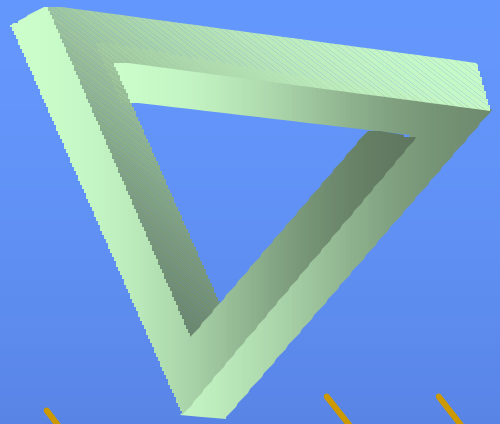
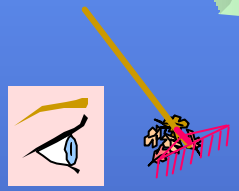
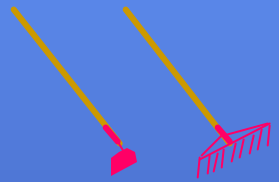


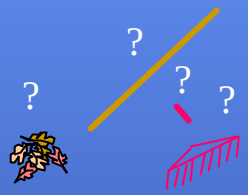
Breakthrough Thinking with TRIZ

2nd Edition





Hoe and Rake?



Partial Solution:

Removal not required:
Falls on Camouflage Mulch

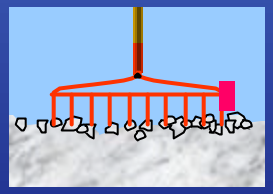
Study & Observe

Main System Function ?

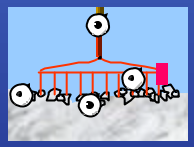
Why Are Parts Required ?

More Ideal Objects (IFR)

Consolidate Parts

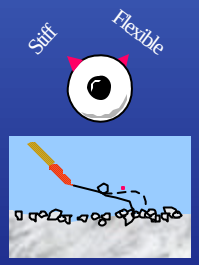


Debris Leakage is High



High Leakage = f (
Surface profile (uneven)
Debris amount (large)
Tine flexibility (stiff) . . .)

Tine flexibility



Improvements or Problems?

Knobs & Settings ?

Turn Knobs to High

Resolve Contradictions

Implement Solutions

Study & Observe

It takes some time and effort to come up to speed on a problem. Lots of questions need to be asked. Do not rely on the experience of others. Gain first-hand experience of the difficulties and disadvantages of the system.

Study

Choose Base System

• Choose a **Base** system. Be as **specific** as possible. (The system may already exist but in highly flawed form)

Study the Existing Situation

• Get **Background** on the situation.
• Ask a lot of questions. **Keep asking why**
• Study what the **subject matter experts** have to say.

Stated Requirements

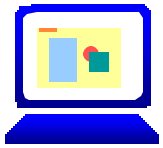
VOC

• Identify stated customer requirements
• In what ways does the base system fall short of these requirements?

Go to the Store

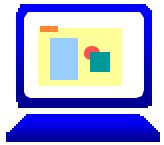
• Go to a store that would sell products similar to the situation.
• Note brands and producers, Do the producers sell more than one product?
• Who are the main producers?
• Look for product trends
• Read the labels. What do they claim?

Internet Product Search



• Use common search engine to determine what products are offered.
• Note common names and nomenclature.

Do Patent Search



6,543,345
5,678,432
3,234,211

• Go to **www.uspto.gov**
• Download **patent viewer** for viewing patent drawings
• Using **Advanced Search**, search by **subject**
• When find a patent, look at classification
• Search by classification. Make sure that classification includes possible patents that cover the field that you are interest in
• When find good representative patents, note and **view all patents**
• Continue process until no new patents regarding your area of interest show up

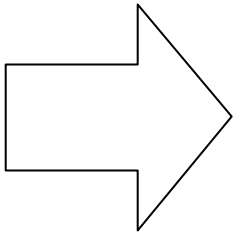
Observe

Observe the Situation

- If possible, look at the physical system in question
- Observe its use in as many of the Life Stages as possible
- **Look for Problems**

Observe the System and other Competing Systems at Various Life Stages

- Observe Competing Systems in as many of the Life Stages as possible
- **Look for problems**



Fabrication
Touch Time
Cycle Time
Variability
Labor

Test
Cycle Time
Touch Time
Waste
Safety

Packaging
Deterioration
Hard Opening
Tampering
Recyclable
Confusing
Disposal
Dangerous
Messy

Transport
Loading
Messes
Volume
Safety
Special Equipment
Contamination

Setup
Difficulty
Labor
Confusing

Operation
Human Intervention
Condition Range
Environment Range
Unusual Uses

Comfort
Long Use
Ergonomic

Consumption
Energy
Materials
Time

Waste
Secondary Harm
Waste of Useful Materials

Safety
Harm User
Harm Bystanders
Harmful Functions during

Security
When Anxious
Non-Value Worry
Tampering
Use as Weapon
Ease of Stealing

Storage
Difficulty
Waste
Environment
Storage Space
Damage to other Objects

Failure Modes
Probability

Convenience
Functions on Hold
Memory Required
Confusion
Complexity

Messes
Frequency
Human Intervention

Life / Reliability
Life
Durability
Reliability

Maintenance
Cost
Waste
Consumption
Human Intervention
Cycle Time
Touch Time

Repair
Ease
Cycle Time
Touch Time
Human Intervention
Waste

Recycling
Ease of Disassembly
Environmental Issues

Disposal
Ease of Disposal
Environmental Issues

Main System Function ?

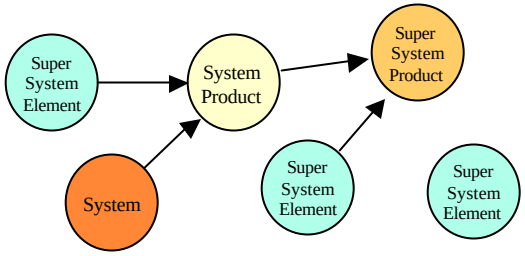
What jobs do people hire this system to do? Can our system take on additional functions from the super-system? The outcome of this problem step is an identification of the main functions that our system perform.

Main System Functions

What Job is System Hired to Do?

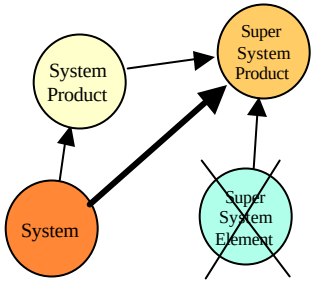
- What **jobs** are people **hiring** this system to do? What is the **final desired effect.** Remember, people want the effect, not the tool that creates the effect!
- **Segment market** into the jobs that people hire it to do. This gives us the Market Segments, or in other words, the customers.
- What are the **competing objects** that perform this job? If nothing else competes, then you are competing against non-consumption.

Functionally Model the Super System



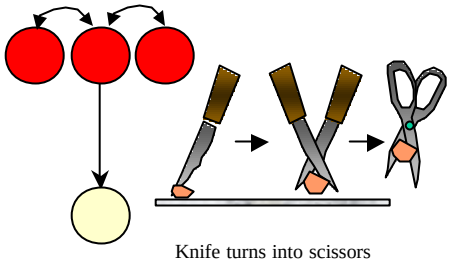
- Identify the **System, System Product** (what the system modifies) **Super-System Product** (what the super-system modifies) **Super System Elements** (Other elements in the super-system. Be thorough by including elements not directly associated with your system. These elements are our **list of object resources** for later uses.
- Identify all functional links (modifications) between elements . Remember the need to be very **careful and precise** in identifying these modifications.
- Verify that all required **human elements** and their functional links are included.

Take Over Super-System Functions



- What other jobs **could** this system do for this particular market segment or the super-system? What are the competing jobs? What performs these jobs?
- Use the methods on the following page to look for opportunities to take over the functions of other super-system elements.
- This provides opportunities to surprise and thus delight the customer with unexpected functions and capabilities.

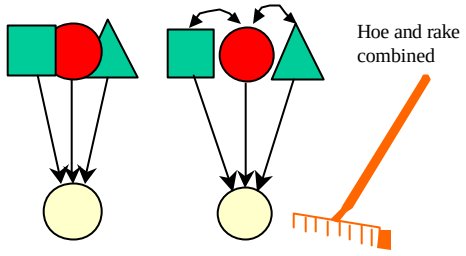
Merge or Interact With Multiplied Tools



Knife turns into scissors

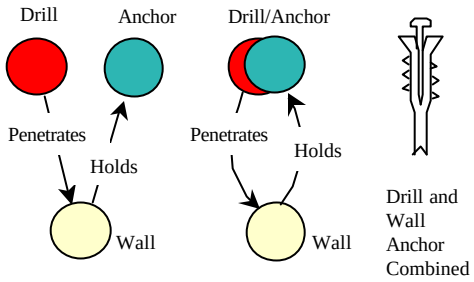
- Multiply the system
- Can these tools be merged or interact together to create an **unexpected capability**? Try different orientations.
- Consolidate Elements

Merge or Interact With Other Tools of System Product



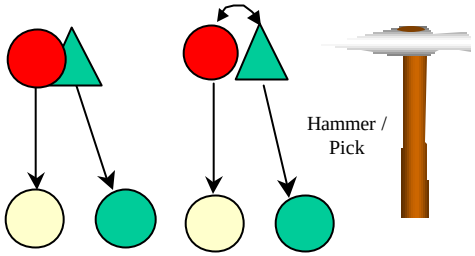
- What Tools in the system perform **different functions** on the system product?
- Can these tools be merged or interact together to create an **unexpected capability**?
- Consolidate Elements

Combine Elements of Contiguous Operations



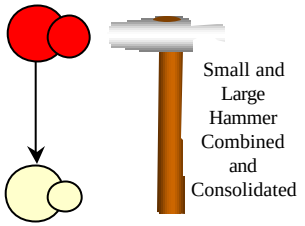
•Identify Contiguous Functions
•Is it possible to combine elements?
•Look for **unexpected capabilities**
•**Consolidate elements**

Merge or interact With Other Super System Elements



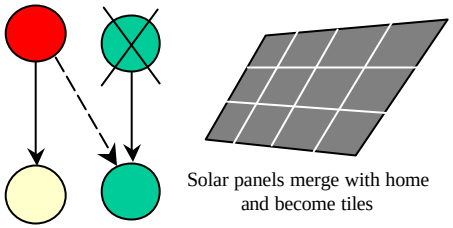
•Can our system be combined or interact with other super-system elements to improve system functions?
•Especially consider **interacting with humans** in the super-system
•Look for **unexpected capabilities**
•**Consolidate elements**

Merge or interact With Biased Tools



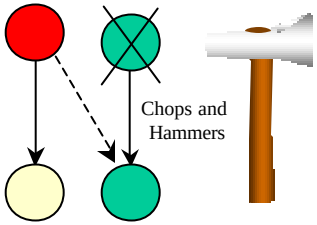
•Are there other tools in the super-system that operate on products that are **slightly different** (biased) than the product our system modifies?
•Merge or interact with these and **consolidate.**

