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In this month's issue:

The Systematic Innovation e-zine is a monthly, subscription only, publication. Each month will feature articles and features aimed at advancing the state of the art in TRIZ and related problem solving methodologies.

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More On Evolution Potential Hierarchies
- The Helicopter View

Gas-turbine engines are among the most complicated systems ever designed and built. A modern-day engine is able to generate several times its own weight in useful thrust. To achieve this feat, the engine is also likely to contain tens of thousands of components.

The Evolution Potential concept is a way of viewing and managing all of the complexities associated with such systems. If we were in the gas-turbine business, we might consider constructing evolution potential radar plots for all of the engine components as a way of helping to see where the best places to spend R&D money might be. Obviously, drawing several tens of thousands of radar plots is not an activity to be undertaken lightly. Evidence from other sectors where large numbers of such plots have been drawn tends to suggest that there is no better way of determining where the best 'bang per buck' R&D investments are to be found.

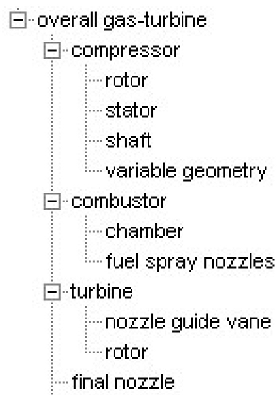


Figure 1: Partial Evolution Potential Hierarchy For Gas-Turbine Engine

As suggested by Figure 1, it is possible to construct a hierarchy of such plots. Drawing this type of hierarchy can be a very effective way of determining which of the component level plots are more important to construct than others. Very often in scenarios where we are looking to get the maximum information by drawing the minimum number of plots, it is useful to start at the major-assembly level in the hierarchy and work downwards towards the individual component level.

The plot hierarchy idea should also get us to the idea of constructing a plot for the overall system. While such overall-system level plots inevitably give us less detailed information about which parts of an engine are going to give us the biggest benefits, they do give us another type of important strategic information.

Figure 2 presents a composite plot describing the history of the gas-turbine since its original conception over 70 years ago. Each of the different colours on the plot represents one of the major evolution jumps that the industry has made. With this in mind, one thing the plot makes clear is that there have been relatively few what we might describe as 'major leaps' forward since the first engine (represented in the figure by the yellow shape at the centre of picture).

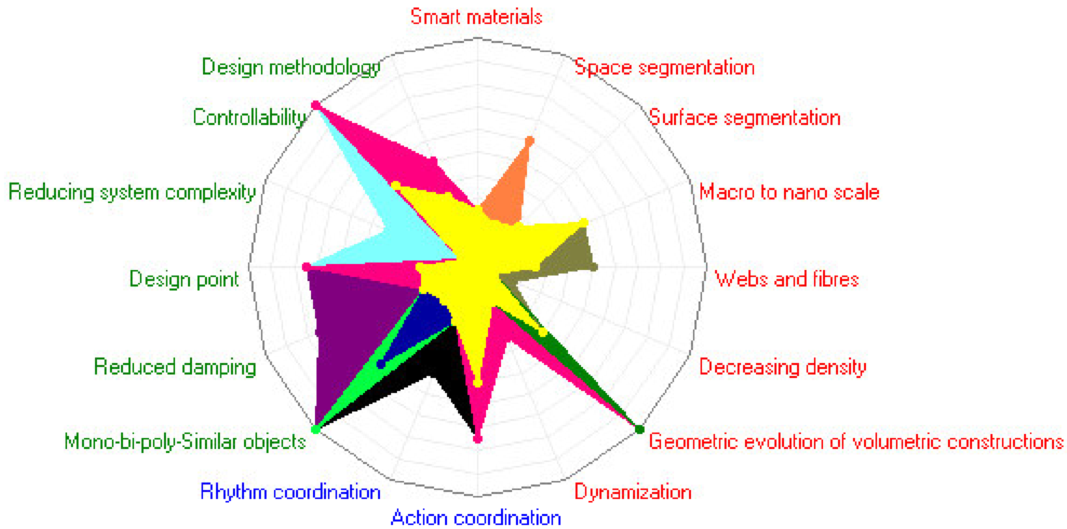


Figure 2: Evolution Potential History For Overall Gas-Turbine

Using this definition of a jump along a trend at the system level as a major leap forward, the few jumps that have taken place are:-

