PRACTICAL APPLICATION OF THE TIPS THEORY
From Tea-Bags To Air-Bags And Beyond

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> *"…manufacturing is about making things that people want, and which work well, and look good. Creating these things, and bringing them to the market is a hugely exciting thing: it is fun, a creative activity and involves high risk gambling based on judgement and intuition. It creates jobs, and, as a by product, money. In industry the stage is always changing, and the players must do the same. You can never rest, never sit still, always thinking, inventing, and creating, finding new ways to challenge established beliefs, and prejudices, and ways of working…."*
> *(James Dyson, Royal Academy of Engineering Workshop, 1997)*

Abstract

The process of innovating new products is generally agreed to occur in three principle stages:-

- Problem Definition
- Problem Solution
- Solution Implementation

This paper concentrates on the first two of those stages; looking at case study examples of good and bad problem definitions and their subsequent solutions. It seeks to do this in the context of the new perspectives and capabilities being offered by the Theory of Inventive Problem Solving (TIPS) methodology; examining the ways in which TIPS has been successful (and unsuccessfully) utilised to help companies define and create better products.

Introduction

Edwin Land, inventor of the polaroid camera once famously said "*If you can define a problem, it can be solved".*

Problem definition is commonly held to be both the most important and, paradoxically, the least well understood of the three stages of product innovation. The paper will look at how TIPS – and particularly it's 'Design Without Compromise' philosophy – can do much to assist companies during this crucial phase.

Useful as it is during the problem definition stage, however, the real strengths of the TIPS method undoubtedly lay in it's power as a problem solving tool. The paper will try and demonstrate that, using TIPS, it becomes relatively easy to experience the truth of Mr Land's words. Within the bounds of current human knowledge, all problems appear indeed to be solvable.

'Within the bounds of current human knowledge' is an important proviso in the all-problems-are-solvable claim, for TIPS is a method built around interpolation. The TIPS method has been constructed from an analysis of a portion of the global patent database. The 'solutions' it will provide, however, are constrained to sit within the bounds of that database. It is undoubtedly a large database, but it is not one, for example, which is likely to mean TIPS will give the world cold fusion.

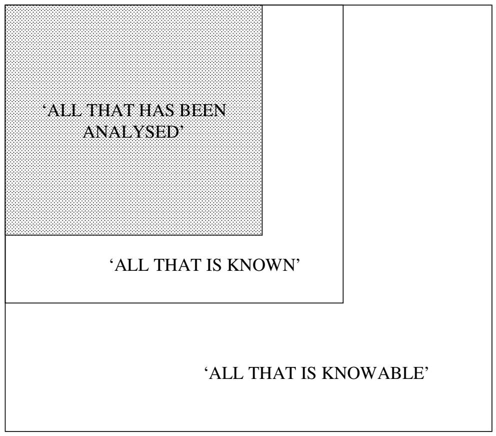


Figure 1: Solution Spaces

Figure 1 attempts to illustrate the TIPS solution space boundaries in diagrammatic form. The all-problems-are-solvable claim holds good so long as we are able to remain inside the shaded area of the total 'all-that-is-knowable' solution space. Fortunately it appears to be a big shaded area.

The paper will look at examples of how TIPS operates as we move around within the shaded area; and particularly what happens when we begin to approach the boundary regions.

The paper examines a number of case study examples. Each one has been selected to illustrate a different, hopefully generic, learning point:-

1) TIPS as a solver of 'simple' problems/TIPS as a reverse-engineering tool. Using the example of a tea-bag to illustrate how TIPS is able, in a very short space of time, to re-invent just about all the tea-bag patents ever devised.
2) Implications of defining the problem incorrectly. Using the example of car air-bags as a way of demonstrating how readily TIPS is able to generate a lot of solutions to the wrong problem.
3) How TIPS can help overcome Psychological Inertia. Here using the example of a particle separator system for a helicopter engine. A demonstration of how TIPS' '40 Inventive Principles' work and how the Contradiction Matrix doesn't always.
4) Problem Hierarchy. A look at how TIPS methods can be applied at the different layers of a problem – from the macro to the micro – both in isolation and in an integrated sense; using human powered flight as an example.
5) TIPS as a solver of heavily constrained problems – 'make it better, but don't change anything' type problems. An example from the catering industry.