Boost Incidental Functions



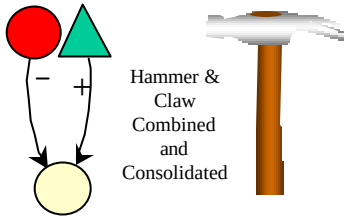
•Does our system perform incidental functions on the super-system that are normally performed by other super-system elements?
• Boost these functions and take over for the other super-system elements.
• **Look for unexpected capabilities to emerge**

Take Over Similar Functions



•Can minor modifications be made to our system to allow it to take over for other super-system elements?
•Especially consider taking over functions that **humans** are required to perform

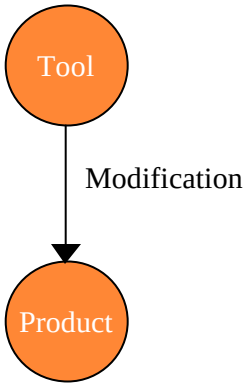
Merge with Anti-Tools



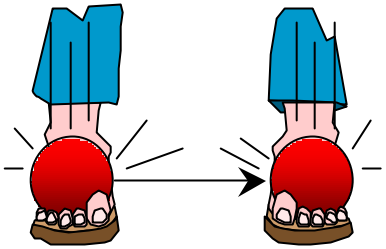
• Identify the Anti-function?
• What effect/tool exists in the environment or could be used to perform the anti-function
•Can this anti-tool be merged with the system? Look for **unexpected capabilities.**
•Consolidate elements

Rules for Writing Functions

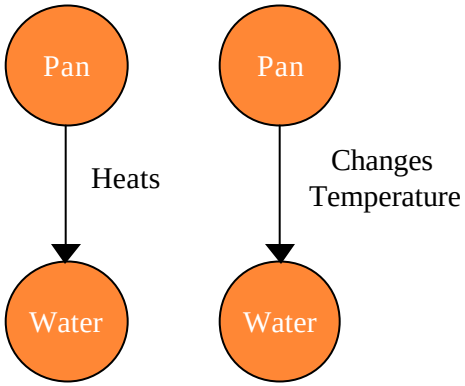
1. Function Parts



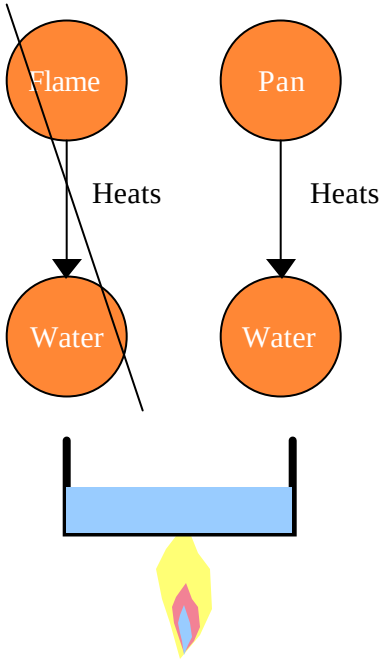
2. The Tool and the Product are generally Physical Objects- Something that you could drop on your foot. (Some objects are virtual objects such as boxes or forms on computer screens. Also, atoms, electrons, photons, etc can be considered objects)



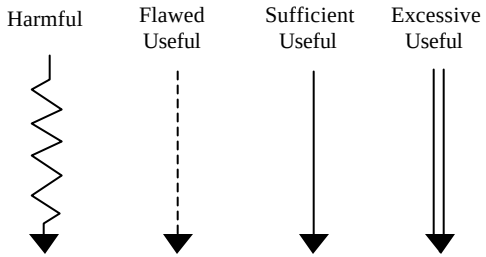
3. Modification uses a verb which describes changing or controlling--Use longhand (changes . . . Or Controls . . .) if confused.



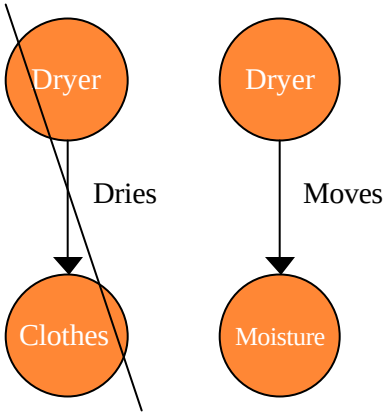
4. The Tools should directly modify the product



5. Types of Modifications



4. Should describe what is really happening. . . Careful with Confusing Functions

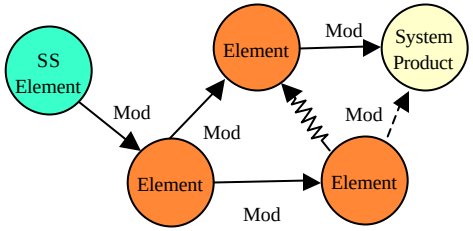


Why Are Parts Required ?

After studying the system in its various life stages, we naturally note problems with the system. These problems can be described with functions. These functions in turn are caused by other harmful functions or are required to remediate other ineffective useful functions. A chain of functions can be formed, which lead from one element to the next. Later, we will consider idealizing functions along this path to reduce the parts.

Main Problems & Penalties

Functional Description of System



Functionally describe the system with sufficient, flawed and harmful functions

- Identify System Elements
- Identify the main system product (what the system modifies
- Identify super-system elements. (Elements you have no control over). Consider only super-system elements which directly interact with the system elements.

Identify Main System Disadvantages or Problems

Y =

What is the main disadvantage of this system compared to the competition?

Sufficient Penalties ?

$ Costs

- Gather **costs and penalties** associated with these disadvantages
- Is there a tangible demand for this system?
- Is there really an interested customer?
- Are the problems worth pursuing?

Identify Low Value Elements

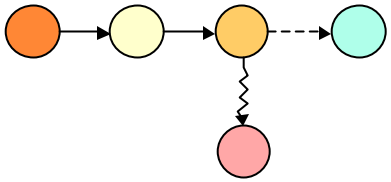
Function Rank:
Basic or Productive = 3
Auxiliary or Enabling = 1
Harmful =0

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

- Identify elements or steps with low value. These elements are candidates for elimination or combination with other elements.

Chain of Functions for Main Problems

Create Function Chain of the Main Problems



- Describe the main problems in terms of a function
- If the main problem is associated with cost then start with the functions that this element performs (Why it is required)
- Consider the following page to construct a Function Chain

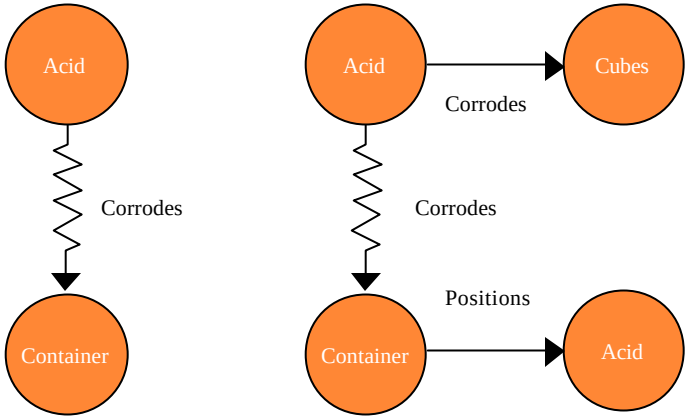
Function Chain Rules

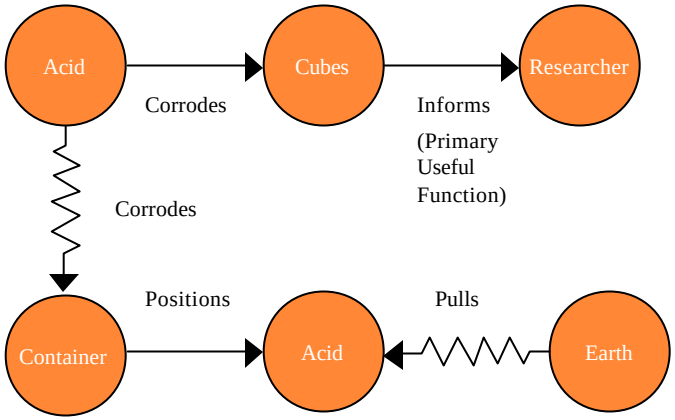
1. Start with
   - A low value element
   - A harmful function
   - A Flawed Useful Function

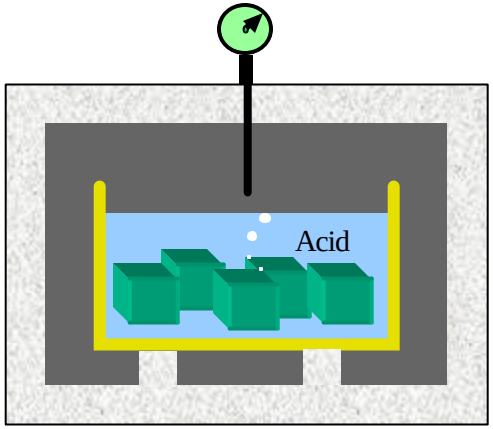
2. Why are **Elements** required-- What other useful functions do they perform

3. Why are **Modifications** required?--What Functions on Products makes the modification a requirement. Look for:
   - Useful functions that the Product performs
   - Harmful functions on the Product
   - Useful but flawed functions on the product

4. Continue with each new element and modification until the primary useful function is reached







Cubes are placed in warm acid to investigate the effect of various acids on the cubes. Unfortunately, the container that holds the acid and cubes is corroded. The container is made from a rare material and is very expensive to replace.

Why is it necessary to corrode the cube? Because a researcher would like to look at the action of various acids on the substance of the cubes.

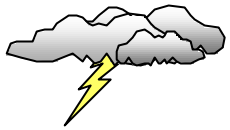
Why is it necessary to position the Acid (relative to the cube?) Because gravity will draw the acid away from the cubes

More Ideal Objects (IFR)

Knowing the chain of cause and effect which urges us to use low value parts helps us to see all of the functions that drive us to use them. Idealizing any of the functions in this chain will allow us to reduce system parts and achieve a more ideal system.

Ideal Final Result (IFR)

Brainstorm New System Parts

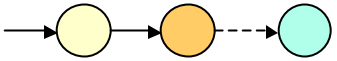


- Brainstorm a more ideal system

Functional IFR for Functions in Chain

- Consider each function of the system in turn. Begin with those **closest to the system product** or functions which **involve human intervention.**
- Use the following pages to idealize each function.
- With each step, make modifications to the system model reflecting the changes.
- **Make drawings** depicting the new system.
- This new system will likely have disadvantages or problems will be considered later.

