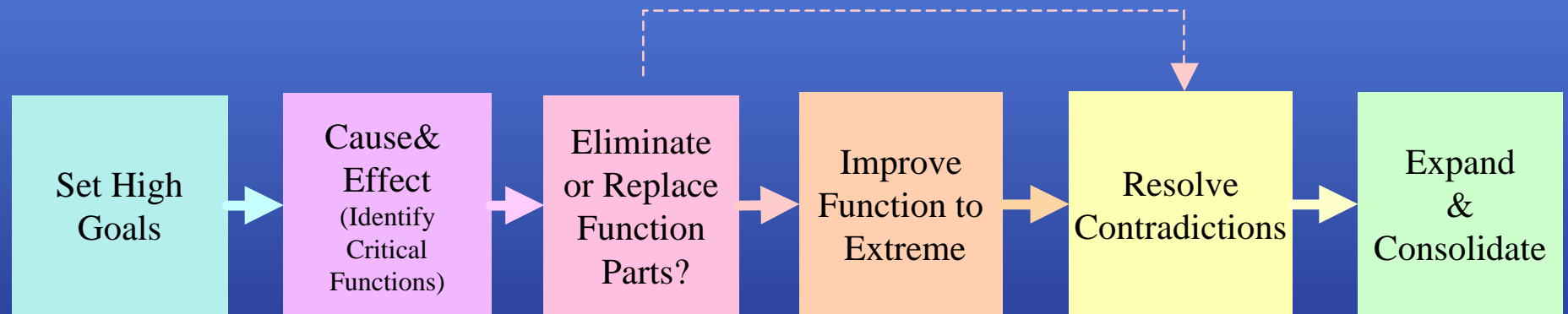


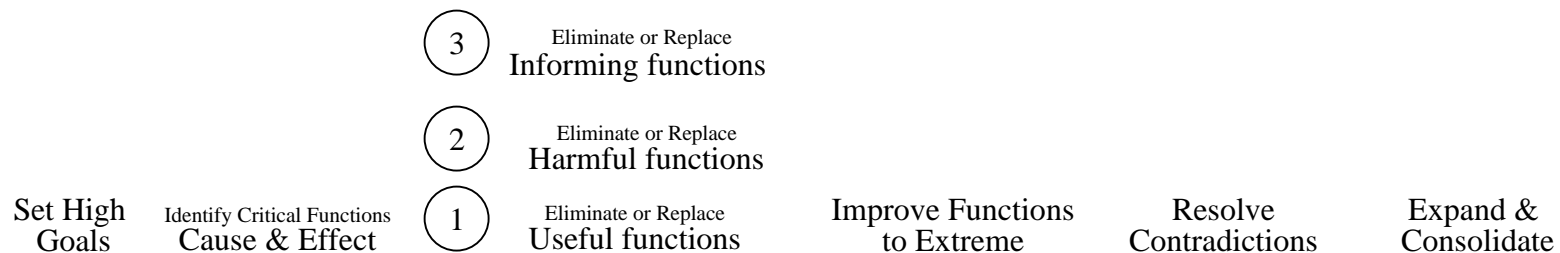


# Breakthrough Thinking

A Linear Sequencing of TRIZ Tools



## 6 Tab Positions (Line up with Process Boxes on Front Cover)



Expand & Consolidate
Resolve Contradictions
Improve Functions to Extreme
Eliminate or Replace Parts? Informing Functions
Eliminate or Replace Parts? Harmful Functions
Eliminate or Replace Parts? Useful Functions
Identify Critical Functions Cause & Effect
Set High Goals

Note: A small mark is placed at the bottom of each divider sheet to indicate where the tab is located. For better results, print divider sheets and tabs on card stock.


**Tab Labels**  
 (Sized for Avery<sup>®</sup> Self-Adhesive Tabs)

# Set High Goals

## Choose Or Create Subject System



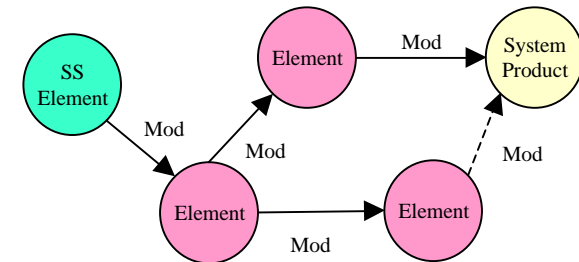
- Be as **specific** as possible.
- The system may already exist but in highly flawed form

## Determine Customer Requirements & System Disadvantages

# VOC

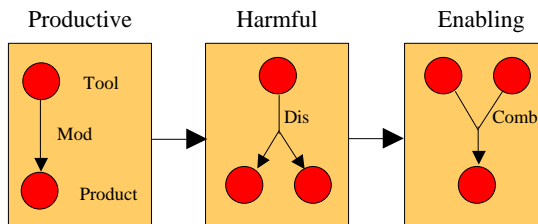
- Identify Customers and Potential Customers? Who is really going to want this?
- Identify system **disadvantages** from the viewpoint of the Customers
- Capture **Customer Requirements**. May use QFD
- Identify the Super-System.
- What does the Super-System want right now?
- Place yourself in the **future**. What will the Super-System want then?
- Gather **costs and penalties** associated with disadvantages
- Determine whether problem is **worth pursuing**

## Model the Current Technical System



- Identify System Elements
- Identify the main system product (what the system modifies)
- Identify super-system elements. Super-system elements cannot be eliminated. Consider only super-system elements which directly interact with the system elements. This bounds the system and sets limits over what can and cannot be changed.

## Or Model the Current Process



- Identify Process Steps as:
  - Productive--Modifies the final product
  - Enabling--Does not modify the final product but makes it possible
  - Corrective--Removes some unwanted aspect of previous steps
  - Harmful--Unintended Function that harms

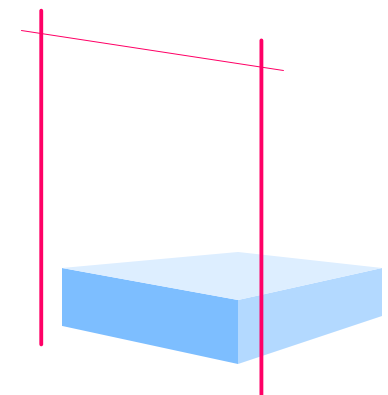
## Determine Element Or Process Step Values

Function Rank:  
Basic or Productive = 3  
Auxiliary or Enabling = 1  
Harmful = 0

$$\text{Value} = \frac{\text{Cumulative Rank}}{\text{Cost}}$$

- Identify elements or steps with low value. These elements are prime candidates for elimination later.

## Set a High Bar



- **System Ideal Final Result:** What do I really want to have happen at the system level? At the Super-System Level?
- How much must it **cost**?
- Set **High Goals and Difficult Constraints** that will galvanize the effort

# Identify Critical functions Cause & Effect

# Form Theories

## Do your Homework



- Study what the **subject matter experts** have to say.
- Books, magazines, internet
- Talk directly to subject matter experts
- Ask **why** something happens. Then ask **why** that happens. **Keep asking why until you get to the root of the problem**

## Crime Scene Analysis



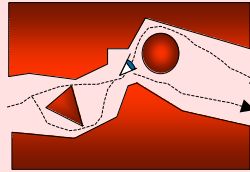
- Examine all objects carefully under a **microscope** or with the best tools available for causal evidence
- Draw (**real art**) what you see at macro and micro level.
- **Compare** to what you are looking at for differences
- **Verify** what you see with others
- All Evidence must be accounted for by theories.

## Catch in the Act



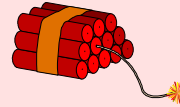
- Devise an experiment to **watch** the interactions. Consider slow motion, etc.
- Use **Redefine** *Informing functions* to find ways to look at what is happening (copies, etc.)

## Empathy



- Put yourself in the place of the objects that you are investigating
- Follow through process from beginning to end

## Subversion Analysis



- If you were a **Saboteur**, how would you cause the problem?
- Find an effect, no matter how weak, which could cause the phenomenon
- **Boost the effect** until it matches the evidence

## Quantify Theories

$$E = mc^2$$

- **Equations**
- **Models**

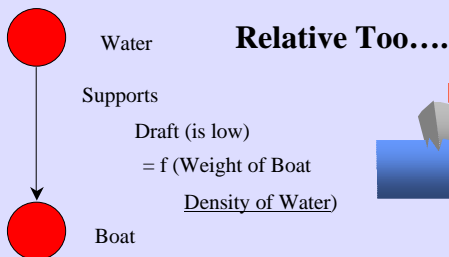
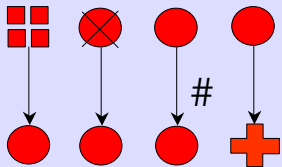
## Verify Theories

Experiments

## Catch Missing Causal / Controlling Variables

### Intuition

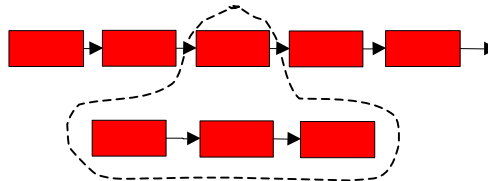
### Table of Controlling Variables



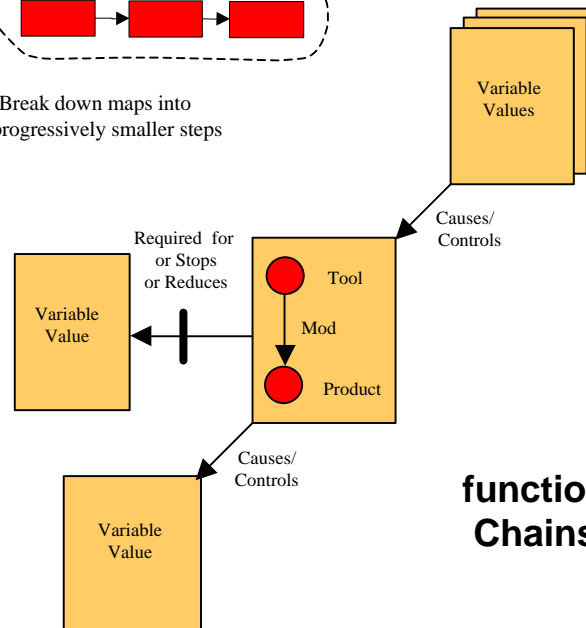
- Every Controlling Variable is measured relative to something. Consider changing that something...

## Link Causal Relationships

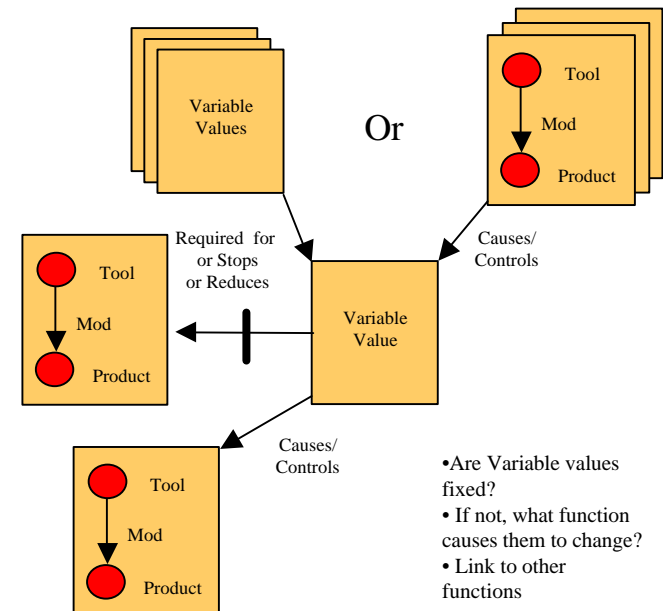
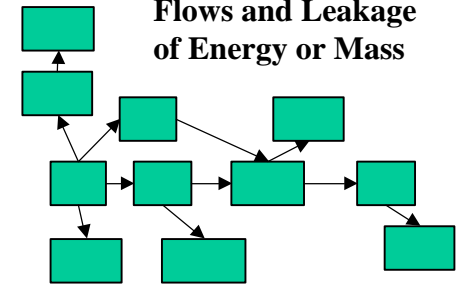
### Flow of Goods & Information



- Break down maps into progressively smaller steps



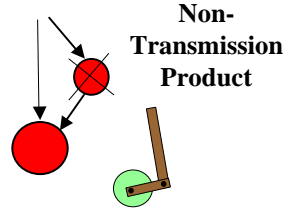
### Flows and Leakage of Energy or Mass



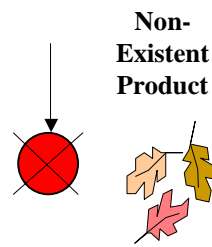
### function Chains

- Are Variable values fixed?
- If not, what function causes them to change?
- Link to other functions

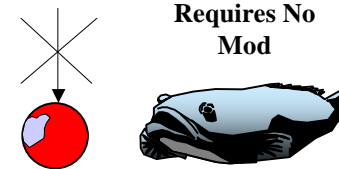
# Eliminate or Replace Function Parts? Useful Functions



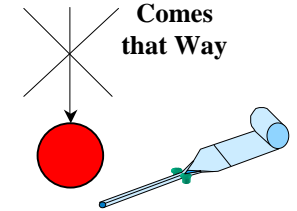
- Is product a transmission element?  
(Does the product transmit, transform or convert energy?)
- Bypass the transmission element



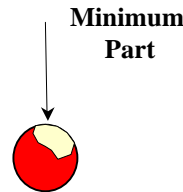
- Is the product ever Harmful, Waste?
- Eliminate Product
- Eliminate Source
- Eliminate Path



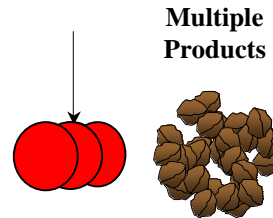
- What undesirable variable value of the product makes the function necessary?
- Permanently reverse or change the variable value.
- What variable value makes the modification so large?
- Change so that required mod is small.



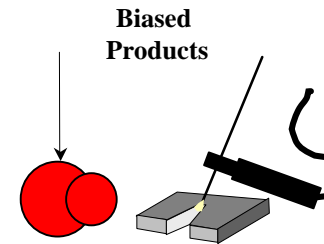
The product does not require the modification because it is already incorporated



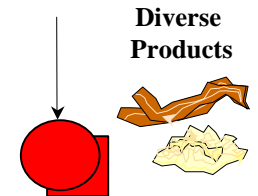
- What minimum part of the product must be modified?



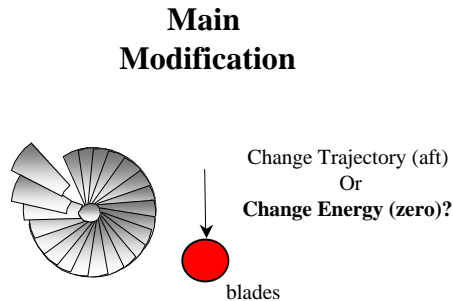
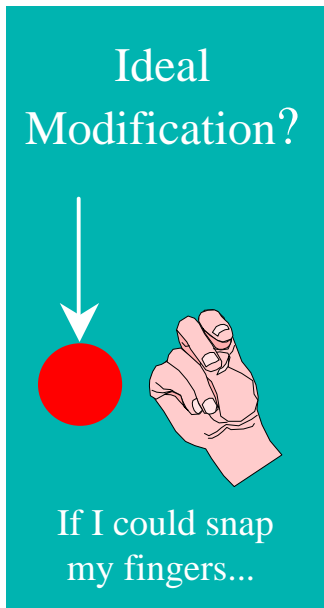
- Does product come in natural batches or groups?
- Is it more ideal to modify the group simultaneously?



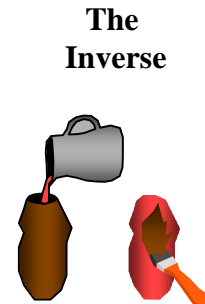
- Are there similar products that might require the same modification?
- Can they also be included?



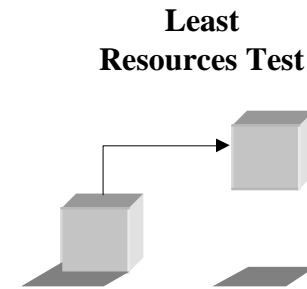
- What other elements in the system or super-system require the same modification?
- Can they also be included?



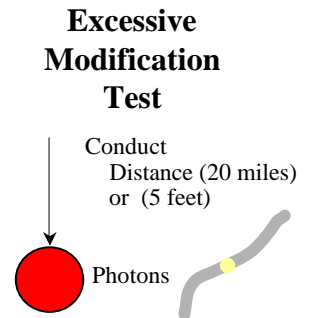
- Using the longhand form of the modification, identify what we really want to modify?
- Work backward by imagining the ideal final state. (Consider drawing a picture of the final state). What is the main variable of the product that is being changed and its ideal value?



- What object is the modification performed **relative to**?
- Invert the problem by modifying the relative object. (Make it the product)

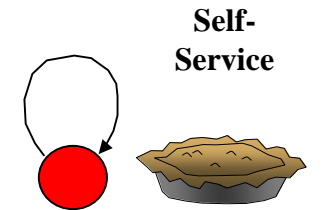
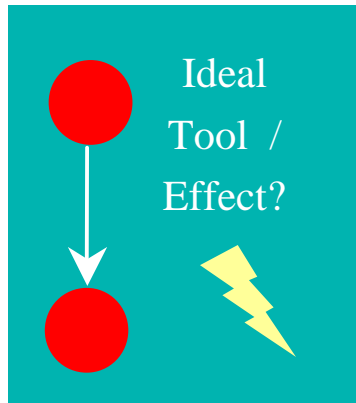


- What is the least energy that is required for the modification?
- What is the least time?
- What is the least volume or space?



- Are any of the Dependant Variable Values Excessive?



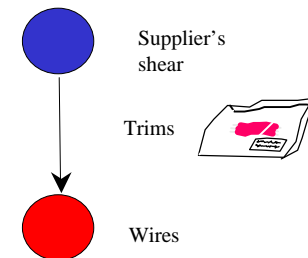


- Process Map beginning to end of life
- What fields does product experience during life?
- Which of these fields perform this function to even poorly?
- Modify the Product to improve the function.
- Model with intelligent little people
- Can the former tool be combined with product?



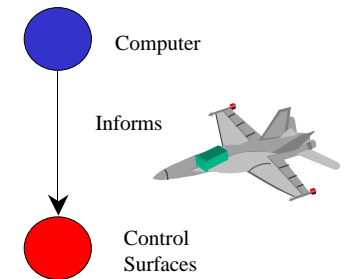
- Is the function now delivered by a super-system tool, even poorly?
- Look through the Table of Fields and identify native fields.
- Which of these perform the function, even poorly?
- Modify the field or tool to improve the Function.

## Comes that Way



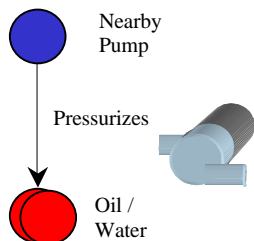
- Continuation of *Comes that Way* for the ideal product
- What tool is best suited for this modification?

## Copy Current Tool



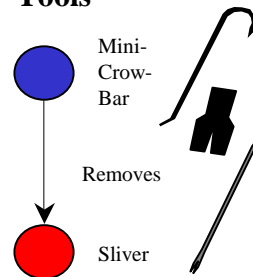
- What part of the current tool performs the function?
- Can a copy of the tool perform the function?

## Nearby Analogous Tool



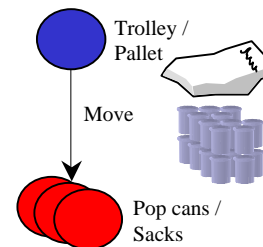
- Identify nearby analogous product
- Identify the Tool
- Combine and Consolidate

## Analogous Tools



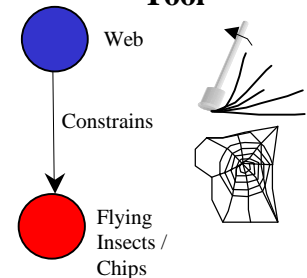
- Identify an analogous product
- Identify its tool
- Identify minimum tool variable
- Transfer Effect/Tool to new situation
- Combine w/ existing tool
- Transfer **minimum** amount of tool

## Mega-trend Analogous Tool



- Identify analogous products in leading industries.
- Identify trends for performing the function?
- What is considered the ideal Product, Modification and Tool?