The paper then concludes with a brief look at future evolution of TIPS and other systematic innovation methods.

Due Apologies

1) Most problems come wrapped in a cocoon of political, company strategic, and historic background circumstances above and beyond the merely technical. Exploration of any of these circumstances beyond an essential minimum is obviously beyond the scope of this paper.
2) Innovations are particularly prone to 20/20 hindsight effects. 'It's obvious' or, 'how could they possibly not thought of that' are oft expressed views which all too readily negate the true facts of a case. Just because something looks obvious now, does not mean that often many man years of effort weren't spent searching for the Eureka moment.

Readers are politely asked to accept that the filtering assumptions necessitated by 1) have been made fairly, and to try and compensate as much as possible for 2).

1) Solving Simple Problems

Billions of tea-bags are manufactured around the world every year. The tea-bag is a fundamentally simple thing. Not so simple, that there aren't over a hundred tea-bag related patents in the US alone, but simple enough.

The job of a tea-bag is essentially to let flavour and water out while keeping leaves in. It needs to do this as quickly and with as little mess as possible.

One of the basic premises of TIPS is to express a problem in terms of a conflict: a feature we are trying to improve versus another feature of the design which tends to get worse as we improve the first. TIPS makes us do this in a manner which can at first appear a little unnatural; in that we are asked to define our conflict in terms of a pair of generic parameters from a standard list of thirty nine – Table 1. This often turns out to be rather troublesome.

In terms of a tea-bag, the features of the design we might like to improve might be:-

- complexity of device
- manufacturability

And the things that will tend to get worse as we improve these two might be:-

- convenience of use
- harmful side effects
- duration of action of moving object

Our description of the problem here has been rather vague. We have generated six possible contradictions to look up in the TIPS Contradiction Matrix and each one could conceivably generate three or four suggestions for means of solving the conflict. This in turn could mean we have up to 24 possible inventive principles to look at. Fortunately when the six contradictions are looked up in the matrix, it turns out we obtain only eight of the forty (Table 2) possible inventive principles:-

- preliminary action
- intermediary
- asymmetry
- periodic action
- segmentation
- dynamics
- blessing-in-disguise
- porous materials

This phenomenon – uncertainty of conflict definition leading to a relatively small confined set of possible 'answers' – appears to occur with a wide range of problems, and seems to suggest that conflict definition (NB **not** 'problem definition') is perhaps not a critical part of the TIPS method after all.

Some of the TIPS recommended solutions for the tea-bag example are re-assuringly obvious – knowing, for example, that there is an inventive principle called 'porous materials', it would have been more than a little disappointing if TIPS hadn't suggested it as a potential source of solutions to the tea-bag problem. Similarly with 'periodic action' and 'dynamics' – where we might imagine jostling the bag in the cup or pot somehow. Others suggestions are perhaps less immediately obvious. Examination of the patent database soon demonstrates otherwise:-

Asymmetry – the current pyramid bag fad plus this intriguing idea from the US –

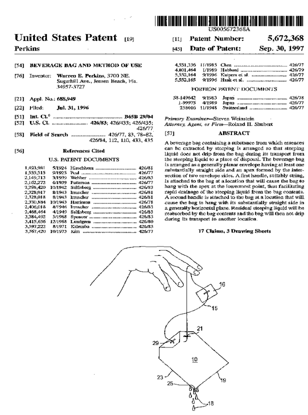


Figure 2: Perkins Patent, 5,672,368

which, incidentally, uses the water retaining characteristics of the tea-leaves as a ‘blessing in disguise’, and also utilises a ‘preliminary action’.

Intermediary – the family of related ideas like this one, again from the US:

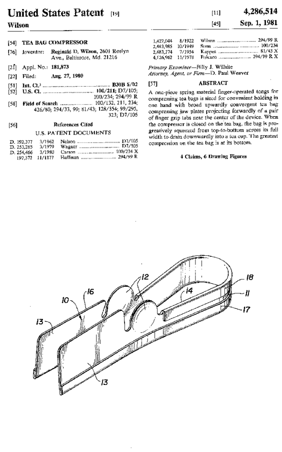


Figure 3: Wilson Patent, 4,286,514

Preliminary action – the idea of staging actions – as seen in the current fad idea for the self-squeezing bag:

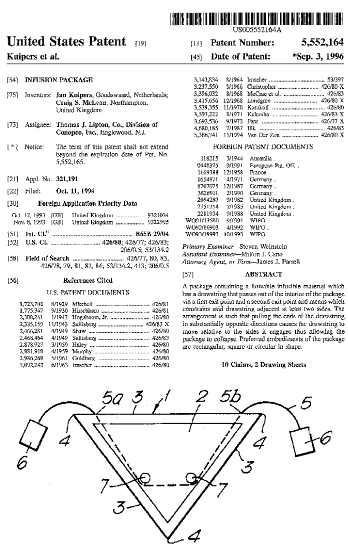


Figure 4: Kuipers Patent, 5,552,164

All in all, the eight inventive principles suggested from the Contradiction Matrix are able to point to just about all of the hundred plus tea-bag patents, and certainly all of the successful ones.

This should give us some encouragement that the TIPS method is a well founded one.

2) Problem Definition

It is very important to distinguish between conflict definition – as tested in the previous example – and the overall definition of the problem to be solved.

A good example here is the air bag system fitted to the majority of new cars on the road today. Whilst undoubtedly a major life-saver in accident situations, current air-bags are some way from being perfect. In fact, US research suggests, for every twenty lives saved by an air-bag, there will be one case where the air-bag causes a fatality which wouldn’t have occurred if the bag hadn’t been fitted. The further you are from being a 5’9”, 165lb male sitting 9” away from the steering wheel going into a head-on collision, the more likely you are to be that one person.

In simple terms, air-bags save lives through a careful trade-off between the time a person takes to be thrown forward in an accident to the time the air-bag takes to deploy. Impact between occupant and bag needs to occur after the bag has fully inflated and has begun to deflate. This turns out to be a very small ‘impact window’ – somewhere between 0.03 and 0.2 seconds. Different sized people and different crash conditions sometimes mean the occupant–bag impact occurs outside this window.

The US-based TIPS community decided that this problem was a very good one with which to demonstrate the TIPS capability. A TIPS air-bag conference was held. The excellent on-line TRIZ Journal featured several articles on the conference and on the overall subject of air-bag design.

One of the key papers showed how TIPS could be used to generate over two hundred ideas for overcoming the impact window problem. Some of the ideas appear to be very good. One of the ideas was 'not an airbag'. It could well be that this is the best one of the lot: All of the hours of study and thought which went into the air-bag impact window problem, appears to this author to have been largely wasted. TIPS has produced some potentially admirable solutions to the impact window problem, but it is likely as not the WRONG problem:-

- what about glancing collisions where there is a tendency for occupants to 'roll' off the sides of a bag onto the doorframe or side-window?
- More importantly, what about the psychological phenomenon whereby the safer we feel in our cars, the more risks we are likely to take and therefore the more likely we are to set the air-bag off? Perhaps that would be a better problem to solve. Some people have suggested a metal spike sticking out of the steering wheel. A less extreme solution might emerge from investigation of a TIPS conflict like 'be safe and yet (appear) not to be safe'.

Either way, the important point here is a GIGO one: define the wrong problem and the wrong solution will emerge. In the case of TIPS, lots of wrong solutions.

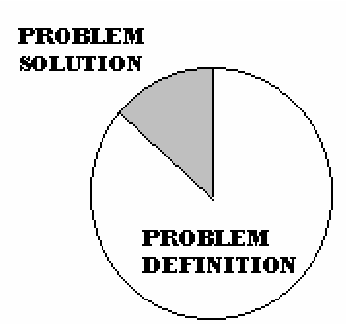


Figure 5: Relative Size of Definition and Solution

Figure 5 is an often useful image to keep in mind when considering the relative size of 'problem definition' and 'problem solution' tasks. Argument over the precise size of the 'solution' slice is futile – a) it is small, and, b) TIPS makes it smaller.

3) Psychological Inertia

The air-bag 'impact window' problem is probably a good example of psychological inertia in action.

Psychological inertia – or, sometimes, 'paradigm paralysis' – is a very common human trait. In very simple terms, it means that once we have an idea in our minds, we find it very difficult to break out of the idea and into another completely separate one.