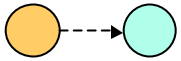
Spend Extra Time Idealizing the Primary Useful function



PUF

- Make certain that the System Product is what you want to Modify
- Make certain that the Modification is Correct
- Make extra certain that the Effect used makes best use of resources

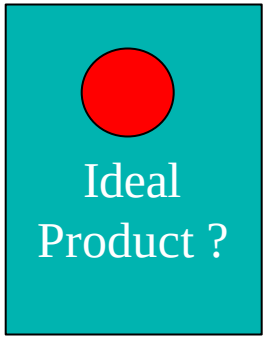
Spend Extra Time Idealizing Human Performed Functions

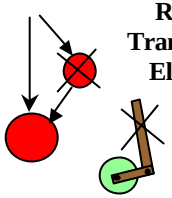


Human

- Make certain to understand why human intervention is required.
- Do everything possible to **remove the human from the system**, especially consider products that do not require the function or products that modify themselves.

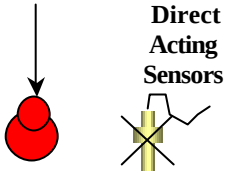
Transform Useful Functions to IFR





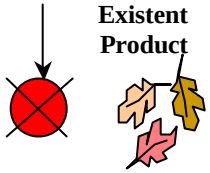
Remove Transmission Elements

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



Direct Acting Sensors

•Is the product a sensing element?
•Demand that the sensor use the **same fields for sense and modulation** (the product is a combined sensor and modulating element)
•Identify the correct physical phenomenon to do this



Non-Existent Product

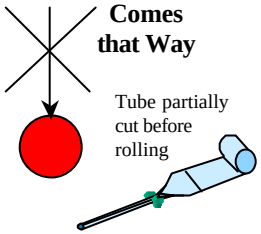
Waste Leaves

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

Modification Not Required

Scales become a delicacy--scaling not required

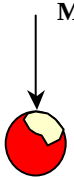
•Based on the Function Chain analysis, what undesirable variable value of the product makes the function necessary?
•Permanently reverse or change the variable value.
•What variable value makes the modification so large?
•Change so that required mod is small.



Comes that Way

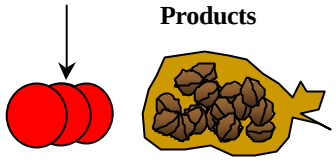
Tube partially cut before rolling

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



Minimum Part

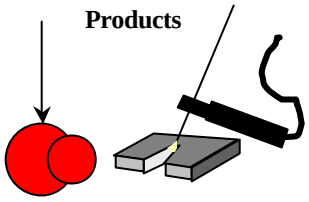
•What minimum part of the product must be modified?



Multiple Products

Crack whole bag of nuts

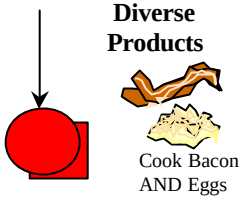
•Does product come in natural batches or groups?
•Is it more ideal to modify the group simultaneously?



Biased Products

Weld variety of metals

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

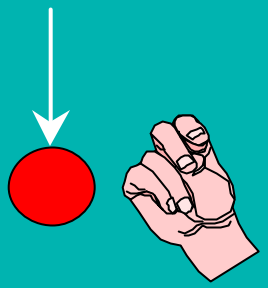


Diverse Products

Cook Bacon AND Eggs

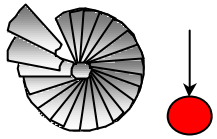
•What other elements in the system or super-system require the same modification?
• Can they also be included?

Ideal Modification?



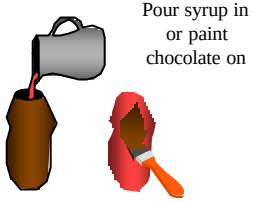
If I could snap my fingers...

Main Modification



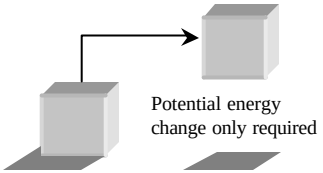
•Using the longhand form of the modification, Consider different ways to describe the modification. (Each way may suggest different tools to accomplish the function depending on abundance of system resources).
•Work backward by imagining the ideal final state. (Consider drawing a picture of the final state). What is the main feature of the product that is being changed and its ideal value?

The Inverse



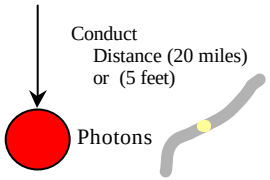
•What object is the modification performed **relative to**?
•Invert the problem by modifying the relative object. (Make it the product)

Least Resources Test

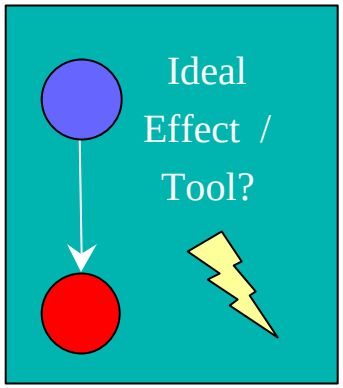


•What is the least energy that is required for the modification?
•What is the least time?
•What is the least volume or space?

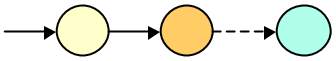
Excessive Modification Test



•Are any of the Dependant Variable Values Excessive?



Important Decision For System Product



PUF

The decision to use a new Effect (Physical Phenomenon) to deliver the Primary Useful Function is important decision for the following reasons:

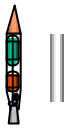
- Many unfamiliar problems may arise.
- If competing systems are not yet mature, the new system may not be able to compete.

• Using the steps on the rest of this page, determine whether a Effect is required. If a new Effect is required, the following page gives possible ways to choose this effect

Determine the Stage of Development of the System

Stage 1: Determining the Parts and Where They Go

Stage 2: Removing the Bad Marks

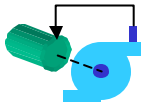


Tanks become structure

Stage 3: Make Adjustable

Removable Boosters

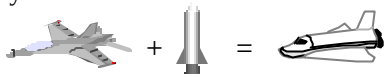
Stage 4 Introducing Feedback



Pressure feedback

Stage 5 Transition to a new Effect in stages (the effect is still present but …) or completely

Combine with Super-system



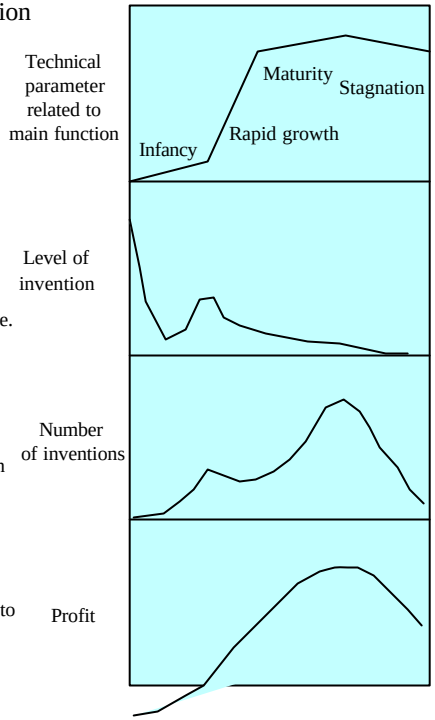
Ionic Drive Engine

Macro to Micro (Make use of Bulk Properties)

How mature is the system?

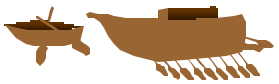
Level of invention

1. No resolution of contradiction
2. Resolves contradiction with small change
3. Resolves contradiction with a major change. Uses technology from same field
4. Resolves contradiction. Complete change in Effect. Usually a technology from another field.
5. Fundamental Effect. Has ability to change the super-system to which it belongs.

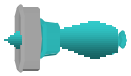


Time For a New Effect?

- Has the super-system become very specialized?



- Has the super-system reached the point of diminishing return?



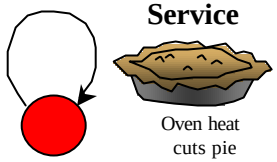
- Is automatic feedback used to perform the main super-system function?

- Must multiple conflicts be resolved for improvement? (Do too many rocks appear when we begin to drain the pond?)

Little People

- Very important for determining the Physical Phenomenon and Objects which will perform the **Main System Function**
- Envision the system as **composed of intelligent little people** who can work together.
- These people also have the capability to disappear and reappear if necessary
- What do they do to accomplish the desired result

Self-Service

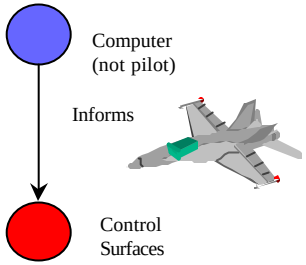


- **Process Map** the product life through relevant life stages. Identify which fields the product experiences at each process step.
- Which of these fields perform this function even poorly?
- What **small change in the product** allows the existing field to perform the modification?
- Can the former tool be combined with product?

Abundant Native Fields

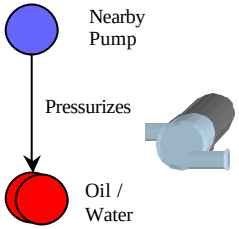
- Is the function now delivered by a super-system tool, even poorly?
- Look through the Table of Fields and identify native fields.
- Which of these perform the function, even poorly?
- Modify the field or tool to improve the Function.

Copy Current Tool



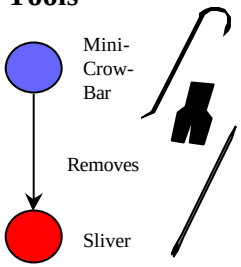
•What part of the current tool performs the function?
•Can a copy of the tool perform the function?

Nearby Analogous Tool



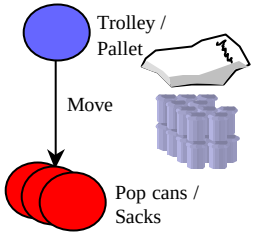
•Identify nearby analogous product
•Identify the Tool
•Combine and Consolidate

Analogous Tools



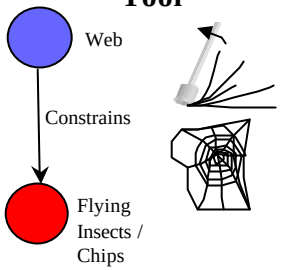
•Identify an analogous product
•Identify its tool
•Identify minimum tool variable
•Transfer Effect/Tool to new situation
- •Combine w/ existing tool
- •Transfer **minimum** amount of tool

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



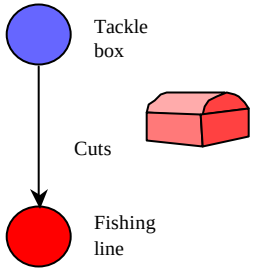
•Identify analogous products in nature?
•Identify the natural Tool/ Effect?
•Transfer the Effect/Tool to the new situation
•Look for primitive natural analogies?

Cheap Abundant Substances

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

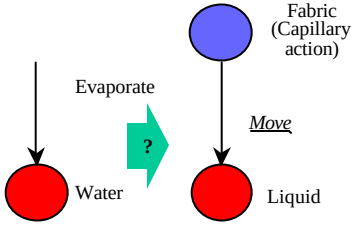
- Look around for cheap abundant substances.
- Could any of these be coaxed to perform the function?