## Natural Analogous Tool



- Identify analogous products in nature?
- Identify the natural Tool/ Effect?
- Transfer the Effect/Tool to the new situation
- Look for primitive natural analogies?

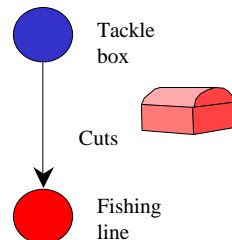
## Cheap Abundant Substances

**Cheap Substances**

- Grocery store products
- Powders
- Foams
- Voids
- Water, ice, steam, hydrates
- Air or its components

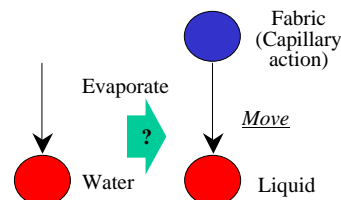
- Look around for cheap abundant substances.
- Could any of these be coaxed to perform the function?

## Adjacent Elements



- Consider a simple modification to an adjacent element.
- Especially effective with low level fields such as elastic, gravity pressure, etc.

## Table of Effects

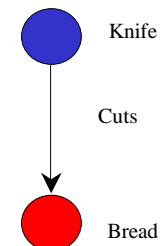


- Convert to General Function
- Find Effect in Table of Effects
- Find tool to deliver Effect

## Patent Data Base

**US Patent Data Base**

## Current tool



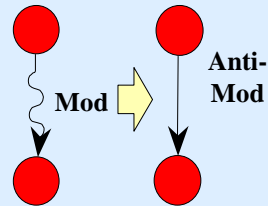
- Can the current tool deliver the ideal modification?

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		
Table of Fields		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

# Eliminate or Replace Function Parts? Harmful Functions

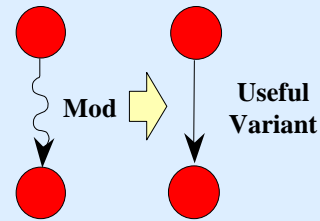


### Identify the Anti-Function



- Carefully identify the harmful function and its **anti-function**
- Verify that this is the most ideal form of the modification.

### Identify a Useful Variant



- Identify all useful functions performed **on the Product**
- Is the harmful function a **useful variant** of any of these useful functions?
- 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).

### Reverse the Fields or Action



- **Reverse the fields to perform the Anti-function.** Boost the anti-function.
- What constitutes the reverse of the current action?
- What is the action performed relative to? Change that instead.

### Make Adjustable



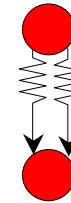
- If the harmful function could be **adjustable**, could it perform the anti-function, the useful variant or a useful function on another system product?
- Find **controlling variables** of the harmful function that can be made adjustable and boost them

### Work With



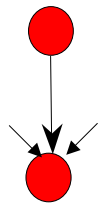
- Is the anti-function performed **with** the harmful function but **not in equilibrium**? Boost the anti-function.
- Is the harmful function useful any place on the product or on other elements **to the least degree**? Boost this function.

### Incorporation



- Can the flaw, caused by the harmful modification be incorporated **aesthetically**?
- Multiply the flaw. **What pattern is useful?**
- Can this aesthetic incorporation perform a useful function?
- Boost this function

### Perform Accurately



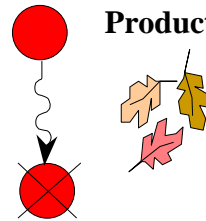
- Is the anti-function or a useful variant of the harmful function achieved by performing the modification **very accurately**?
- Boost the accuracy to the extreme.

### Non-existent Tool



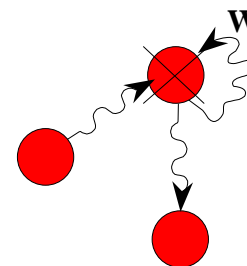
- The Tool no longer Exists
- Eliminate the Source
- Eliminate the Path

### Non-Existent Product



- The product no longer exists
- Use if the product is considered **harmful or waste**.

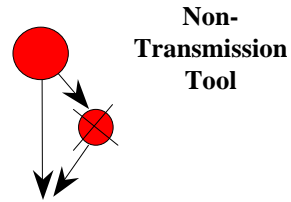
### Working with Harmful Effects to Eliminate



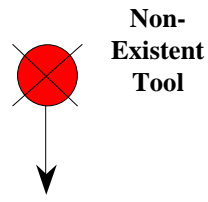
- Boost existing harmful functions on the tool to eliminate it.



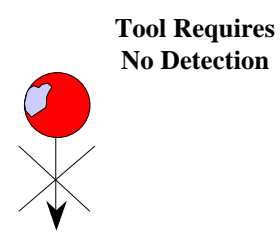
# Eliminate or Replace Function Parts? Informing Functions



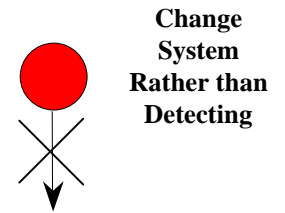
- What **Exact Variable of the Tool Requires Detection?**
- Is the Tool a transmission element? (Does the tool transmit, transform or convert energy?)
- Bypass Transmission Element



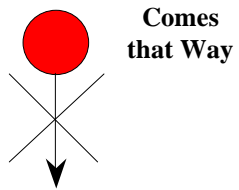
- Is the tool ever Harmful, Waste?
- Eliminate Tool
- Eliminate Source
- Eliminate Path



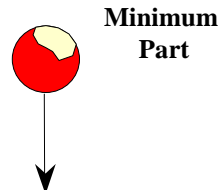
- What variable value of the tool makes the function necessary?
- Reverse or change the variable



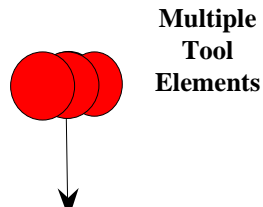
- Change the system so that detection is not required
- Use passive regulation effects.



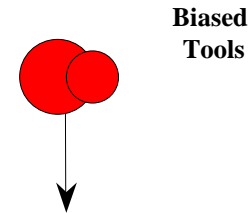
The Tool does not require detection because the detection is already incorporated



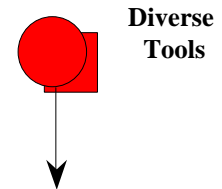
- What minimum part of the Tool must be detected?



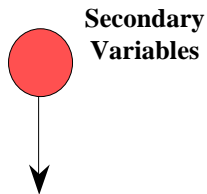
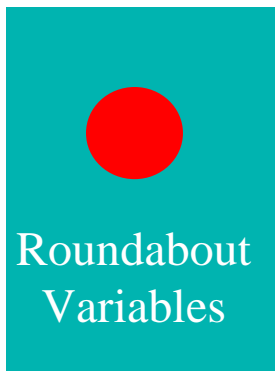
- Does the tool come in natural batches or groups?
- Is it more ideal to detect the group simultaneously?



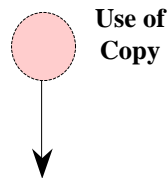
- Are there similar tools that require detection?
- Can similar tools be included?



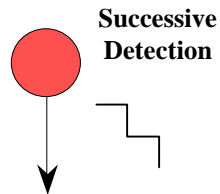
- What else requires the same detection at the same time?
- Can these also be included?



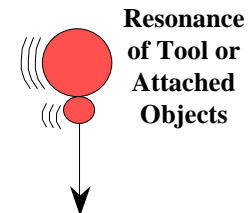
- What **exact variable requires detection?**
- List Secondary variables that Change when the main variable changes. Detect these variables



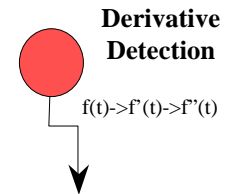
- A picture or copy of the article becomes the tool that is measured.



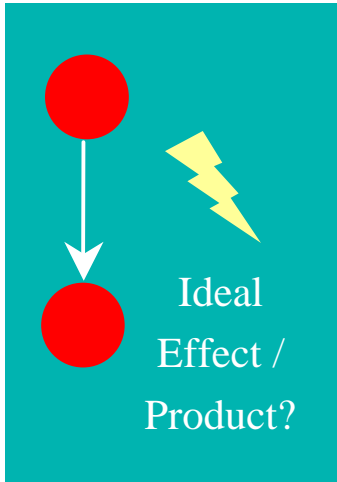
- Measure discrete events such as balls popping up or lines on a ruler to measure the main variable.



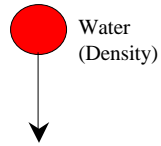
- Measure resonance amplitudes and frequencies of the Tool or Attached Objects to detect main variable.



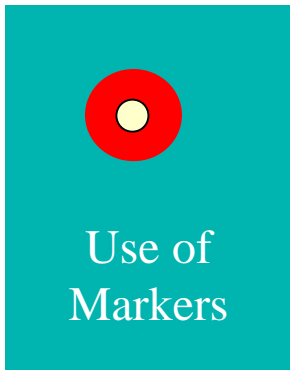
- Measure **higher order derivatives** and then integrate if necessary



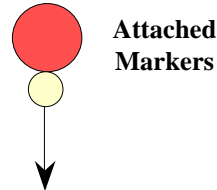
### Table of Effects



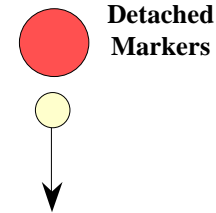
- Determine the variable or property to be measured
- Find Effect in *Table of Effects* under *Measurement*
- Determine a suitable product to receive the effect



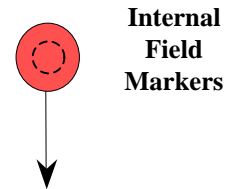
- Add an internal substance with a paired field



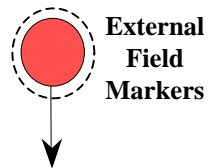
- Attach a substance with a paired field



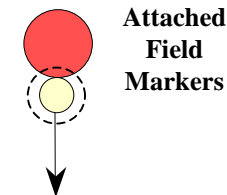
- Add a substance into the native environment with a paired field



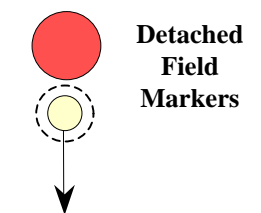
- Add an internal field



- Add an external field



- Add a field to an attached substance



- Add a field to a substance in the native environment.

## Additives

Especially Active  
Concentrated  
Temporary  
Copies

Chemical Decomposition  
Decomposing Native Media

Self-Elimination of Depleted Substances

# Improve Functions to Extreme



# Improve to Extreme



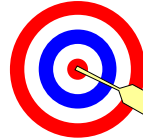
Modification

Improvement

= f ( temperature (hot)  
humidity(50%)  
color (red)... )

## Identify Improvement (Dependant Variable)

Enduring Outcome



- What feature of the function would you like to **improve**? Improving this feature could lead to removing the primary system disadvantage or other undesirable flaws of the function.
- State the improvement as a dependant variable
- What value would you like to change this dependant variable to. What would be an IDEAL or ENDURING Goal?

Or Flaw Remains

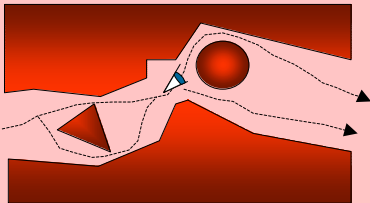


- The flaw is **not improved**, but no harm or weakness occurs....
- Leads to automatic contradiction

## Identify Controlling (Independent) Variables

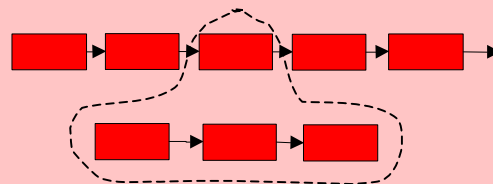
- Intuition
- Equations
- Models
- Experiments

Empathy



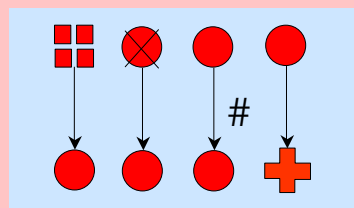
- Put yourself in the place of the objects that you are investigating
- Use Miniature Intelligent People (MIP)

Flow of Goods & Information

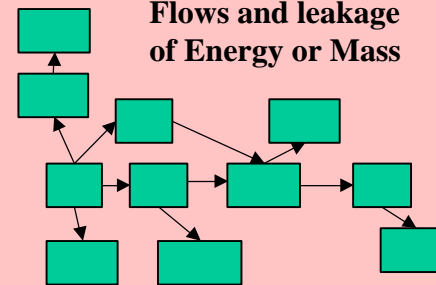


- Break down maps into progressively smaller steps

Table of  
Controlling Variables

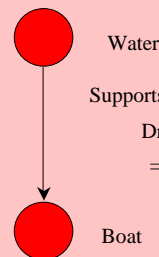


Flows and leakage  
of Energy or Mass



- Break down maps into progressively smaller steps

Relative Too....



Supports

Draft (is low)  
= f (Weight of Boat  
Density of Water)



- Every Controlling Variable is measured relative to something. Consider changing that something

## Drive Values to the Extreme

Setting

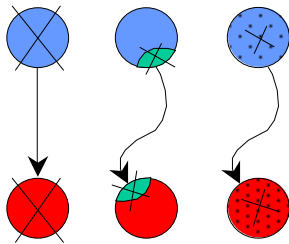


Drive the Value of the Controlling Variables to Hit the Enduring Goal without regard for other things that become worse

# Table of Controlling Variables

## Existence

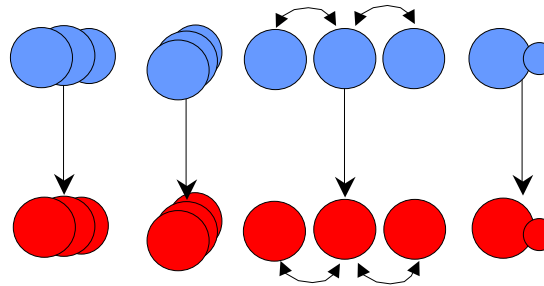
### Change Existence



- Eliminate the **tool**, its **source** or its **path**
- Eliminate the **product**, its **source** or its **path**
- Identify and eliminate only the interaction site on the tool or product.
- Remove only the **micro-constituents** that interact.
- Contradiction often solved by transparency

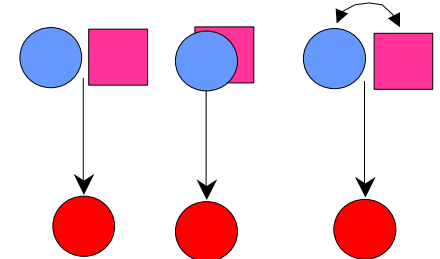
## Multiplying

### Multiply Like Elements



- Multiply the product
- Multiply the tool
- Combine multiple elements in different orientations. New capabilities should emerge.
- Make the multiplied elements modify each other. New capabilities should emerge.
- **Nest or stack** the elements
- **Bias** some of the elements to handle different operating conditions

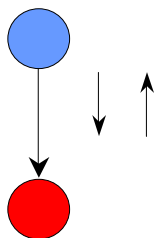
### Multiply Diverse Tools



- Identify another effect/tool which performs the same function.
- What is the variable value of the new tool which would extend the capability of the two together?
- Identify the cheap tool which should deliver most of the function.
- Transfer the whole new tool or just the variable and its value.
- Merge the tools. A new capability should emerge.
- Make the tools modify each other. A new capability should emerge.

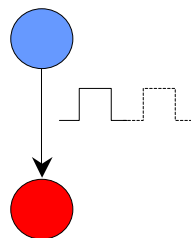
## Change Timing

### Coming & Going



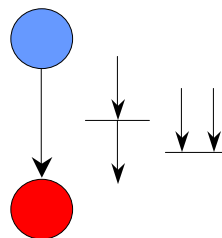
- Does the Tool Follow a Path?
- Can the Tool perform the function on the entire path?

### Different Time



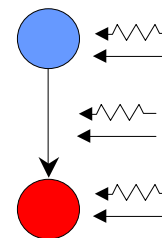
- Process Map the changing conditions over time.
- Does the requirement for the function vary over time?
- Could other tools help out at another time?
- If the modification is performed as a step in a process, can the sequence be changed to a more favorable time?

### Partial Modification



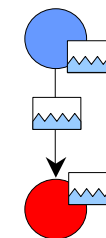
- Can the modification be broken into two (or more) **stages**?
- Can the operation be broken into **parallel** stages
- Can setup be performed at same time as operation?
- Implies use of a **previously placed tool**.

### Uncouple Other Functions



- Identify other functions performed on the tool, product and field.
- Does uncoupling these other functions improve the function?

### Storage of Action or Field



- Identify the main fields of the function.
- Consult the next page for ways to store this field
- Is this field stored, even for an instant in the tool, product or in space? (is there a lag between field generation and application?)
- Is there energy storage in oscillations?
- Does storage improve the function?
- Can storage be a mediator between the tool and product?

Elastic Force Internal & External  
**Springs**  
**Elastic Media**

Gravity  
**Height of Objects**  
**Weight or Density**

Friction

Adhesive

Centrifugal Force  
**Momentum**

Inertia of Bodies (Note Direction)  
**Momentum**

Coriolis Force  
**Momentum**

Buoyant force  
**Average Density of**  
**Buoyant Object**

Hydrostatic Pressure  
**Pressure Vessel**

Jet Pressure  
**Fluid Momentum**

Surface Tension  
**Surface Tension**  
**Area**

Odor & Taste  
**Container**

Diffusion  
**Pressure**  
**Vessel**

Osmosis  
**Container**

Chemical Fields  
**Explosives**  
**Chemical Potential**

Sound  
**Oscillation Chamber--Distance**  
**of Travel--Resonance of Objects**

Vibrations & Oscillations  
**Oscillation Chamber--Distance**  
**of Travel--Resonance of Objects**

Ultrasound  
**Oscillation Chamber--Distance**  
**of Travel--Resonance of Objects**

Waves  
**Oscillation Chamber--Distance**  
**of Travel--Resonance of Objects**

Corona Discharge  
**Low Field**  
**Vacuum**

Current  
**Inductance**  
**Super-conducting media**

Eddie Currents (internal and skin)  
**Inductance**  
**Super-conducting media**

Particle Beams  
**Low Field**  
**Vacuum**

Thermal Heating or Freezing  
**Thermal Mass**

Thermal Shocks  
**Thermal Mass of Two**  
**Objects**

Nuclear Forces  
**Radio-active**  
**Materials**

# Storage of Fields

Electrostatic Field  
**Capacitance--Piezo**  
**Electric Materials**  
 Electromagnetic (Voltage)  
**Separation Space**

Magnetic Field  
**Permanent**  
**Magnet**

Information  
**Data Fields**

Radio Waves  
**Separation Space**  
**Oscillating Circuits**

Micro-waves  
**Separation Space**  
**Oscillating Circuits**

Infrared  
**Separation Space**  
**Hot Objects**

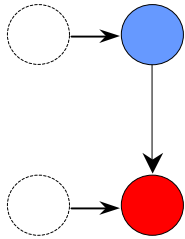
Visible Light  
**Separation Space**  
**Hot Objects**  
**Fluorescence**

Ultra-violet  
**Separation Space**  
**Hot Objects**  
**Fluorescence**

X-Ray  
**Separation Space**  
**Radio-active Material**

## Change Location or Movement

### Change Location



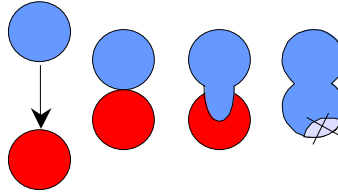
- Define the entire location Envelope for the tool and product (What space can the tool and product be located in?)
- Move the tool about in higher dimensions. Are the fields affected?
- Move the product about in higher dimensions. Are the fields Affected?