Extending an initial analogy used by Edward de Bono, is the idea of digging for treasure in a field. Psychological inertia is the trait that often prevents us, once we have started digging for our treasure, we find it very difficult to come out of the hole we've begun to start a new hole. If we are digging in the right place, then we don't have a problem – dig deep enough and we will find the treasure ('solution'). But if we are digging in the wrong place, we are in trouble. Often whole companies find themselves in this situation – digging a deeper and deeper hole looking for a better horse-drawn carriage, while someone else has started a different hole called 'motorised vehicles'.

If nothing else, TIPS is an excellent technique for not only getting us out of a hole, but giving us a good idea where we ought to begin digging new holes.

Consider here the example of particle separators for helicopter engines.

Helicopter engines are particularly vulnerable to damage from sand and dust particles. Helicopter rotor blades tend to like stirring up these particles so helicopter engines tend to have a problem. This was particularly the case for the US Army when they were flying in Korea and then Vietnam. They decided after those two wars that where possible all their engines would be fitted with an engine mounted particle separator of the type illustrated in Figure 6. The devices were largely axi-symmetric with an intake annulus bi-furcating into an annulus taking clean air to the engine and a second 'scavenge' annulus taking dirty air out of harm's way.

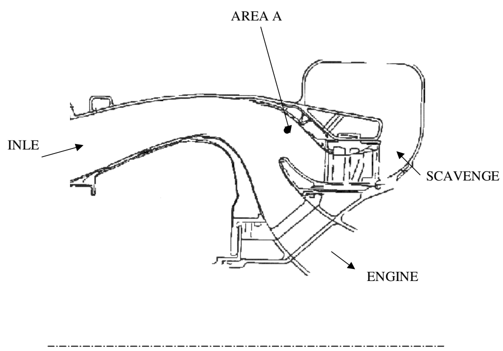


Figure 6: Typical Axi-symmetric Particle Separator

The separator's operate on the principle of particle inertia; air coming into the separator is taken around a sharp bend, which the sand and dust particles, because of their inertia, are not able to turn quickly enough to follow. They are hence forced to pass into the scavenge duct and away from the engine.

As of today, every helicopter in the world fitted with an engine mounted separator, is fitted with one which looks and operates in exactly this way. That's a lot of helicopters and an awful lot of R&D to develop the separator technology to a mature state. In all probability, several tens of millions of pounds worth of R&D.

The separator, however, has a problem. It doesn't work very well. All of the contaminated air which passes along the scavenge duct has to be pumped. The energy required to provide the pumping force can be quite large – and on an aircraft every little bit counts. Therefore, the designs all attempt to minimise the amount of scavenge air. Unfortunately, but hardly surprising, the less air scavenged, the worse the separator performance becomes.

The fundamental problem here is that the scavenge annulus area has to be large in order to trap as many particles as possible, but on the other hand needs to be small because there isn't very much flow passing through it and so that flow will tend to stagnate. A flow separation in Area A is very common. Particles entering this region are reasonably likely to come to a halt and end up being sucked into the engine duct anyway.

An awful lot of R&D effort has gone into optimising the delicate trade-off between wanting a scavenge duct which is both large and small. It is a traditional design compromise situation. It is also a classic case of psychological inertia.

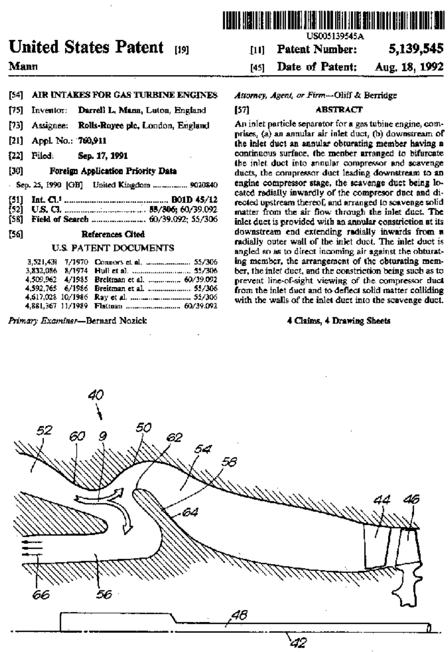
The 40 inventive principles found in TIPS are a very good means of breaking out of this type of psychological inertia.

Inventive principle number 13 'The Other Way Round' is a particularly useful one. (In fact it is an idea often suggested by de Bono in his own problem solving texts). It was used to particularly powerful effect in this particle separator problem.