Adjacent Elements



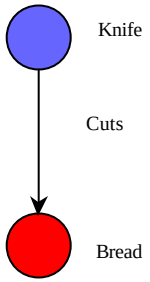
- Consider a simple modification to an adjacent element.
- Especially effective with low level fields such as elastic, gravity pressure, etc.

Table of Effects



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

Current Tool



- Can the current tool deliver the ideal modification?

Table of Fields

Elastic Force Internal & External

Gravity

Friction

Adhesive

Centrifugal Force

Inertia of Bodies (Note Direction)

Coriolis Force

Buoyant force

Hydrostatic Pressure

Jet Pressure

Surface Tension

Odor & Taste

Diffusion

Osmosis

Chemical Fields

Sound

Vibrations & Oscillations

Ultrasound

Waves

Corona Discharge

Current

Eddie Currents (internal and skin)

Particle Beams

Thermal Heating or Freezing

Thermal Shocks

Nuclear Forces

Electrostatic Field

Magnetic Field

Electromagnetic (Voltage)

Information

Radio Waves

Micro-waves

Infrared

Visible Light

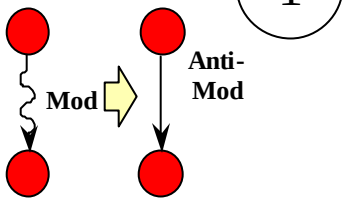
Ultra-violet

X-Ray

Transform Harmful Functions to IFR

Identify the Anti-Function

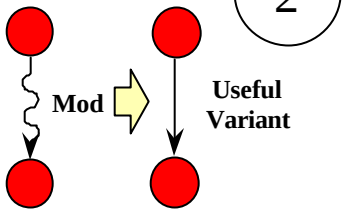
1



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

Identify a Useful Variant

2



• 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).

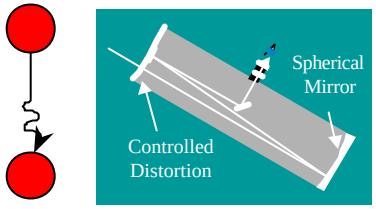
Reverse the Fields or Action

• **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

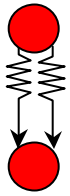
• If the harmful function could be **adjustable**, could it perform the anti-function, the useful variant or a useful function on another system product?
• Find **controlling variables** of the harmful function that can be made adjustable and boost them

Work <u>With</u>



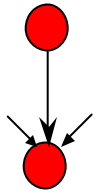
• Is the anti-function performed **with** the harmful function but **not in equilibrium?** Boost the anti-function.
•Is the harmful function useful any place on the product or on other elements **to the least degree?** Boost this function.

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

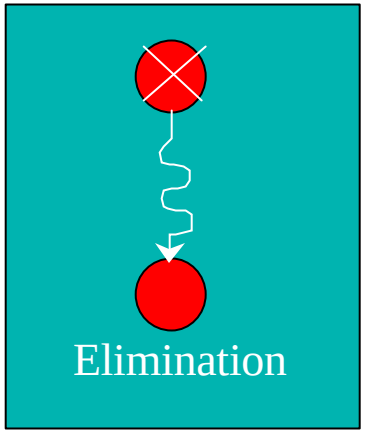
Perform Accurately



•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.

Little People

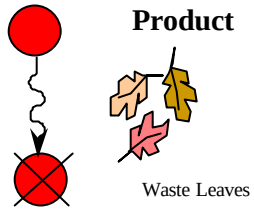
Envision the system as **composed of intelligent little people** who can work together.
• These people also have the capability to disappear and reappear if necessary
• What do they do to perform the harmful function in a useful way?



Non-existent Tool

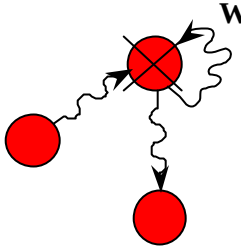
•The Tool no longer Exists
•Eliminate the Source
•Eliminate the Path

Non-Existent Product



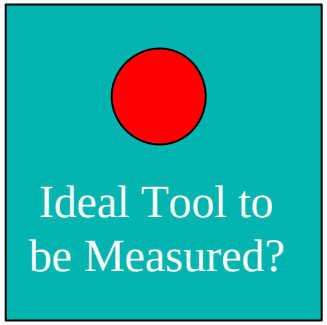
•The product no longer exists
• Use if the product is considered **harmful or waste**.

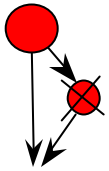
Working with Harmful Effects to Eliminate



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

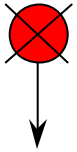
Transform Informing Functions to IFR





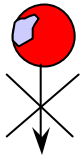
Non-Transmission Tool

•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



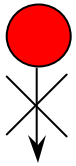
Non-Existent Tool

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



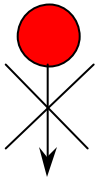
Tool Requires No Detection

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



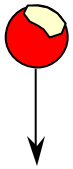
Change System Rather than Detecting

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



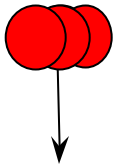
Comes that Way

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



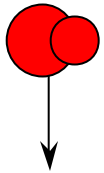
Minimum Part

•What minimum part of the Tool must be detected?



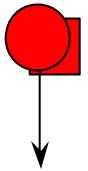
Multiple Tool Elements

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



Biased Tools

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



Diverse Tools

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

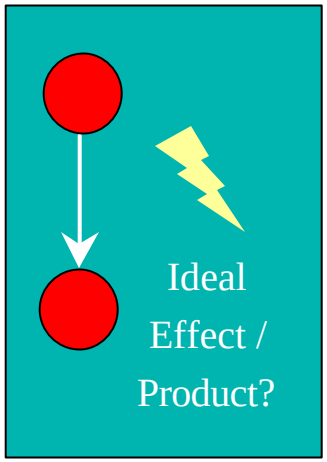
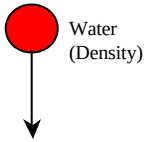


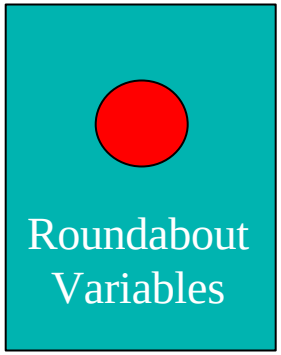
Table of Effects



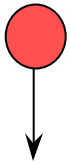
•Determine the variable or property to be measured
•Find Effect in *Table of Effects* under *Measurement*
•Determine a suitable product to receive the effect

Little People

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

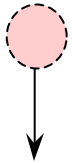


Secondary Variables



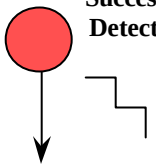
•What exact variable requires detection?
•List Secondary variables that Change when the main variable changes. Detect these variables

Use of Copy



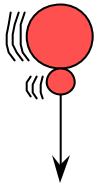
•A picture or copy of the article becomes the tool that is measured.

Successive Detection



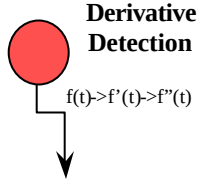
•Measure discrete events such as balls popping up or lines on a ruler to measure the main variable.

Resonance of Tool or Attached Objects

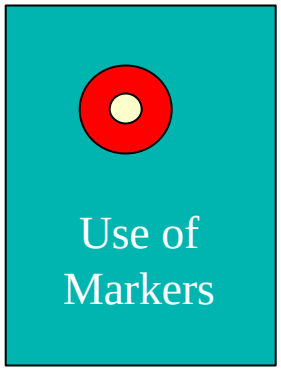


•Measure resonance amplitudes and frequencies of the Tool or Attached Objects to detect main variable.

Derivative Detection

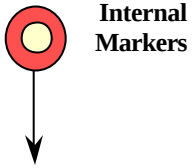


•Measure **higher order derivatives** and then integrate if necessary



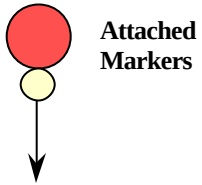
Additives

Especially Active
Concentrated
Temporary
Copies
Chemical Decomposition
Decomposing Native Media
Self-Elimination of Depleted Substances



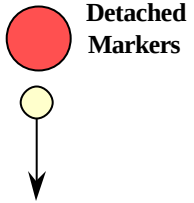
Internal Markers

•Add an internal substance with a paired field



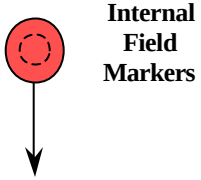
Attached Markers

•Attach a substance with a paired field



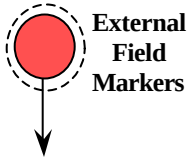
Detached Markers

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



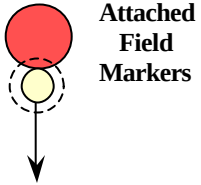
Internal Field Markers

•Add an internal field



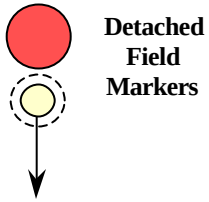
External Field Markers

•Add an external field



Attached Field Markers

•Add a field to an attached substance



Detached Field Markers

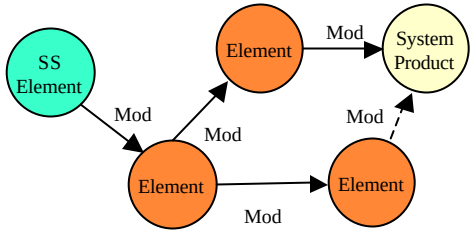
•Add a field to a substance in the native environment.

Consolidate Parts

Individual Parts can often be reduced in number when elements take on more functions

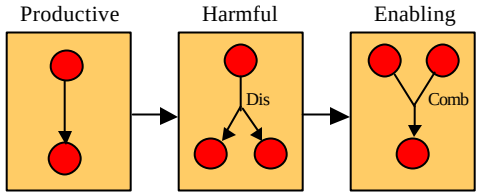
Combine & Consolidate Elements

Model Resulting 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.
- Identify all functional linkages--Harmful and useful

And/Or Process Map

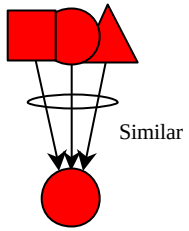


Identify Process Steps as:

- •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

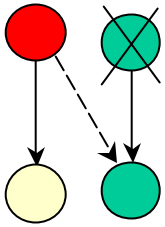
Break down steps into progressively smaller steps

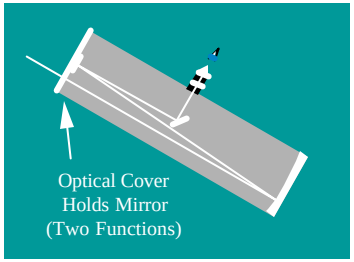
Combine Elements with Similar Functions



- •Identify Elements with similar functions on the same product
- •Can the similar functions be performed by one or fewer elements?
- Consider different configurations. **New capabilities may emerge**

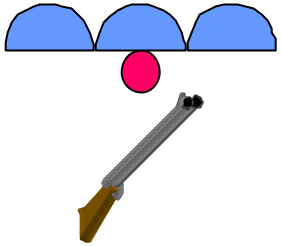
Reduce Penalty of Expensive Parts





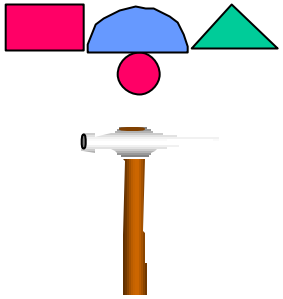
If elements are costly, look for ways to increase the number of functions performed by the new costly element.

