# Hierarchical TRIZ Algorithms

## 2nd Installment-- June 2005

Hierarchical TRIZ Algorithms is a how-to TRIZ book. It is designed to assist both beginning and advanced users. Each month, the TRIZ-Journal will publish another chapter of the book. This month's installment includes one of the appendices which is required to perform several of the steps:

**K. Appendix--Idealizing Functions**

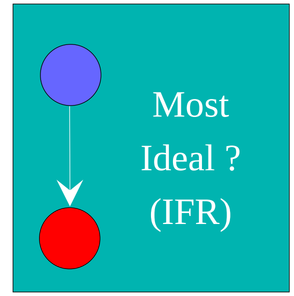
Next month's installation will cover the second process step:

**B. Clarify the System Functions**

In all, there will be 12 installments. Should you decide to purchase the most current edition of the complete book contact the publisher at:

http://www.3mpub.com/TRIZ/

# K Appendix
# Idealizing Functions




**Introduction**

It is a shame that one of the most important sections of the book is hidden back in the appendix, but it proved to be necessary because it is used in four of the steps:

1. Clarify System Function
2. Identify the Physical Phenomena
3. Identify the System Objects
4. Simplify the System.

The first three steps help us to idealize the system function, the last step helps us to idealize the subsystem functions.

It is an observation by the author that few people seem conversant in the use and manipulation of functions. Every step of the algorithm provides the opportunity for startling insights. The manipulation of functions heads the list for startling insights.

By looking at a function and asking what we *ideally* want to have happen, we diverge earlier than we normally would and consequently have a greater impact on the final result.

Classical TRIZ spreads the processes discussed in this chapter across a variety of tools.

The main classical TRIZ concept is called the Ideal Final Result or IFR. With this tool, we ask ourselves what final result we would really like to have happen. Then we tell ourselves that we will achieve this result without the use or addition of any object or substance to the system.

The second classical concept is the Standard Solutions. The Standard Solutions were created as an all-in-one tool. If you have a problem, try this solution. The Standard Solutions were written in a format which made use of Substance Field Analysis. The Standard solutions handled creation of systems and improvement of systems. Some solutions included the resolution of contradictions.

The primary focus of Idealizing Functions is asking the two questions: What do we really want to do? And: What will do it? While we would like to treat every function the same, this would be quite ineffective. Useful functions need to be treated differently than harmful functions which need to be treated differently from measurement or informing functions

The beginning focus for useful functions is the product, or object that is being modified.

The beginning focus for harmful functions is the harmful modification. The beginning focus for informing functions is the tool or object that is being detected.

Because of this change in beginning focus, we require a new hierarchy for harmful and informing functions.

Lets look at the hierarchy for each type of function.

Useful:

1. Ideal Product
2. Ideal Modification
3. Ideal Effect (Physical Phenomenon)
4. Ideal Object to deliver the Effect

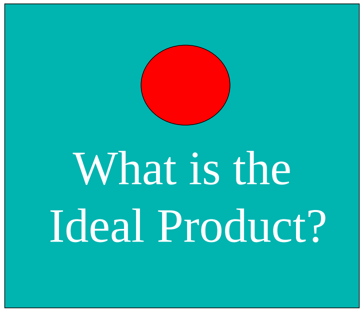
Harmful:

1. What is the harmful modification
2. What is the reverse modification or a useful variant
3. What knobs can boost the new useful function
4. Elimination of Product or Tool

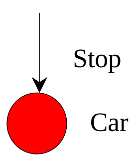
Informing or Measurement:

1. Ideal Tool (Object we are trying to measure a property of, such as temperature)
2. 
3. Ideal Effect
4. Ideal Product and Modification
5. Roundabout ways and Markers

# Rules for Transforming Useful Functions to the IFR




In this step we consider the most ideal forms of the product. Regardless of whether or not the function already exists, we want to identify the most ideal embodiment of the element that is being modified. Lets take the instance where we are trying to create a function. Lets say that we are trying to come up with a way for the police to stop a speeding car without harming the occupants or other motorists. At this point, may or may not know a way to do this. If we know a way to do this, for the moment we will ignore this and concentrate on only two elements: the product and the modification that we are trying to achieve.



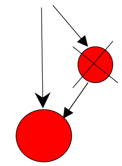

The product is the "car" and the modification is "stop". Knowing only these two parts of the function allows us to ask the important question: What is the ideal product? The answer is surprising. The most ideal product is one that does not exist. (The car should not exist)

If it does not exist, the function is not required and hence the tool and all attending auxiliary functions are not required. Thus we come very close to the realization of the classical Ideal Final Result (IFR). We may not require the product for a variety of reasons. It may be a transmission element that we can bypass. (Is the car a transmission element? Not really) It may be a waste element that does not require existence in the first place. (Is the car considered waste? Not really) A slight modification of the product may make the modification unnecessary. (If the car could be easily tracked, then I might not require stopping it) or the product may already come with the modification performed. (By the time that the police reach the car, the driver is compelled to not want it anymore and it is already stopped).

If the product is required, then we ask the question: what minimum part must be modified. (Is it the car that we want to stop? Maybe we only want to stop a part of the car such as the engine or the occupant) If only a small part requires modification then the resources required to perform the modification can also be minimized.

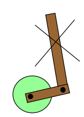
Finally, if the product is required, how can we get the most bang for the buck? Lets make the modification as far reaching as possible. If the product comes in natural groupings, lets modify the whole group. If other objects nearby require the same modification then lets modify as many things as possible. This increases the value that user derives from performing the function. (Perhaps the police signal all cars on the road to slowly decelerate thus making the situation more safe for everyone).

## Remove Transmission Elements



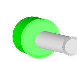
According to the laws of evolution of systems, Transmission elements will shorten and eventually be eliminated. In this step we consider whether the transmission can be eliminated all together. If the product of the function that we are considering is a transmission element, then we should consider whether it is required or if we can find some way to bypass it all together.

1. Is product a transmission element? (Does the product transmit, transform or convert energy?) Some elements masquerade as important functioning elements but are transmission elements instead.



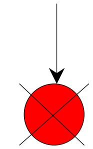
The current system operated on a linkage assembly to turn an object.

2. Bypass the transmission element



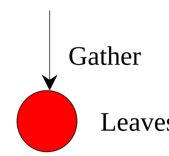
The new system directly rotates the element with a rotary actuator

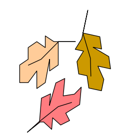
## Non-Existent Product



It is easy to lose track of whether the product is required in the first place. If the product is harmful or even a waste product (such as sawdust or leaves) wouldn't it make more sense to not have it around in the first place?

1. Is the product ever Harmful, Waste?



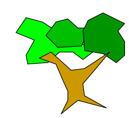



Waste Leaves

2. Eliminate Product

The leaves don't exist--This creates a contradiction- The must and must not exist.

3. Eliminate Product Source

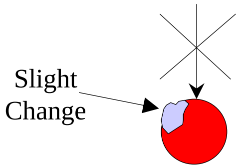


Remove the tree

4. Eliminate the Path of the Product

Remove the path to the ground

## Modification Not Required




All useful functions can be thought of in a remedial or preventative context. This may not seem intuitive at first, but let us consider a couple of cases. A lawn mower cuts grass. Is this a remedial action? Yes, because it remedies the height of the grass. One could reason that if the grass were doing its job better, it would be even and slow growing. Consider scaling a fish.

1. Ask:
   - What does it prevent?
   - What does it fix?
   - What does it make up for?
   - Does it counter something?

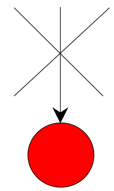
Follow this reasoning back through the chain of functions that need to be fixed.

Is scaling done to fix something? Yes, it removes scales and underlying tissue that may change the flavor during cooking and are also disgusting to certain cultures to eat. This is a remedial action.

3. A slight change to an object in the system (often the object that we are serving) removes the requirement for the main function and hence the objects that deliver the function. In other words, if something did its job better then our system wouldn't be needed

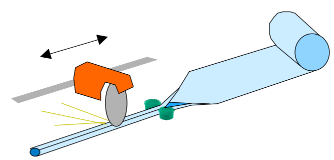

Consider changes to cooking methods that make scales a delicacy-- Now the function of scaling is no longer required.

## Comes that Way



In certain situations, a modification can be performed upstream by the provider of the product more conveniently than later. The product may be in a much more convenient form to perform the function. This is often true in a manufacturing environment such as during assembly. Pre-coated or pre-assembled parts can be more conveniently assembled. Forming and cutting operations can be more conveniently done when the material is in a more convenient form. Pre-modifying the product often leads to a contradiction. The modification must and must not be made. The following example shows the use of this tool and the resulting contradiction and solution. Pipe forming machines feed a flat ribbon into a forming machine that rolls the ribbon into a tube and welds it.

Cutting tool moves with the moving tube

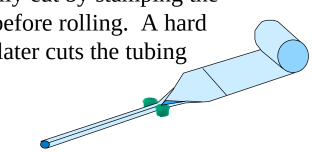


The tubes are cut to length by a saw that moves with the formed tube while it is cutting to reduce the time to cut. Faster and faster forming rates require the cutter to return more rapidly. This results in many additional problems. Consider the ideal product.

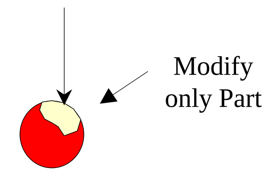
1. The product does not require the modification because it is already incorporated

The tube must be cut before it is formed. This slows production (compared to a single ribbon) so the tube must be cut and not cut.