Problem definition is again important here. As is the realisation that at the same time there is the flow/area conflict with the scavenge annulus, there is a similar but opposite conflict relating to the engine annulus - where the wish is to pass a large amount of air down a duct which, because it sits inside the scavenge annulus, will tend to always be smaller. Passing a lot of air down a relatively small passage will give a number of problems – not least of which is a high level of pressure loss.

In other words, problems often operate at different levels. TIPS could have helped us to solve the micro-level scavenge flow/area conflict, but by going up a level and looking at the whole separator, it is able to produce a far better set of solutions.

And so, to cut an eight man year story short, one day a connection was made between the two ducts - each with it's own conflict – and 'The Other Way Round'. The result is the separator design illustrated in Figure 7.



US005139545A

United States Patent [19]
Mann

[11] **Patent Number:** **5,139,545**
[45] **Date of Patent:** **Aug. 18, 1992**

[54] **AIR INTAKES FOR GAS TURBINE ENGINES**
[75] Inventor: **Darrell L. Mann**, Luton, England
[73] Assignee: **Rolls-Royce plc**, London, England
[21] Appl. No.: **760,911**
[22] Filed: **Sep. 17, 1991**
[30] **Foreign Application Priority Data**
Sep. 25, 1990 [GB] United Kingdom 9020840
[51] **Int. Cl.**[5] **B01D 45/12**
[52] **U.S. Cl.** **55/306**; 60/39.092
[58] **Field of Search** 60/39.092; 55/306
[56] **References Cited**
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Primary Examiner—Bernard Nozick
Attorney, Agent, or Firm—Oliff & Berridge

[57] **ABSTRACT**

An inlet particle separator for a gas tubine engine, comprises, (a) an annular air inlet duct, (b) downstream of the inlet duct an annular obturating member having a continuous surface, the menber arranged to bifurcate the inlet duct into annular compressor and scavenge ducts, the compressor duct leading downstream to an engine compressor stage, the scavenge duct being located radially inwardly of the compresor duct and directed upstream thereof, and arranged to scavenge solid matter from the air flow through the inlet duct. The inlet duct is provided with an annular constriction at its downstream end extending radially inwards from a radially outer wall of the inlet duct. The inlet duct is angled so as to direct incoming air against the obturating member, the arrangement of the obturating member, the inlet duct, and the constriction being such as to prevent line-of-sight viewing of the compressor duct from the inlet duct and to deflect solid matter colliding with the walls of the inlet duct into the scavenge duct.

4 Claims, 4 Drawing Sheets

Figure 7: Improved Axi-symmetric Particle Separator

In addition to fully resolving the above described conflicts by switching the positions of the engine and scavenge ducts, it is perhaps interesting to further note that this new separator is about half the size, weight and cost of the old one.

Also of interest is the fact that for an extensive variety of combinations of TIPS Contradictions using the 39 fundamental parameters of Table 1, not one resulted in TIPS recommending 'The Other Way Round' as a possible solution. Unfortunately this doesn't seems to be a unique situation. In other words, some caution is advised while using the Contradiction Matrix: it may not necessarily be pointing towards the best place to be digging for solutions.

(For example, going back to the first tea-bag study, it is difficult to see how an inventor might get to a 'non-tea-bag' (e.g. 'tea granules') solution from the inventive principles suggested by the Matrix.)

4) Multi-Layered / Interacting Problems

The particle separator example above begins to touch on one of the main difficulties newcomers to TIPS have with the method; that of how to use it in conjunction with problems which possess multiple layers and multiple interacting aspects.

How, for example, does something as complex as 'human powered flight' get distilled down to a single, fundamental design conflict?
Answer: it doesn't.

The current human powered flight state of the art is that we are able to design a craft that a fit cyclist can pilot in still air at low altitude for about 72 miles. The race is on for the first team through the 100 mile barrier.

The latest aircraft project is the Raven (Figure 8). The Raven is a 28m wingspan monoplane weighing around about 34kg – or about half the weight of it's pilot.

Figure 8: RAVEN

The problem of how we might design a better Raven is actually a hierarchy of different problems as illustrated in Figure 9.

In actual fact, it is more like a matrix of problems because the Raven has several major assemblies (wings, cockpit, under-carriage, power transmission, etc), each of which then have a whole host of major and sub- components. All in all, the aircraft is probably made up of several thousand individual components. Almost all of these components then have to integrate with the others in some way or other.