Consolidate Multiple Like Elements



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

Consolidate Unlike Elements



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

Folding Elements

- •Consider how elements may be folded **into themselves**.
- •Consider different orientations of other elements which allow them to be folded **into one another**?

Improvements or Problems ?

We may be starting with an existing system or the idealized system from the previous steps. In either case, the system is likely to have problems or disadvantages (compared to other existing competing systems).

- What are these disadvantages
- Is it worth removing the disadvantages?
- What are our goals to remove them?

Determine Main Improvement, Problem or Disadvantages

How Serve Market Segment Better?

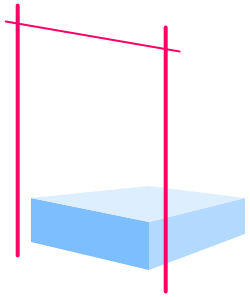
- Focus on the main jobs that this system does for the market segment.
- What would constitute "doing a better job" for this market segment?

Identify Main System Disadvantages or Problems

Y =

There will likely be some drawback to the system as a result of the previous step. It may only be confusion. Here is where we sort it out

Set a High Bar



- Set **High Goals**
- The constraints determine the height of the bar. Higher goals can galvanize the effort in the initial stages but may delay the resolution.
  - What disadvantages must be removed?
  - How much must it cost?
  - When must the solution be completed?

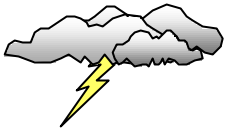
Knob Settings ? (Problem Cause)

With a clear idea of the disadvantage that we want to remove, we must become detectives and discover the chain of causes which give rise to this problem. By the end of this step, we will know the knobs and their settings which cause our problem.

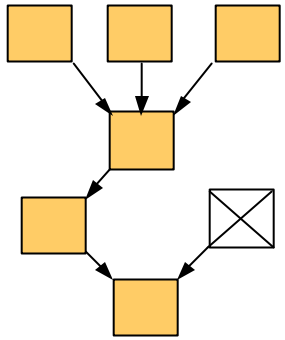
Identify and Organize Knobs

Brainstorm Knobs

$Y = f(X_1 \quad X_2 \quad X_3 \quad X_4 \ldots)$



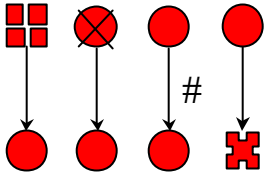
Form Cause-Effect Chains



- Create Cause-Effect Chain according to the rules on following pages.

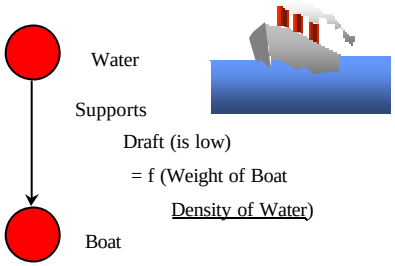
Catch Missing Knobs

Table of Controlling Variables



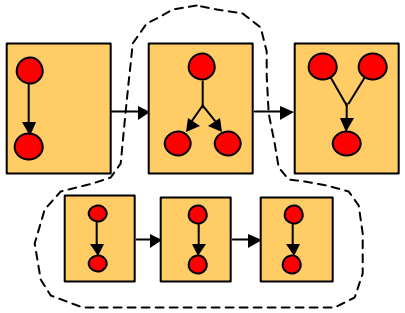
- Use the table of controlling variables to identify knobs (potential solutions) that might be otherwise missed
- Remember, each discovered knob represents a possible solution

Relative To



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

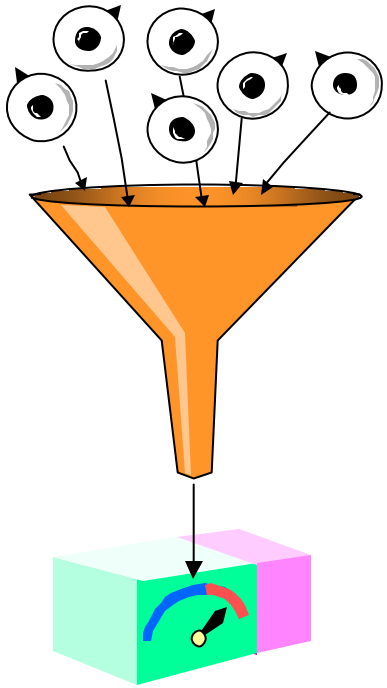
Flow of Goods, Information, Leakage, Energy, Signals or Mass

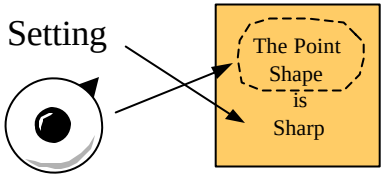


- Break down into progressively smaller steps
- Show loops

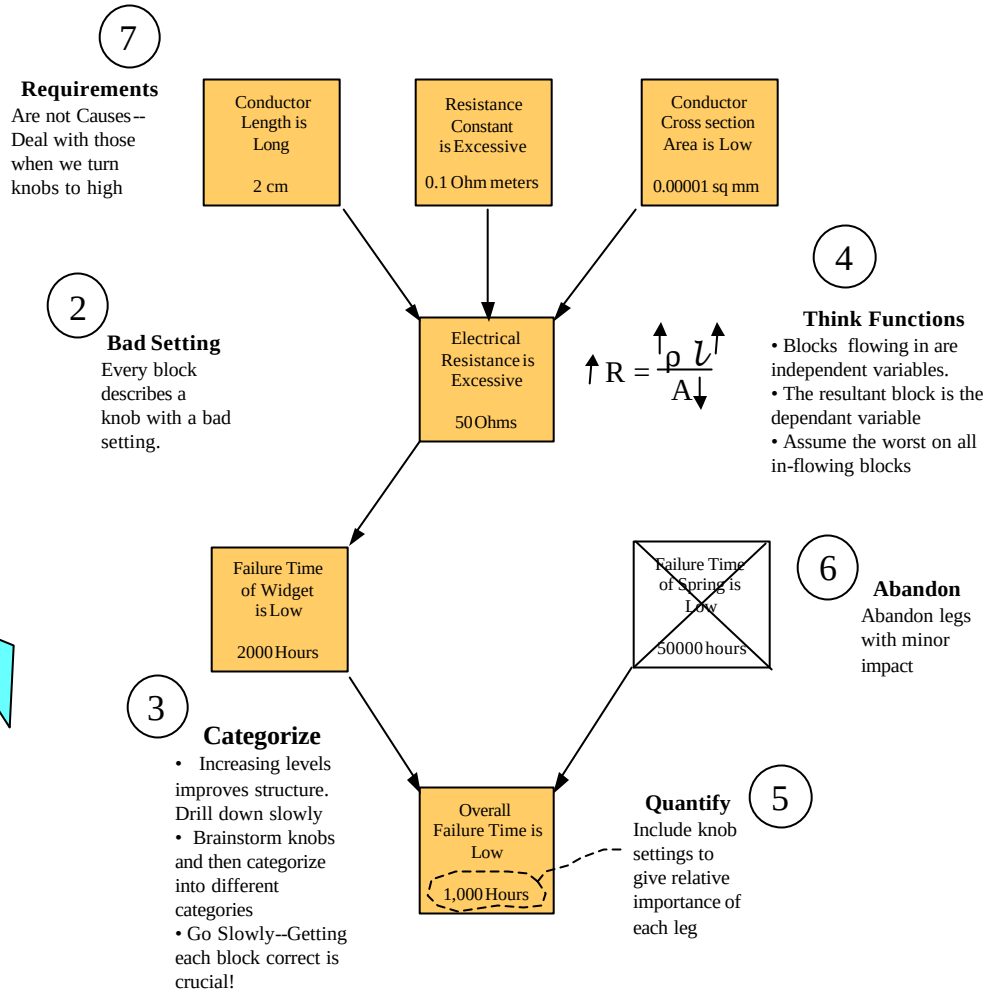
Cause-Effect Chain Rules

Identify knobs and Settings Leading to the Main Disadvantage





1 Every box represents a knob and a setting--**No exceptions**
Be Brief



If It is Hard to Tell What is Causing the Problem

Form Theories

Subject Matter Experts

- 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.**

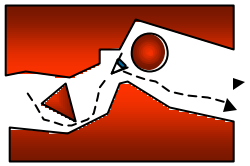
Crime Scene Analysis

- 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

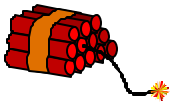
- Devise an experiment to **watch** the interactions. Consider slow motion, etc.
- Use *Redefine Informing functions* to find ways to look at what is happening (copies, etc.)

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

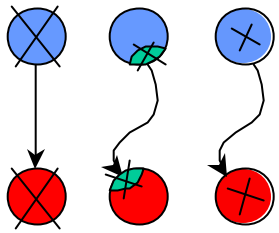
Verify Theories

Perform Experiments

Table of Controlling Variables (Xs, Knobs, Object Resources)

Existence

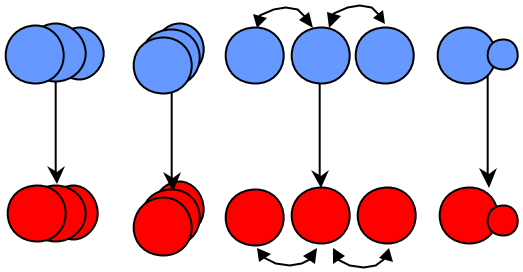
Existence



- 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

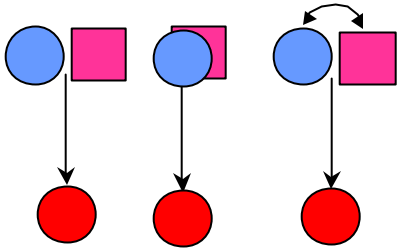
Multiplying

Number of 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

Diversity of 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.

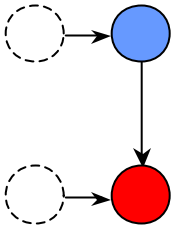
Storage of Fields

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

Location or Movement

Location

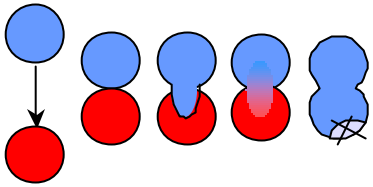


- Define the entire location Envelope for the tool and product (What space can the tool and product be located in?)
- Move the tool about in higher dimensions. Are the fields affected?
- Move the product about in higher dimensions. Are the fields Affected?

