts of Asia. A recently completed programme run by the Hong Kong Productivity Council (Reference 5) has done much to make the TRIZ trend tools available to companies in and around the region. By all accounts that programme has been very successful in not only facilitating the creation of considerable amounts of intellectual property, but also getting a number of new products and processes to market.

Evolution Potential

We should make one more step forward before closing this paper. Thus far the discussion has centred around how *individual* discontinuous evolution trends can be used to accelerate the evolution of a given system. So what about when we consider all of the 35 trends together? The first thing we will find when we do this is that not all 35 are likely to

be relevant to a given system. If it is a piece of software, for example, or a business model, then few if any of the trends relating to physical appearance will be particularly relevant. The first task, then, is to identify the trends that are relevant. Let us imagine that we have a desire to examine the light projection keyboard illustrated at the far right hand side of Figure 5. Clearly this is a system that has evolved right to the end of the Dynamization trend as we currently know it (incidentally there is a considerable research team in place whose job is to uncover new trends and new stages at the end of existing trends, so there may be something out there in the future that goes beyond a 'field'). If we imagine the trend as a line containing five distinct stages then the projection keyboard is at the fifth stage – Figure 10. The traditional keyboard, on the other hand, is still at the first 'immobile' stage.

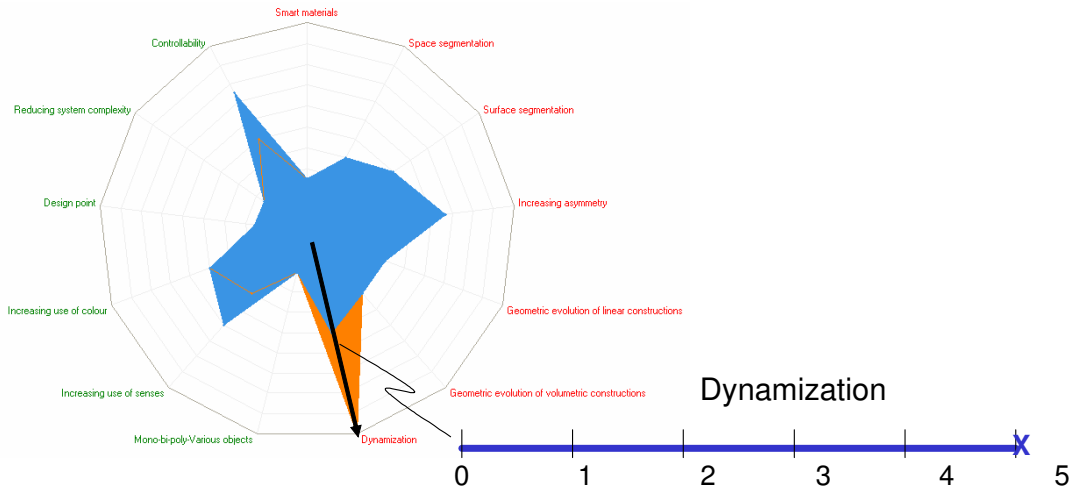


Figure 10: Typical 'Evolution Potential' Radar Plot

The radar plot shown in the figure is simply a way of presenting a repetition of this comparison – how far along the trend is my system? – for each of the other trends. By arranging the results into a radar plot, with each trend comparison as one spoke in the plot we end up with a composite picture that says, 'this is how evolved your system currently is'. The perimeter of the plot, of course, represents where we would be if our system had evolved all the way along all of the trends. The radar plot for the traditional and projection keyboards shown in the figure highlights the fact that both still have considerable 'untapped evolution potential'. In simple terms, what this means is that for all of the other trends, the system has not reached the known final evolution stage.

This plot is in fact typical of just about all of the plots that we construct during our research on new patents. If we can imagine translating the area of the radar plot area filled by our system relative to the total area of the circle defining the perimeter we can obtain a percentage evolution potential used. We currently construct about 4000 of these plots a month for the new patents and other systems we analyse and the overall average evolution potential usage is something around the 45% mark. That equates to a considerable amount of untapped potential in the technical and business systems of the world. Why might this be so? The simple (although no doubt incomplete) answer to this question is that ideas tend to travel slowly between different industries. We all tend to think that our problems are unique to us. The Systematic Innovation trend patterns beg to differ.

The Evolution Potential radar plots do one additional thing for us. Some readers may be familiar with the light-projection keyboard and know that it has thus far been a relative failure commercially. Why should this be so when the Dynamization trend has so clearly identified this evolution as a jump to a more ideal state? The answer comes when we look

at the other trends in the radar plot, two of which show that the light projection keyboard has evolved backwards relative to the direction of increasing ideality. We don't need to get too far into the detail of these two backward jumps (one relates to use of senses and the other to feedback – both of which are impaired in a keyboard design that gives no tactile feedback to the user upon 'pressing' a key) to make the relevant point. That point is that any time we see an apparent innovation making both forward and backward trend jumps, we can be certain that the market is being presented with a trade-off. In such situations it is usually considerably less than clear that the idea will be a successful one. The evolution potential plots thus give us a test to determine whether an idea is likely to be commercially successful or not. Any kind of backward jump along any trend provides a sure sign that we can and ought to try harder.

Summary

Systematic Innovation research, starting in 1946 and now taking into account close to 3 million successful innovations, has uncovered 35 discontinuous technical trends and 31 business trends. Awareness of these trends offers the potential for business leaders, engineers and scientists to both accelerate the evolution of the systems they are responsible for and also to provide objective tests to determine whether a given idea is good enough to be successful on the market.

In essence the Trends provide clear guidance on the *where* of system evolution (see Reference 6 for a discussion on the more difficult *when* question). Whilst it is doubtful that any of the trends can be proven to be correct, at the very least they offer a series of heuristics that look set to have a profound impact on the innovation process. If we are all in the 'value' business, then here – we think – are tools that permit the systematic identification of higher value design solutions. The race is on to see who can make the best use of the trends.

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