Solution: the Tube is partially cut by stamping the tube before rolling. A hard twist later cuts the tubing fully

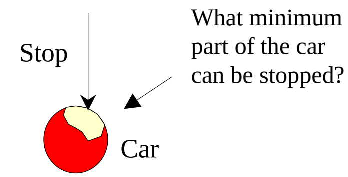


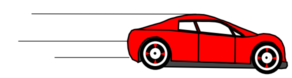
## Minimum Part




If we have concluded that it is not possible to avoid the requirement for the modification, then we should consider modifying the least amount of the product as possible. For instance, if we are considering stopping a speeding car,

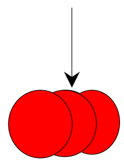
1. what minimum part of the product must be modified? Produce a list of alternative products which are a minimized subset of the main product.



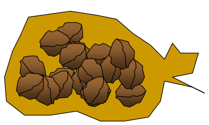
By asking this, we can consider all subsets of the original product down to the molecular level. For instance, what if we only stop the driver, the tires, the drive shaft, the engine computer or carburetor, the tire, the electrical ignition spark? Considering the minimum part does not necessarily guarantee that we will require the least amount of resources to accomplish the modification. For instance, arresting the spark, might require tremendous resources to generate large fields.

## Natural Groupings



If we have concluded that the function is required, then let us get the most bang -for-the-buck as we can. Here we consider extending the function to as many elements as possible. Extending the function to more of the same elements at the same time can reduce the overall amount of resources required. For example, let us consider shelling nuts. We ask ourselves the following:

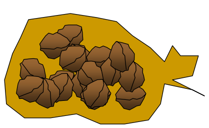
1. Does product come in natural batches or groups?



The nuts come in a bag

Other examples of natural groupings are a flock of geese, a mouthful of teeth, a pallet of objects, or a box of cereal.

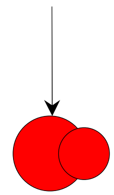
2. Is it <u>more ideal</u> to modify the group simultaneously?



Crack the whole bag of nuts

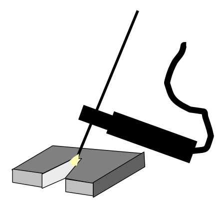
Once again, There are no guarantees that modifying the whole natural group will require fewer resources. At this point, we may not know how we may accomplish this feat, but we continue in hope of finding a physical phenomenon that can do this.

## Biased Products



Biased products are products that are in some significant way different than each other. Nails come in different sizes. If a hammer can effectively drive a tiny nail and a large framing nail, it is more valuable to the user. Lets consider a welder.

1. Are there similar products that might require the same modification?

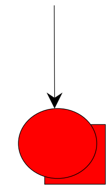


Should our welder be able to weld a variety of metals?

2. How much variation is there in the product? If the variation is small, then there is little requirement to modify a biased product. If the variety is large, then if the ability is too narrow, the system may have limited use.

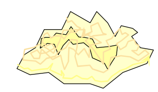
Welders are frequently required to weld a variety of metals with a variety of thickness and energy requirements

## Diverse Products



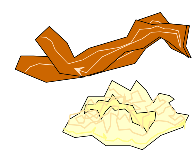
Diverse products are products that are so different that while they are associated with the same function, they are not associated with the same tool. I need to perform the same function on staples and nails, yet the tool to perform these functions are generally different. Let us consider the cooking of foods. If we are considering baking bacon we ask:

1. What other elements in the system or super-system require the same modification?



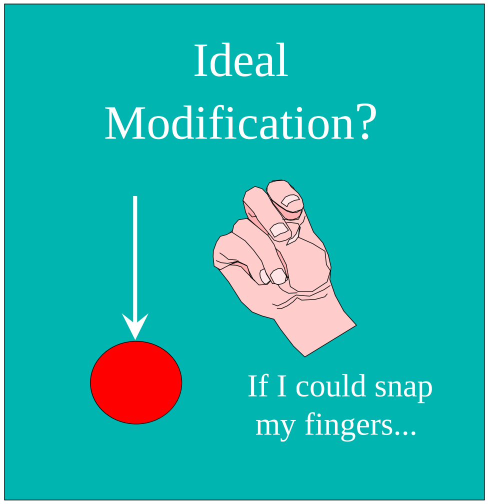
Eggs are generally associated with bacon

2. Can they also be included in the modification?



Cook Bacon AND Eggs

Remember that we have only considered the possibility of doing these together. In some cases, finding the means to do this is simple.

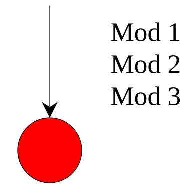



The second part of a useful function that we focus on is the modification. The modification can be written in either long or shorthand form. In the shorthand form, the modification is a verb. This cannot be just any verb, but only verbs that describe a change or control of the product. The change must be a physical change directly to the product. The rules of writing functions given in "Clarify the System Function" describe the correct form of the modification verb. The selection of the verb can often be confusing. If there is confusion, one should consider using the longhand form of the modification. This starts with the words "Change" or "Controls". This makes it clear that some physical parameter of the product must be physically changed. This helps to clarify confusing functions.

It is important that the modification be properly described in order to perform the next steps.

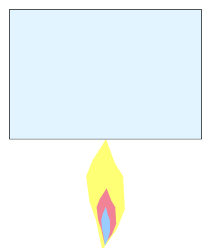
Describing the function properly is only the first consideration. There may be many ways to describe the modification that will not give new insights. Here, we consider a variety of ways to think of the modification that allow us to make better use of resources, thus making the function more approach the Ideal Final Result.

## Variety of Modification Descriptions



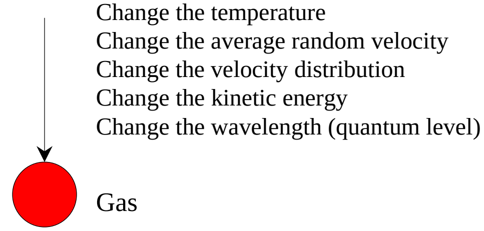

There may be several ways to describe the modification. We would like to consider several ways because each way may lead to a different physical phenomenon to accomplish the function (depending on abundance of system resources). Let us consider the simple heating of a gas.

1. Are we changing or controlling? Which makes the most sense?

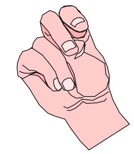


Unless we are trying to heat the gas up to a certain temperature, we are "changing"

2. Using the longhand form of the modification, consider different ways to describe the modification. Consider moving from the macro world to the micro world (atomic level and beyond)

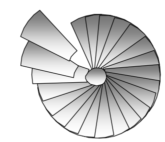



## The Ideal Form of the Modification



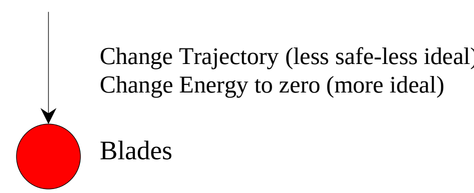
If I could snap my fingers...

While there may be many ways to describe modification, some will be more ideal than others. Some may provide greater safety or longevity of action. Let's consider what happens when a jet engine fan looses some fan blades. This is sometimes referred to a blade-out condition. It can be caused when an object is ingested into the engine such as a bird.



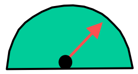
Each of the blades carries a tremendous amount of kinetic energy. When one blade goes, it often takes out other blades. The effect is explosive. The question is: what would we **ideally** like to do with these flying blades

1. Work backward by imagining the ideal final state. Write the modification using the longhand form.



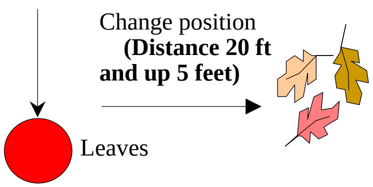

2. Consider drawing a picture of the final state.

## Most Ideal Level of Modification

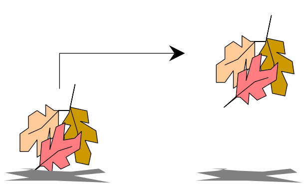


Sometimes it is difficult to understand what the most ideal modification is. The most ideal functions require the fewest resources. We have already asked ourselves what the minimum amount of the product must be modified. Now we ask ourselves, what the minimum modification must be. We ask in a disciplined way by reviewing the resources that will be required to perform the modification Again, lets consider the leaf collecting problem and ask, what theoretical minimum resources will be required.

1. Look at the main parameter of the modification that is being changed and ask: **how much** modification is necessary? How far? To what level? Have we been excessive in the past?

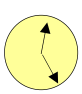



2. What is the <u>least energy</u> that is required to do the modification this much?



Only the potential energy change is required ( energy to change height which is very small)

3. What is the most ideal time? The least, the most? Some functions are most ideally done for a long time or a set time such as exercise.

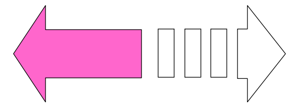


The most ideal time would be instantaneous. This saves the time of the laborer. . . Unless this is for exercise . . . hmmm

4. What is the least volume or space?

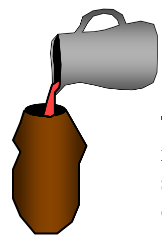
The volume of the path that the leaves take. This volume can be quite small if the leaf pile is crushed or reduced in size before moving

## The Inverse Modification

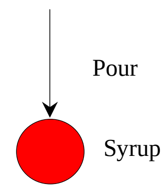


Sometimes it is more ideal to do the reverse of the required action or modification. For instance, it may actually require fewer resources to move a person relative to a work object than it is to change the height of a heavy work object. In order to consider reversing a modification, it is necessary to consider what the action or modification is relative to. If two objects are moving relative to each other, it is usually easy to determine what the modification is relative to. With other modifications, it may take more thought. Let's consider the example of pouring a syrup into a chocolate container.