Interaction Zone Location

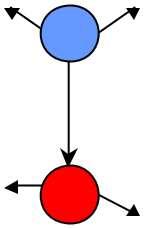
- Locate the **exact zone** of the modification on the tool and product.
- Does changing the location affect the fields of the function?

Distance Contact or Combining



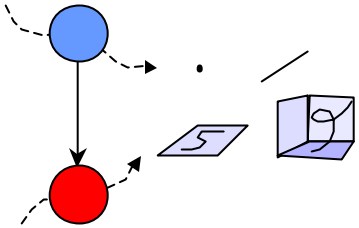
- Does changing the **distance** change the fields?
- Does **contact or separation** change the fields or introduce new fields?
- Try different locations for contact.
- **Nestle** one into the other
- **Mix** the tool and product
- **Combine** the tool and product. Consolidate. Look for new capabilities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

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?

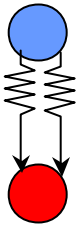
Path



- 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.

Scale

Intensity or Scope



- Is the modification sometimes weak, at least in one direction?
- Does grossly increasing the intensity help in <u>any</u> 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.

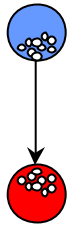
Size of Interaction Zone

- 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.

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.

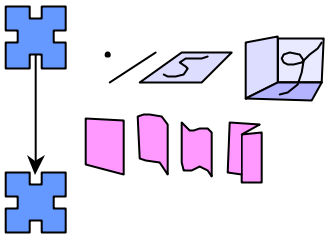
Use of Micro-Sites



- 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.

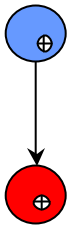
Object Structure

Shape or Size



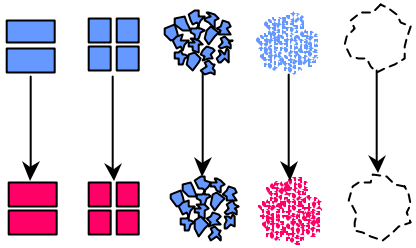
- Identify **poorly used space** around the tool and product
- Identify the dimensional construction of the interaction zone.
- If you were looking at a dimensioned drawing of the tool and product, what would be the **critical dimensions** for the function?
- Play like the tool and product are made from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

Symmetry



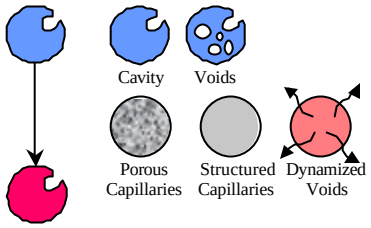
- Are the variables critical to the function symmetrically located?
- Change symmetry to **another axis**
- Make the tool or product **unsymmetrical**
- Make **symmetrical**

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

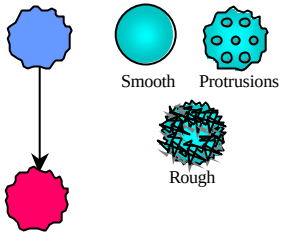
Voids and Capillary Structures



- 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

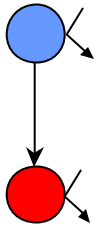
Surface Properties

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

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

Surface Properties

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

Gravity

Friction
Protrusions--Roughness--Matter State--Friction Couple--Slipperiness

Adhesive
Adhesiveness--Matter State--Cohesiveness

Centrifugal Force

Inertia of Bodies (Note Direction)

Coriolis Force

Buoyant force

Hydrostatic Pressure
Surface State

Jet Pressure

Surface Tension
Bulk Properties--State--Wetted Circumference--Temperature

Odor & Taste
Chemical Composition
Surface State

Diffusion
Surface Porosity
Surface State

Osmosis
Surface Molecular Structure
Surface State

Chemical Fields
Chemical Reactivity
Surface State

Sound

Vibrations & Oscillations

Ultrasound
Surface State

Waves

Corona Discharge
Surface Protrusions Roughness--Surface State

Current
Continuity--Surface State
Conductivity

Eddie Currents (Internal and Skin)
Continuity--Surface State
Conductivity

Particle Beams
State--Chemical Reactivity
Surface Molecular Weight

Thermal Heating or Freezing
Surface Protrusions or Roughness--Surface State

Thermal Shocks
Surface Protrusions or Roughness--Surface State

Nuclear Forces
Nuclear Particle Type

Electrostatic Field
Protrusions Roughness

Magnetic Field

Electromagnetic (Voltage)
Continuity Conductivity

Information

Radio Waves
Reflectivity--State --Absorbtivity --Emissivity

Micro-waves
Reflectivity--State --Absorbtivity --Emissivity

Infrared
Reflectivity--State --Absorbtivity --Emissivity

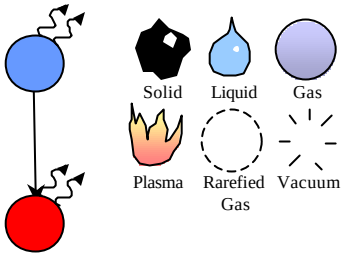
Visible Light
Reflectivity--State --Absorbtivity --Emissivity

Ultra-violet
Reflectivity--Absorbtivity Emissivity--State --Fluorescence

X-Ray
Atomic Weight

Bulk Properties

State of Matter



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

Bulk Properties of Substance

Cheap Substances
- Grocery store products
- Powders
- Foam
- Void
- Loose Bodies
- Waste or transformed waste
- Garbage
- Water, Steam or Hydrates
- Air and its components

- 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?

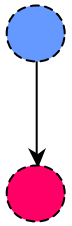
Use of Foam

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

Match or Mis-Match of Properties

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

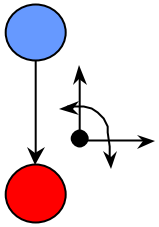
Inert Substances



- Change the tool or product to an inert substance

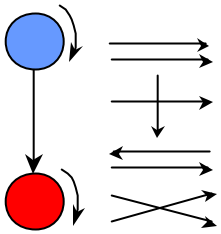
Direction

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.

Relative Orientation

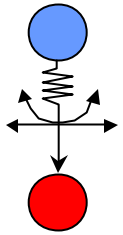


- Try different rotational orientations, relative to each other.
- Change from linear to rotary motion.

Reverse of 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?

Bulk Properties

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

Gravity
Density--State

Friction
Temperature--Viscosity--State

Adhesive
Temperature
State of Mater

Centrifugal Force
Density

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

Coriolis Force
Density

Buoyant force
Density--State

Hydrostatic Pressure
Gas Constant--State--Gamma--Temperature

Jet Pressure
Density--State

Surface Tension
Cohesiveness--State

Odor & Taste
Chemical Composition--State

Diffusion
Molecular Weight--State

Osmosis
Molecular Size
Ionization Potential--State

Chemical Fields
Chemical Composition--State

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

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

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

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

Corona Discharge
Ease of Ionization
Rarefaction--State

Current
Conductivity--State
Trans-conductance

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

Particle Beams
Molecular Weight

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

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

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--State--Image Splitting
Refractive index

Micro-waves
Transparency--State--Image Splitting
Refractive index

Infrared
Transparency--State--Image Splitting
Refractive index

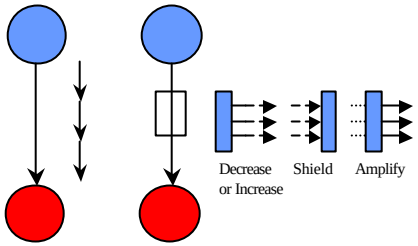
Light (Coherent & light Pressure)
Transparency--State--Image Splitting
Refractive index

Ultra-violet
Transparency--State--Image Splitting
Refractive index

X-Ray
Molecular Weight

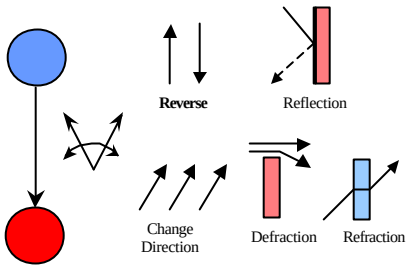
Field Structure

Field Intensity or Conductance



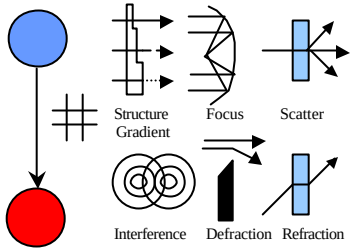
- Draw Field Potential Lines and Gradients
- Increase or Decrease the field intensity from the Tool
- Use an intermediate substance to shield, amplify or decrease the field
- Change the Conductivity of the Mediator

Field Direction



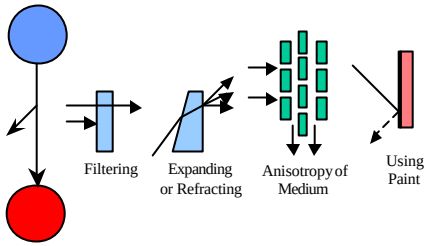
- Identify the field gradients and potential lines
- Is the field **direction** ideal? Change to the ideal field direction.
- What would happen if the fields were **reversed**?

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**

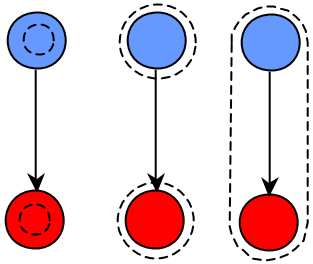
Separation of Field Components



- 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

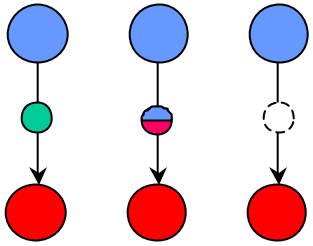
Adding or Superimposing Fields



- 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

Mediators

Use of Mediators



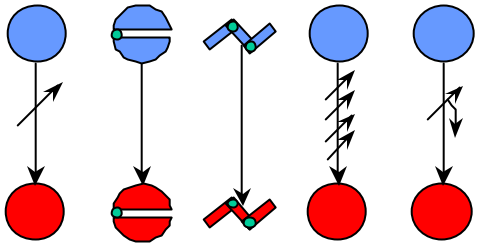
- Is direct contact required?
- Identify the field and gradient
- Make a good guess at an **alien mediator**
- Use a **modification** of the tool substance
- Use a **modification** of the product substance
- Try **mixtures** of the tool and product
- Try **multiplied versions** of the tool or product
- 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

- State of Matter
- 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

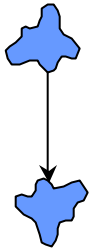
Making Adjustable

Making Adjustable



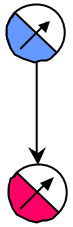
- Which of the controlling variables of the tool, product or field can be made adjustable? (Include relative controlling variables).
- Place **Joints** in the tool or product
- Increase the **number of joints**
- If a variable is already adjustable, **increase** the degrees of freedom.
- Make **several**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

Flexibility



- **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**.