### Change Zone Location



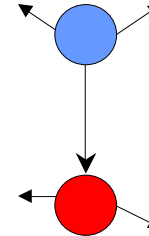
- Locate the **exact zone** of the modification on the tool and product.
- Does changing the location affect the fields of the function?

### Change Distance Contact or Combining



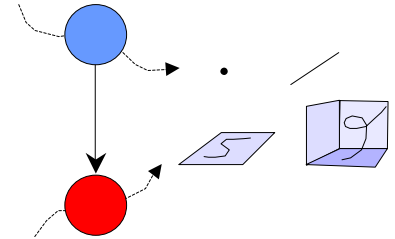
- Does changing the **distance** change the fields?
- Does **contact or separation** change the fields or introduce new fields?
- Try different locations for contact.
- **Nestle** one into the other
- **Combine** the tool and product. Consolidate. Look for new capabilities
- **Combine with super-system.** Look for much consolidation, new capabilities and room for growth.

### Change Velocity Acceleration Or Jerk



- Does changing the velocity or relative velocity improve the function?
- Try **stopping** the tool or product
- Does changing the **acceleration** improve the function?
- Does changing the rate of change of the acceleration (jerk) improve the function?

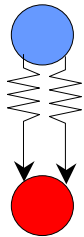
### Change the Path



- Does changing the path or relative path change the function?
- Try different paths in different dimensions.
- Useful functions **increase** path dimensions. Harmful functions **decrease** path dimensions.

## Change Scale

### Change Intensity or Scope



- Is the modification sometimes weak, at least in one direction?
- Does grossly increasing the intensity help in **any** way?
- If you were an **artist**, how would you work the defect into the picture?
- How would you extend the defect?
- Imagine the **defect multiplied**, what pattern would you multiply it to yield a useful function?
- **Excessively perform** the function and then remove the excess.

### Change Size of Interaction Zone



- Does volume or surface area of the interaction site affect the function?
- Does the interaction zone cross a **critical boundary**?
- Try changing the size of the interaction zone.
- Try increasing the **dimension** of the zone. Increase for useful. Decrease for harmful.

### Change the Number of Interaction Sites



- How many interaction sites are there now on the tool and product?
- Try changing the **number** and locations of the sites.

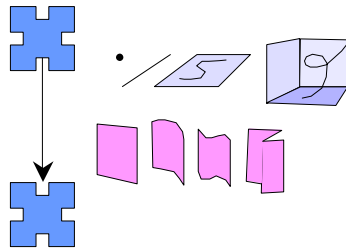
### Change to Micro-Sites



- Imagine the function at smaller and smaller scales at multiple small interaction sites.
- Are the sites on the surface or in the volume?
- Can the tool be multiplied to make this happen?
- Does the function **already exist, to any degree**, at the bulk material level? Boost this function.

## Change Object Structure

### Change the Shape



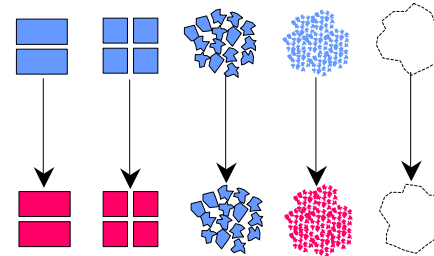
- Identify **poorly used space** around the tool and product
- Identify the dimensional construction of the interaction zone.
- If you were looking at a dimensioned drawing of the tool and product, what would be the **critical dimensions** for the function?
- Play like the tool and product are made from expandable clay. Form the tool and product into the ideal **shape, size and aspect ratio**.

### Change Symmetry



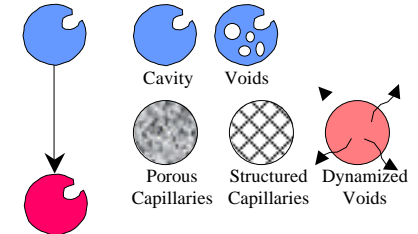
- Are the variables critical to the function symmetrically located?
- Change symmetry to **another axis**
- Make the tool or product **unsymmetrical**
- Make **symmetrical**

### Segmentation



- Would increasing the number of **interaction sites** improve the function?
- Make the sites **independent**
- Visualize dividing into **multiple copies** of the original elements.
- Change to a **powder or aerosol**
- Does the **shape** of the particles matter?
- **Decompose:** Grains--Dust--Molecules--Atoms--Ions--Sub Atomic Particles
- **Combine:** Sub Atomic Particles--Ions--Atoms--Molecules--Dust--Grains
- **Solidify a liquid** or its constituents into particles

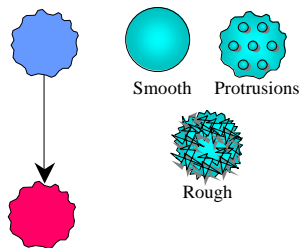
### Voids and Capillary Structures



- Place a specially shaped cavity in the tool or product.
- Place **specially shaped** voids in the tool or product (honeycomb, spherical, random)
- Use open or closed celled **porous** materials
  - Sintered powders
  - Dried or fired clays
  - porcelain
  - Sand
  - Loose Powders
  - Pumice
- Make the tool or product from **structured capillary** materials such as:
  - Fabrics
  - Fiber batting
  - Fiber bundles (thread, string, rope...)
  - Screen or layers of screens
  - Capillary tubes or tube bundles
- Fill the porous material with special **fluids** or allow fluids to move through the porous material

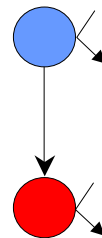
## Change Surface Properties

### Change Surface Shape



- Make the surface **smooth** if it is not already
- Make ridges **protrusions** in the surface of the tool or product (Random or structured)
- Make the surface of the tool or product **rough** (random or structured)
- Use a finer and finer surface roughness

### Change Surface Properties



- Identify the fields which deliver the modification.
- Consult the **Table of Surface Properties** to see which ones modify the fields of the function

Elastic Force Internal & External  
**Creep Coefficient--Strength--**  
**Elasticity--Toughness--Ductility**

Gravity

Friction  
**Protrusions--Roughness--Phase**  
**Friction Couple--Slipperiness**

Adhesive  
**Adhesiveness--Phase**  
**Cohesiveness**

Centrifugal Force

Inertia of Bodies (Note Direction)

Coriolis Force

Buoyant force

Hydrostatic Pressure

Jet Pressure

Surface Tension  
**Bulk Properties--Phase**  
**Wetted Circumference--Temperature**

**Surface Phase**

Odor & Taste

**Chemical Composition**  
**Surface Phase**

Diffusion

**Surface Porosity**  
**Surface Phase**

Osmosis

**Surface Molecular Structure**  
**Surface Phase**

Chemical Fields

**Chemical Reactivity**  
**Surface Phase**

Sound

Vibrations & Oscillations

Ultrasound

**Surface Phase**

Waves

Corona Discharge

**Surface Protrusions**  
**Roughness--Surface Phase**

Current

**Continuity--Surface Phase**  
**Conductivity**

Eddie Currents (Internal and Skin)

**Continuity--Surface Phase**  
**Conductivity**

Particle Beams

**Phase--Chemical Reactivity**  
**Surface Molecular Weight**

Thermal Heating or Freezing  
**Surface Protrusions**  
**or Roughness--Surface Phase**

Thermal Shocks  
**Surface Protrusions**  
**or Roughness--Surface Phase**

Nuclear Forces  
**Nuclear**  
**Particle Type**

# Surface Properties

Electrostatic Field

**Protrusions**  
**Roughness**

Magnetic Field

Electromagnetic (Voltage)

**Continuity**  
**Conductivity**

Information

Radio Waves

**Reflectivity--Phase**  
**Absorbitivity**  
**Emissivity**

Micro-waves

**Reflectivity--Phase**  
**Absorbitivity**  
**Emissivity**

Infrared

**Reflectivity--Phase**  
**Absorbitivity**  
**Emissivity**

Visible Light

**Reflectivity--Phase**  
**Absorbitivity**  
**Emissivity**

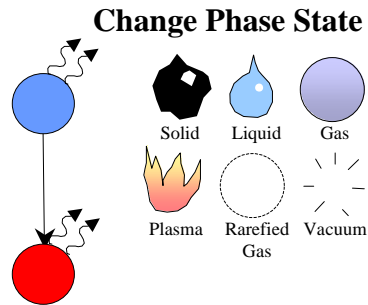
Ultra-violet

**Reflectivity--Absorbitivity**  
**Emissivity--Phase**  
**Fluorescence**

X-Ray

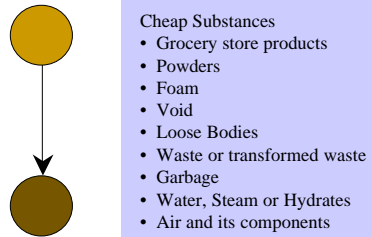
**Atomic**  
**Weight**

## Change Bulk Properties



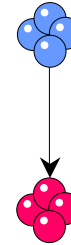
- Change the Phase of the tool
- Change the Phase of the Product
- Change the Phase of the Environment
- Try each phase separately
- Note that **state of phase controls most fields**

## Change of Substance



- Identify the fields of the function
- Look in the **Table of Bulk Properties** for controlling fields
- Identify different materials which have these properties
- Can the bulk properties be changed by chemically transforming, decomposing, combining existing materials or by heat treatment?
- Can the material be further enhanced by adding a field?

## Change to Foam



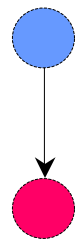
- If the tool or product were made of foam, would the function be improved?

## Match Tool & Product values



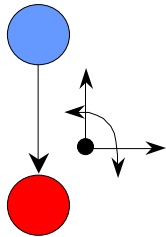
- Match or mismatch tool and product properties, especially if they are in contact or must move or expand together

## Inert Substances



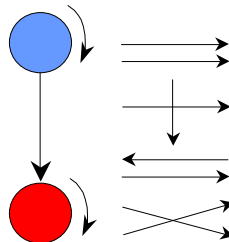
- Change the tool or product to an inert substance

## Change Direction of Action or Fields



- Identify the Field Gradients
- Identify current direction of Action or fields
- Change or reverse the direction of the action or fields.

## Rotate or Change Orientation



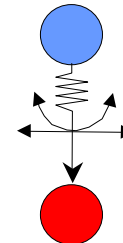
- Try different rotational orientations, relative to each other.
- Change from linear to rotary motion.

## Reverse the Action



- What constitutes the reverse of the current action?
- What is the action performed relative to? Change that instead.
- Drive the reverse action to the extreme.

## Avoid Field Gradients



- **Draw the field lines** and the equipotential lines
- Does either element move or rotate through a field gradient?
- Make elements move **along** equipotential lines
- If either element already moves along equipotential lines, **changing the field slightly** can make the function adjustable. How can the fields be changed?

## Changing Direction

# Bulk Properties

Elastic Force Internal & External  
Creep Coeff...--Strength--Elasticity--  
Toughness--Ductility--Physical Phase

Gravity  
Density--Phase

Friction  
Temperature--Viscosity  
Phase

Adhesive  
Temperature  
State of Phase

Centrifugal Force  
Density

Inertia of Bodies (Note Direction)  
Density--Phase--Elasticity  
Coeff.. of Restitution

Coriolis Force  
Density

Buoyant force  
Density--Phase

Hydrostatic Pressure  
Gas Constant--Phase  
Gamma--Temperature

Jet Pressure  
Density--Phase

Surface Tension  
Cohesiveness  
Phase

Odor & Taste  
Chemical Composition  
Phase

Diffusion  
Molecular  
Weight--Phase

Osmosis  
Molecular Size  
Ionization Potential--Phase

Chemical Fields  
Chemical Composition  
Phase

Sound  
Coeff... of Restitution  
Viscosity--Density--Phase

Vibrations & Oscillations  
Coeff.. of Restitution  
Viscosity--Density--Phase

Ultrasound  
Coeff.. of Restitution  
Viscosity--Density--Phase

Waves  
Coeff.. of Restitution  
Viscosity--Density--Phase

Corona Discharge  
Ease of Ionization  
Rarefaction--Phase

Current  
Conductivity--Phase  
Trans-conductance

Eddie Currents (internal and skin)  
Conductivity--Phase  
Trans-conductance

Particle Beams  
Molecular Weight

Thermal Heating or Freezing  
Thermal Conductivity  
Coeff.. Thermal Expansion  
Thermal Capacity--Phase

Thermal Shocks  
Thermal Conductivity  
Coeff.. Thermal Expansion  
Thermal Capacity--Phase

Nuclear Forces  
Atomic Weight--Density  
Temperature

Electrostatic Field  
Dielectric Constant

Magnetic Field  
Magnetic Permeability  
Magnetic Hysteresis--Curie Point

Electromagnetic (Voltage)  
Permeability--Conductivity  
Dielectric Constant

Information

Radio Waves  
Transparency--Phase  
Image Splitting  
Refractive index

Micro-waves  
Transparency--Phase  
Image Splitting  
Refractive index

Infrared  
Transparency--Phase  
Image Splitting  
Refractive index

Light (Coherent & light Pressure)  
Transparency--Phase  
Image Splitting  
Refractive index

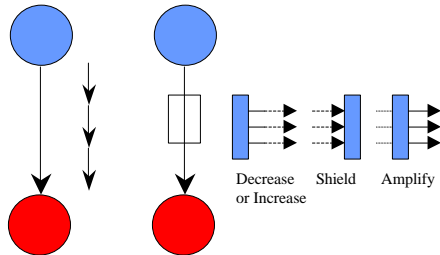
Ultra-violet  
Transparency--Phase  
Image Splitting  
Refractive index

X-Ray  
Molecular  
Weight



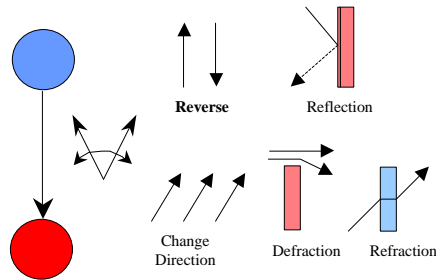
## Structure Fields in Space

### Change Field Intensity or Conductance



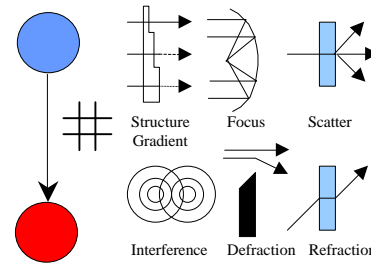
- Draw Field Potential Lines and Gradients
- Increase or Decrease the field intensity from the Tool
- Use an intermediate substance to shield, amplify or decrease the field
- Change the Conductivity of the Mediator

### Change Field Direction



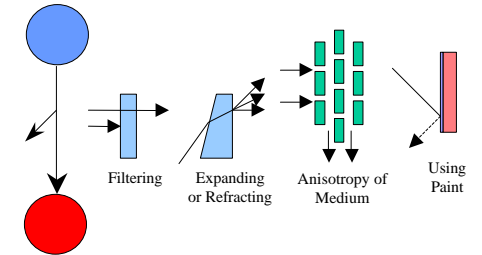
- Identify the field gradients and potential lines
- Is the field **direction** ideal? Change to the ideal field direction.
- What would happen if the fields were **reversed**?

### Change Field Gradient or Concentration



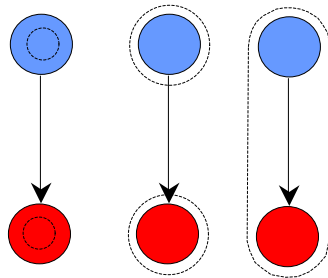
- Draw the field gradients and field potential lines as they currently exist
- Change the **gradient** to the ideal
- Move to higher dimensions
- Change the dimension of the affected area of the product
- Use heat to change the refractive index
- Sharply change the field gradient to eliminate harmful functions
- Make the Field **Coherent**

### Separate Field Components



- Can the field be broken into various components?
  - Direction
  - Frequency
  - Variety of Fundamental Fields
- Identify the **truly useful components**
- Use a different Color: Filter field or reflect only certain frequencies
- Change the receptivity of the product to certain field components
- Search the **Table of Effects** for ways to separate field components
- Can Changing to a higher dimension help the filter?

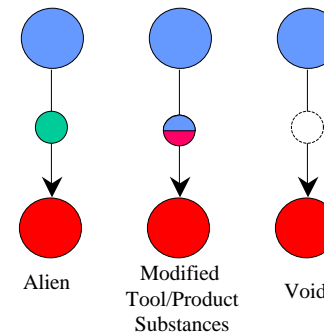
### Adding or Superimposing Fields



- Draw existing field lines and gradients
- Identify substances and constructions which react strongly to the existing fields
- Identify fields which would react strongly to the existing substances
- Identify other existing fields in the environment
- What field constructions, new or existing could be **superimposed** on the existing field construction?
- Consider adding a **counter field**
- Superimpose a new **Field Receptivity** on the product
- Superimpose a new field type
- Pre-stress the parts
- Consult the table of **Storage of Fields** for consideration of residual fields

## Adding or Superimposing Fields

## Mediators



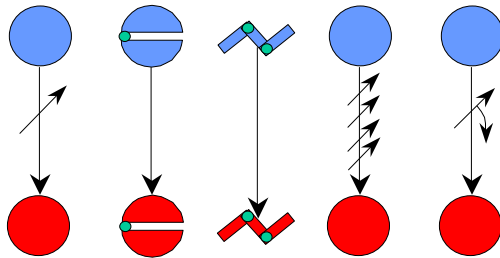
- Is direct contact required?
- Identify the field and gradient
- Make a good guess at an **alien mediator**
- Use a **modification** of the tool substance
- Use a **modification** of the product substance
- Try **mixtures** of the tool and product
- Try **multiplied versions** of the tool or product
- Place a **void** or rarified gas between the tool and product
- Would **enclosing** both the tool and the product in the mediator help?
- Break down into **two functions** and then go back through and idealize both functions.

### Possible Modifications to Substances

- Phase
- Chemically altered
- Heat treatment
- Electrification
- Heated
- Foam
- Decomposed
- Mobilized
- Internal additives
- Ionized
- Recombined
- Dilution of constituents
- Concentration of constituents
- Change of Bulk Properties
- Form structures at micro level

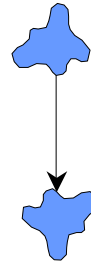
## Make Adjustable

### Make Adjustable



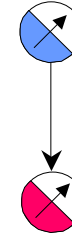
- Which of the controlling variables of the tool, product or field can be made adjustable? (Include relative controlling variables).
- Place **Joints** in the tool or product
- Increase the **number of joints**
- If a variable is already adjustable, **increase** the degrees of freedom.
- Make **several** controlling variables adjustable
- Make an existing or new variable **continuously adjustable**.

### Make Flexible



- **Everything** is flexible. Look at the system as a collection of springs, masses and dampers.
- Change the flexibility of the **tool**.
- Change the flexibility of the **product**.
- Change the **direction** of flexibility.
- Make very flexible by transforming to a **liquid or gas**.

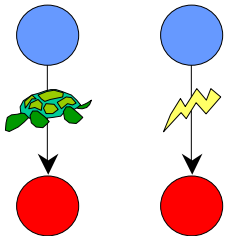
### Operate Near or Far from Critical Point



- Does the controlling variable have a **natural critical condition** or threshold, such as boiling point or curie temperature?
- Can a critical condition or threshold **be created** for a variable which does not normally have one, such as a bi-stable condition?
- If the function is useful, **operate near the critical condition** so that small inputs can trigger large results.
- If the function is harmful, operate **far away** from the critical point.

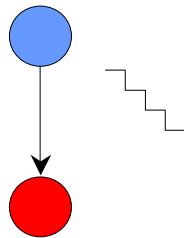
## Vary in Time

### Change Speed



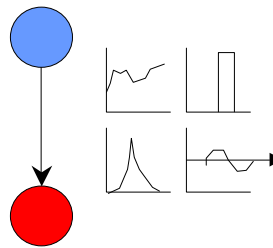
- What would happen if the function were slowed way down (hours, days, weeks, months, years)
- How are the fields changed by performing the modification more slowly?
- Is the function improved if the modification is performed very rapidly? (Days, hours, minutes, seconds....)
- If the modification were performed more rapidly, would other harmful functions be precluded?