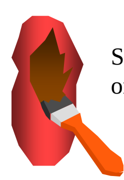
1. What object is the modification performed **relative to**?



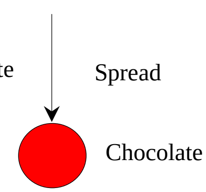
The pouring is relative to the stationary chocolate form

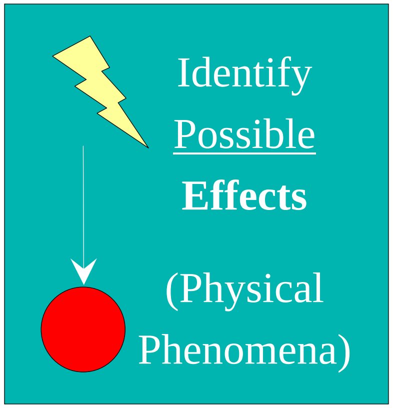



2. Invert the problem by modifying the relative object. (Make it the product). Thus, instead of pouring the syrup relative to the stationary chocolate form, we spread the chocolate relative to a stationary syrup form which has been frozen



Spread the chocolate onto the syrup

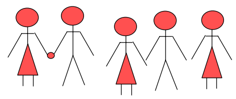





In this step, we consider what physical effects can perform the modification to the product that we desire. In effect, we are sensitizing our minds for the next step in which we consider the substance, object and field resources around us. Armed with the knowledge of what is possible, it will be easier to identify the value of a resource when we see it.

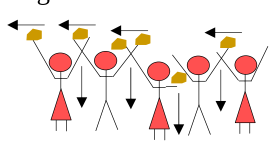
Some of the effects that we may consider in this stage may seem a little wild or too weak to perform the function. Remember that such weak effects can often be boosted in latter stages of the algorithm. Therefore, it is important to keep an open mind to the possibilities.

## Intelligent Little People



One of the most important tools of investigation is empathy. This is the ability to become a part of the system that we are investigating and to see it from this unique perspective. The principle of empathy is very powerful, but has a few limitations. First, we provide only one perspective from which to view the problem. Secondly, we must exist in order to view the problem. In other words, we cannot dissolve or disappear. Third, there is just one of us to interact with the system. If there were more of us to interact, this would open up new possibilities. These difficulties are largely overcome by using the principle of little intelligent people. Let us take the example of a self cleaning air filter.

1. Envision the system as **composed of intelligent little people** who can work together. These people also have the capability to disappear and reappear if necessary. What do they do to accomplish the desired result How do they intelligently act together?

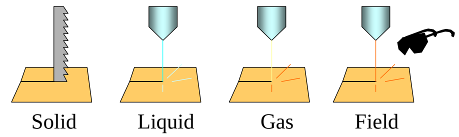


The little people pass the particulates from one to the next while allowing air to flow

2. Consider possible physical phenomena that can accomplish this cooperation.

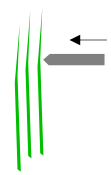
A separate liquid moves along the surface due to a mechanical action. The liquid acts to trap and carry the particles. Lungs clean themselves using this same action.

## Evolution of Field Phenomena




Go to two pages following and look at the Table of Fields at the end of this appendix. Note that the top fields are the most abundant fields and the bottom fields are typically the less abundant. In general, systems tend to use the top fields first for muscle and then the lower fields. In the beginning of a system, the lower fields are used primarily for control. By examining the fields currently being used by your system, or similar systems, you can guess the fields that might be used next. Let us take the example of a lawn mower.

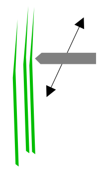
1. What fields are currently being used to deliver this function?



Currently, the blade is cut by a mechanical high-pressure field that makes use of the grasses inertia

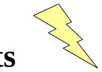
2. What are the next fields that will be likely used?

Jet pressure



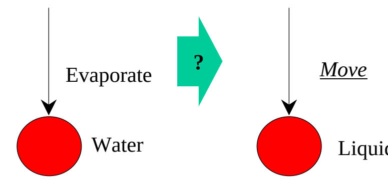
oscillations.

## Table of Effects



The Table of Effects is table of physical phenomena that can be used to deliver functions. Once we know the modification that we desire, we can find a similar function in the table. Usually, this is a generalization of the the desired function. The table usually gives many physical phenomena that can deliver the desired modification to the product. Let us take the example of a clothes dryer.

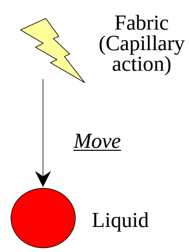
1. Convert given function to a *Generalized Function*



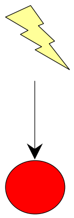

2. Find Effect in *Table of Effects* :go to one of the sources for the table of effects. Some of the commercial software have a table. A trimmed down version can be found at

www.creax.com

Locate the generalized function and then consider all of the physical phenomena that can be used.

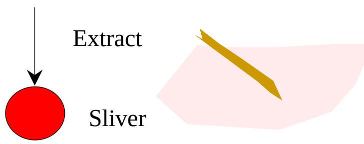


## Analogous Effect

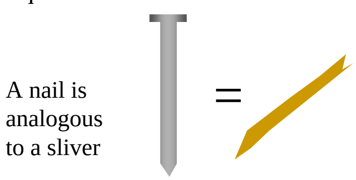


Product = ?

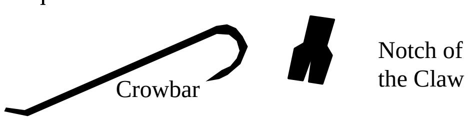
An analogous effect produces the same result that we want on other objects. This effect can be transferred to our situation with satisfying results. Take for instance the removal of slivers.



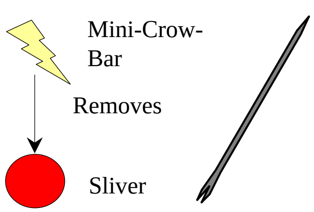

1. Identify an analogous product What other types of objects require the same modification?



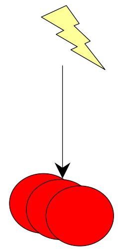

2. Identify its common tool and the minimum feature required for the modification




4. Transfer this feature to the new situation
   - Combine w/ existing tool
   - Transfer **minimum** amount of tool

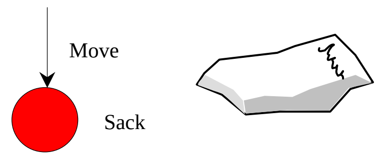



## Mega-trend Analogous Effect

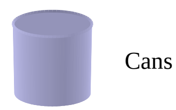


Mega - Product = ?

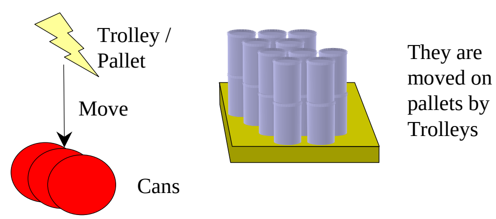
We would like to move sacks from a truck shipment to a location on the factory floor. Typically, this is done hand, unloading one at a time.



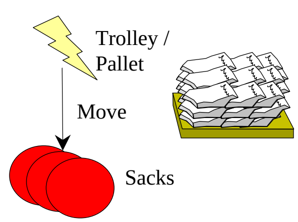

1. Identify analogous products in leading industries.



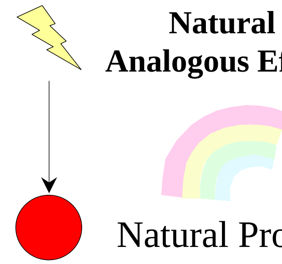

2. Identify trends for performing the function where a large amount of this product requires the same modification?




3. Apply this to the product that you are considering?

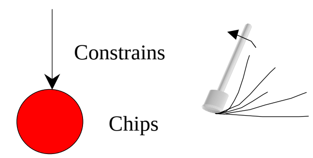



## Natural Analogous Effect

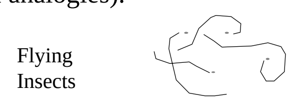


Natural Product = ?

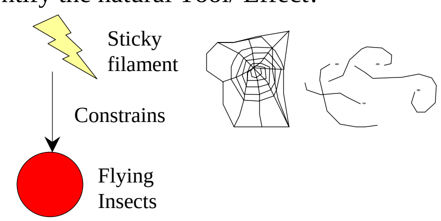
Nature has developed many analogous effects that can be employed to perform functions. When we are grind an object, small chips are ejected. We would like to constrain these chips.