- Orange jump – the introduction of hollow geometry turbine and fan blades permitted increases in operating temperature (strongly related to efficiency) and improved dynamics.
- Blue and pale green jumps – the shift from single shaft to two and three shaft engine configurations; permitting the introduction of bypass engine configurations and large improvements in dynamic performance
- Olive green jump – the introduction of computational fluid dynamic calculation methods and advanced manufacturing technologies permitted the use of turbomachinery making full use of the three special dimensions.
- Purple jump – the shift towards super-critical shaft designs again permitted improvements in dynamic performance
- Green/Grey jump – representing the introduction of composite materials into certain engine components permitted large weight reductions and consequent increases in thrust/weight ratio
- Turquoise jump – more recent cost reduction initiatives driven into all of the engine companies by airlines wishing to have lower first cost and better reliability
- Pink jump – mainly lead by military engine performance demands, the latest generation engines are beginning to use variable geometry features to enable improved performance and efficiency across wide ranges of operating conditions
- Black jump – hasn't happened yet, but a recently published article from Rolls-Royce has indicated that they are actively researching pulsed combustion systems. If they succeed, according to this system-level radar plot, they will have achieved a major leap forward in the gas-turbine state of the art.

Gas-turbines are generally considered to be at the mature end of their ultimate capability. What the system level plot shows, on the other hand, is that even when pulsation is added to the system, there are still considerable amounts of untapped potential left in the system.

This is not to say that any of the available jumps will be easy, merely that someone, somewhere has already made such jumps.

Irrespective of the interest in gas-turbines, the idea of evolution potential plot hierarchies as a means of discriminating between different levels of invention is believed to be conceptually quite important. Given the opportunity, we always seek to construct the whole hierarchy. Clearly doing this takes some amount of time. We believe the value of the output produced easily justifies the cost and time involved.

Optimization/Innovation Cycles

Systematic Innovation methods are primarily concerned with step-change rather than incremental improvements. A systematic innovation solution is more likely to deliver tens of percents of improvement than the ones and twos that are the norm in optimization strategies. This is not to say that one is better than the other, of course, but merely that 'step-change innovation' are two different things. We often use the image shown in Figure 1 as a way of comparing the two different approaches.

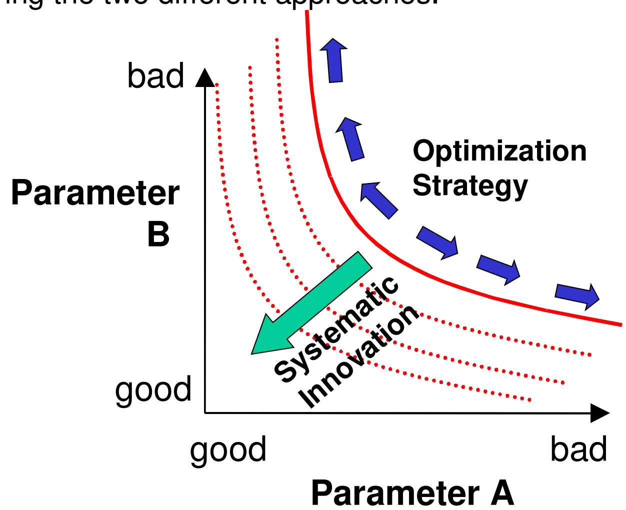


Figure 1: Simplified Relationship Between Optimization and Innovation

The picture depicts a useful comparison, but in so doing misses a lot of important information relating to the relationship between step-change innovation and incremental optimization. The aim of this article is to explore some of that missing information.

One of the fundamental ideas concerning the relationship between innovation and optimization is that the two operate sequentially in repeating cycles. In order to illustrate the cyclical relationship between the two, we begin by looking at a typical design optimization scenario.