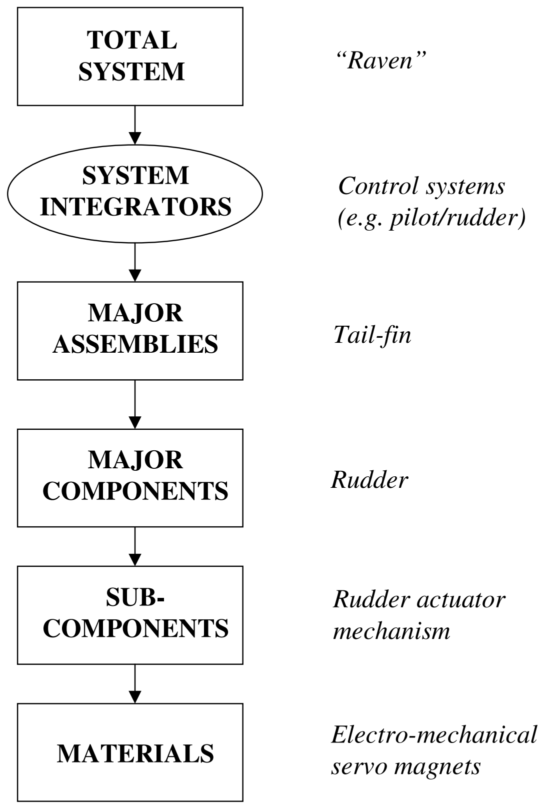

Figure 9: Typical Problem Hierarchy

So, how is TIPS able to help in these situations? In all probability; everywhere:-

At the **Total System** level we might choose to look at whether a single-seat, recumbent cyclist, propeller driven mono-plane is the best answer to the human powered flight challenge. A few facts might be needed here; The Raven weighs around half that of it's pilot – a very impressive achievement for a 28m wingspan structure – but even so, when coupled with the pilot the overall power/weight ratio comes to about 2W/kg. A seagull has an equivalent ratio of around about 70. A starling is around 120. The world's heaviest flying bird (Trumpeter swan) weighs around 12kg. Clearly, there is some serious catching up to do if humans are to fly. Fortunately, humans are already able to design a wing about twice as 'good' (in terms of gliding flight sink rate at least) as nature has managed. There is still a fairly massive shortfall. A good conflict for TIPS here would appear then to be to achieve a wing which is both big (for generating lots of lift) and small (so that it is light). At first this might appear to be a wing component issue rather than a total system issue. Except that we know that if small quantities of air are blown judiciously over the wing we can increase lift by several times. Could we therefore achieve a much smaller wing while achieving the same lift if we take some of the energy of the pilot to pump a little bleed air to the wing? Possibly.

The **System Integrator** level of the problem hierarchy is often forgotten. In fact, in a whole range of instances, the greatest levels of system benefit may be accrued through examination of these system integration issues. With respect to Raven, we might look to the method, for example, by which the pilot's control instructions (e.g. 'turn left') are translated into movement of the rudder. This is a classic control conflict; that of how to transmit a control signal without requiring transmission hardware.

At the **Major Assembly** level, we might look at how, for example, the tail fin of the Raven is attached to the fuselage, and at how the vertical and horizontal control surface functions are achieved. (This assumes of course that the total system analysis indicates that a tail-fin is required at all – i.e. use a 'flying wing' concept instead). A good conflict to examine at the tail-fin, though, might be 'tail-fin must be a long way from the centre of gravity (for better control) and tail fin must be very close' (for lightness). TIPS suggests inventive principles 'anti-weight', 'dynamics' and 'discarding and recovering' for resolution of this conflict which might just lead to some very interesting design features.

At the **Major Component** level we might look at how a rudder could be improved. A conventional rudder often has a fairly moving surface area which has to be turned through relatively large angles to achieve the required turning performance. Here is another example – like the wing – of a 'big and small' type of conflict; we want the rudder to be big to give the required aerodynamic forces and we would like it to be small to make it easier to turn. Example conflict solution (bearing in mind, we're hopefully trying to fly the aircraft in a straight-line for the vast majority of the flight): turbulence generators on the sides of the rudder which pop-out on one side or the other to increase the air turning capability as the (smaller) rudder turns.