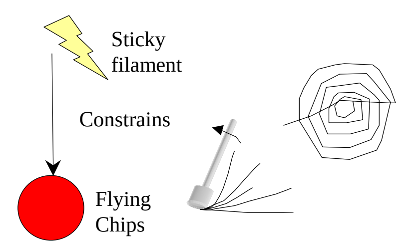

1. Identify analogous products in nature? (Look for primitive natural analogies).



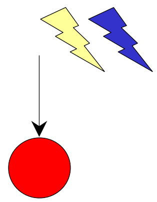

2. Identify the natural Tool/ Effect?




3. Transfer the Effect/Tool to the new situation

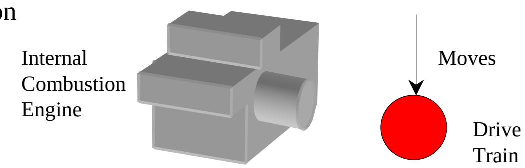


## Hybrid Combination Of Effects



This tool if extremely useful when you are working with a demanding sustaining market and the resources of the current effect are becoming limited. This is a way to move to the new physical phenomena while increasing (rather than sacrificing) performance, as is often the case when jumping to a new effect. There is little question that cars will, one day, become electric. Jumping entirely to a fully electric car would sacrifice too much.

1. Begin with a common effect that is normally used to deliver the modification

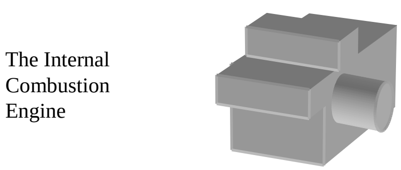



2. Identify another effect which performs the same modification

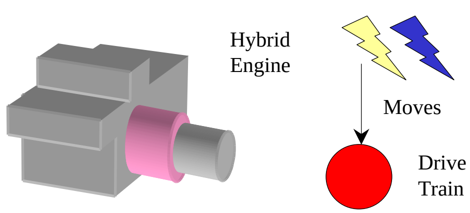

3. What is the feature of the new tool which would extend the capability of the first tool?

Torque at low speeds

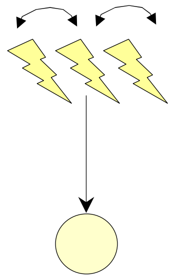
4. Identify the cheap tool which should deliver most of the function.




5. Combine both effects into a hybrid. **A new capability should emerge**. Try each of the following
   - Combine both as whole tools
   - Transfer just the desirable feature
   - Make the tools modify each other.

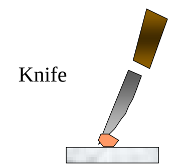



## Merge or Interact With Multiplied Tools

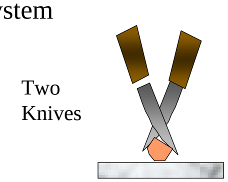


If you are aware of a physical phenomena which can perform the function there is a possibility that a completely new physical effect can be created by multiplying the common tools and then making the multiplied tools interact with each other. A well known example is the common scissors.

1. Identify an object related to a physical effect that is similar to the one required.



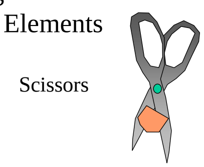

2. Multiply the system
   Start with two.

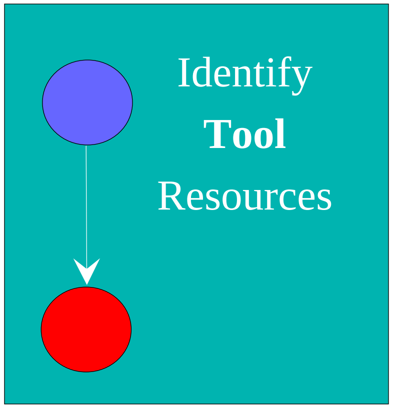



2. Can these tools be merged or interact together to create an **unexpected capability**? Try different orientations

- Try Merging

3. Consolidate Elements

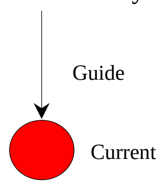




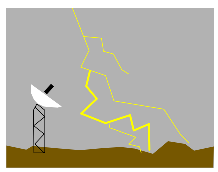

Now that we know some of the physical phenomena and fields that can be put to work, we look to see what object resources are available and what fields and physical phenomena might be associated with these object resources. Once again, we are trying to add as little substance or objects to our system as possible. We would still like to perform our function without adding any object. If possible, existing objects and ambient fields should perform the modification. If this is not possible, only then do we consider adding objects. The best situation is a small change to the product that allows an ambient field to perform the function. If all else fails, **use the existing tool.**

## Already <u>Poorly</u> Performed by Native Fields

Sometimes, a function is already performed by some natural phenomenon but it is done very poorly or even harmfully. With a little help, we can boost these functions until they become useful. A classic TRIZ example is the radio tower requires lightening rods to protect it. We must guide the current, but we would like to do this by using native fields.



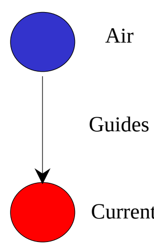

1. Is the function already delivered by a super-system tool, <u>even poorly</u>?



Yes, the air guides the current poorly. The charge comes to the ground in concentrated form

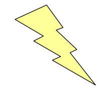
2. What Effect or physical phenomena is employed to poorly deliver this function?

To initiate this, the air must be locally ionized. The air then becomes conductive. As the current is conducted, there is a self concentrating effect caused by many moving charges traveling in the same direction.

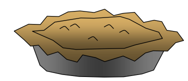



In the next steps we can ask what modifications to the fields or the tool allow the function to be boosted? These modifications may require the small addition of substances or structures which react strongly to the native fields.

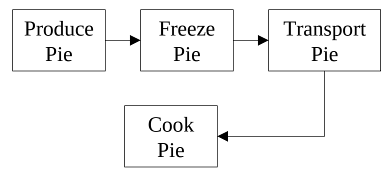
## Abundant Native Fields



Most objects are awash in native fields. These fields do not remain constant throughout the product life cycle. By identifying the fields all around the product, we locate tool resources that can perform the function. Let's consider producing pies. We would like to cut the pie before consumption.



1. **Process Map** the product life through relevant life stages.

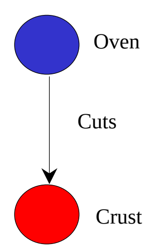



2. Look through the **Table of Fields at the end of this appendix**. Identify which native fields the product experiences at each process step. Which of these native fields perform this function <u>even poorly</u>?

Thermal Fields

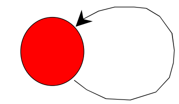
3. What Effect or physical phenomena can be employed to deliver this function?

- Melting
- Chemical Reaction

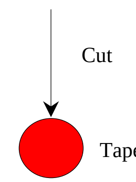


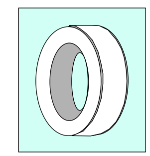

In the next steps we can try to boost this function

## Self-Service



The product in question has native fields associated with it. Can we make some small change to the product so that it performs the modification on itself? (It is likely that any energy used will still need to come from outside). Let us reconsider the example of a roll of tape that must be cut. Normally it is cut by a blade supported to the base element. Let us begin with the tape alone and the modification "cut".



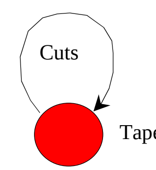



1. Search the <u>Table of Fields</u> at the end of this appendix for fields that are always associated with the product?

<u>Adhesive</u> Fields & <u>Mechanical</u> Fields

2.. What Effect or Physical Phenomena can be used to deliver this function?

The Creation of directed forces by use of adhesive forces




3. What does this mean in this context?

The adhesion between layers must create forces which grossly overpower adhesion of the tape material to itself.

In the next steps we can try to boost this function.

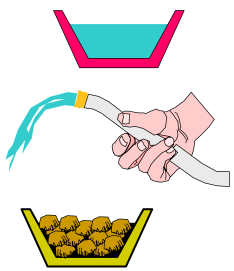
## Laundry List of Adjacent Elements

In this step we consider ordinary elements about us that might be pressed into service to deliver the required physical phenomena. This method is especially effective with low level fields such as elastic, gravity pressure, etc.

1. Make a laundry list of adjacent elements, especially those which were not considered in the super-system functional models

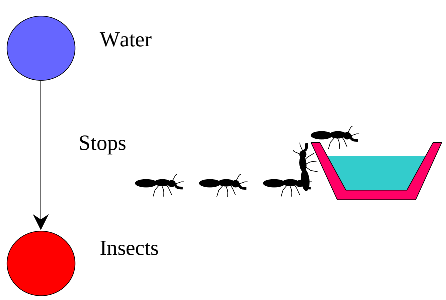
**Laundry List**

- Pet Food
- Water Bowl
- Water Hose
- Water in Water Bowl
- Food Bowl
- Cement-Ground



2. What fields are associated with these objects
   - Surface Tension--Water Bowl
   - Mechanical fields--Food Bowl & Water Bowl
   - Water Pressure--Water hose

3. Consider ways in which elements on the list might be pressed in to service to perform the required modification
   - Simple modification
   - Decomposing or disassociating into new components




## Cheap Abundant Substances

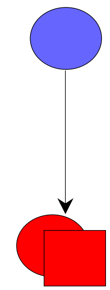
**Cheap Substances**

- Powders
- Foams
- Voids
- H20
  - Water
  - Ice
  - Steam
  - Hydrates
- Air
  - Nitrogen
  - C02
  - Oxygen
- Waste
  - Waste Water
  - Sawdust
  - Waste Glass
  - Waste paper
  - Garbage
  - Yard Waste
  - Industrial Wastes
- Corrosion
- Decay
- Sand, Soil, Rocks
- Disassociated forms of any of the above

When a function can be delivered at low cost, the value of the system increases. If there is a way to use a cheap abundant substance, try to use it. If the effect is weak, it may be possible to boost the effect later.