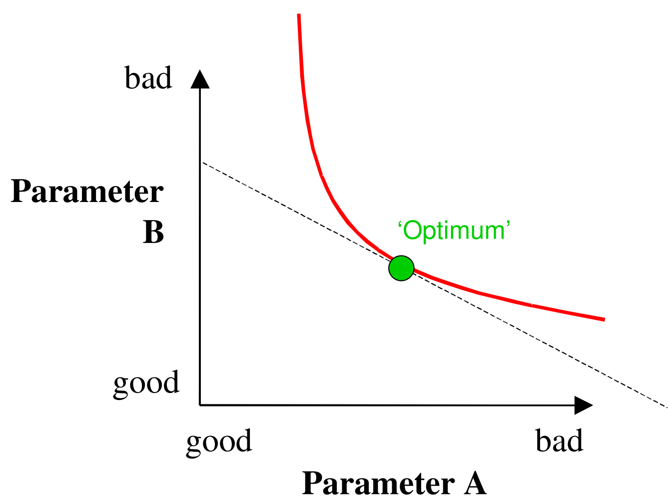


Figure 2: Typical 'Optimum-Finding' Activity

This scenario involves an often detailed examination of all of the parameters that influence the outcome of a design and establishing the relationships between them. In Figure 2, we have shown just two of the (potentially very large) number of influencing factors. If Parameter A and Parameter B are in conflict with one another – which will be the case with a very large proportion of the design parameters we will consider – then we will frequently conduct experiments in order to establish the relationship between the two (the red-line in the figure). We will then also somehow determine the relative importance of each (the dotted black line). This can be a somewhat subjective process, although tools like QFD are often helpful in allowing us to identify how the customer values different parameters. Once we have the relationship and the relative importance, we are then able to calculate the magic 'optimum' values for the two parameters. Either in parallel or sequentially, we will repeat this type of exercise for all of the other influencing parameters. Taken over a realistic number of influencing parameters, this optimization task can often be an expensive and time-consuming process.

At some time after we have found the magic 'optimum' point, it becomes necessary to find a better optimum. This is usually because our competitors have all managed to do the same sorts of optimization experiments and market assessments that we have and are now able to deliver the same sort of performance as we are. When this happens, it is necessary for us to 'innovate'.

When we do this innovation job – whether using a systematic innovation technique or not – we are essentially finding a way to break some or all of the known trade-off relationships. In systematic innovation terms, someone decides they want their cake and to eat it, and finds a new way of doing things. This type of innovative jump is illustrated in Figure 3. Again the figure just illustrates just two of the parameters important to the design; whereas in practice the situation will be much more complicated.

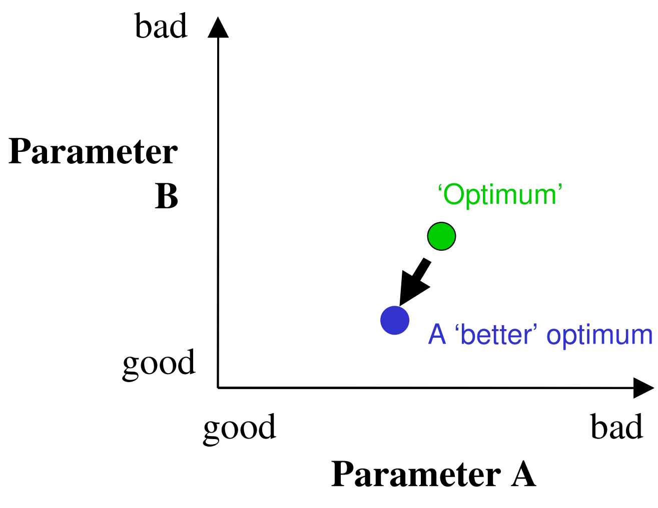


Figure 3: Innovating To A 'Better' Optimum

After this innovation has occurred, the competitive advantage is restored. Unfortunately, the innovation is likely to have shifted many of the established trade-off and optimization rules. Consequently, the innovation tends to spark a whole new series of optimization experiments and customer surveying in order to find out what the new relationships are. As illustrated in Figure 4, these new optimization experiments allow the new relationship between the conflicting parameters to be understood and the blue characteristic line can be plotted. Likewise, new customer feedback allows us to re-calculate the relative importances of the two parameters. Taken together, as illustrated in Figure 4, we are then able to establish the 'new' optimum:

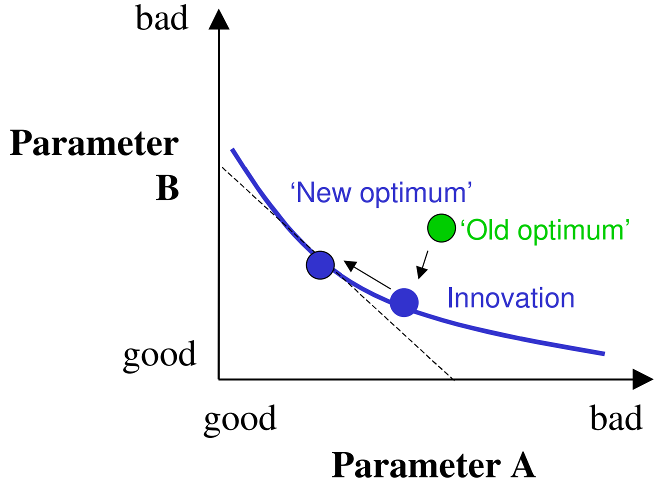


Figure 4: New Optimisation and Customer Survey Information Allows Calculation of New Optimum

At some time after this new optimum has been found, the competition again catch up, and the need for innovation arises again. Hence we tend to see the sort of successive chain of optimization and innovation activities illustrated in Figure 5.