### Discrete Steps



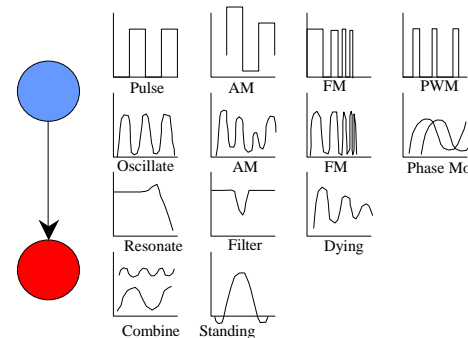
- **Multiply or segment** the tool into separate pieces.
- Each piece moves into action in discrete steps or into fixed positions or amplitudes.

### Vary in Time or Pulse



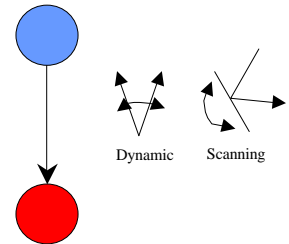
- If you could continuously vary the action in time, what would be the **perfect shape** of the curve?
- Square pulse the action.
- Shape the pulse.
- Make the pulse travel.

### Pulsate or Oscillate



- Pulsate or oscillate the tool
- Pulsate or oscillate the product
- Pulsate or oscillate the field
- Pulsate or oscillate the product receptivity
- Resonate the tool, product or field
- Create standing waves
- Cancel oscillations in the tool, product or field
- Mismatch the product natural frequency with the tool driving frequency

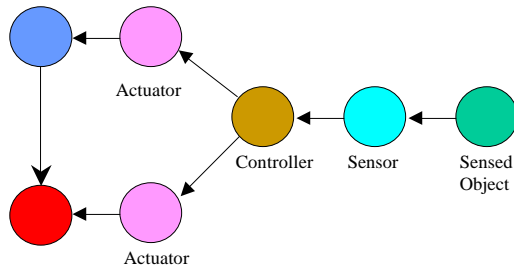
### Vary Field Direction



- Identify the field gradient and potential
- Does varying the field direction improve the function?

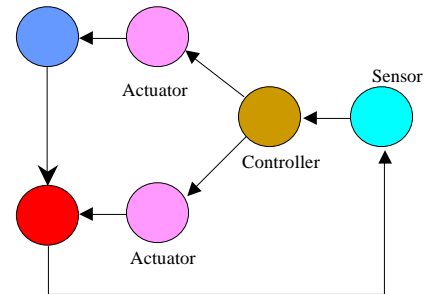
## Control

### Add Control Elements



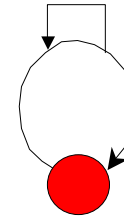
- Does the modification need to be more precise?
- Is the tool or product already adjustable?
  - Discrete positions=bang-bang
  - Continuously adjustable?
- Are means provided to sense changing conditions
- **Add Actuator** to tool or product
- **Add Controller**
- **Add Sensors**

### Closed Loop Control



- Does the modification need to be yet more precise?
- Sense the important modified variable
- Increase the number of variables sensed
- Increase the order of the variable sensed (first derivative, second derivative...)

### Passive Control



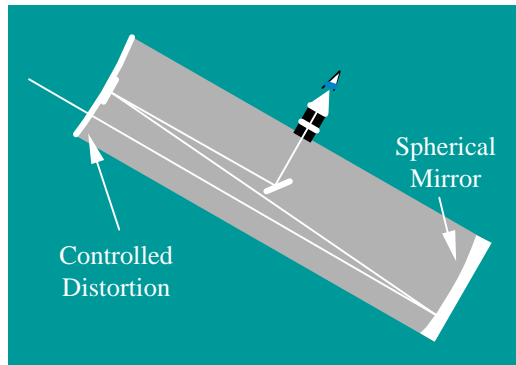
- **HIGHEST FORM OF CONTROL**
- Does the system ideally use one field for operation and control?
- Provide for self-service operation (Ideal Tool / Effect)
- Identify the **critical point** at which small changes in input cause large changes in output
- Move the critical point to the desired control point.

# Resolve Contradictions

# Removing the Problems of Improving to the Extreme

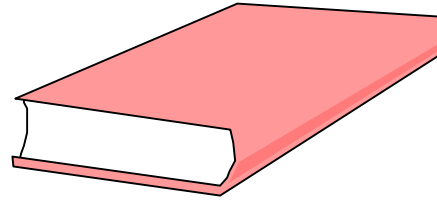
## Alternative Approaches

### Fix the New Offending Function



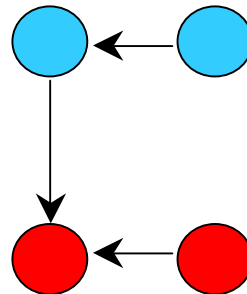
- Identify functions which become worse or harmful due to the extreme change.
- Go back and identify this as the function which must be improved.

### Table of Contradictions



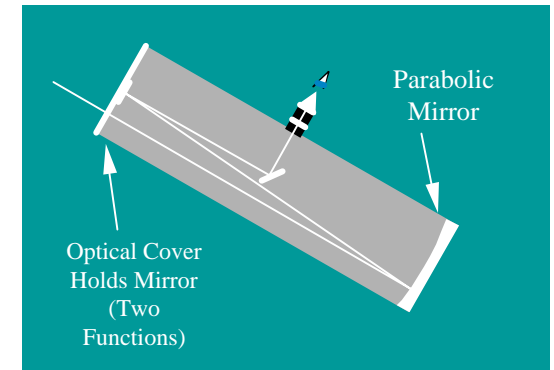
- Consider this alternative first as it generally creates the most ideal solutions

### Introduction of New Functions



- Sometimes there are no objections to a change, yet the change requires the introduction of a new function and there are no elements which perform this new function.
- Go back to Redefining Useful Functions and consider appropriate ways to add the new function
- This is usually done as a last resort as the addition of elements is less ideal

### Reduce the Cost Penalty



If new elements are costly, increase the number of functions performed by the new costly element.

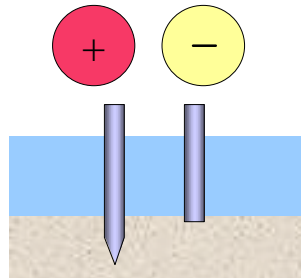
# Table of Contradictions

## Separate in Space

Sharp

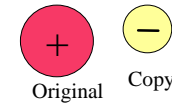
Blunt

### Complete Separation



- Which element must have conflicting values? Begin with that element and its duplicate
- Modify the duplicate element so that it has the anti-value

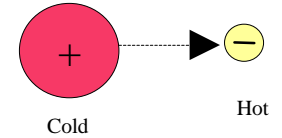
### Copy



Photographs  
Movies  
Paint Coverings  
Molds  
Time lapse photos  
Impressions  
Silhouettes  
Castings  
Resists  
Projections

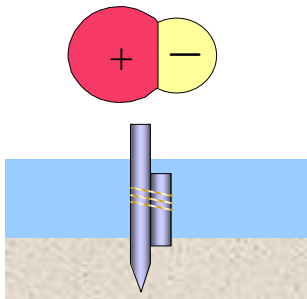
- Make a *copy* of the element that requires conflicting values. The Original has the required value. The copy has the anti-value

### Take Away



- Does the contradiction exist because one of the elements is at risk or causes a dangerous situation?
- Separate out the part of the element which is dangerous or at risk and make it as small as possible. (Both parts still interact).
- One has the anti-value of the other

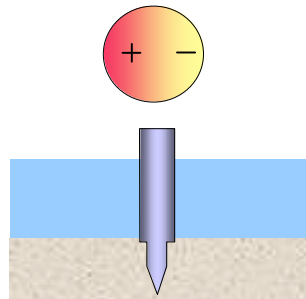
### Carrier



Inert Carriers  
Dual States-same material  
Dual Phase Substances  
Thin Films  
Paint

- One element has the desired value. It is attached to another element, (the carrier), having the anti-value

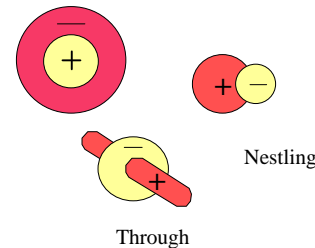
### Non-uniform



Transformers(electric, levers, etc.)  
Standing Waves  
Concentrated Additives  
Especially active Additives

- One element** has both conflicting values
- Part of an object has the anti-value
- Consider a smooth transition between values

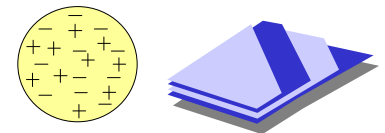
### Nesting



Dual Phases-Change of State  
Foams  
Porous materials  
Paint  
Inert Environments

- Separate into two elements with opposing values
- Nest the elements

### Mixture



Fabrics and Matrix  
Multi Fiber Fabrics  
Multi Property Laminates  
Mixtures of Different Molecules  
Gels (Liquids + Solids)  
Pastes (Liquids + Solids)  
Foams (solid or liquid)  
Capillary Structures (Solid + Liquid)  
Components of Solids or Liquid

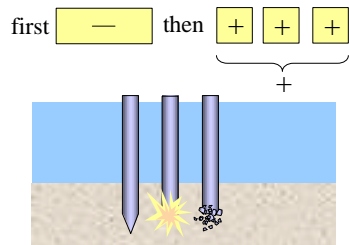
- The element becomes a composite structure which is a mixture of both values
- Could existing bulk constituents be modified to have the anti-value?
- Consider finer and finer scales down to sub-atomic particles

# Separate in Time

First **Sharp** then **Blunt**

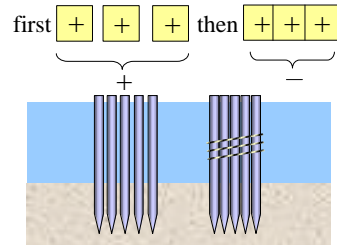
(Usually Requires Addition of Function)

## Segmentation



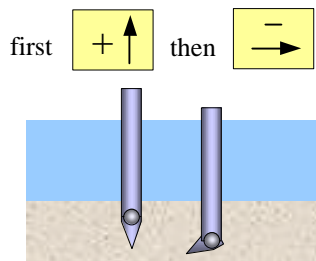
The values of the system are changed when the object is segmented.  
• Consider performing this at the micro-level. Dissolving, etc.

## Merging or Interacting



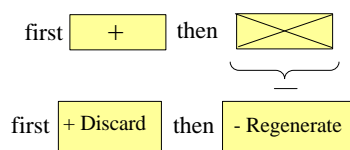
• Begin separated and then merge the pieces, or vice versa.  
• Begin separate and then make individual pieces interact.

## Changing Direction



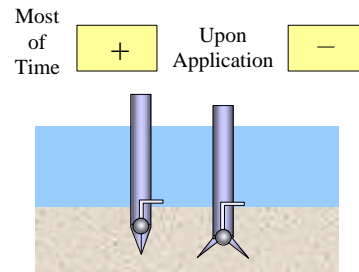
• Can variable be oriented in direction?  
Change orientation in time.

## Discarding and Regenerating



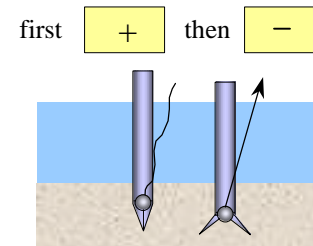
• Change of State (Solution, phase, breakable, chemical stage, heat effect, phase accompanying effects).  
• Self elimination or “disappears”  
• Chemical decomposition  
• Physical Transition to new state

## On Condition



• What changing conditions drive the need for the conflicting values?  
• Can these changing conditions, themselves, drive the change?

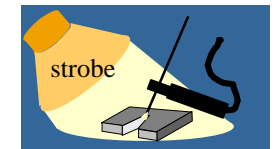
## Make Adjustable



• Is the Variable Currently Adjustable?  
• **CHANGE OF STATE:** Solution, phase, breakable, phase accompanying effects, heat effect, chemical stage, etc.  
• **TEMPORARY ADDITIVES**  
• **VIBRATION EFFECTS:** First vibration Effect #1 then Effect #2

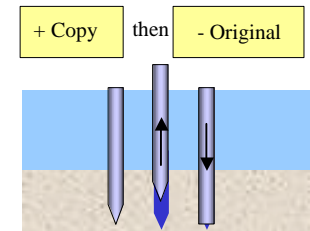
## Periodic Action

first **+** then **-** then **+** ...



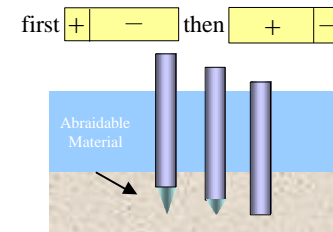
• First the value, then the anti-value, then the value, etc.  
• Bright to see puddle, dark to see arc...

## Copy



• Can the **essential part** of one of the opposing values be **copied** into another object?

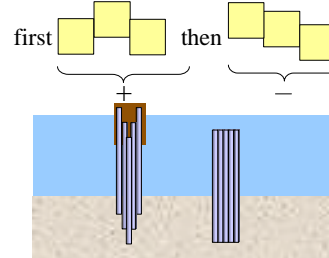
## Transformable States



- Solid to Liquid
- Solid to gas
- Gas to liquid
- Combustible materials
- Soluble or dissolvable materials
- Fissable
- Glue
- Settable liquids--(increase of volume)
- Easily breakable or abradable
- Explosive
- Exo-Endothermic
- Polymerizing or de-polymerizing
- Mixture decomposition --Electrolysis
- Disassociation- recombination
- Shape Memory Materials
- Magnetic materials using Curie Effect

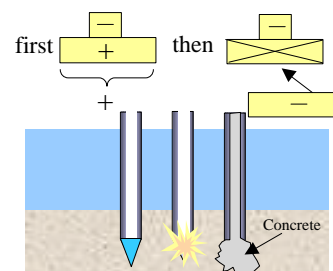
• Consider the **list** of Transformable substances  
• Can **both** variable values be present at all times, but only one is in abundance at a time?  
• Operate the substances near the **critical point** so that small inputs create strong outputs.

## Reconfiguring or Nesting



• Multiply elements and form them for merging and moving about.  
• Consider Nesting

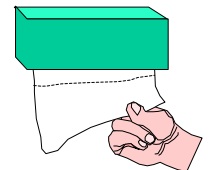
## Intermediary (Discarding the Carrier)



• **Discard** or disengage the **carrier** after use  
• Consider **Replacing** with an object having the anti-value

## Preliminary Action

**+ way(partially)** then **- way(fully)**



• Are the opposing variable values **the way** that the modification is performed?  
• Can the modification be performed one way **partially** and then finished the opposite way? (Cut slowly and rapidly)  
• Can **part of a tool** be preinstalled to perform the modification partially?  
• Can the modification be **excessively** performed and then remove the excess later?  
• If the **reliability** of the modification is the variable with opposing values, can another element be placed to take over in the event of a failure? (Previously Placed Cushion).

## Separate by Scale

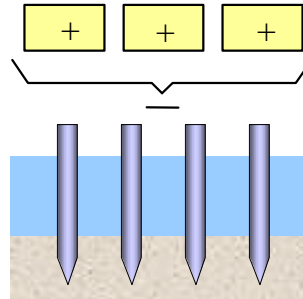
Sharp

Sharp

Sharp

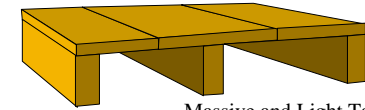
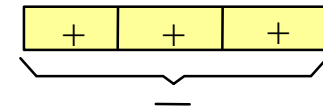
Blunt

## Segmented and Separate



- **Multiply** or **Segment** the object and separate in space
- The parts have the anti-value of the whole

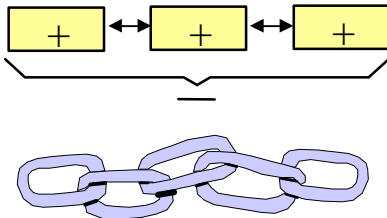
## Merging



Massive and Light Table

- **Multiply** or **Segment** the object and merge
- The merged whole has the anti-value of the individual parts
- **POROUS MATERIALS** (Many Small volumes = large volume)
- **SPHEROIDALITY** (Many curved thin sections = thick section)
- **MACRO-MICRO VIEW** (3 colors on micro level = 1 color at the macro level such as stamps, color TV)
- **EXCESSIVE ACTION** (Uncontrolled + Uncontrolled = Controlled)
- **BLESSING IN DISGUISE** multiply a harmful variable and then arrange and merge to make useful

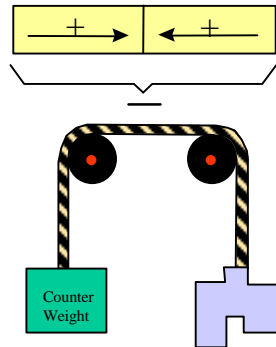
## Interact



Flexible Chain made from Stiff interacting Parts

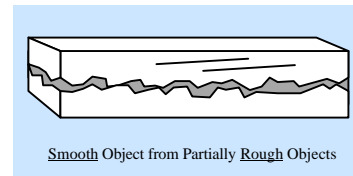
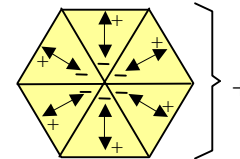
- **Multiply** or **Segment** the main object
- The parts have the anti-value of the whole
- Make the parts interact
  - Parts Adhere
  - Parts Nestle into each other
  - Parts Shaped to Inter-link
  - Parts linked by transmission elements
  - Parts interact by field (Consult table)
- **BLESSING IN DISGUISE** multiply a harmful variable and then arrange and interact to make useful

## Counter-Variables



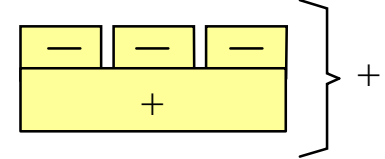
- Does the variable have direction or can it be changed in some way to have direction?
- Draw the field gradients or vectors. Can **same, biased, or different** elements be oriented such that the fields overlap, counter or otherwise nullify each other? (COUNTER WEIGHT) Can the elements **Butt or Tension** each other? (Consider a **transmission** between elements).
- **NEGATIVE + POSITIVE SPRING RATE**
- **NEGATIVE RATE CHANGE OF LEVER ARM**

## Hidden variables



- Does any part of the object have the **desired macro variable**, even in the slightest degree?
- Merge **same, biased, or different** elements and orient them in such a way that the undesirable anti-value is **hidden**, (at least functionally).

## Carrier



Sand Paper: **Inflexible** Particles on a **Flexible** Carrier



- Multiply objects with one value and attach them to a second object with the anti-value.
- **COMPOSITE MATERIALS**
- **USING PAINT**: The field reacts with the paint with (+) value and with the painted object with (-) value.