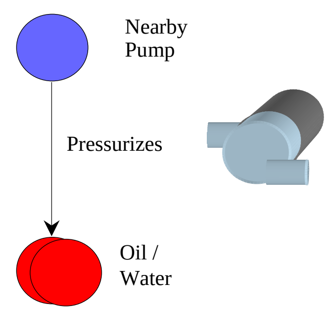
1. Consider the above substances. Could any of these be used to deliver any of the Effects that you are considering.

## Nearby Similar Tool



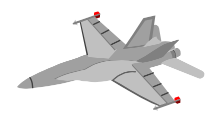
Depending on how systems evolve, it is common that several elements in the system perform the same function. Several objects may perform the same function on different or biased products. Sometimes, this same product can be pressed into service to perform the function on both products. A super-system contains both a water pump and an air pump.

1. Identify a similar tool nearby which performs the same function.
2. Combine and Consolidate both elements into one system.



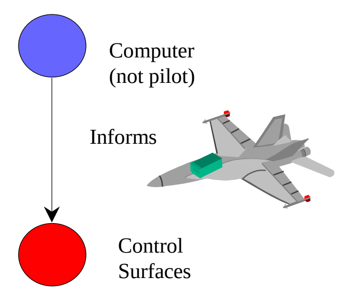

## Simplified Copy of the Current Tool

Use of the current tool can be overkill, especially if the tool is a human. A simplified copy can often perform the same function as the full tool. Jets are often required to perform dangerous recognizance missions. The pilot controls the sophisticated aircraft. The pilot is capable of performing unexpected maneuvers during combat or if failures occur, but during a recognizance mission, these functions are rarely required.



1. What part of the current tool performs the function?
   - The brains and hands of the pilot perform the current function.

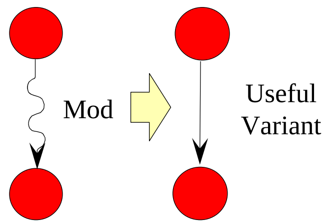
2. Can a copy of the tool perform the function?



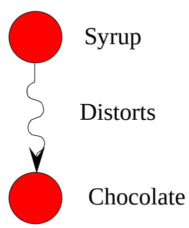
# Rules for Transforming Harmful Functions to the IFR


There are two main ways of handling harmful functions. 1) Turn the harmful function into a useful function and then boost it. 2) eliminate elements. The first should generally be considered first, since here are often physical phenomena resources in harmful functions that can be used to simplify the system. If this fails, we next consider eliminating harmful or waste elements and then finding something else to perform the useful functions that were delivered by the eliminated elements. 3) Decrease the harmful function. Since this third consideration does not generally call for the elimination of elements, it will be considered in further steps

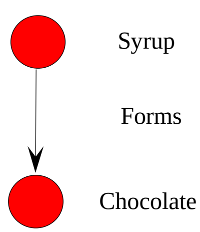
## 1 Identify a Useful Variant




The first step to turning a harmful function into a useful function is to cast the harmful function in a useful context--Any useful context. This often takes a little practice, but the change in perspective can be very satisfying. In order to increase production of a chocolate factory, the syrup that was normally pumped into the chocolate was heated. This reduced the viscosity, allowing for larger volumes to be pumped through the existing pipes. Unfortunately, the heated syrup now distorted the chocolates.




1. Identify the **anti-function.** Would this be considered a useful function in the system?

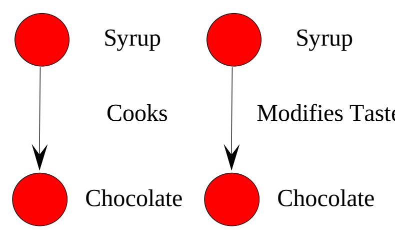



The syrup must form the chocolate or complete its forming.

### Examples

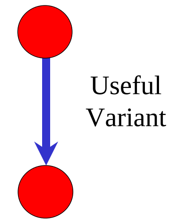
- Melt --> Form
- Wear --> Form
- Break --> Disassemble
- Tear --> Cut
- Burn --> Cook
- Disturb --> Control
- Corrode --> Secure
- Corrode --> Form

2. Identify all useful functions already performed on the Product.
3. Is the harmful function **a useful variant** of any of these useful functions? Write a new useful function as a variant of the harmful function.




4. Is the function **useful in any context**? (Somewhere on the product or in the system a useful form of the function is being performed, but unnoticed).

## 2 Boost a Now-Useful Function

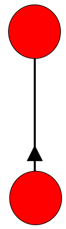



Now that a useful variant of the harmful function has been identified, we boost this function. We may need to consider modifications to other elements in the system. In the end, the system must become simpler, or we should abandon the idea of turning harm to good.

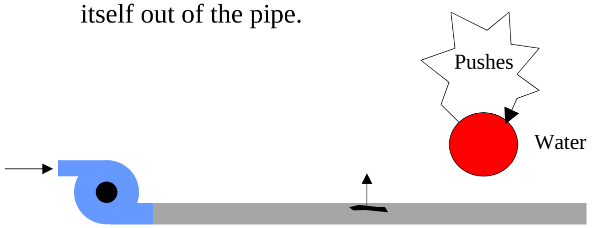
1. Use any of the methods from the Table of Knobs (Appendix K) to boost this now-useful function
2. The following pages give examples of some of the more powerful means of boosting such a useful function.

Modify the syrup to a new substance which changes the texture or taste of the chocolate.
Introduce the syrup earlier to force the shape of the chocolate into the mold.

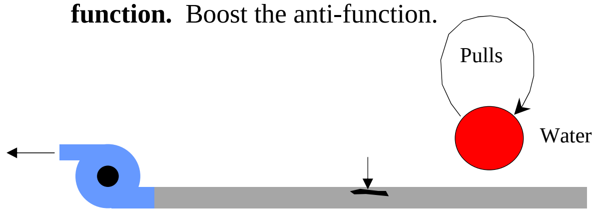
## Reverse the Fields or Action



One of the simplest ways to reverse or create the anti-function is to directly reverse the fields. Consider a situation where water escapes from cooling pipes into the refractory bricks of a smelter. The water explodes upon contact with the bricks. One of the harmful functions is that the pressurized water pushes itself out of the pipe.



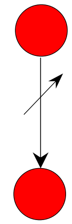

1. **Reverse the fields to perform the Anti-function.** Boost the anti-function.



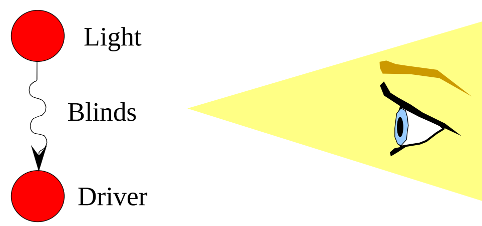

Reversing the fields means that the water in the pipe is under vacuum. The pump pulls the water rather than pushing it.

2. What constitutes the reverse of the current action?
3. What is the action performed relative to? Change that instead.

## Make Adjustable



Almost <u>any</u> harmful function can be made useful if it can be made adjustable. Adjustable friction becomes traction control. Adjustable wear becomes forming. Consider the blinding light that is seen from oncoming traffic with their high beams on.

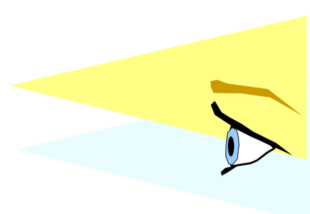



1. If the harmful function could be **adjustable**, could it perform the anti-function, the useful variant or a useful function on another system product?

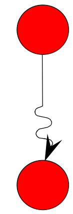
If the intensity of the beam is adjustable, it could be used to communicate the alertness or intoxication of the driver.

2. Find **fixed knobs** of the harmful function that can be made adjustable and boost them

The Light changes the color of one of the beams if the driver's reaction time is slow. It does not distract the driver, but it does alert others of their danger.



## Work <u>With</u>

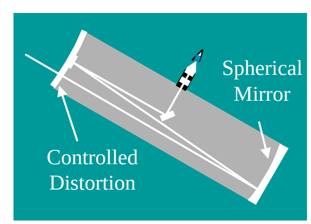


Sometimes an object will perform a a harmful function and a useful variant at the same time. The useful function may be formed to such a low degree that it is not recognized. Boosting the useful variant effectively eliminates the harmful. A telescope uses a transparent dust cover. Small irregularities in the cover distort the incoming light.

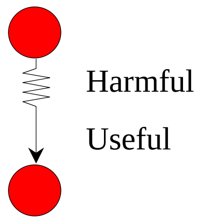
1. Is the useful variant performed with the harmful function, but so slightly as to not be noticed?
2. Is the anti-function performed **with** the harmful function but **not in equilibrium?** Boost the anti-function.
3. Is the harmful function useful any place on the product or on other elements **to the least degree?** Boost this function.

Some of the distortions actually help to focus the light. Can this be used if it were boosted?

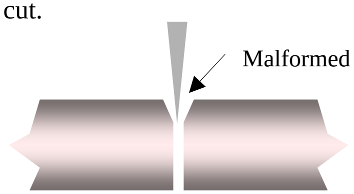
The distortions could be used to correct the effect of a spherical (non-parabolic) mirror which would be cheaper to fabricate.



## Aesthetic Incorporation



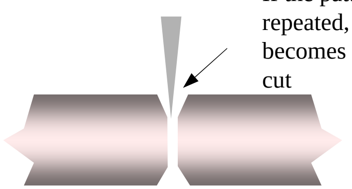

Many forms of art require the artist to incorporate flaws which inadvertently occur during the creation of the art. A small and accidental scribble on an India ink drawing becomes the beginning a bush, etc. A plastic tube is cut. In the process, the tube is malformed where the blade begins to cut.