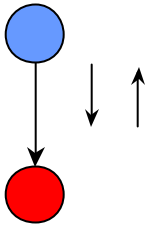
Operation Near or Far from Critical Point



- 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.

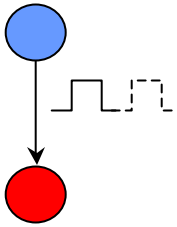
Timing

Coming & Going



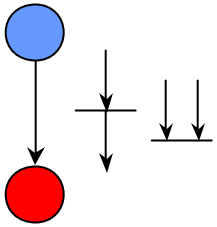
- Does the Tool Follow a Path?
- Can the Tool perform the function on the entire path?

Different Time



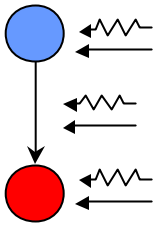
- Process Map the changing conditions over time.
- Does the requirement for the function vary over time?
- Could other tools help out at another time?
- If the modification is performed as a step in a process, can the sequence be changed to a more favorable time?
- Perform during transportation or while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

Partial Modification



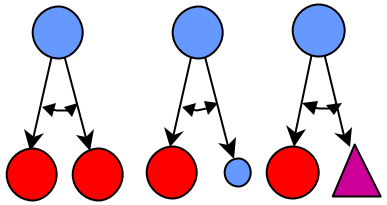
- Can the modification be broken into two (or more) **stages**?
- Can the operation be broken into **parallel** stages
- Can setup be performed at same time as operation?
- Implies use of a **previously placed tool**.

Uncouple Other Functions



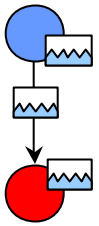
- Identify other functions performed on the tool, product and field.
- Does uncoupling these other functions improve the function?

Uninterrupted Operation



- 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?

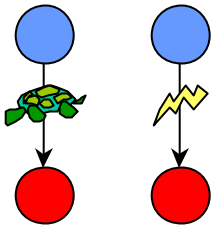
Storage of Action or Field



- 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?

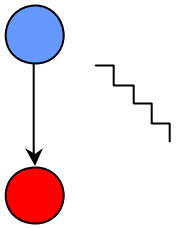
Time Variation

Speed



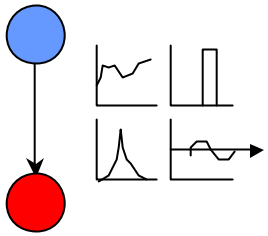
- What would happen if the function were slowed way down (hours, days, weeks, months, years)
- How are the fields changed by performing the modification more slowly?
- Is the function improved if the modification is performed very rapidly? (Days, hours, minutes, seconds….)
- If the modification were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

Use of Discrete Steps



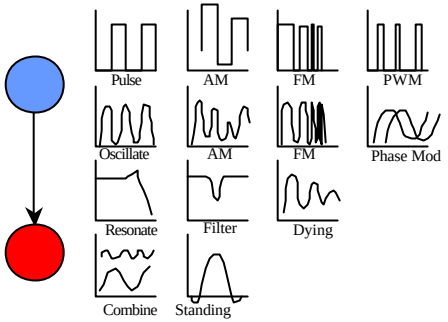
- **Multiply or segment** the tool into separate pieces.
- Each piece moves into action in discrete steps or into fixed positions or amplitudes.

Time Variance or Pulse



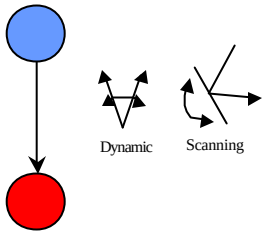
- If you could continuously vary the action in time, what would be the **perfect shape** of the curve?
- Square pulse the action.
- Shape the pulse.
- Make the pulse travel.

Pulsation or Oscillation



- 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

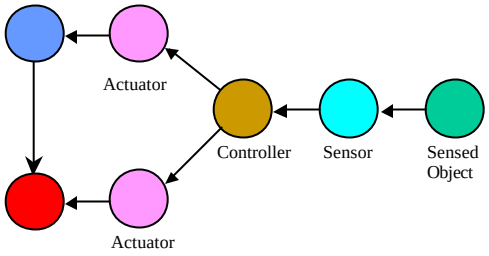
Field Direction



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

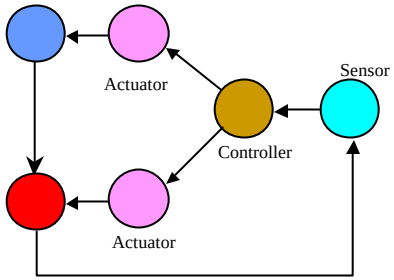
Control

Addition of 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**

Use of 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…)

Use of 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.

Turn Knobs to High

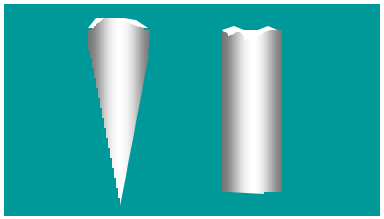
Knowing the chain of cause and effect means that we know the knobs and their settings which cause the problem. Now we must turn the knobs to settings which will give a long enduring change to the disadvantage. In effect, we turn the knobs to high. Some knobs are well behaved, we can easily turn them without anything getting worse. Other knobs cannot be turned, or turning them causes something else to get worse. Trying to turn these knobs results in a contradiction.

Turn Knobs to High

Pick a Knob with Large Impact

- Get **Background** on the situation.
- Ask a lot of questions. **Keep asking why**
- Study what the **subject matter experts** have to say.

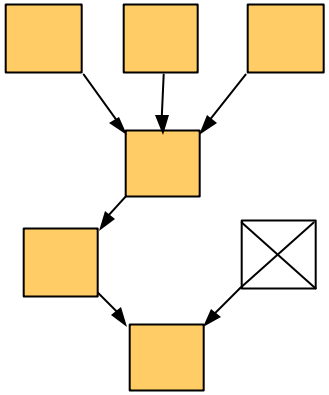
Form Contradictions



Very Sharp | Very Blunt

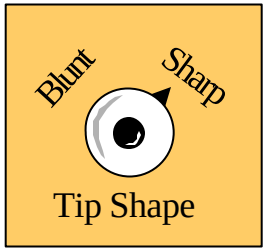
- **Draw the interaction zone both ways**. Draw it in the most **ideal or extreme** conditions.
- Form the short-hand version of the **contradiction**.

Choose Critical Knobs from Cause Effect Chain



- Form alternative problem paths.
- Study the chain and choose knobs that, if turned, would have a large impact on what you are trying to improve.

Turn Knob to the Extreme (What If. . .)



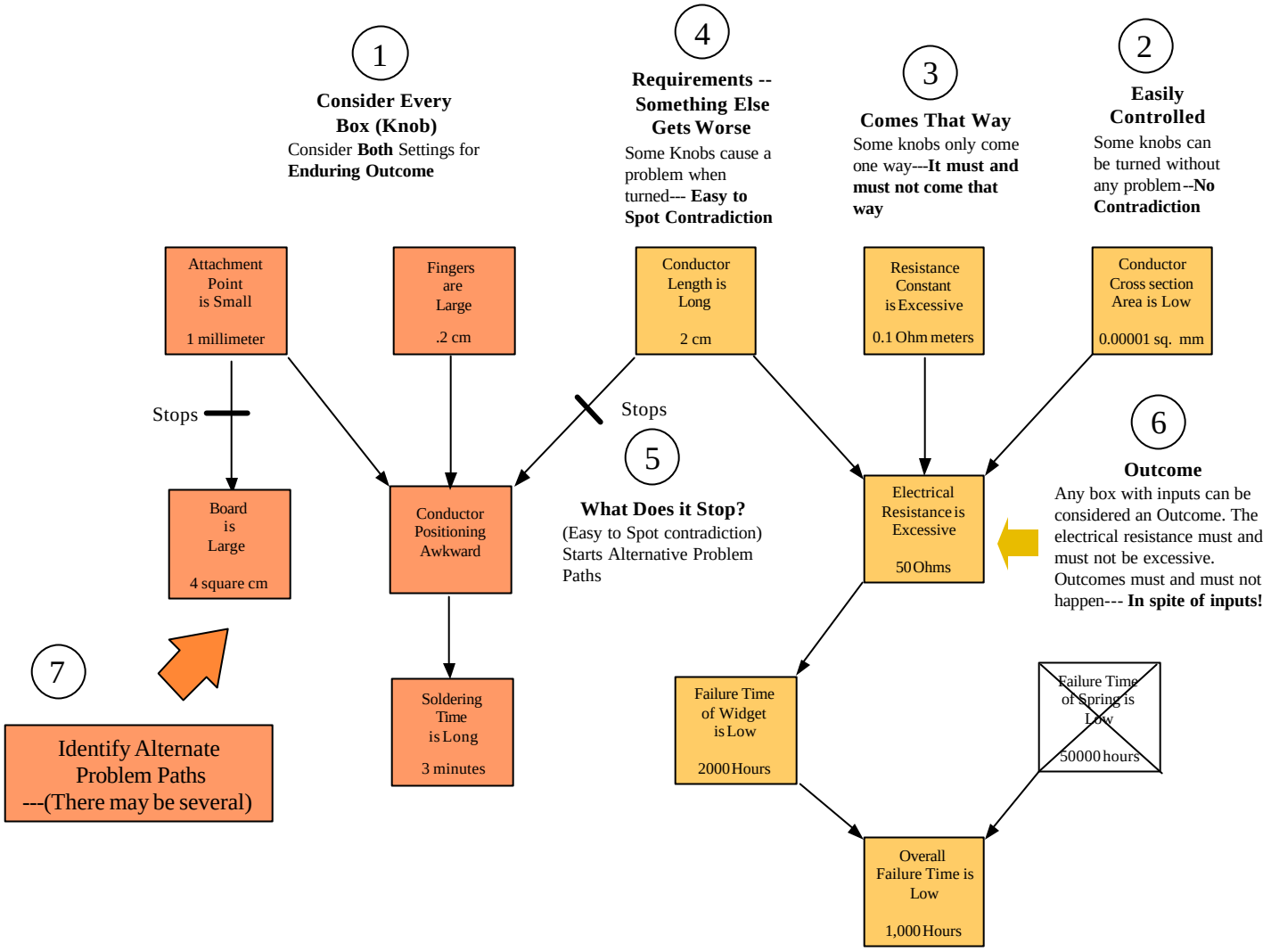
- Identify stated customer requirements
- In what ways does the system fall short of these requirements

Types of Knobs

- Knobs That Turn Easily
- Only Come in One Flavor
- Something Else Gets Worse
- Knob is an Outcome
- Knob Has Little Effect

Cause-Effect Chain Rules

Turning Knobs---Identifying Contradictions and Alternative Problem Paths



Resolve Contradictions

Turning the knobs to high has caused other problems. Now we must find a way of setting the knobs to both settings and thus removing the contradiction.