At the **Sub-Component** level we might chose to look at things like the rudder actuation mechanism. The Raven currently uses an electro-mechanical servo. This means there is a mechanical linkage; which in turn probably means weight and another good power/weight contradiction for TIPS.

At the **Material** level we are at the base micro level of a problem. A good example here might be the magnets used in the above servo. As usual on an aircraft, we find a big/small conflict – we require big magnetic force but small (light) magnets. TIPS suggests 'periodic action' and 'segmentation' as two possible inventive principles which appear to offer useful new insight into this particular force/weight conflict.

And thus it may be seen that TIPS is able to offer help at all levels of a problem from the micro to the macro. In this and the majority of case studies conducted by the author, it is seen to be generally more productive to start from the macro and work towards the micro.

As was seen with the earlier particle separator problem - where the best solution eventually came from looking at two conflicts together (scavenge flow/area conflict, engine flow/area conflict) – inventors are required to achieve a high degree of flexibility in recognising and moving between the different levels of a problem. This problem (i.e. 'conflict') integration process can often be particularly intangible. Altshuller's Algorithm for Inventive Problem Solving ('ARIZ') may be of some help in some circumstances, but, so far at least, not many.

5) Constrained Problems

Beyond the multi-layered/interacting problem family described above, the next most common difficulty cited by TIPS newcomers is the constrained problem. The problem where there is no possibility of starting from a blank sheet of paper. The sort of problem which comes with a variety of pre-conditions:-

- don't change X
- don't touch Y
- stay away from Z
- don't spend more than A
- don't take any longer than B
- etc

This type of problem exists everywhere. It is there in the Raven example in the form of a human pilot with inevitably human dimensional and performance characteristics, and it is particularly common in complex products like jet engines – where there are often thousands of interacting components and a problem with any one is often discovered only after the engine has entered service. In these cases, the expense of 'starting again' is wholly prohibitive.

Is there anything TIPS can do to help in these circumstances where 'Design Without Compromise' is impossible, where the compromises have already been made?

The simple answer is yes. In fact TIPS has been used to solve several such jet engine problems. For the sake of simplicity, however, we will look at another type of example. One that anyone who has had a drink in a motorway service station or café will undoubtedly had the misfortune to experience at some time or other; the non-pouring jug or tea-pot; the stainless steel monstrosities that seem hell-bent on emptying their contents into your saucer rather than your cup.

Here is a situation where there must be several million such receptacles in use. To scrap them and start again is a highly unrealistic expectation. Is there anything TIPS can do to help in this situation? A problem where we basically have a finished product we don't want to touch?
Answer: probably.

The reason these receptacles don't pour is due mainly to the Coanda effect. You've seen the Coanda effect in operation when you stick your finger into the edge of the jet of water coming from a running tap and the jet gets deflected. The same thing is happening at the spout of a tea-pot – albeit with a stainless steel one at a much smaller scale – Figure 10 illustrates a side view cross section through the end of a typical spout showing how the liquid can be affected by the Coanda forces.

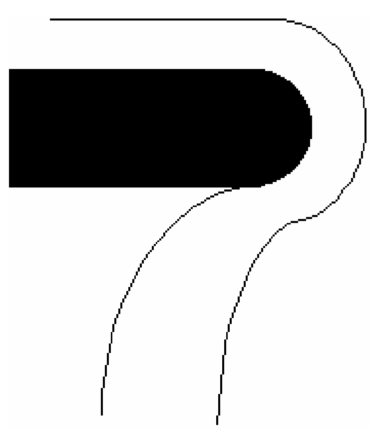

Figure 10: Coanda Effect At Spout Lip

The rounded finish at the tip of the spout is the source of the problem. If we were able to eliminate this rounded finish – Figure 11 – we would find that we are able to effectively eliminate the Coanda effect and achieve a good pouring action. Unfortunately, however, if the tea-pot was manufactured with such a sharp edged lip, it would be potentially hazardous to users and would be more prone to damage if the pot were dropped, etc.

We have thus discovered a conflict: the problem would be solved if we had a spout tip which was both sharp (for good pouring) and not sharp (for safety).