## Separate by Scale in Time

Sharp

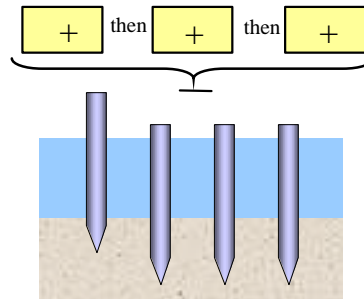
Sharp

Sharp

Sharp

Blunt

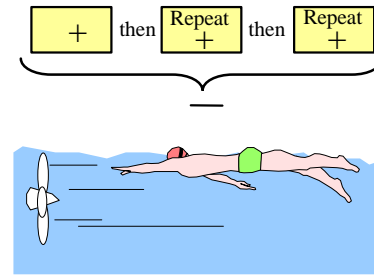
### Separated Use



The variable or action comes into use, one at a time. Over the course of time the values add up to the anti-value

- CHEAP SHORT LIFE: Un-durable+Un-durable = Durable
- SEGMENTATION: Part + Part +Part = Whole
- PARTIAL ACTION: Partial action + Partial action = whole action
- PREVIOUSLY PLACED CUSHION: Unreliable + Unreliable = Reliable

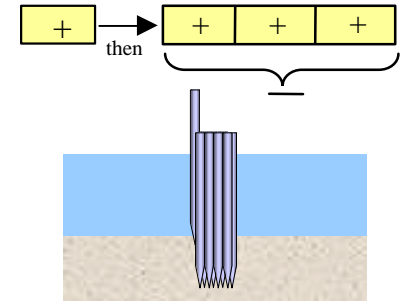
### Repeated Use



A variable is used repeatedly, perhaps after being recovered. **Usually involves a repeated or circular process.**

- SPHEROIDALITY: repeated circular path = long path
- REUSE: Little + Same Little + Same Little = Lots
- UNINTERRUPTED EFFECT: One + Same + Same = Multiple
- REGENERATION: Little + Regenerated little + Regenerated little = Lots

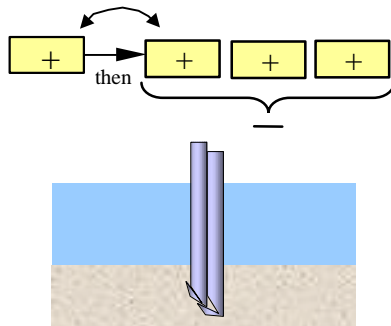
### Merged Use



**Multiply or Segment** the object and merge one at a time. The merged whole has the anti-value of the individual parts

- SEGMENTATION AND REMERGING: Part + Part + Part = Reunited whole
- STORAGE: Little Stored + Little Stored = Lot
- MERGE AT MICRO LEVEL

### Merged Interaction

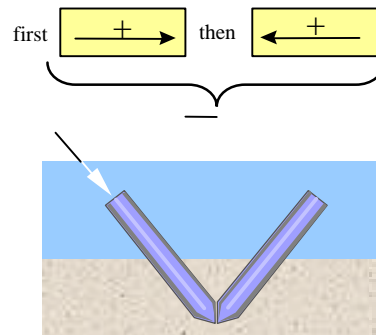


- How can the added part modify the parts already in place to cause them to have the anti-value? (At least a little with each addition until the whole has the anti-value).

#### Interact:

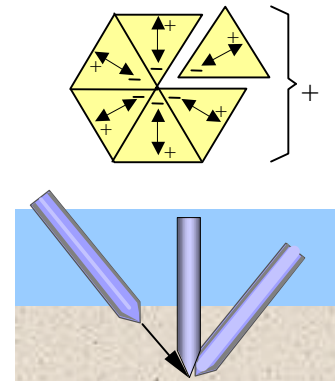
- Parts Adhere
- Parts Nestle into each other
- Parts Shaped to Inter-link
- Parts linked by transmission elements
- Parts interact by field (Consult table)
- Parts reshape the existing parts

### Preliminary Counter-Variables



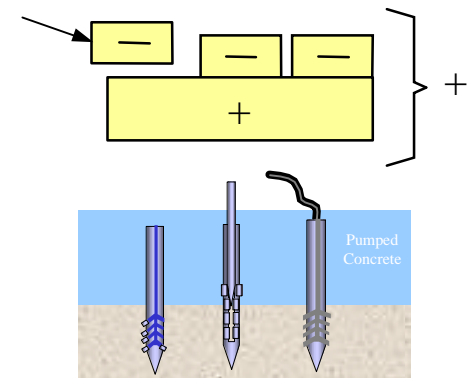
- Does the variable have direction or can it be changed in some way to have direction?
- Gradually orient **same, biased, or different** elements to nullify each other. If different, implies previous placement of a tool.
- **Butt or Tension** the directions
- Consider using a **transmission** between elements
- Consider performing at micro level
- COUNTER WEIGHT
- VIBRATION CANCELLATION
- NEGATIVE + POSITIVE SPRING RATE
- NEGATIVE RATE CHANGE OF LEVER ARM

### Slowly Hidden



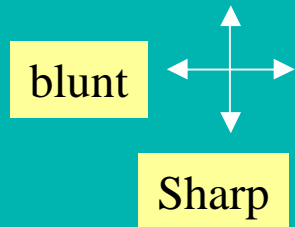
- Does any part of the object have the desired **macro variable**, even in the slightest degree?
- Gradually merge **same, biased, or different** elements and orient them in such a way that the undesirable anti-value is hidden, (at least functionally).

### Adding to Carrier

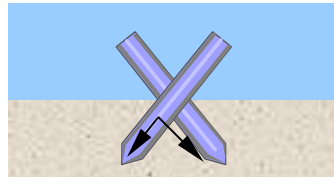
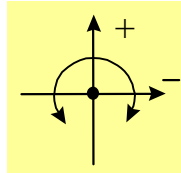


- Multiply objects with one value and gradually attach them to a second object with the anti-value.
- COMPOSITE MATERIALS
- USING PAINT: The field reacts with the paint with (+) value and with the painted object with (-) value.

# Separate by Direction, Path or Plane

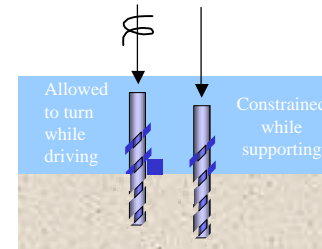
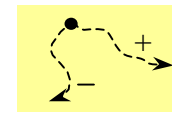


## Direction



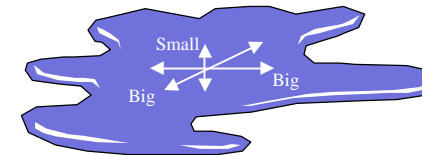
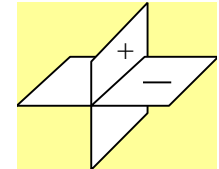
- Does the object have the value in one direction and not in the other? Can it be made to?
- Identify the two functions that it must perform.
- The object performs one function in one direction and the other in the other direction
- EQUIPOTENTIALITY: In a potential field, limit position changes against the potential gradient. For example, eliminate the need to raise or lower objects against gravity. Moves (+) rotationally but No Movement (-) up or down.
- SPHEROIDALITY: Joints or shafts allow rotating but prohibit translating.

## Path



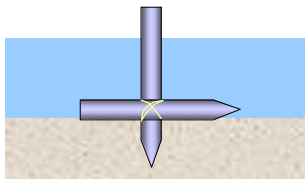
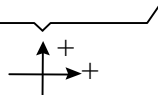
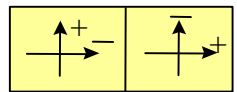
- Can the object operate along a path with two end points?
- Can the object be envisioned as a path with two end points?
- Consider paths in other dimensions
- SPHEROIDALITY: A path may be long (+) around a section of a circle and short (-) around another section of a circle

## Plane



- Does the object have the value in one plane c surface and the anti-value in another?
- Can the object be formed to be this way?
- For example, a city is large in only one plane

## Complimentary Variables



- Can the variable be oriented in a direction, such as force or velocity?
- Do all other directions have the anti -value?
- Combine **same, biased, or different** elements which are oriented in complimentary directions, the whole now has the required value in both directions. A seat belt constrains in one direction. A side impact bag constrains in another. They compliment each other.

## Change Relative Measurement Standard

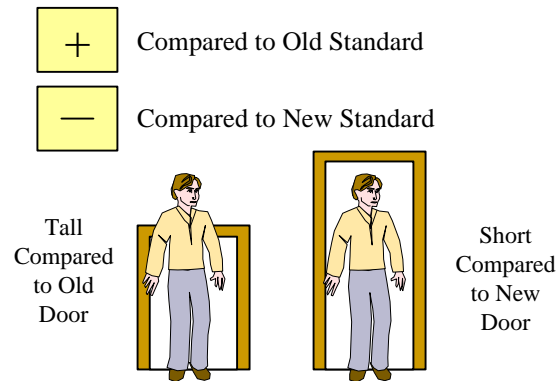
Sharp

Compared to old standard

Blunt

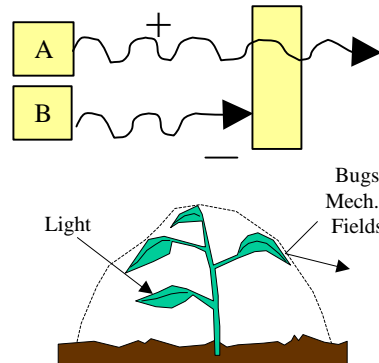
Compared to new standard

### By Comparison



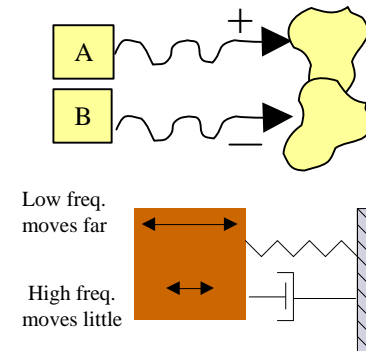
- What is the variable compared to? Change that object instead. (Change the standard by which it is measured)
- **STRONG ACIDIFIERS:** Strong (+) compared to small objects and Weak (-) compared to large objects
- Easy (+) for you and Hard (-) for me
- It is \_\_\_\_\_ in my eyes and \_\_\_\_\_ in someone else's eyes

### Transparency



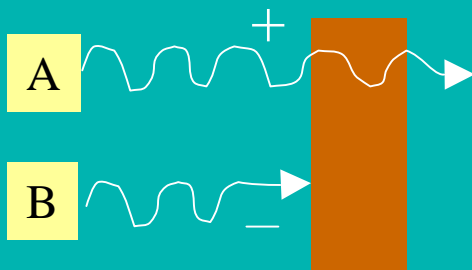
- The system is transparent (+) to Field A and opaque (-) to Field B
- Consult list of fields.
- **INERT ENVIRONMENTS:** Opaque to oxidizing environments
- **PAINT:** Passes certain types of radiation.
- **FILTERS, SIEVES, FABRICS, FILAMENT WRAPS, MOLECULAR SEIVES:** Passes liquids and gasses.
- **FOAM:** Passes solids in motion.
- **FLUIDS:** Passes solids in motion.
- **FABRICS:** Passes solids in motion

### Two Field (or Field Component) Effects



- **PAINT:** Field A reacts with the paint with the (+) effect and the painted article with the (-) effect
- **INERT ENVIRONMENT:** Field A reacts with the inert environment with the (+) effect and with an object in the inert environment with the (-) effect.
  - Nitrogen
  - Nobel gasses
  - Oxidized materials
  - Non-reactive chemicals
  - Foams
  - Water

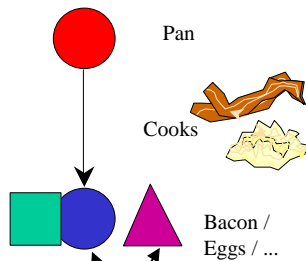
## Field Susceptibility



# Expand & Consolidate

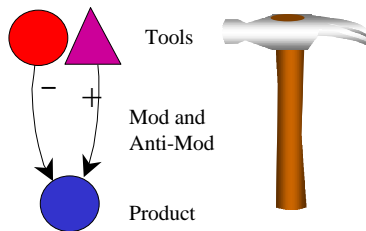
# Expand the Solution

## Diversify the Product



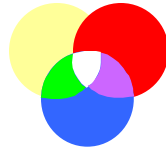
- What other Products in the immediate environment can the tool operate on?
- What modification to the tool would be required to operate on these products?
- Combine the products and see if new capabilities emerge.
- In what useful ways can the products modify each other?

## Merge Anti-Tools



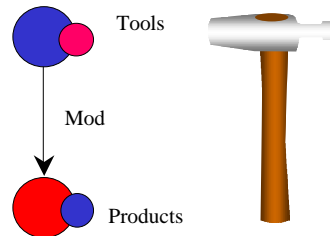
- Identify the Anti-function?
- What effect/tool exists in the environment or could be used to perform the anti-function
- Can this anti-tool be merged with the system?

## Combine Solutions



- When several solutions are found, consider different ways that they can be combined. Especially if the ideal solution is not created.

## Merge Biased Elements



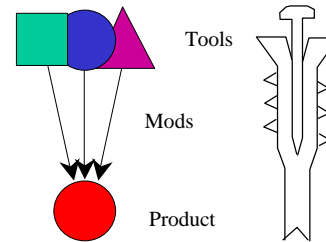
- Can two or more tools with biased properties be merged to operate on slightly different products?

## Permutate the Elements

ABC  
ACB  
BAC  
BCA  
CAB  
CBA

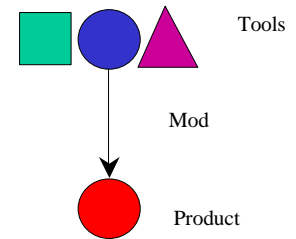
- Must the elements come in a certain order ? Must they be nested in a certain order?
- Can the order be changed?

## Merge Different Tools



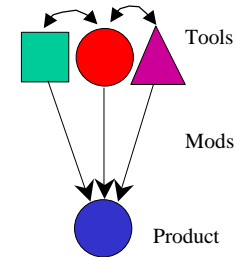
- What Tools in the system perform **different functions** on the product?
- Can these tools be merged into one to create an **unexpected capability**?

## Diversify the Tool



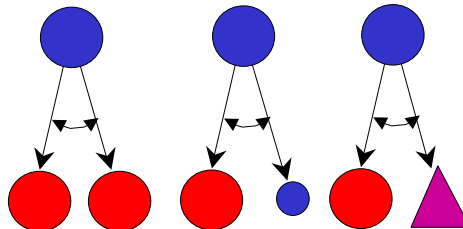
- What other effects/tools perform the **same** function? Consider again combining solutions where alternate tools have been used
- Can several different effects/tools be used to broaden the range of modification?

## Make Different Tools Interact



- What other tools in the environment operate on the product?
- Can these tools interact with each other to create an **unexpected capability**?

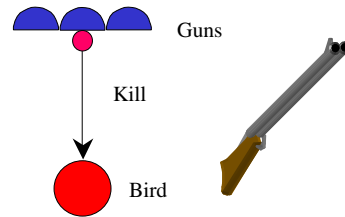
## Switching Back and Forth



- Are all parts of the system at full load?
- Have dummy runs and downtimes been eliminated?
- What else in the system requires the same modification?
- Can biased products be modified?
- Can diverse products be modified?

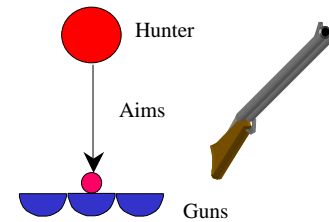
## Consolidate Elements

### Consolidate Multiple Tool Elements



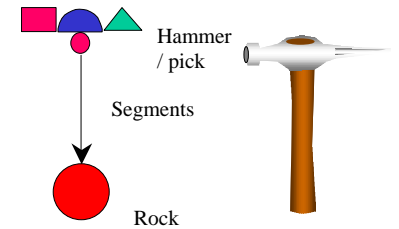
- What part of the tool elements could be made to serve all of the elements?

### Consolidate Multiple Product Elements



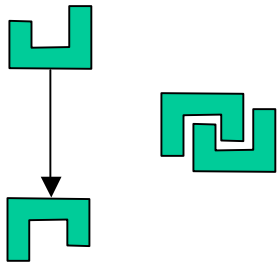
- What part of the product elements could be consolidated?

### Consolidate Unlike Elements



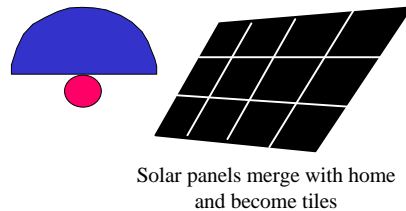
- What part of the tool elements could be made to serve all of the elements?

### Folding Elements



- Consider how the tool and product may be folded **into themselves**.
- Consider different orientations of the tool and product which allow them to be folded **into one another**?

### Merge with Super System and Consolidate



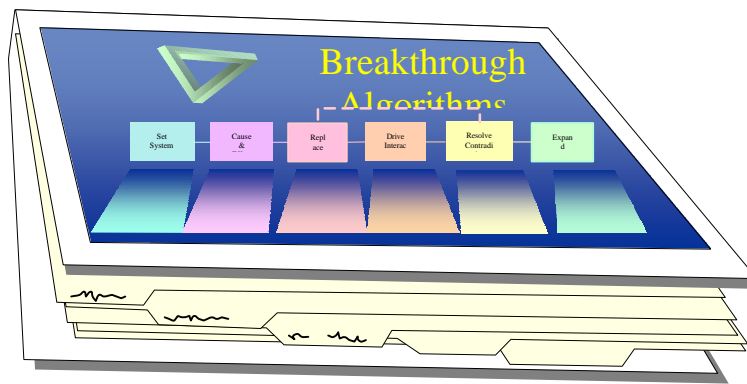
- What elements of the system have functional duplicates in the super system?
- Combine with the super system and then consolidate the parts which are functional duplicates? **Look for unexpected capabilities to emerge**

# Users Manual for *Breakthrough Thinking*

By  
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480-592-5919

***Breakthrough Thinking*** This paper explains another article in this issue of the TRIZ Journal entitled *Breakthrough Thinking*, which presents a sequencing of TRIZ tools in a linear solution process. This material is available to individual readers for use in their own TRIZ studies. Those who seek to use the material for class instruction or other uses are requested to contact the author. While the author's company has given him permission to publish TRIZ articles and solution processes and communicate with the TRIZ community, it does not make direct or implied endorsement of any of the author's publications or communications.

Readers are encouraged to print out *Breakthrough Thinking* and place it into a binder. Tabbing is included to assist navigation. Each tab corresponds to one of the six top-level steps shown on the front of the binder.

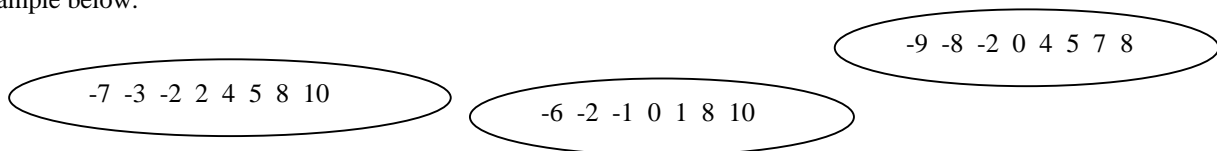


## Binder

Several levels of the class are preferred to match the students capabilities and interests. The highest level of the solution process is presented here.

This work is the result of ten years of classes, personal instruction from TRIZ experts, research, teaching and application and represents dozens of rewritings. It centers around the concept of *functions*.

**Sequencing of TRIZ Tools** One of the purposes of presenting this article is to introduce a train of study that may be productive in moving TRIZ to a new level of science. The current TRIZ tool-sets grossly overlap each other. This overlap makes it difficult to know which tool is the most appropriate for a given application. When the tool steps are broken out and regrouped into relevant groupings, patterns emerge that were not visible before. This method of investigation can be illustrated by the number patterns in the example below.



Each of the groupings represents a TRIZ tool such as S-field Analysis or 40 Principles. Note that there is over-lap between the groups where numbers are repeated. Although each number group is placed in sequence from lowest to highest, no patterns emerge. Without patterns to guide us, it is difficult to see what is missing. Now extract the numbers from the groups and reassemble them into groups of positive even numbers, positive odd numbers, negative even numbers and negative odd numbers as shown below.



*In the context of these groupings, patterns emerge.* For instance, we note that -4 is missing from the negative even numbers, while +6 is missing from the positive even numbers.

The material presented in *Breakthrough Thinking* is the result of reassembling the standard tool-sets into the relevant steps of a solution procedure. Care was taken to sequence the steps to ensure that in order to perform a given step, previous steps *must* be performed, or their output assumed. For example, in order to resolve a contradiction, certain key pieces of information *must* be known. These pieces of information are either developed in previous steps or they are unconsciously assumed. As a result, the solution process follows natural decision points, which branch to multiple solutions.

It is recognized that some well-known and useful tools have not yet been included. The reader is invited to make suggestions for improvement. Requests for the original PowerPoint® presentation will be considered, should the reader be interested in arranging the steps in a more preferred sequence for personal use.