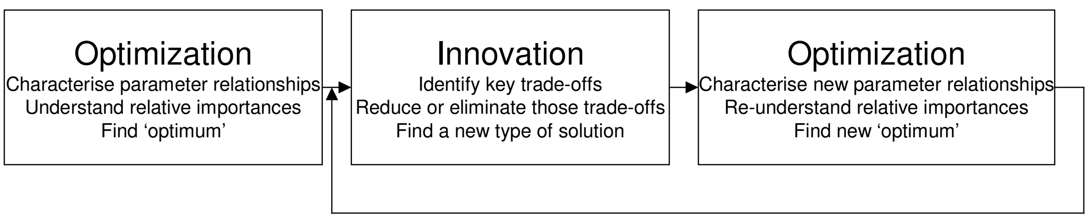


Figure 5: Optimization/Innovation Cycles

This optimization/innovation cycle will continue as long as there are competitive pressures to drive it. Two issues of interest emerge from the model:

1) why are companies seemingly reluctant to innovate? One of the great paradoxes of the systematic innovation community – if this stuff really works and is literally capable of delivering step-change improvements in performance of systems, why don't more people want to do it. Possible answer; the innovation carries with it the fact that much of the investment in optimization data for the old design becomes irrelevant, and is therefore 'lost'. Even worse, the innovation carries with it the future promise that there will need to be a potentially comparable investment in the acquisition of new optimization data in the not too distant future. Sad as this may be, it is a fundamental of the innovation process; increasingly if we don't make the investment in the innovations, someone else will.
2) A possible answer emerges from some of the most rapidly evolving industries; what is increasingly happening in these sectors is that if the innovations are being demanded more rapidly than the optimization data acquisition can be accrued, then there is no time (or money!) to bother with the optimization; better to just make sure you have a solid string of step-change innovations up your sleeve and ready to go.

What this article tries to make clear is that there is no such thing as a black and white choice between innovation and optimization. Each has its place and time, and the two go together in cycles.

Not So Funny – Bad Design Solutions of the World Part 247 – Sink Plug

Spending the large majority of our time in hotel rooms around the world it never ceases to amaze us how difficult it is to find a sink plug that works. Once upon a time the whole thing was easy – you had a plastic stopper roughly the same size as the hole you wanted to block, and you attached a chain to it to facilitate the removal of the plug when you had finished with the water in the sink. But then, I guess someone thought that the chain looked a bit ugly, and that a more 'sophisticated' solution that could be achieved. Enter the chrome-plated system of discs, handles and levers found in many modern installations. The plastic plug has been replaced with a solid lump of metal (flexible goes to rigid – a backward step along one of the technology evolution trends perhaps?). It sure looks neater, but does it perform it's intended function any more? Sit in a nice full bathtub in a hotel room featuring one of these new plugs and it is a fair bet that the water will have leaked away around those nice rigid edges of the plug before you can say 'Eureka'. So, probably, no it doesn't.

If you thought these plugs were the pinnacle of bathroom evolution, however, then think again, because a recent trip to Colorado revealed another stage in the advancement of the art:

In this novel installation (the hotel chain responsible shall remain nameless) there has been a neat advance along the Mono-Bi-Poly trend in which the sink fittings have been integrated with a wonderfully expensive looking marble surround.

Just one problem though. In order to cut down on the use of all that expensive marble, the plug release mechanism has been allowed about 10mm of vertical movement. Unfortunately, the mechanism requires considerably more than 10mm of vertical movement before the plug seals the sink. Net result; it is impossible to fully close the plug and hence is impossible to run a sink of water.