1. Can the flaw, caused by the harmful modification be incorporated **aesthetically**?

Not yet

2. Multiply the flaw. Make different patterns with the multiplied flaw. What pattern looks the best or performs a useful function?

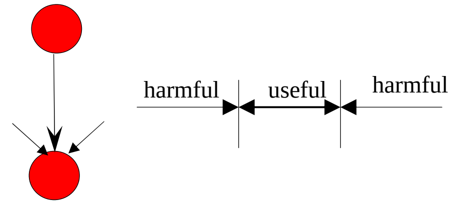


If the pattern is repeated, it becomes a rolled cut

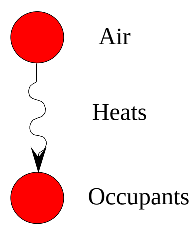
3. Can this aesthetic incorporation perform a useful function?

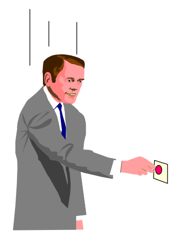
The bevel can act to guide elements that might be attached to the tube ends

## Perform Accurately

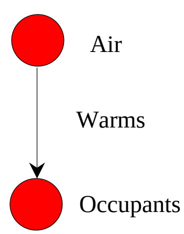



Sometimes a useful function becomes harmful when it goes outside of its useful bounds. In this case, it may become useful by simply putting it within bounds. If the temperature of a room becomes too hot, then it performs a harmful function on the occupants.



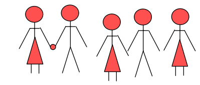



1. Is the anti-function or a useful variant of the harmful function achieved by performing the modification **very accurately**?
2. Boost the accuracy



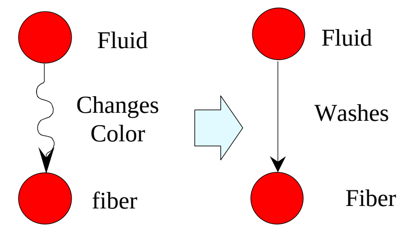

Bringing the temperature into bounds makes the normally useful function of warming useful again

## Intelligent Little People

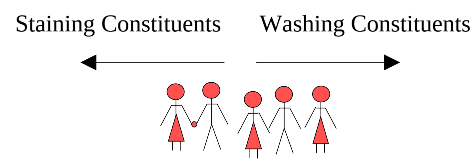


Intelligent little people allow us to see the situation from an empathetic point of view. After going through the previous step of identifying a useful variant, it may not be obvious how the given fields and elements perform this useful function. The physical phenomena is given, but how do we employ it to perform the useful variant? Some liquids can badly stain the fibers of a carpet.

1. Define a useful variant of the harmful function.



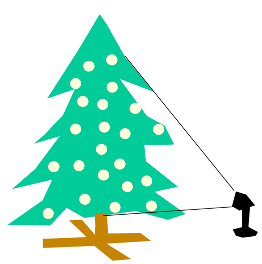

1. Envision the system as **composed of intelligent little people** who can work together. What do they do to perform the useful variant?
   - These people also have the capability to disappear and reappear if necessary




The Little People separate the staining and washing constituents. The washing constituents are used to clean the fiber and the staining constituents are discarded at the base of the fiber

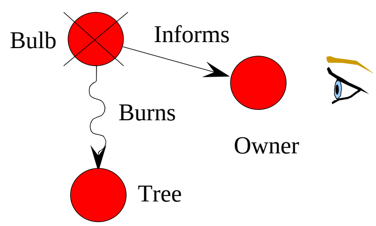

Elimination is one of the most commonly taught methods of dealing with harmful functions. If the user is successful at eliminating an object, then the system is simplified and we come closer to the ideal final result.

Elimination of harmful objects often leads to another problem. The harmful object likely performed a useful function. Now, the function either needs to be performed by another element in the system or environment, or the requirement for the useful function needs to go away.



## Non-existent Tool

It is very common for a tool to cause both harmful and useful functions. Eliminating the tool will remove the harm, but now there may be a necessity to transfer the performance of the useful function to something else. Many homes are burned each year during Christmas due to electrical fires caused by bulbs. The bulbs perform a harmful and a useful function.

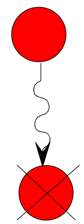



1. The Tool no longer Exists.
   - It is no longer manufactured
   - Eliminate the Source of the product
   - Eliminate the Path of the product

The bulb must be eliminated. Now we consider what will perform the function of the bulb. The ornaments must replace the bulbs and give off small points of light. Small luminescent stickers on the ornaments glow when illuminated with a black light

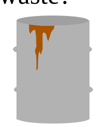
2. Is the tool a waste product? Eliminate the tool directly, since it serves no useful purpose.

## Non-Existent Product



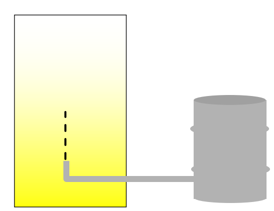
Some products are not <u>required</u> in a system. They may be harmful or waste products. If they are waste products, they may be entirely eliminated. One way to make them not exist is to not allow the waste in the first place. At industrial sites, waste liquid products are often spilled, polluting ground water. This spillage is accomplished by corrosion of the vessels, clumsy handling, etc.

1. Is the product considered harmful or waste?



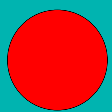
The spent liquid is waste, waiting for recycling

2. The product no longer exists
   - It is no longer manufactured
   - Eliminate the Source of the product
   - Eliminate the Path of the product
3. The waste product becomes useful and is eliminated by its usefulness.



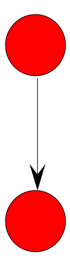
The waste oil is immediately burned as an energy source.

# Rules for Transforming Detection / Measurement Functions to the IFR

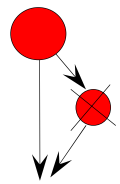


Ideal Tool to be Measured?

Detection and measurement functions need to be treated in a different manner from other useful functions. For one thing, the focus is first on the tool (the object that is being measured) rather than the product (the measuring device). The tool has the task of informing the product of how it is changing. It does this by modifying the measuring device (product) in some way

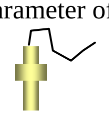



## Direct Acting Sensors



Any physical phenomena can be made to have a critical point. A critical point is a region of operation where the properties of an object change abruptly. The boiling or melting point of a substance is a good example. Operating near this critical point allows for direct acting elements. For passive control, we demand that the sensor use the **same fields for sense and modulation** (the product is a combined sensor and modulating element). Consider a control system that measures the temperature of a fluid and then actuates a fluid closure element.

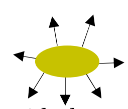
1. Identify the fields associated with the parameter of the tool that is being sensed.



Temperature

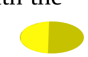
3. Identify a physical phenomena which reacts to the parameter change.

Expansion during Phase Change



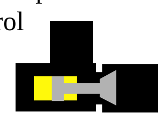
4. Identify a critical point associated with the phenomena.

Melting Point

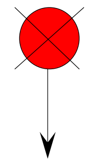


5. Identify how crossing this critical point can be used to both sense and control

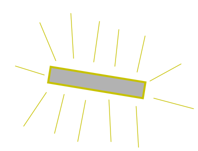
Expansion upon melting provides muscle to move closure element



## Non-Existent Tool



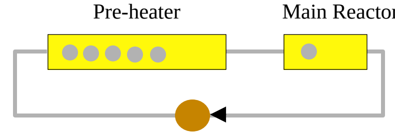
Measuring and detecting objects may not be required if they are not required in the first place. It is usually because we have difficulty discarding them that there is now a need to measure them. (Spent nuclear fuel, waste chemicals). It is usually much more ideal to find a way to get rid of them in the first place.



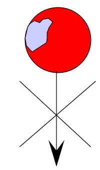
Nuclear Waste and its storage medium must be monitored

1. Is the tool ever Harmful, Waste?
2. Eliminate Tool
3. Eliminate Source
4. Eliminate Path
5. The Waste becomes useful and thus is eliminated by its usefulness

The Nuclear Waste becomes a pre-heater. As the pre-heater grows, the main reactor material is reduced

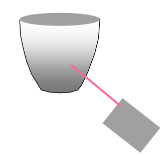



## Measurement / Detection not Required



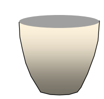
Any useful function can be thought of in terms of preventing harm or fixing something. This is also true of measurement functions. The temperature of a crucible in a vacuum furnace is constantly measured.

1. Why is the tool being measured? Is detecting or measurement required in preparation for fixing or preventing something?



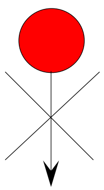
The temperature is being measured to ensure that the operator knows when the crucible is about to melt.

2. What modification to the tool or other element in the system would make it so that measurement is not required.

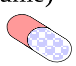
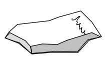


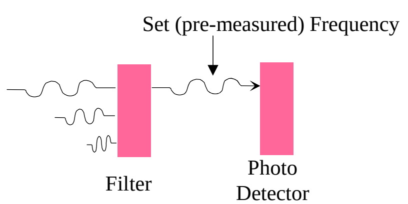
The crucible is made of a material with a high enough melting temperature that it cannot melt. Temperature measurement is no longer required.

## Comes Pre-measured

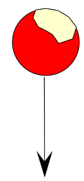


The Tool does not require detection because the detection is already incorporated. In order to measure light intensity, the frequency of the light must be known.