**Goals of the Solution process** The form of the solution process has been guided by the following goals:

**Adjustability** The solution process should be teachable at a variety of levels to suit the capability and interest of the student. The top six steps are always taught, but sub-steps are simplified or eliminated and then added as the student gains greater mastery. This method of teaching is widely used to teach many subjects from music to mathematics. The focus should be on gradually increasing the ability of students while allowing success during the learning process.

**Focus on Functions** Functions are rapidly becoming the language of problem-solving in many disciplines. In this problem-solution process, virtually all steps revolve around the concept of functions.

**Simple Nomenclature** As with many disciplines, the nomenclature of TRIZ is often difficult to learn. One goal of the solution-process is to make the nomenclature fit ideas that the student is already familiar with. For instance, “Dynamism” is changed to “Make Adjustable,” and “Local Quality” is changed to “Make Non-uniform.” A certain amount of new nomenclature is unavoidable, and care should be taken to introduce it at higher levels of the class so as not to intimidate beginning students.

**Smaller Steps** Most beginning students are baffled by the seemingly “obvious” target-solutions presented in TRIZ literature. Many of these solutions are only obvious after the fact and represent large jumps in intuition. Some teachers may feel that these large jumps are a testament to the power of TRIZ and will try to impress the student with them. Unfortunately, many students are discouraged that such solutions are not as obvious to them. One goal of this solution-process is to decrease the step size, so that solutions are the result of several smaller steps rather than a few major leaps.

**Visualization** Along with the concept of “smaller steps” is the idea that solutions need to be visualized in order to become reality. Each step should aid the practitioner in visualizing a final solution. Some may feel that elegance or compactness is sacrificed by expanding classical TRIZ steps, but the goal must always be to make the solution more easily visualized.

**Completeness of Solution** The term “solution” means different things to different people. For the sake of this solution-process, a solution is a sketch that someone could work from to design hardware. No difficult contradictions or problems would remain to be solved. Simply pointing out a physical phenomenon that might be used to solve a problem would not, in this context, be considered a solution, since difficult challenges would inevitably be encountered before a practical solution was evident.



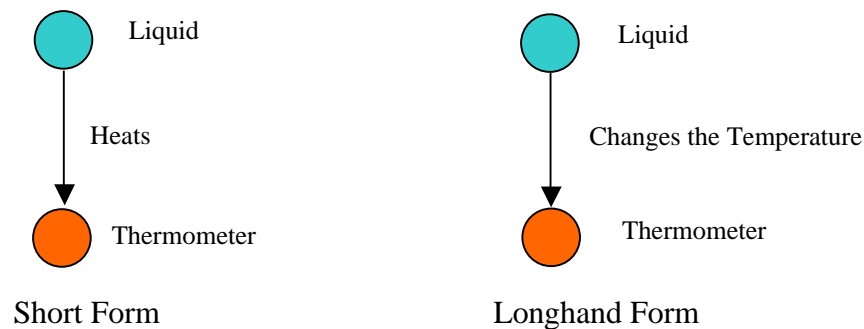
## Functional Nomenclature

It is recognized that the proliferation of TRIZ terms is objectionable and makes it difficult for the new student to translate between different authors. Sometimes different terms are used to mean the same thing. In order for the reader to “translate” while reading *Breakthrough Thinking*, a consistent nomenclature will be established.

A **System** is a collection of objects which provide a function.

In this text and in *Breakthrough Thinking*, the physical element which is acted on will be referred to as the **Product**. In other texts, it may be referred to as the object or artifact. The object which acts on the Product is referred to as the **Tool**.

The action or change which the tool performs on the product will be referred to as the **Modification**. In some texts, this is referred to as the action. It is usually a verb. The use of the term “Modification” will be new to many readers, however it is used to stress the requirement that the action verb must describe a *change or maintenance*. This is sometimes difficult for new students to grasp. Students of the author are encouraged, in the beginning, to use a longhand form of the modification. The longhand form begins with “Change” or “Maintain”. For example, we can describe the action that occurs between a tool “liquid” and a product “thermometer” which is immersed in the liquid. The short form of the modification is “heats” or “cools.” The longhand form of the modification would be “Changes the temperature.”



The use of the term “modification” helps the student to understand that the tool and product must be physical elements. It also helps the student to correctly describe “confusing functions,” such as how paint protects wood. New students often say “Paint—protects—wood”. While the word “Protects” is a verb, it is not a modification as it does not describe a *change* to the wood. Insistence on using the word “Protects” will hamper the problem solver in later steps. The longhand form immediately encourages the student to correctly write “Paint—maintains the location of ---moisture” and “wood—maintains the position of ---paint.” The short version now becomes “paint -- stops-- moisture” and “wood—holds—paint”. Once the long-hand form is firmly entrenched, the student can usually revert back to the short form of the modification for brevity.

The modification to the product is *delivered* by an **Effect**. The term “Effect” is an artificial convention, introduced by TRIZ practitioners that allows us to group physical phenomenon into recognizable groupings. An example of an Effect would be “capillary action.” The Effect of capillary action actually arises from complex physical interactions involving several different fields at the atomic level. However, most people readily recall the phenomenon of capillary action from demonstrations of liquids rising in tubes. TRIZ literature contains tables of these Effects which are very useful.

A **Field**, as described in TRIZ literature, is another artificial grouping convention which allows us to talk about different manifestations of *fundamental fields* as recognizable groups such as vibration, electromagnetic radiation, gravity, mechanical stress and pressure. Some of these “fields” such as Odor & Taste may seem a little off-beat. Effects, as described above, are delivered by one or several objects and their associated fields.

In summary, the **Tool** delivers the **Effect**, which delivers the **Modification** to the **Product**.

# Solution-process Steps

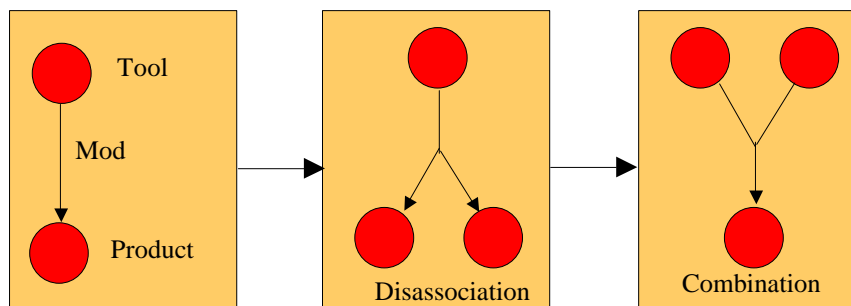
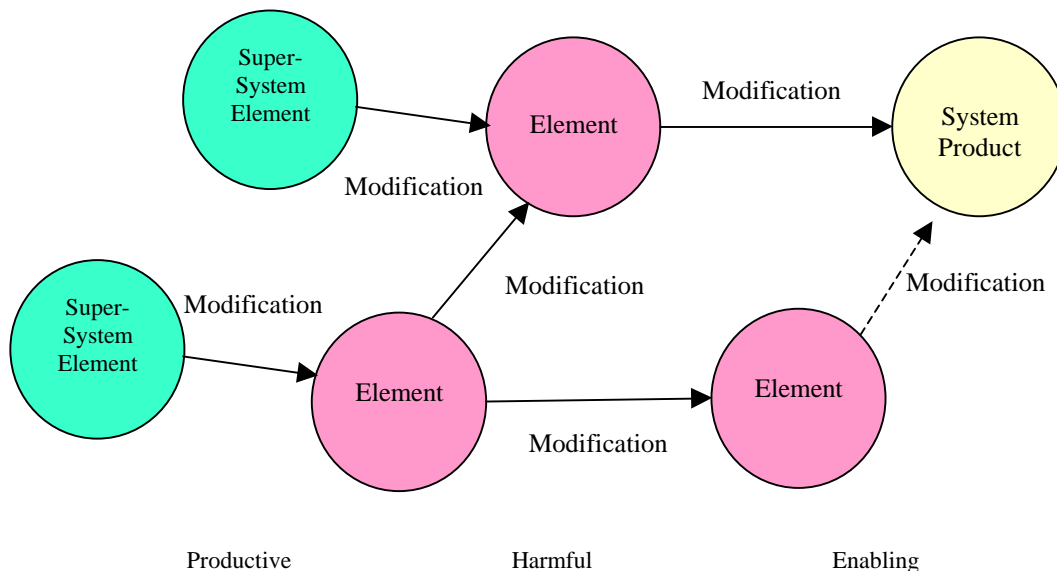
Following are explanations of the solution-process steps as described in *Breakthrough Thinking*.

**Set High Goals** The important outputs of this step are: a clarification of what the system is; what we will and will not try to change within the super-system; the main disadvantage that we want to overcome; what we want to happen to the system and super-system as a result of the changes; and the maximum system penalties which we will allow, such as cost.

**Choose or Create the Subject System** Identifying a system that needs improvement helps to focus the problem solver and to more clearly determine system disadvantages. If the subject system does not currently exist, it is acceptable to guess at or create a surrogate system.

**Determine Customer Requirements and System Disadvantages** Identify customers and then work with them to determine system requirements and current disadvantages. It is important to *verify* that a disadvantage really exists. This is especially true in the area of reliability improvement. Shop data can be misleading. For instance, a repair shop sees a certain product failure over and over and concludes that the product is unreliable. What the repairman does not see is all of the units that operate successfully for long periods of time, making the overall reliability very high.

**Model the Current Technical System or Process** Use Function Analysis to model the system or process. Although modeling the current process will aid in the process of determining what is causing the disadvantages, this is not the main tool for cause-effect analysis. This step helps to determine what the system really is and what the penalties are for delivering the modification to the product. (Note that a function-like structure for disassociation and combination are introduced in the process diagrams. Classical function modeling is clumsy at describing these spontaneous chemical processes).



**Determine Element or Process Step Values** Knowing the penalties for delivering the required function to the system product will influence our goals.

**Set a High Bar** It is extremely important to set high goals. A goal is only high when we sufficiently constrain the system penalties (such as cost--Anyone can make a system improvement that costs a lot and requires increasing complexity). Because TRIZ practitioners gain the confidence to tackle harder and harder problems, they are not hesitant to set high goals. High goals can galvanize the solution effort, especially when working with groups.

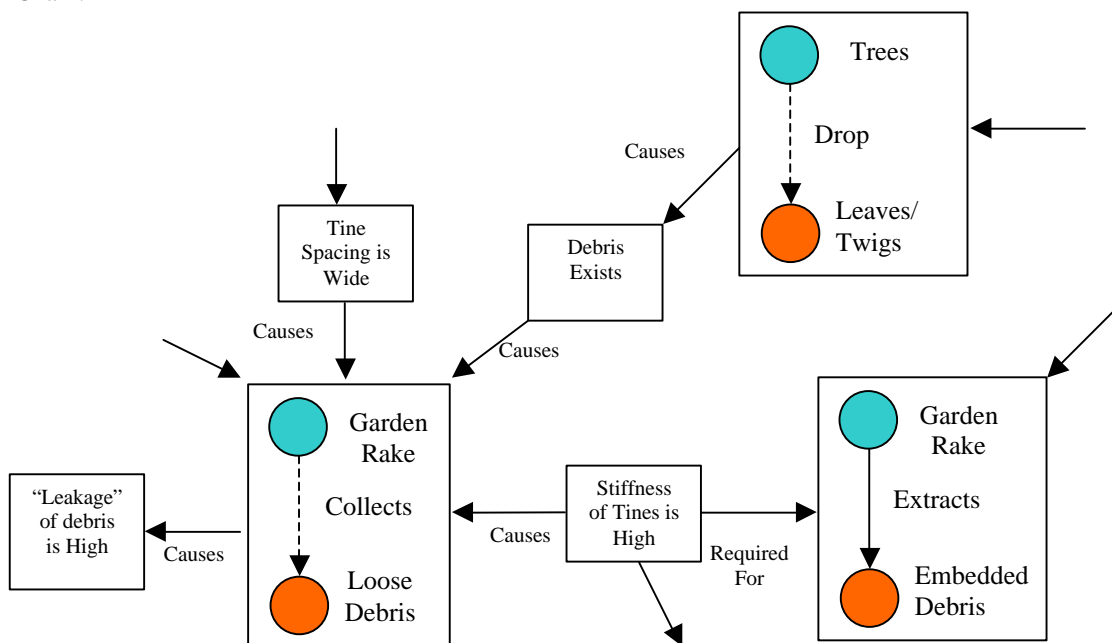
**Identifying Critical Functions (Cause & Effect)** When a system has a problem or disadvantage, usually there are *chains of critical functions*, where functions are linked to each other by cause or by requirement. If these functions can be discovered early in the problem solving process, the “right problem” can then be solved. One of the first steps in any problem solving methodology should be to identify the most important functions through some form of cause-and-effect analysis.

A common mistake is to assign cause-and-effect from armchair observations. Do your homework! Search the Internet. Read books on the subject. Talk to subject matter experts and weigh their words carefully. (There is a lot of misinformation *even among experts*). Get your hands dirty with experiments and microscopic observation. Develop theories, quantify them and verify them, even when you think the theory of operation is obvious. It is very common that new theories of operation will be developed. This step is usually the most time consuming, but it yields huge benefits if the appropriate time is taken.

The problem solver is encouraged to do five main things:

- 1) Form theories
- 2) Quantify theories
- 3) Verify theories
- 4) Identify controlling variables
- 5) Link causal relationships

**Function Chains** link causal relationships. This method, as shown in the solution process, is similar to the “Problem Formulation” step described in *Systematic Innovation*. Below is an example of the beginning of a Function Chain:



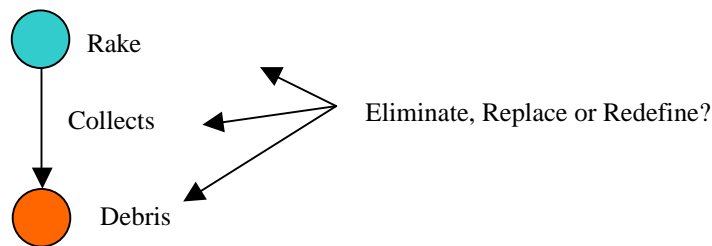
**Example Function Chain for a Garden Rake**

In this example we are considering why a common garden rake (with stiff tines) is poor at collecting loose debris. The independent variable of debris “leakage” is high. It occurs in the function of “garden rake collects loose debris” and is controlled by a number of independent variables such as tine spacing, existence of debris and stiffness of the tines. Note that a value is given to the dependent variable of leakage (high) and that values are given to the independent variables of spacing (wide), existence (exists), and stiffness (high). These values cause the dependent variable, leakage, to be high. In turn, each of these independent variables are either required to perform other useful functions or are designed-in for trivial reasons. For example, the stiff nature of the tines is required to perform another function, the extraction of embedded debris. The current shape of the tines may be unimportant.

Interesting contradictions become apparent. We note that the stiffness of the tines is high in order to extract embedded debris, but must be low in order to follow the contours of the earth and extract loose debris. There are other reasons that the tines must be stiff, such as for arranging soil. So, the tines must be stiff and flexible. Later we will consider how to resolve this contradiction.

The author encourages his students to use flow-charting software to make these diagrams as they can become complex and there is a need to arrange figures quite often.

***Eliminate or Replace Parts*** Once the critical functions are determined, the question becomes “How can these functions be improved?” The improvement of a critical function is broken into two steps. The first step, *Eliminate or Replace Parts*, deals with determining what the function parts should be. Only after the elements are determined, will we concentrate on the next step, *Improve to the Extreme*, by boosting the function or removing flaws. Let us first consider *Eliminating or Replacing parts* to make the most ideal use of system resources. Each part (product, modification, Effect/Tool ) is considered in turn and the question is asked, “Do I want to eliminate or replace this with something more ideal?”



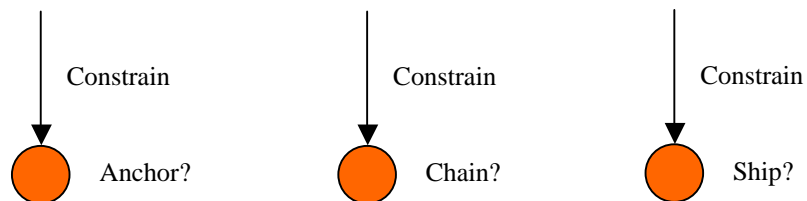
Another name for the step *Eliminate and Replace Parts* might have been the Ideal Final Result, a familiar tool of classical TRIZ. The Ideal Final Result, is included in this step but not in its most familiar form, since it is broken up into smaller steps to aid visualization. The “Standard Solutions” of S-field analysis that deal with eliminating, redefining or replacing function parts are placed in this step. When combined with the concept of Ideal Final Result, this part of the solution process becomes very powerful. This is the opportunity to greatly reduce the system penalties by decreasing the number of elements and allowing elements take on more functions.

The solution path depends upon whether we are considering Useful, Harmful or Informing (measuring or detecting) Functions. This is because the initial focus changes. (Note that the tab system for the binder differentiates between these function types). For Useful Functions, the initial focus is on the modification of the product. For Harmful Functions, the initial focus is on the tool and modification. For Informing Functions, the initial focus is on the tool .

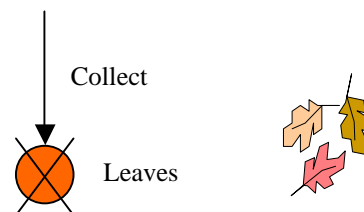
***Useful Functions*** As mentioned, the initial focus for a useful function is the modification of the product. In essence, we are asking, “What do we really want to have happen to the product?” Many problem solvers skip over this step, unaware of their unconscious presumptions. In doing so, some of the most powerful solutions are ignored. Once we are firm on the most desirable outcome, we can ask how the modification to the product will be accomplished.

**The Ideal Product** The first question that we ask ourselves is “What product do we really want to modify?”

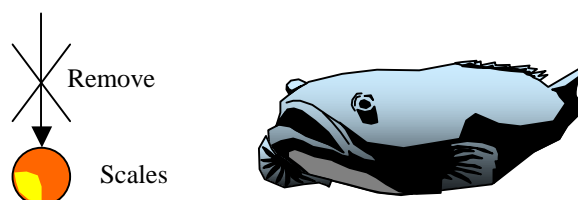
**Non-Transmission Product** If the tool is currently operating on a transmission element, we consider bypassing the transmission and operating more directly on the product that the transmission operates on. This is consistent with the evolutionary law which states that transmission paths are shortened and the number of energy transformations are reduced. Take the example of a ships anchor. In functional language, the sea bed constrains or holds the anchor. The anchor holds or constrains the chain and the chain holds the ship. By realizing that the anchor and the chain are transmission paths to the ship, we now have a decision to make. Do we want to constrain the anchor, the chain or the ship directly? Each decision begins a different solution path.



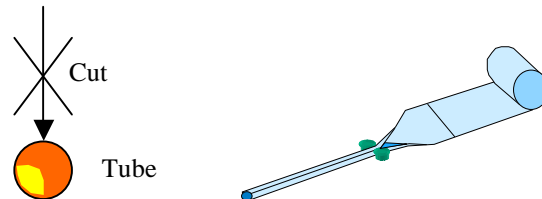
**Non-Existent Product** Next, we ask if the product is normally considered waste. If it is, then we consider ways that it can be eliminated. Once the product is eliminated, the tool or system that performs the modification is no longer required. This changes the problem to that of removing the source or path of the product. For example, if there is no source for the leaves or there is no path for them to reach the lawn, then they do not need to be collected. Elimination of the product often leads to a direct contradiction in that the product must exist and must not exist.



**Product Requires Little or No Modification** Next, we look for ways that the product does not require the modification in the first place. Often there is something about the product that makes the modification necessary. If that one thing can be changed then the function may not be required. For example, the scales of a fish are often removed before consumption. If the scales were considered a delicacy, they would not require removing. The problem now becomes one of improving the texture and taste of scales.