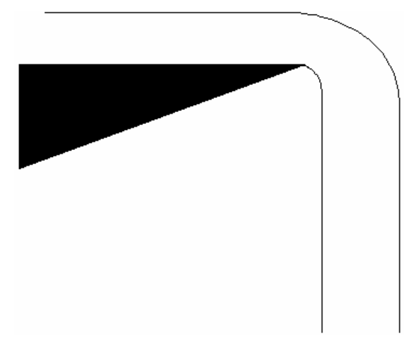

Figure 11: Alternative Sharp-Lipped Spout

We could try translating this conflict into the terms of the Contradiction Matrix – for example; thing we are trying to improve – length of stationary object (i.e. thickness of material at tip); thing which gets worse – 'object generated harmful effects', or 'strength', or possibly 'accuracy of manufacturing' or 'convenience of use'. Or we could look up possible inventive principles directly from the list of 40.

'Local quality' and 'another dimension' are always useful principles. Here they generated the idea illustrated in Figure 12 – a local modification to the rounded end of the lip such that there are sharp edged sections and rounded ones. In retrospect, 'partial or excessive action' or 'combination' or possibly 'asymmetry' could have taken us to the same place.

Either way, although presented in a simplified manner, the basic idea is there: a localised feature which can be readily incorporated into a mass-production process and be introduced manually on existing pots by some kind of filing action or (preferably) some kind of manual form tool. No extra material required, no effect at all on other parts of the pot, and about ten seconds per pot to implement.

Figure 12: End View Of Improved Spout Lip Profile

Conclusions

The paper has examined a number of different aspects of practical product innovation processes – solution of simple problems, problem definition, psycho-logical inertia, multi-layered/interacting problems and constrained problems. In each case, the TIPS method has been seen to offer a number of tangible benefits.

That is not to say the method is perfect. It is still very much an evolving method. Significant enhancements may be expected through incorporation of Western innovation strategies into the existing Eastern-derived foundation and as more and more case studies and human knowledge become integrated. Of particular interest are the potential synergies with methods like Basadur's 'Simplex' innovation scheme, Goldratt's Theory Of Constraints, the Thinking With Diagrams initiative, Stafford Beer's Viable System Model, and parts of Edward de Bono's work on lateral thinking.

Meanwhile, in the author's opinion TIPS remains far and away the most potent innovation aid available anywhere at this time. If all problems are indeed solvable, it is in no small part thanks to the capabilities being offered by TIPS.

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A list of sources for further reading:-

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Not forgetting the excellent on-line creativity bibliography to be found at http://www.buffalostate.edu/~cbir/cbirgenb.htm.

1. Weight of moving object
2. Weight of stationary object
3. Length of moving object
4. Length of stationary object
5. Area of moving object
6. Area of stationary object
7. Volume of moving object
8. Volume of stationary object
9. Speed
10. Force
11. Tension, pressure
12. Shape
13. Stability of object
14. Strength
15. Duration of action - moving object
16. Duration of action - stationary object
17. Temperature
18. Brightness
19. Use of energy by moving object
20. Use of energy by stationary object
21. Power
22. Waste of energy
23. Waste of substance
24. Loss of information
25. Waste of time
26. Amount of substance
27. Reliability
28. Accuracy of measurement
29. Accuracy of manufacturing
30. Object affected harmful effects
31. Object generated harmful effects
32. Manufacturability
33. Convenience of use
34. Repairability
35. Adaptability
36. Complexity of device
37. Complexity of control
38. Level of automation
39. Productivity

Table 1: 39 Elements of Contradiction Matrix

1. Segmentation
2. Extraction
3. Local Quality
4. Asymmetry
5. Combination
6. Universality
7. 'Nested Doll'
8. Counterweight
9. Prior Counter-Action
10. Prior Action
11. Prior Cushioning
12. Equi-potentiality
13. 'The Other Way Round'
14. Spheroidality
15. Dynamics
16. Partial or Excessive Action
17. Another Dimension
18. Mechanical Vibration
19. Periodic Action
20. Continuity of Useful Action
21. Skipping
22. 'Blessing in Disguise'
23. Feedback
24. Intermediary
25. Self-Service
26. Copying
27. Cheap/Short Living
28. Mechanics Substitution
29. Pneumatics and Hydraulics
30. Flexible Shells/Thin Films
31. Porous Materials
32. Colour Changes
33. Homogeneity
34. Discarding and Recovering
35. Parameter Changes
36. Phase Transitions
37. Thermal Expansion
38. Strong Oxidants
39. Inert Atmosphere
40. Composite Materials

Table 2: 40 Inventive Principles