1. Can the tool substance amount be apportioned in such a way that the required properties are already known? (Pre-measured weight or volume)
   - Medication--Pills 
   - Food--Packets 
   - Tubes--Pre-fabricated diameters (very accurate) 
2. For measurement of fields, make the source of the fields come in discrete forms. Following are several examples
   - Sound or Vibration-- Set frequencies (resonance) and duration
   - Light--Set frequencies or duration
   - Buoyancy--discrete volumes
   - Pressures--Saturated liquid gas phase gives one pressure
   - Temperature--Saturated liquid-gas phase gives on pressure
   - Current--Use of current driver




## Minimum Part

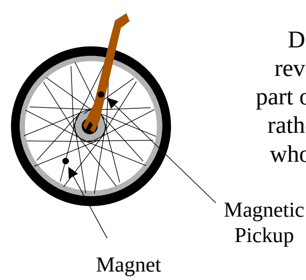


Detecting or measuring a parameter of a system composed of a variety of elements allows for the possibility of simplifying by measuring the parameters for only part of the system. How can the speed of a bicycle be determined?

1. If the tool is a single element, what minimum part of the Tool must be detected?

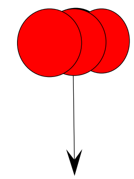
The tool is not a single element

2. If the tool is composed of multiple elements, identify parts of the system that could be measured, rather than measuring the whole system.




Detect the revolution of part of the wheel rather than the whole bicycle

## Multiple Tool Elements



Often, it is easier to detect the average parameter of many objects than it is to detect the properties of a single object. This is almost always true when detecting the properties of small things such as particles, molecules, atoms. Consider measuring the temperature of an insect.

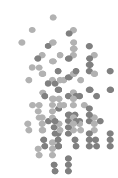
1. Are the objects small?

Yes, insects are small

2. Does the tool come in natural batches or groups, or are they hard to separate?

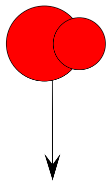
Not usually, unless they are swarming insects

3. Is it_more ideal or easier to detect the group simultaneously? For instance, is it advantageous to know the average value as opposed to individual values of measurement?



Measuring the insects as a group makes it easier and gives an average value which may be more ideal in some situations

## Biased Tools

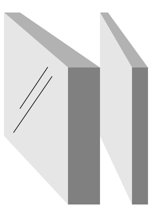


An inspection machine would be very limited if it could only measure objects within a narrow range of values. The requirement to measure a large range of objects will greatly affect the physical phenomenon used to perform the measurement. Consider the measurement of glass thickness. The glass to be measured has a variety of thickness.

1. Are there similar objects (tools) that require detection?

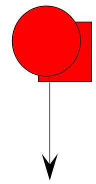
Yes, the glass comes in a variety of thickness

2. Would it be more ideal if the system could measure a larger variety of objects?



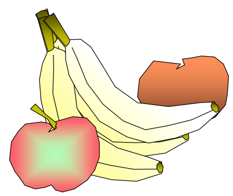
Yes, especially if anticipating a large number of jobs coming through from a variety of customers

## Diverse Tools



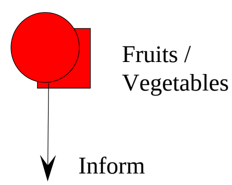
Would it be more ideal if the object to be detected or measured were not similar to each other? Consider automatic checkout of fruits and vegetables in a grocery store. Each fruit or vegetable comes in a variety of weights. Yet, the speed of weighing and assigning costs must be done rapidly.

1. Are there a variety of objects that require the same type of measurement or detection?

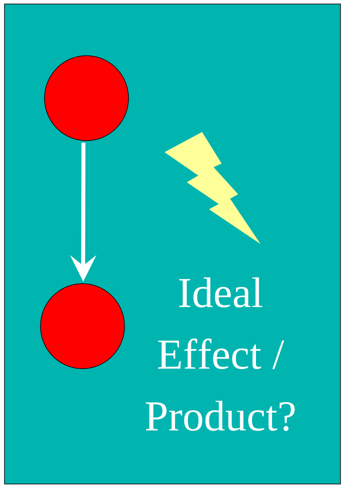


Yes, there are a variety of fruits and vegetable s that require weighing

2. Would it be more ideal if these objects could all be measured by the same device?



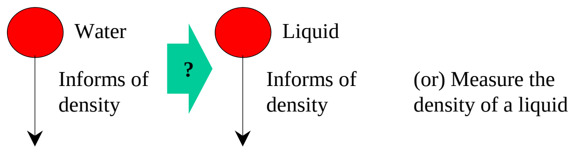

An automatic checkout would be greatly enhanced if it could detect the presence of a large variety of items.




## Table of Effects

The Table of Effects can also supply different physical phenomena used for measuring and detection. Once we know the measurements that we desire, we can find a similar measurement requirement in the table. Usually, this is a generalization of the the desired measurement. The table then gives a variety of phenomena that can be used. Let us consider measuring the density of water.

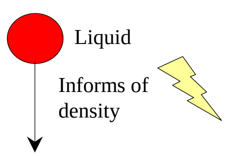
1. Determine the parameter or property to be measured
2. Convert given function to a *Generalized Function*. The table does not generally use functional language.




3. Find the desired physical phenomenon in *Table of Effects* :go to one of the sources for the table of effects. Some of the commercial software have a table. A trimmed down version can be found at

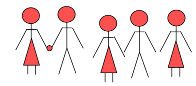
www.creax.com

4. Locate the generalized measurement and then consider all of the physical phenomena that can be used.



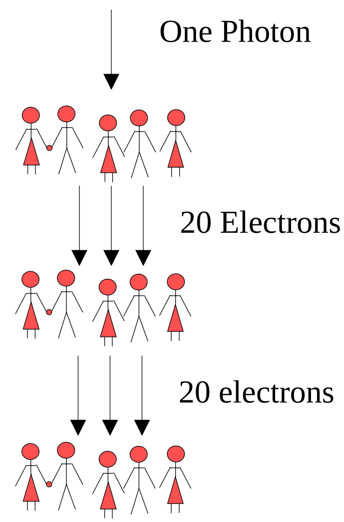

5. Determine a suitable product to receive the effect

## Intelligent Little People



Consider the measurement of light intensity.

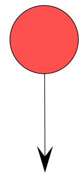
1. Envision the system as **composed of intelligent little people** who can work together.
   - These people also have the capability to disappear and reappear if necessary
2. What do they do to make the detection of a parameter change possible? How do they work together?



# Roundabout Parameters

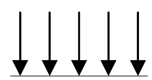
Sometimes it is difficult to detect an object or field parameter directly. This section presents possible ways to measure a parameter by doing it indirectly. In general, this is possible because all things are interconnected. When we change a parameter of an object, many other parameters of the object and environment are affected. We can indirectly measure the desired parameters by measuring one of these other affected parameters.

## Secondary Parameters



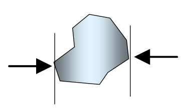
Rather than measuring the parameter, a second parameter can be measured which is influenced by the one that you would like to measure. Object parameters always influence each other. The temperature of an object affects its dimensions. The weight of an object affects its buoyancy. In reality, almost all parameters are measured by measuring a secondary parameter and then inferring the required measurement. Consider the measurement of pressure.

1. What exact parameter requires detection?

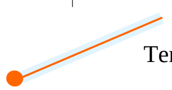


Pressure

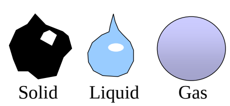
2. List Secondary parameters that Change when the main parameter changes.



Shape Change

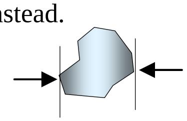


Temperature



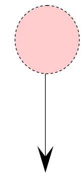

Physical State

3. Detect these secondary parameters instead.



Measure the change of dimension

## Use of Copy or Facsimile

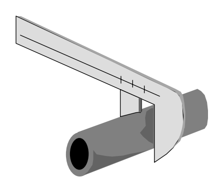


When it is difficult to measure a parameter, consider measuring a copy of the object, or a facsimile that mimics the important aspects of an object. Following is a list of possible copies from the Table of Contradictions.

- Photographs
- Movies
- Paint Coverings
- Molds
- Time lapse photos
- Impressions

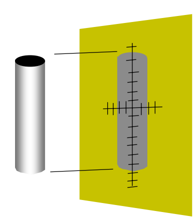
- Silhouettes
- Castings
- Resists
- Projections
- Computer Model

Consider measuring the dimensions of an elastic article. Traditional measuring instruments such as calipers tend to deform the article during measurement.

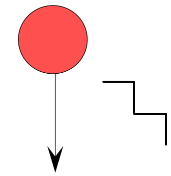


1. Consider measuring one of the facsimiles of the article above.

Measure the Silhouette



## Successive Detection



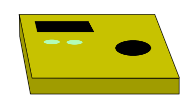
- Discrete volumes
- Filters
- Musical notes
- Go / No Go gage
- Measuring spoons
- Set of Weights

This tool is very similar to the concept of pre-measurement. In this step, we compare the parameter of an object to the same parameter of another object that comes only at discrete levels. Consider measuring the resonant frequency of objects

1. How accurate does the measurement need to be?

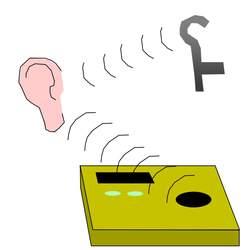
Within 50 Hz

2. Break the levels of measurement, or the measurement of a secondary parameter into discrete levels. Create these levels in a second device.