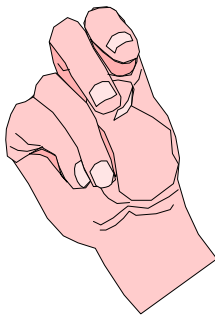


**Comes That Way** Next, we consider a product that does not require the modification because it is already incorporated. Altshuller gives an example of the need to rapidly cut tubes formed by a rolling machine that processes flat metal stock. As the forming machine gets faster and faster, the cutting of the tubes becomes more difficult. The question is asked “What if the tube comes already cut?” Then no cutting will be required. Again, this method often leads to a contradiction. The tube comes in a cut condition, but it must not because it arrives as flat stock on rolls. (In Altshuller’s book, the contradiction is finally resolved by cutting the flat stock, but only partially. The final cut comes from a rapid pull of an electromagnet).

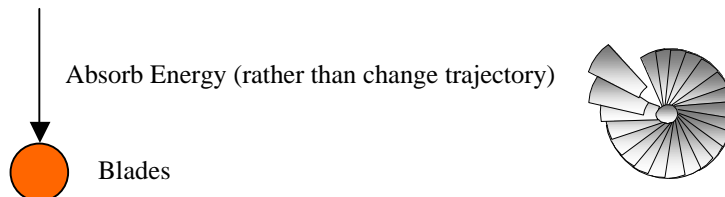


Other considerations in this section of *Breakthrough Thinking* are modification of the **Minimum Part**, **Multiple Products**, **Biased Products** and **Diverse Products**.

**The Ideal Modification** In this section we ask “What is the modification that I really want to perform on the product?” (This assumes that the product still requires a modification). We are in effect replacing or redefining the modification requirement of the useful function. In an overall sense, we ask “If I could snap my fingers what would I want to have happen to the product?”

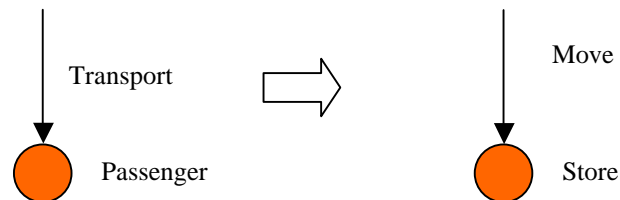


**Main Modification** Our first task is to look into the future and ask what the final, final state of the product should be. The example is given of a fan “blade out” condition where rapidly rotating blades break off from their hub. This is an extremely harmful condition that sometimes occurs in jets and fan jet engines when the blades are struck by flying objects. Usually a “containment ring” is placed around the blades. As the blade fly off, they strike the containment ring, protecting other engine components and passengers. Now we ask “What is the modification to the broken blades that we really require?” Do we want to deflect the broken blade pieces or do we really want to completely absorb their energy?



It is important to take time with this step and ask “what do I really want to have happen?” Or, “If I could snap my fingers....What would happen?”

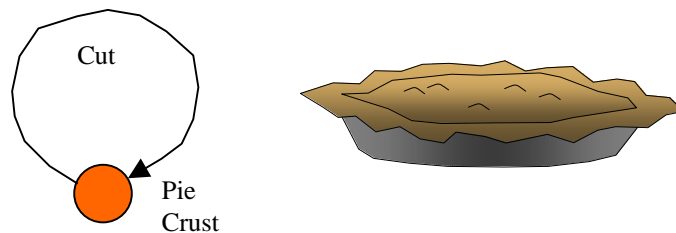
**The Inverse** Every modification is performed relative to something else. For instance, the function may be to transport a passenger. We ask “in relation to what?” In this case, the passenger is being transported in relation to a store. The inverse would be to transport the store to the passenger. Is this possible? By considering the inverse, we may have discovered a more ideal product and modification.



Additional tests are given to determine whether the function is **excessive** or to focus our thinking on the **minimum resources** that are required to perform the modification (time, volume, and energy).

**The Ideal Tool / Effect** Finally, a tool with its accompanying Effects and Fields is required to deliver the modification. The Tool and Effect are considered together because we want to consider resources that are readily available, especially objects that are already part of the system or super-system and if possible, already act on the product.

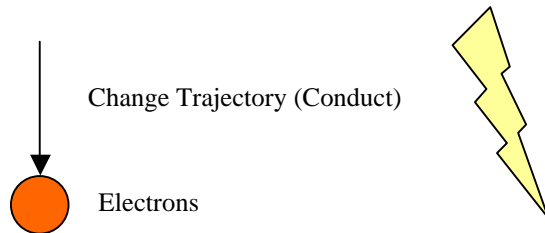
**Self Service** Definition: *a slight change to the product allows an existing external field which already acts on the product to deliver the required modification.* No new Tool or field should purposely be introduced. Instead, the field should exist at some point during the product’s life-cycle but before the modification is actually required. Let us take a self cutting pie for example. We ask, “What fields does the pie experience during its making but before consumption?” (Page 10 contains a list of fields). We note that sometime during the life, the pie will experience a thermal field while it is being baked. We then ask, “what modification *to the pie* crust causes the crust to segment when it experiences this thermal field?”



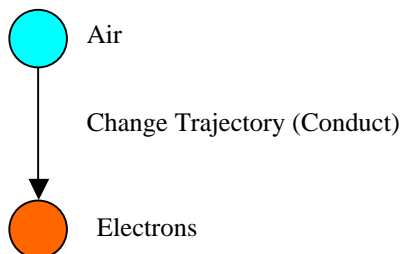
**Abundant Native Fields** Where Self Service requires a slight modification *to the product* to make use of an abundant native field, “Abundant Native Fields” *requires a slight change to fields which already exist in the super-system and which may already act on the product.* Again, no new Fields or Tool are required. On page 10 of *Breakthrough Thinking* is a list of fields. Usually, a couple of these fields will exist in the environment and *already* deliver the required modification to some slight degree. If such a field is identified, sometimes it can be boosted in the next solution step.

In the book *Creativity as an Exact Science*, an example is given of lightning rods being used to protect radio telescopes from lightening. The problem is that when metallic rods are constructed to safely conduct the electrons, the rods corrupt the radio signals from space. This example is often used to illustrate the concept of Ideal Final Result. Unfortunately, for many students, this conceptual leap is too great. Use of Abundant Native Fields provides a smaller step towards the Ideal final Result.

If we have been following the steps, we will have already recognized that the ideal product that is being modified is the electrons of the lightening bolt. The useful modification is to change their trajectory or to conduct the electrons.

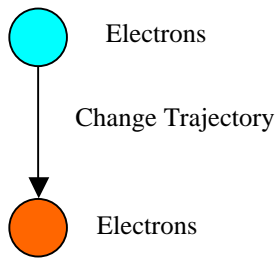


Now, we search for a Tool to deliver this modification. The question is poised “Is there a tool in the system or super-system that *already* delivers the required modification, even poorly?” The answer is Yes, the air already conducts the electrons, though with little control.” Thus, a new solution path is created. In the next step, we will see how this function can be boosted to give more control to the trajectory of the conducted electrons.



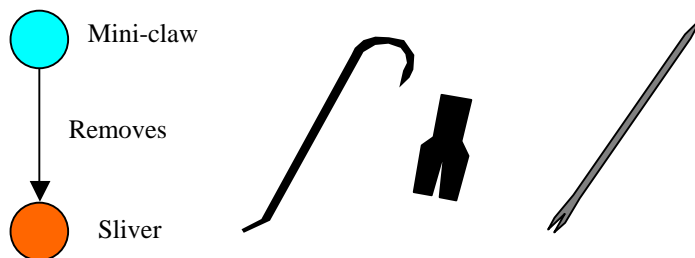
If there were not a tool which already delivered the modification we would search for one in the vicinity by looking for abundant native fields. We would have asked, “what abundant native fields can change the trajectory of electrons.” Examining the table of fields found on page 10, we might recognize that electrostatic and magnetic fields have the potential to change the trajectory of electrons. Are these fields abundant? Yes, both are abundant but self-generated and poorly controlled. In other words, the electrons, themselves will deliver the modification by changing the trajectory of the electrons.





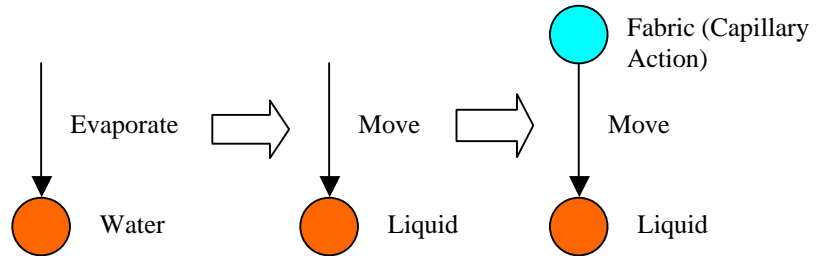
At this point, we may be scratching our heads over how air or electrons could be used to change the trajectory of air. That is expected because we are taking small steps toward the solution. The solution may not be apparent at this point. Take heart. In the next step *Improve to the Extreme*, we will examine how these functions are boosted to give a more complete solution.

**Analogous Tools** Several means for discovering new tools to perform the modification are considered, which invite the problem solver to consider how the modification is *already* delivered in other systems. Four types of analogous tools are considered. *Nearby Analogous Tools*, *Analogous Tools*, *Mega-trend Analogous Tools*, and *Natural Analogous Tools*. In order to understand the concept of analogous tools, the concept of, analogous products must first be understood. Analogous tools modify analogous products. An analogous product is one that requires the same modification as the product in question. For example, consider the removal of a sliver. We ask “What other products require the same modification as the sliver (removal) while firmly embedded in a much larger object?” Products such as nails and weeds come to mind. Nails and weeds are analogous to our sliver in the context of the modification (removal). Now, we consider the tools which deliver the modifications to these analogous products. Claws on crowbars and hammers remove nails from larger objects. Forked digging tools likewise remove weeds. Next we transfer the Tool or part of the Tool to the new situation. The final Tool is a mini-claw which removes the sliver.



**Cheap Abundant Substances** and **Adjacent Elements** are methods to use objects in the system or super system to deliver the modification. The successful use of this method usually involves low-level fields (fields toward the top of the list of fields) which are more abundant, yet more difficult to control.

**Table of Effects** The table of effects is a good tool for finding new Effects to deliver the modification. First convert the modification into a form that most closely matches the modifications given in the Table. Then look for the suggestions in the Table. *Breakthrough Thinking* does not contain this table as it would be too large. The best tables are found in invention software.



**Patent Data Base** The U.S. patent data base can be used from the internet. Do not expect the data base search tools to have the same search capabilities as an internet search engine. It takes time to learn effective search techniques, but the patent data base is a rich source of ways to deliver a modification, and it is still free.

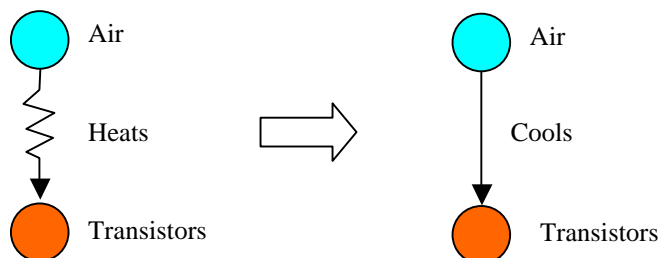
**Current Tool** When all else fails, use the current tool. There is no great shame, this is a common solution path.

**Harmful Functions** Harmful functions have a different focus than useful functions. There are two ways to eliminate and replace function parts: Turning Harm to Good and Elimination.

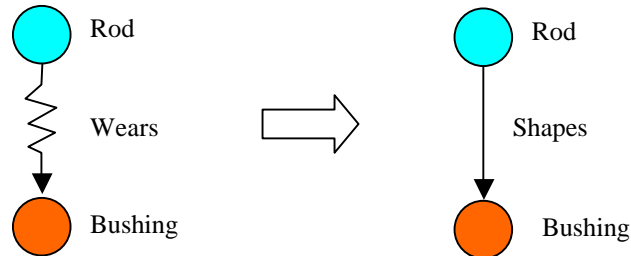
**Turning Harm to Good** In America, there is a saying, “When life gives you lemons, make lemonade.” A harmful function, like a useful function, contains the same parts. There is Tool which delivers a harmful modification to a Product. In turning harm to good, we consider keeping the tool with its attendant fields and effects and replace the harmful modification with a useful one.

The Product of this new useful modification is *usually* the current product of the harmful function. For this reason, we first consider useful functions on the current product, the anti function and a useful variant of the harmful function.

**Anti-function.** If heating is the harmful modification, then the anti-function would be to cool.

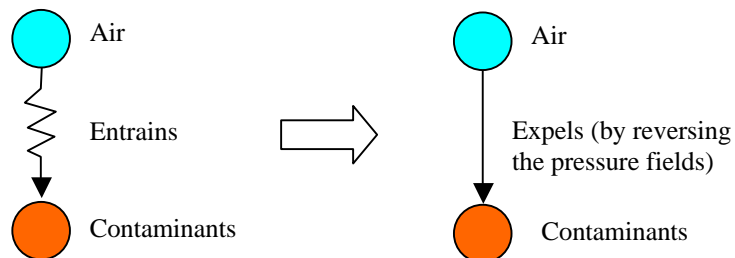


**Useful Variant** of the harmful function: If a Tool wears the product then a useful variant of the harmful modification to “wear” is to “shape.”

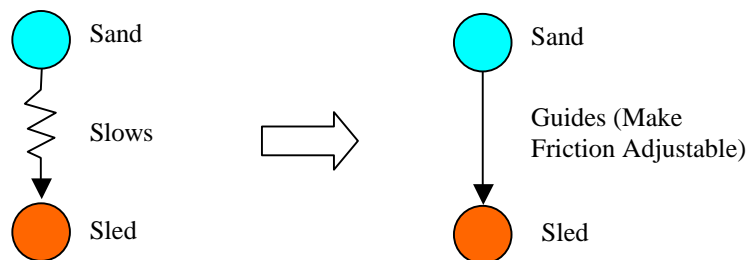


Once a useful modification is identified, then one of the five following methods is used to achieve this useful modification. Of the five methods, the two most important methods are to reverse the fields and to make adjustable. Almost any harmful function can be turned into a useful function by reversing the fields or making it adjustable.

**Reverse the Field or Action** The easiest way to achieve the anti-function is to reverse the fields or the action. If the pressure is pushing the product one way, reverse the pressure field. Make something pull rather than push. If air is entraining contaminants, then make it expel the contaminants by reversing the pressure field.



**Make Adjustable** Perhaps the easiest way to achieve useful variant of the harmful modification is to make it adjustable. As stated, almost any harmful modification can be made useful by making it adjustable. Note that later we will make suggestions on how to make a useful modification adjustable. This involves identifying controlling variables of the interaction between the two elements and then making one or more of these adjustable.



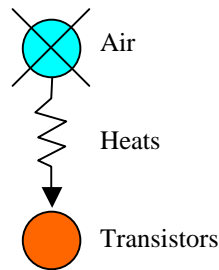
**Work With** Often, the useful modification will be performed at the same time as the harmful function. Because they are not in equilibrium, the harmful function predominated. For instance, wear is actually the process of removing and adding material. The amount that is removed is more than the amount added. If we can boost the useful component of this equilibrium state, then we can perform a useful function.

**Incorporation** Artists often use this technique to hide flaws in a work of art, especially if the medium does not allow “erasing.” One technique is to multiply the flaw in a useful way. For example, a blade cuts off a piece of plastic pipe. In the process, the pipe is deformed on one side. Although this flaw may not reduce the usefulness of the pipe, it is unsightly. This flaw is improved by multiply it around the whole pipe, thus creating a pleasant bevel. This bevel may now help to guide the pipe during installation.

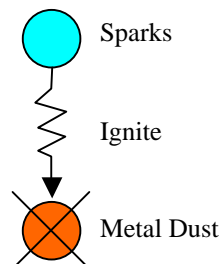
**Perform Accurately** The final method for making a harmful modification useful is to perform it more accurately. Many harmful actions are harmful only because of the variation. The task that remains is to identify where or when the task should be performed precisely to make it useful. This method is a subset of making adjustable.

**Elimination** One of the most direct routes to improving a harmful function is to eliminate either the tool or product. Usually a contradiction results. When it does, we bypass the next step “Improve to the Extreme” and go directly to “Resolve the Conflict.”

**Non-Existent Tool** This is the most commonly used and useful consideration. Since the tool harms the product, consider that it no longer exists. During the resolution of the conflict, two general paths are followed. Either resolve the contradiction or consider a new system where the Tool does not exist. Any useful function performed by the Tool must be performed by something else.

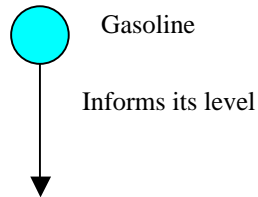


**Non-Existent Product** Sometimes a harmful modification is delivered to a product, which is not required in the system in the first place, such as a waste product. Consider removing the Product, its path or its source.



**Informing Functions** Although informing functions are useful functions, their beginning focus is on the tool and the variable in the tool that requires detection.

**Ideal Variable that Requires Detection.** What is the variable or feature of the Tool which requires detection? As with the ideal modification, some thought is required to determine this variable in an ideal manner. A longhand method can be used for clarity.

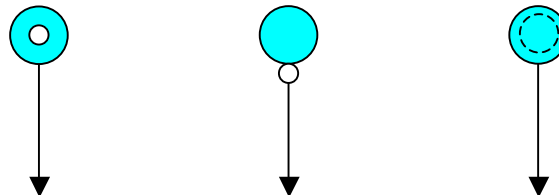


**Ideal Tool** In useful functions, we considered the ideal product. Here, we consider the ideal Tool using the same process steps. For instance, in useful functions, we considered products which required no modification. Here we consider tools which require no detection or measurement. There is nearly a one-to-one correspondence with useful functions.

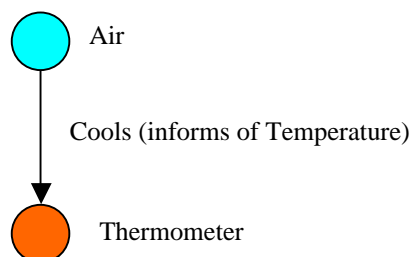
**Roundabout Variables** Once we have determined the variable, we can consider means that allow us to detect or measure the variable indirectly.

**Ideal Effect** The Table of Effects has a special section on detection and measurement. Search this table to determine phenomenon which can be used to deliver the detection required.

**Use of Markers** One method which requires special consideration is the use of Markers. This includes both substance and field markers which can be detected by the product.



**Ideal Product** Although not Shown, a product is required to be acted on by the tool. At this point, a more clear Useful Function can be drawn. With a clearer picture of the Informing Function, we are ready for the next step of improving this function to the extreme.

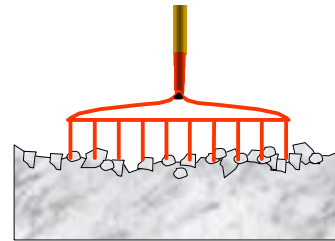
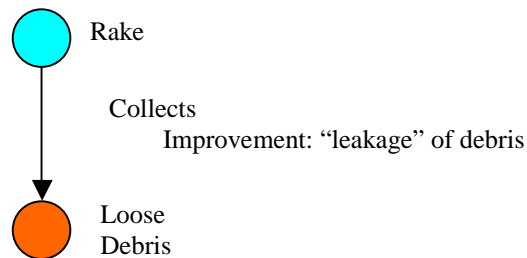


**Improve to the Extreme** (It is assumed, beyond this point, that the Tool, Modification and Product will be preserved). Once we have eliminated or replaced function parts, there is usually something which is undesirable about the function. For instance, the performance of the function may require too much energy or time.

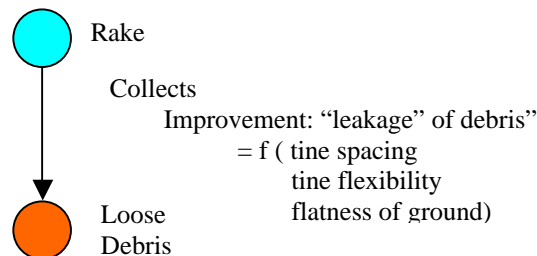
The focus in this step is to concentrate on this one function and its improvement. It will be improved to the extreme without consideration for anything else that might become worse. It is precisely this form of extreme thinking which allows the formation *many* useful contradictions.