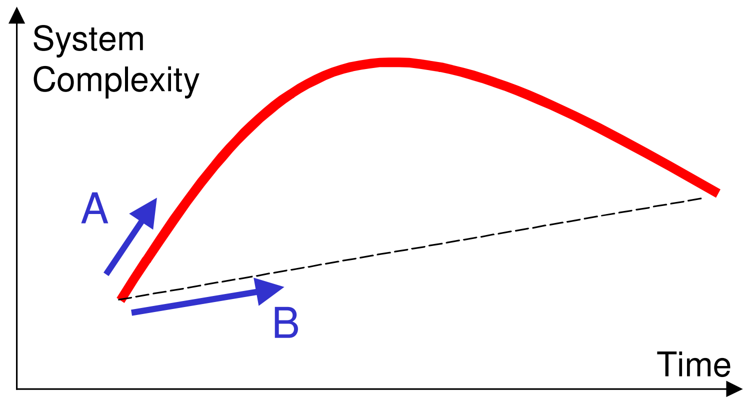
A work of true genius if preventing sleepy guests from over-flowing the sink was the aim of the design. On the other hand, if the intention was to allow a user to have a wash, the end result leaves rather a lot to be desired. Congratulations, in either case, to the designer; we award you our TK (Total Kwolity) Award for the month and trust that you are happy with the outcome of your efforts.

Patent of the Month

Patent of the month award this month goes to a group of inventors in Japan for US patent 6,708,115, granted on 16 March 2004. The invention describes a vehicle speedometer based on the use of information from GPS systems. Yet another example of an 'it's obvious' solution that may well have some very important consequences from a technology deployment standpoint.

In addition to being a very neat use of GPS, the invention allows us to examine a pair of useful learning points relating to the systematic innovation methodology:

The first of these relates to the complexity-increases-and-then-decreases trend of evolution shown in the figure below:



We are often asked why this increase-followed-by-decrease characteristic exists and, more specifically, why designers don't try to follow the more ideal evolution direction marked B on the figure.

There are various answers to this question of course. At one end of the spectrum of answers is that when a system first emerges, the motivation of the inventor is driven much more by a need to get things onto the market than to optimize the design and so simply, there is no strong incentive to maximize efficiency of resource usage. At the other end of the spectrum is the idea that at the start of the evolution of a system we simply aren't smart enough to work out the most efficient use of resources.

The US6,708,115 invention describes an evolution course somewhat closer to the second rather than the first of these two extremes. In actual fact, however, it describes a process that is neither. Rather it illustrates an important evolution dynamic relating to the concept of *displacement*.

As far as the invention goes, *displacement* works something like this:

1) as cars evolve, there is a need o be able to measure their speed. The speedometer is thus created. It usually involves some form of mechanical device who's job is to monitor the rate of rotation of something in or around the transmission system that correlates to vehicle speed (e.g. rpm). The incorporation of a speedometer increases the complexity of the vehicle slightly.
2) Later on in the evolution, the GPS appears. The function of the GPS system is to inform the driver about geographic position.
3) The inventors of US6,708,115 realise that the GPS system is also able to calculate the actual speed and velocity of the car using just the information that the system already has available to it.

4) Assuming that the market (or more likely the car companies) accept the invention, then the need for the mechanical speed measurement system disappears because there is now something already present in the vehicle that can perform the function in its place.

Thus the mechanical speedometer can be displaced by the GPS version. This displacement has only become possible since the GPS technology was proven and the capability was added to cars.

The general rule of displacement that may be drawn, then, from this example is that not only can emerging technologies add new functionality to the systems into which they are added, but, once they are accepted, they may be able to take on some of the existing functions in the vehicle. As such, even though they may add additional complexity to a system at first, if they are able to displace other aspects of the system, then over time net complexity may be able to be reduced again. Importantly, the increase in complexity is a necessary precursor to the subsequent complexity reductions that displacements are able to allow.

The second interesting aspect of the invention relates to the conflict that it solves. As described in the invention disclosure:-

Conventionally, a speedometer installed at a passenger car or the like indicates a vehicle speed and a travelling distance by utilizing vehicle speed pulse signals outputted from a vehicle speed sensor mounted at a propeller shaft or the like which connects both a transmission and a differential gear.

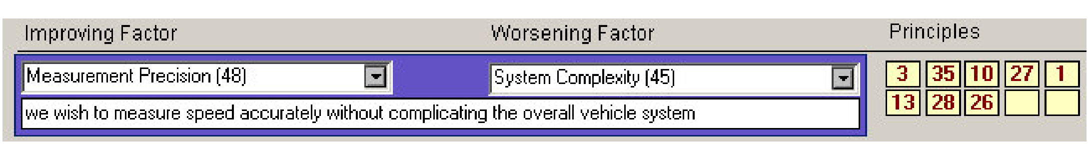
As to the vehicle speed pulse signal, the number of outputted pulses per a rotation of a wheel is established, and a travelling distance per a pulse is also previously established on the assumption that the tire attached to a vehicle is standard. Namely, the travelling distance can be determined by counting the number of pulses of the vehicle speed pulse signal and by multiplying the counted value by the travelling distance per a pulse. Further, a vehicle speed can be determined by determining a travelling distance per unit time.