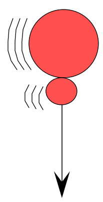
A digital musical instrument plays discrete notes

3. Compare the object being measured or detected to the discrete values.



By ear, compare the musical note to the resonance. The musical note has a known frequency

## Resonance



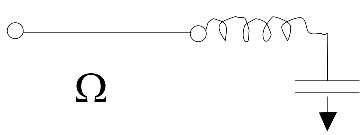
Resonance
- Mechanical
- Centrifugal
- Surface Tension
- Fluid vibration
- Sound
- Ultrasonic
- Waves
- Electrostatic
- Current
- Electromagnetic
- Luminescent

Resonance is an important type of secondary parameter. Many parameters can be measured by the resonance of an object or an attached object. Virtually every field can be detected by resonance. The resonance can be mechanical, fluid vibration, electromagnetic or luminescent. (Thermal resonance is difficult to achieve). It can occur at all levels from macro object to particles to molecules to atoms to electrons. Consider the measurement of resistance of a long wire and its connections.

1. When the measured parameter changes, what types of resonance are affected?

Resistance changes current resonance

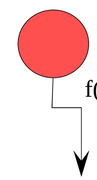
2. Consider measuring the resonant amplitudes or frequencies of the object to detect the desired parameter.




Attach a resonant circuit to the wire. The resonant amplitudes give information on the resistance

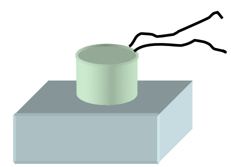
3. Consider measuring the resonant amplitude or frequency of different parts of the object to detect the level of the parameter
4. Consider attaching an object and measuring the resonant amplitude or frequency to measure the desired parameter.

## Derivative Detection




One of the most powerful ways to measure a parameter is to measure the rate of change and then integrate. (Measuring and then differentiating is also possible, but it is quite noisy). With modern computing, integration schemes can be easily done. It is also possible to integrate with analogue circuits. Consider the problem of determining the relative position of an object.

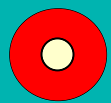
1. Measure **higher order derivatives**



Place an accelerometer on the object and measure acceleration.

2. Integrate as many times as necessary to determine the desired parameter.

$$\iint \ddot{X}\, dt = X$$



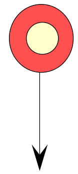
# Use of Markers

When it is difficult to detect or measure a desired parameter, often it is because the materials and fields involved do not have strong interactions. Markers are a special type of additive that strongly couple with a field and are, therefore, easily detected. Often, the detection comes directly by sight, feel, smell or taste.

Remember that the ideal additive is one that <u>does not exist.</u> Consider these ways to produce additives that come close to not existing:

1. Especially active additives (very little is needed)
2. Concentrated additives (very little is required)
3. Temporary additives (eliminated or self-eliminated when not needed)
4. A decomposition of native materials. (Use only the part which delivers the function)
   - Chemically decomposed
   - Segmented
5. Add a field instead of a substance

## Internal Markers

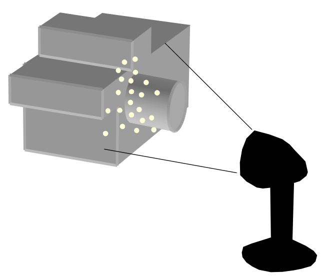


An internal marker is a substance additive that is mixed with or nested in the tool. This substance interacts with a matching field to aid detection. Consider the detection of refrigerant leaks.

1. Do the existing materials that are being measured react strongly to any field? Search the Table of Fields at the end of this appendix.

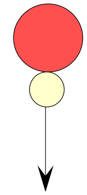
No

2. If not, then introduce an additive (according to the rules at the left) internally into the substance to be measured which has a strongly coupled paired field



A luminescent material is introduced into the lubricant. A black light shows the location of the leak.

## Attached Markers



An attached marker is a marker which sits on the outside of the tool. This may be done to avoid the contamination or because it does not easily mix with the tool. An example of this is measuring the position of animals in the wild. It is difficult or dangerous to add a substance internally to the animal.

1. Does the tool react strongly with any field-Check the Table of Fields at the end of this appendix.

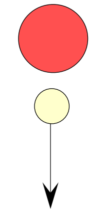
No

2. If not, identify a field-substance couple that can be attached to the tool.
   - Attach the object
   - Coat the object


The animal wears a large collar with a visible number.

3. If problems arise, consider resolving the contradiction in subsequent steps.

## Detached Markers



A detached marker may be necessary if interaction with the tool and marker must be kept to a minimum. In this case, a secondary effect which the tool has upon the environment is detected. For example, consider detecting the movement of bacteria.

1. Is it not possible to find an internal or attached marker?

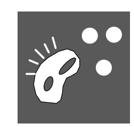
No

2. If the marker cannot be mixed or attached to the tool then identify secondary effects that a parameter change has on the immediate environment.

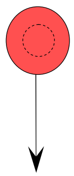
The movement of the bacteria leaves waste products in the environment

3. Add the marker to the environment and then detect the change in the marker.

The medium is modified to react with the waste products to form bubbles.



## Internal Field Markers

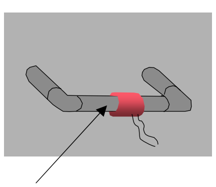


One of the best ways to not add a market to the tool is to add a temporary or permanent field instead. This page considers different ways to add fields. Consider how one might be able to determine the direction of movement of fluid in a pipe.

1. Search the Table of Fields at the end of this appendix for fields which can safely inhabit the tool.

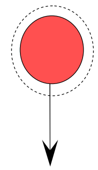
- Pressure
- Surface Tension
- Sound-Ultrasound
- Vibrations
- Current
- Thermal fields
- Electromagnetic fields
- Electrostatic field

2. Once the tool has this added field, search the Table of Effects (physical phenomena) for ways to detect these fields.



A heat cuff is attached to the pipe. The pipe becomes hotter in the direction of flow

## External Field Markers

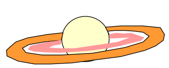


Sometimes, a field will disrupt a substance enough that it should not inhabit the tool. Also, some fields are principally associated with surface phenomena and cannot inhabit the tool. Here we consider fields that reside on the tool, but are not associated with any other substances but the tool. Consider measuring the speed of the rings of Saturn.

1. Search the Table of Fields at the end of this appendix for fields which are principally associated with surface phenomena. Allow for fields which are only there momentarily.

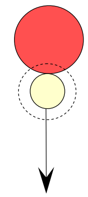
- Surface Stress
- Friction
- Adhesion
- Surface Tension
- Odor-Taste
- Corona Discharge
- Skin Current
- Electrostatic fields
- Reflected light or radiation

2. Search the Table of Effects for ways to detect these fields.



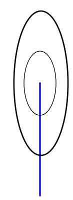
Doppler shift of reflected light allows detection of ring velocity. (Opposite sides of ring have different shift).

## Attached Field Markers



If no fields can inhabit the tool or it's surface, then consider adding a substance to the tool that can be inhabited by a field with a strong coupling. Consider the tracking of wild animals.

1. Search the Table of Fields at the end of this appendix for fields. For each field in the Table of Fields at the end of this appendix, identify a substance which is easily inhabited by a field which retains and exhibits the field.

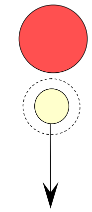


An antenna can be inhabited by an alternating electric current which gives off an electromagnetic field

2. Consider ways of attaching the substance to the tool.

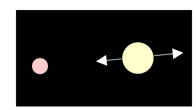
An emitting antenna is attached to the animal. The antenna's field is detected by another antenna and amplifying circuit. Triangulation tells where the animal is

## Detached Field Markers



Some of the field-substance couples in the attached field materials will disrupt the tool. If this is the case, then there may be secondary effects that the tool causes on the environment which can be measured by introducing a substance-field combination into the immediate environment and then detecting the field. How can planets be detected in other solar systems?

1. Identify a secondary effect of the measured parameter on the environment.

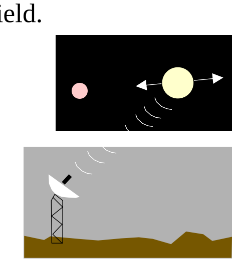


Other Large Objects wobble due to the gravitational attraction of the planet

2. For each field in the Table of Fields at the end of this appendix, identify a substance which is easily inhabited by a field which retains and exhibits the field easily.

The star maintains a thermal field and gives off light

3. Consider ways to attach or mix the field into the environment and then detect the field.



Detect the wobble by a slight Doppler shift

# Table of Fields

| | | | | | |
|---|---|---|---|---|---|
| Elastic Force Internal & External | Gravity | Friction | Adhesive | | |
| Centrifugal Force | Inertia of Bodies (Note Direction) | Coriolis Force | | | |
| Buoyant force | Hydrostatic Pressure | Jet Pressure | Surface Tension | | |
| Odor & Taste | Diffusion | Osmosis | Chemical Fields | | |
| Sound | Vibrations & Oscillations | Ultrasound | Waves | | |
| Corona Discharge | Current | Eddie Currents (internal and skin) | Particle Beams | | |
| | Thermal Heating or Freezing | Thermal Shocks | Nuclear Forces | | |
| | Electrostatic Field | Magnetic Field | | | |
| | Electromagnetic (Voltage) | | Information | | |
| Radio Waves | Micro-waves | Infrared | Visible Light | Ultra-violet | X-Ray |