We are about to create a diagram whose form is very useful and bears repeating. It includes the function, the improvement, the controlling variables and the contradiction. Improving the function to the extreme is performed in three steps:

**Identify the Improvement (Dependant Variable)** This step requires that we first determine the *dependent variables* of the flaw that we want to improve. In this case, we are considering the function of a rake to collect loose debris. Since we are using a garden rake rather than a leaf rake, the rake does not collect as much as we would like on each pass. We want to improve the “leakage” of debris past the tines. In doing this, we also consider the ideal outcome. In this case, “ideal outcome” means an enduring solution. If possible, we would like all of the debris to be collected on each pass.



**Identify Controlling (Independent) Variables** Next we determine the *independent variables* used to control the improvement. We can look at this several ways. Most people simply start with intuitive guesses. If we were going to write an equation, what would “leakage” be a function of? Each of the variables of the equation would be candidate variables which control the leakage of the rake. If we have gone to the trouble of developing models, we can often use input variables from these models. Without quantitative data, we can still consider variables that we know from experience or from crude experiments. On the function diagram, we write that leakage is a function of those things which we have identified through the given methods. We note that were the tine spacing closer, less debris would slip through. If the tines followed the unevenness of the ground, it would collect more efficiently. Also, if the ground were more flat, there would be no need to follow it so closely.

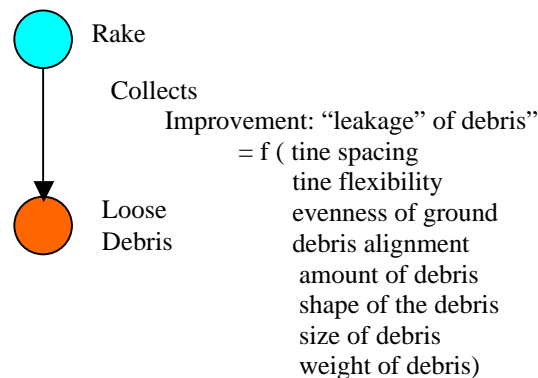


Having exhausted our own knowledge, we turn to the Table of Controlling Variables which are on the next nine pages of *Breakthrough Thinking*. Sub-steps are given with each controlling variable to make the identification of each Controlling Variable more clear.

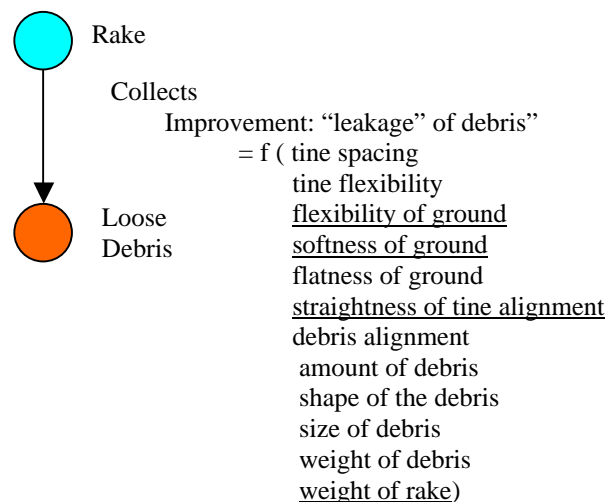
It is noted that this table is mostly a derivative of the “Standard solutions.” That is because a large part of the Standard Solutions already deal with the control of functions. Since we have already used the Standard Solutions that deal with the replacement of function parts, and moved them forward in the thinking process, what remains are the controlling variables that can be used to improve the function. Indeed, almost every method for controlling a function can be found in the Standard Solutions.

In its original form the Standard Solutions contained solutions with the contradictions already removed. A notable case for this is the addition of internal, external, and environmental additives. In Contrast, the Table of Controlling Variables assumes that to improve the specific dependent variable, the whole tool or product is made of the required substance. This causes all kinds of problems. The removal of the contradiction is delayed in favor of creating a greater number of ways to resolve the contradiction than those included in the Standard Solutions.

Experience shows that using the Table of Controlling Variables will help the problem solver uncover several unanticipated ways to control the function. We note that the debris has uneven shapes and would be collected better if it were aligned more favorably with the tines. If there were less debris, there would be less leakage. If the debris shapes and sizes were more favorable, it would collect better. And, if the debris were light, the tines would have less tendency to roll over it.

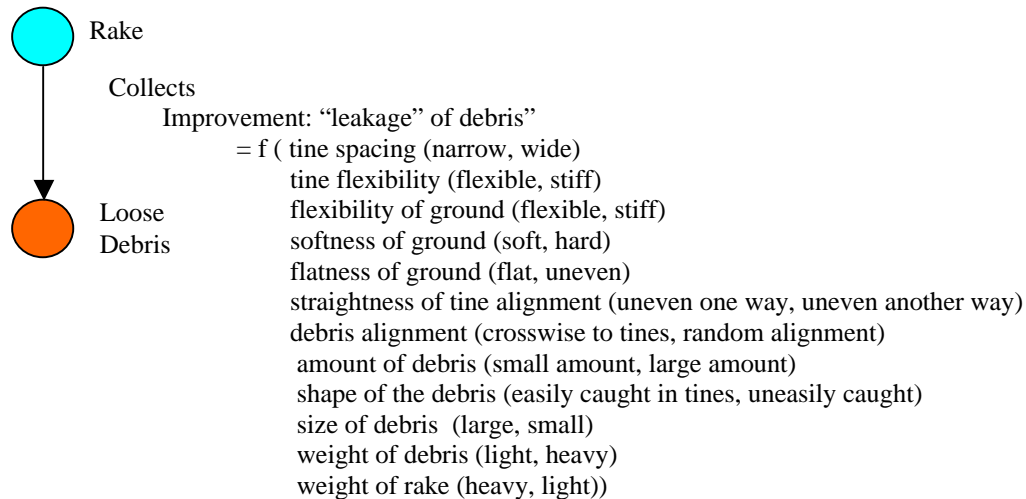


Finally we consider each variable in turn and ask the question: What is this variable measured relative to? Consider changing this “relative to” variable in addition to the others. This is part of “Doing the Reverse.” If the ground were flexible or easily penetrated (soft), there would be no need for the tine flexibility. If the tines were instantaneously uneven to match the shape of the ground, there would be no need for the ground to be even. If the tines were heavy compared to the debris, it would have less tendency to roll over the debris.



**Drive Variable Values to the Extreme** Finally, the variable values are driven to the extreme to improve function flaws. This is done without consideration for anything else that might get worse. Focusing this way is precisely what is needed to break psychological inertia.

When we drive a controlling variable to the extreme, something else usually gets worse, or it appears impossible. Thus we see that the variable must have the new value and it must not. Without noting the reason that the extreme value will not work, we include the anti-value in the diagram and thus capture the contradiction as a natural result of this step.



Infrequently, a variable can be pushed to the extreme without affecting anything else. If this happens, consider yourself lucky.

Sometimes we do not know why such a solution wouldn't work. Fortunately, others are always on hand to point out the fallacy of our thinking. "That won't work because...." Criticisms are often a good way to discover contradictions.

**Resolve Contradictions** While improving to the extreme, it is common to develop many contradictions. Each of these contradictions represents a new branch or solution path. Classical TRIZ considers three types of contradictions, Administrative, Technical and Physical.

The Administrative Contradiction states that there is a problem with an unknown solution. This form of contradiction informs us of little and is ignored here.

The Technical Contradiction states that as something improves something else gets worse. In the rake example, we could have stated that the tines needed to be flexible and stiff. No rationale was given in the function diagram. In reality, the tines need to be flexible to collect and they need to be rigid in order to extract embedded debris from the ground. The resulting Technical Contradiction is: as collecting improves, extracting becomes worse. (No mention of tine stiffness is included).

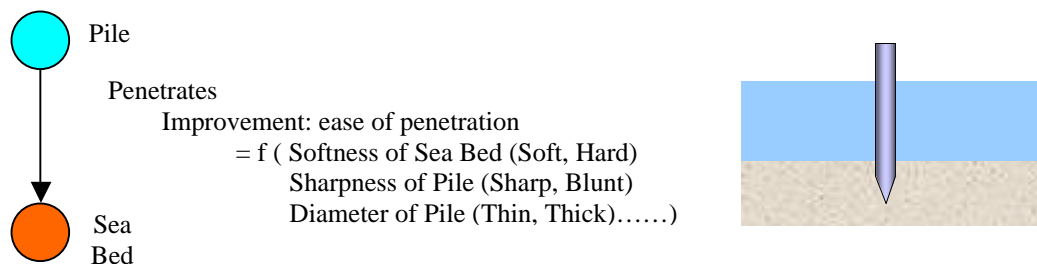
The Physical Contradiction states that the value of a controlling variable must be either one value and an extremely different value referred to as the "anti-value" or "anti-property" (usually the opposite or null value). In the rake example, we developed several Physical Contradictions. For instance, the tines must be stiff and flexible.

In this text, Technical Contradictions are not articulated in favor of Physical Contradictions for the following reasons:

- An acknowledgement of at least one thing that gets worse, when we drive a controlling variable to the extreme, is usually sufficient.
- Technical contradictions arise *from* physical contradictions and not the reverse. In other words, Physical Contradictions are not discovered by peeling away the layers of the technical contradiction, as implied by some texts. Note that in the example of the rake, we first drive the controlling variable of tine stiffness to the extreme and then look around to see what got worse. (It is interesting to note that some algorithms for creating the Technical Contradiction inadvertently create a Physical Contradiction first and then deduce the Technical Contradiction).



- Most algorithms strive to develop the Technical Contradiction. Actually, for some Physical Contradictions, *several* Technical Contradictions can be formed. In other words, there may be *several* reasons that an object cannot be both hot and cold. Since we have shown that it is easy to develop multiple Physical Contradictions, the resulting number of Technical Contradictions increases the complexity of the solution process.
- Creation of the Technical Contradiction does not increase the ability of the problem solver to directly visualize the solution. Although it appears that the problem is made more difficult by forming the Physical Contradiction, the problem solver is brought much closer to the solution because of the enhanced ability to visualize the solution. If an object needs to be both flexible and stiff, the Table of Contradictions brings us directly to a visual possibilities for solutions. For instance, if an object must be both sharp and blunt, visual images can be created directly from the application of suggestions from the table.
- The Table of Contradictions is so rich with possibilities for solutions that the Contradiction Matrix is not required. This can be illustrated by the well known example of driving piles to support piers. In order to drive the pier into the seabed, a pile driver is used. Driving the pile can be difficult when the seabed is dense or rocky. Following is the function which describes the problem. The improvement is ease of penetration.



Note that one way to drive the function to the extreme is to make the pile sharp. Unfortunately, a sharp pile continues to sink once a heavy structure is placed on top. The Physical Contradiction is that the pile must be both sharp and blunt. Please scan the Table of Contradictions in *Breakthrough Thinking* and note how many solutions to this problem are used as examples.

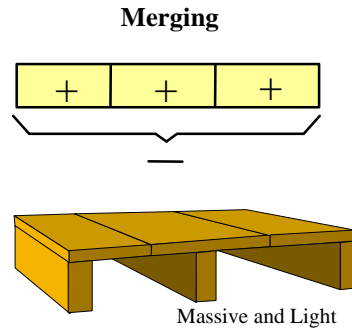
The first step to resolving the physical contradiction is to consider the various tools at a higher level. Four considerations are given when something else gets worse.

**Reduce the Cost Penalty** Often the contradiction arises that an improvement must be made, but the cost appears to get much worse. In this case, any new costly objects must take on additional functions. A good example of this is the recent introduction of solar panels that double as roof tiles. If a new house is being built, or an existing house requires re-tiling, the cost penalty of the separate systems are shared, thus dramatically reducing the combined cost.

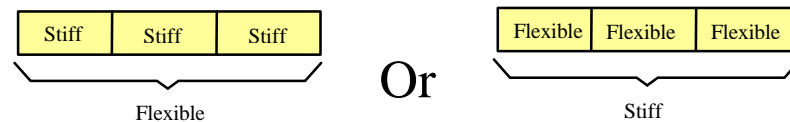
**Fix the New Offending Function** If no solution can be found in the Table of Contradictions, identify the function that gets worse and begin the solution process again at Eliminating and Replacing Function Parts.

**Introduction of New Functions** Sometimes, the only thing that gets worse is that while we know that a controlling variable must be driven to the extreme, we do not have a way in mind to make this happen. This requires the introduction of new functions. Since the function is known, we move back to the step of Eliminating and Replacing Function Parts for Useful Functions. Here we consider the ideal modification and the ideal tool to deliver this new modification.

**Table of Contradictions** The Table of Contradictions (Physical) is the most common method for resolving contradictions. The contradiction is that a controlling variable must have a value (+) and an anti-value (-). In addition to solution steps, each of the methods in the Table of Contradictions gives an example and a diagram with contains pluses and minuses. For example:



The diagram is used by inserting the value and anti-value into the diagram in place of the pluses and minuses. For example, if the controlling value needed to be flexible and stiff, the diagram would be modified in this fashion:



The number of methods for resolving contradictions is large. Usually, several of the solution methods will work. Take your time with each solution method. Work through the steps and consider ways to make it work. It is rare that a contradiction cannot be resolved by at least one solution method from the table. As mentioned, the pier driving solution is used in many places to illustrate various solution methods.

In classical TRIZ, the principal tools for resolving Physical Contradictions are separation in Space, Time, and Scale (Parts have anti-property of the Whole). The Table of Contradictions was mostly derived from these three separation principles and the 40 principles used to solve technical contradictions. A few tools were broken out of the Standard Solutions.

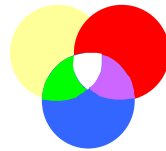
Four categories have been added.

- *Separation by Scale in Time:* Allows for the contradiction to be resolved gradually as elements are added over time. A minimum of two elements are required
- *Separate in Direction Path or Plane:* Here it is recognized that an object can occupy the same space and time and exhibit both contradictory properties. For instance, a flat pane can be stiff when the force is applied in one direction and very flexible when applied in another direction. The whole pane is both flexible and stiff in the same time and space.
- *Relative Measurement Standard:* This method of solution also allows for an object to carry both conflicting properties at the same time and in the same space. An object floating in a liquid can be either heavy or light when compared to the density of the liquid it is floating in.
- *Field Susceptibility:* Allows for an object to carry both contradictory properties at the same time, depending upon the field applied.

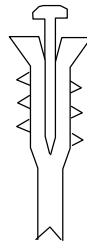
***Expand and Consolidate*** To this point in the solution-process, the focus has been on one function at a time. Next, we consider expanding the solution to include more functionality or to consolidate elements. Tools were drawn from S-Field analysis, earlier version of ARIZ, and System Evolution Theory.

**Expand the Solution** At this point, the main disadvantage has been overcome. Now we look for ways that we can expand the solution out to other products or merge tools which perform different functions on the same product. The most important tools will be detailed here.

**Combine Solutions** One of the most important considerations is to combine some of the best solutions to this point. Often, the relative strength of each solution is not known. Rather than testing the solutions one-at-a-time, the solutions can be combined DOE style. As with any experiment, we stand to learn something of the physics in this step.



**Merge Different Tools or Make Different Tools Interact** Look at the several tools that operate on the same product. Can they be merged or made to Interact with each other. The example is given of wall anchors and drills. When a picture is hung, a hole is drilled in the wall and then an anchor screw is inserted. Both the drill and the screw operate on the wall. The wall, likewise, operates on the screw. Merging the drill and the screw makes the operation much faster and less complex to perform.



**Merge the Anti-Tool** Identify the opposite or anti-modification. Does a tool exist to perform the anti-modification? Combine the Tool and the Anti-Tool. If one does not exist, consider the possibility of creating one and then combining it with the Tool that performs the modification. The example is given of a common hammer which performs both drives nails and removes nails.



**Consolidate the Solution** Most solutions are not as compact and efficient as they could be by this point. Consolidating elements that perform like functions reduces the number of elements.

**Consolidate Multiple Product and Tool Elements** If part of the tool or product can be shared between multiple elements, then consolidate the element. This is especially true when the solution involves multiplying Tool or Product elements. The example is given of a hammer and a pick which are combined. Two handles would be unwieldy and inefficient. The handles are merged.

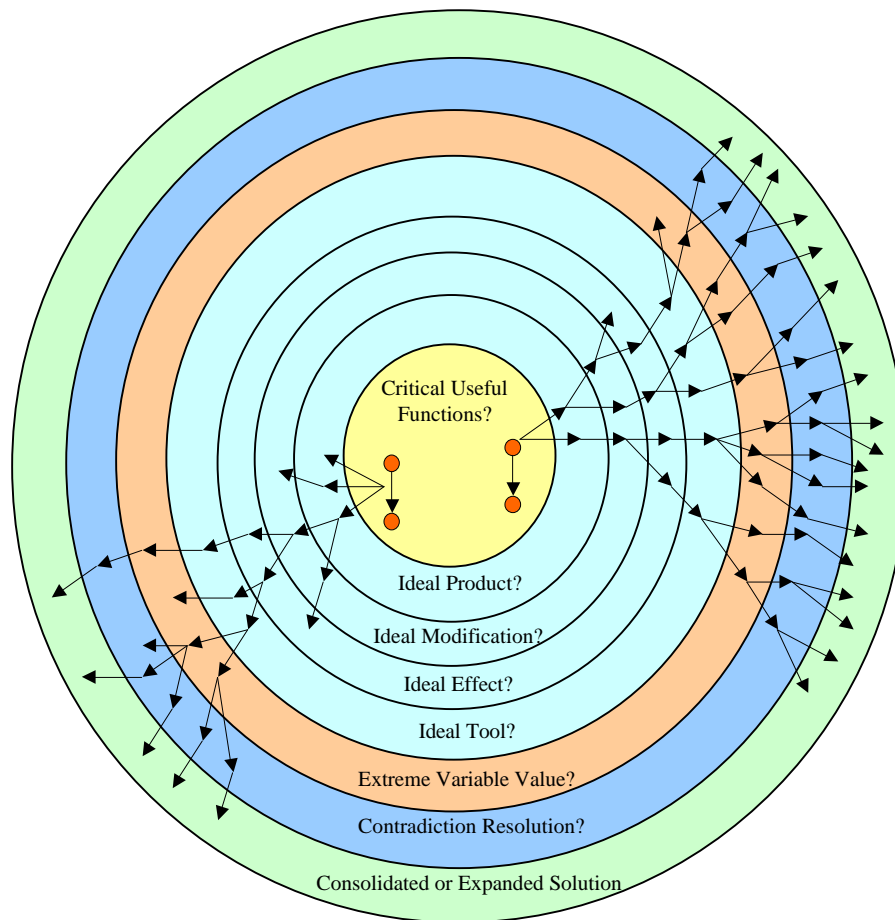


**Folding Elements** Folding elements into each other makes the system more compact. Sometimes, unexpected useful benefits will emerge

**Merge with Super-System and Consolidate** One of the most important considerations is to merge with the super-system. Often, the super-system will have elements which perform duplicate functions. A house is part of the super-system for most refrigerators. What elements in the house are duplicated in the refrigerator? The structure and insulation are duplicated. If the refrigerator merges with the house, it can make use of the house structure and insulation.

**Solution Branches** Each decision point in this linear sequence of tools falls in a logical and natural order. The output of each step is required in order to move to the next. That output may be assumed or actively created. For example, consider a problem solver who wants to start solving an apparent contradiction with no other consideration. He or she has *already assumed* a critical function along with its attending parts (product, modification, effect and tool) as well as a controlling variable which has an extreme property.

The following figure shows the branching of the solution paths at each decision point for a Useful Function. (Branching is slightly different for Harmful and Informing functions). Each step allows for multiple decisions, with each decision forming a new solution path.



## Solution Branches

As shown by the above diagram, dozens of practical solutions are possible and, in fact, occur commonly in practice. These solutions should be evaluated on the basis of ideality and business and customer needs.

**Conclusion** It is hoped that the reader will recognize that a separation and regrouping of tools is necessary to allow for the further advancement and growth of TRIZ. A linear sequencing of TRIZ tools has been presented that results in a branching solution path. The output of each step must be actively sought or presumed in order to proceed with the next step.

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