However, when a tire is worn or when a tire size is changed, in some cases, the travelling distance previously established per a pulse and the actual travelling distance per a pulse do not correspond to each other. Further, when vehicles are of the same car family, in some cases, tire sizes thereof are different from one another in accordance with their grades. Accordingly, even when the same, in some cases, travelling distances per a pulse thereof are different from one another, depending on their grades. Therefore, a computed vehicle speed or a computed travelling distance may cause an error.

In recent years, due to the increasing demand for the control of automobiles, for example, there have been proposed various systems using speed information such as an AHS (Automated Highway System) for performing an automatic drive. In a system utilizing such speed information, there is highly demanded for the greater accuracy of speed information or travelling distance.

In view of the aforementioned facts, an object of the present invention is to provide a speedometer for a vehicle capable of indicating a highly accurate speed or a highly accurate travelling distance and of providing highly accurate speed information to a system utilizing the speed information.

The conflict being solved, in other words is as follows:-



The strategy used by the inventors involves the shift from a mechanical speedometer to one using a GPS signal – an illustration of Principles 28 (Mechanics Substitution) and 35 (Parameter Changes) in action.

Best of the Month

If you haven't checked out the new trends site at http//trends.creax.net, then you ought to. We are continually looking for new trends to add to the site. One of our most recent additions comes from analysts at the RAND Corporation. In a recent article they laid out ten international-security developments that they suggest are not getting the attention they deserve. The ten issues highlighted are: the proposed wall between Israel and Palestine; implications of the shrinking population of Russia; the Hindu-Muslim divide; AIDS and African armies; the Tehran-New Delhi axis; anti-satellite attack; defense-industry Goliaths; the aircraft carrier shortage; the Indus water fight; and finally, urban warfare.
Somewhat grim reading in places, but an essential piece of research nevertheless. Check it out at:-

http://www.theatlantic.com/issues/2003/07/rand.htm

Investments – Spray-on Computers

A slightly longer term recommendation for this month:

Nano-technology is emerging in many areas of science and engineering. One of them is medicine. Researchers are working with staff at Edinburgh hospitals to develop a method of using nano computers to monitor heart patients at home. They plan to spray the nano computers on to the chests of coronary patients, where the tiny cells would record a patient's health and transmit information back to a hospital computer. "In the future, computers will be able to be diffused into the environment. There won't be a sharp division - barricades will just disappear into the background." Researchers expect to see the technology working within four years and in general use in about ten.

http://www.edinburghnews.com/index.cfm?id=891382003

Biology – Humpback Whale - *Megaptera novaeangliae*

Humpback whales use an extremely effective strategy when it comes to feeding. To concentrate the shoals of small fish that they prey on, they use a strategy called bubble-netting. In some cases, the whales fish in groups of 20 or more. The group begins at the surface, blowing to replace air reserves before diving. After locating a suitable shoal of fish, they begin herding them toward the surface. They emit a feeding call which scares the prey into a tighter group. And to ensure the concentration of the prey, one whale begins to release air bubbles through its blowhole while spiraling towards the surface. This results in a circle of bubbles rising towards the surface, entrapping the prey. Rising through the middle of the bubble ring, the whales then lunge at the prey as they break the surface.

The example illustrates an extremely effective use of existing resources. The 'low-cost' and plentiful resource in use here is air, and the humpback has developed a capability to move that air and dispense it in a way that performs a useful function.

In terms of the conflicts that the whale has solved, we might observe the following:-

Improving Factor	Worsening Factor	Principles
Energy used by Moving Object (16)	System Complexity (45)	5, 2, 28, 27, 12, 13
the humpback needs to use the minimum amount of energy and the simplest possible system to do it		
Productivity (44)	System Complexity (45)	6, 12, 10, 1, 28, 27, 17, 31
the humpback wishes to maximise productivty with the simplest possible system		

Interesting to note from the recommendations of the new Matrix that the strategies used by the humpback – firstly hunting in groups (Principle 5, Merging), then using a non-mechanical netting technique (Principles 28, Mechanics Substitution) and 'adding holes' (Principle 31) are all present.