Table of Contradictions

Under what **condition** must each conflicting property exist?

It must be hot when . . . (high altitude)
It must be cold when . . . (low altitude)

Must conflicting properties **overlap** in time? (high and low altitude overlap?)

Yes

No

Separate on Condition

Can the fields, positions . . .which accompany the different conditions be used to Drive the Change? (Can pressures at different altitudes be used?)

Yes

No

Can **at least two** objects be used at the same time or can the object be **segmented**?

Yes

No

Separate in Time

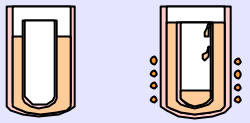
- Mixing / Eliminating---Page 49
- Segmentation / Unification---Page 50
- Separation / Merging---Page 50
- Rearranging / Unfolding---Page 50
- Interacting---Page 51
- Merged Interaction---Page 51
- Adding / Subtracting Parts 51

- Copy / Facsimile --- Page 52
- Two Objects---Page 52
- Extraction---Page 52
- Touching---Page 53
- Reorienting Attachments---Page 53
- Non-Uniform---Page 53
- Adding a Carrier---Page 49
- Discarding the Carrier---Page 49
- Unrolling---Stretching---Page 54
- Transformable States---Page 54
- Discarding---Page 54
- Preliminary Action---Page 55
- Preliminary Counter Action---Page 55
- Excessive Action---Page 55
- Changing Direction---Page 56
- Switching Fields---Page 56
- Input / Output---Page 56

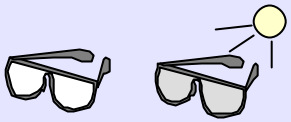
On Condition

First + On Changing Conditions −

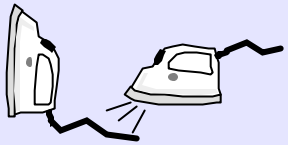
- What objects change orientation relative to each other
- Consult the chart of fields . What fields change in the new conditions?
- Can these changing conditions, themselves, drive the change?



Oil Height is Low at Low Temp--High at High Temp



Glass Tint is Light and Dark depending on light conditions



Constrains water when upright and Flows water when Pressing

Can one of the conflicting properties **build up** over time?

Yes

No

Separate Gradually

- Separate Use---Page 57
- Repeated Use---Page 57
- Gradually Merged---Page 57
- Gradually Hidden---Page 58
- Maturing / Proliferation--- Page 58

Where must the conflicting properties exist and not exist?

Must they exist in the same space?

No

Yes

Separate in Space

- Two Objects--- Page 59
- Extraction---Page 59
- Guided / Nesting---Page 59
- Attached---Page 60
- Mixture--Page 60
- Non-Uniform---Page 60
- Part Merged--Page 61
- Part Carried--- Page 61
- Part Interacts---Page 61

Can the object be **segmented** or can **more than one** be used at once?

Yes

No

Separate by Scale

- Multiplication---Page 62
- Segmentation---Page 62
- Merging---Page 62
- Interacting---Page 63
- Countering---Page 63
- Hiding---Page 63
- Carrier---Page 64
- Nesting---Page 64
- Mixture---Page 64

Do the conflicting properties **already exist in different directions** or can they be made to?

Yes

No

Separate by Direction

- Direction---Page 65
- Path---Page 65
- Sectioning---Page 65
- Complimentary---Page 66

Separate by Perspective

- By Comparison---Page 67
- How You Look---Page 67
- Looks Like---Page 67
- Facsimile--Page 68
- Frame of Reference---Page 68

Separate by Field Properties

- Transparency---Page 69
- Frequency / Speed---Page 69

Separate Between Substance and Field Page 69

Table of Fields

Elastic Force Internal & External

Gravity

Friction

Adhesive

Centrifugal Force

Inertia of Bodies (Note Direction)

Coriolis Force

Buoyant force

Hydrostatic Pressure

Jet Pressure

Surface Tension

Odor & Taste

Diffusion

Osmosis

Chemical Fields

Sound

Vibrations & Oscillations

Ultrasound

Waves

Corona Discharge

Current

Eddie Currents (internal and skin)

Particle Beams

Thermal Heating or Freezing

Thermal Shocks

Nuclear Forces

Electrostatic Field

Magnetic Field

Electromagnetic (Voltage)

Information

Radio Waves

Micro-waves

Infrared

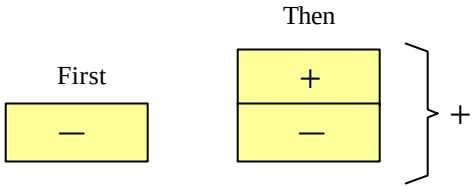
Visible Light

Ultra-violet

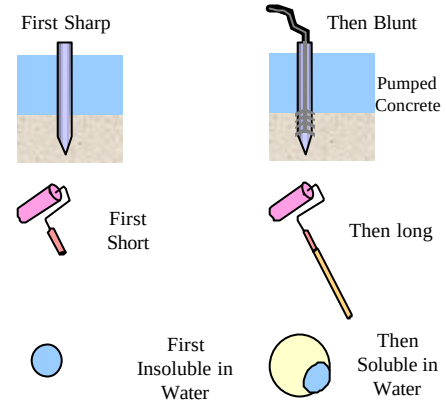
X-Ray

Separate in Time -- Under what conditions must the properties exist? When . . .

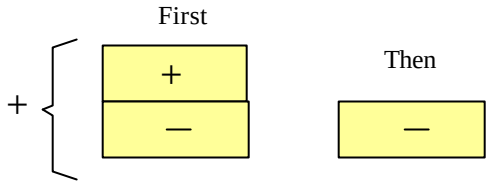
Adding a Carrier



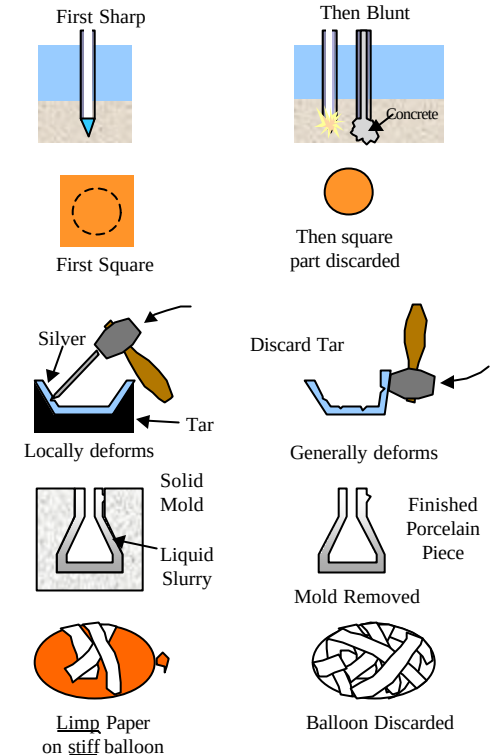
•One element having one property is used first
•The second element having the conflicting property is added (attached)
•The whole now has the property of the added element
• Consider adding multiple elements



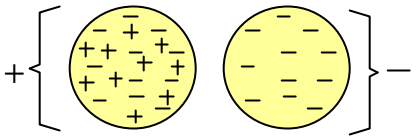
Discarding the Carrier



• Two elements having conflicting properties are attached together.
• The whole has the conflicting property of one of the elements
• **Discard** all or part of the element having the main property
• Consider **Replacing** with an object having the conflicting property

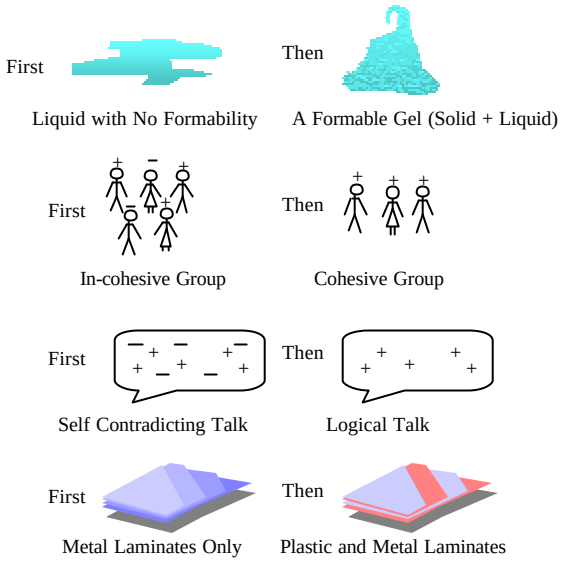


Mixing / Eliminating

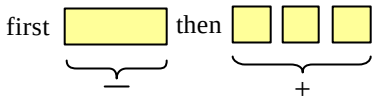


• Either mix in or eliminate a mixture component to give the whole the opposite property
• Consider finer and finer scales down to sub-atomic particles

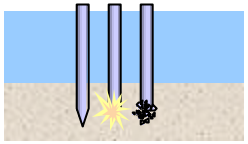
Fabrics and Matrix
Multi Fiber Fabrics
Multi Property Laminates
Mixtures of Different Molecules
Gels (Liquids + Solids)
Pastes (Liquids + Solids)
Foams (solid or liquid)
Capillary Structures (Solid + Liquid)
Components of Solids or Liquid



Segmentation / Unification



- The properties of the system are changed when the object is segmented or unified
- First segment, then separate
- Or segment and then unify
- Consider performing this at the micro-level. Dissolving, etc.



First Sharp then Blunt

Square Fireworks Charge

Round Display

Wheat: Long life

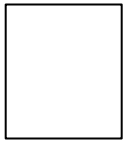
Flour: Short Life

Pill: Slowly Dissolved

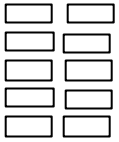
Powder: Rapidly Dissolved

Garlic: Weak Smell

Powder: Strong Smell



Pass-around to Read

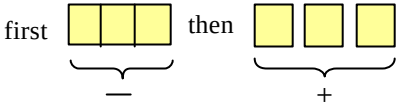


Hand Out at Once

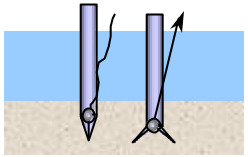
Molecule with One Property

Opposite Property when Dissolved

Separation / Merging



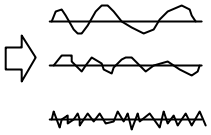
- The properties of the system are changed when a segmented object is separated or merged
- Consider performing this at the micro-level. Dissolving, etc.



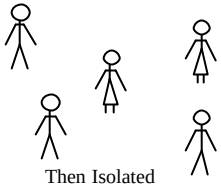
Sharp when Merged-- Blunt when Separated

First Round

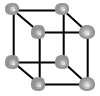
Then Square



First a Group



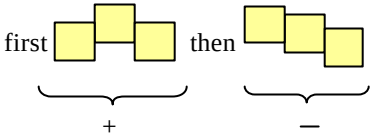
Then Isolated



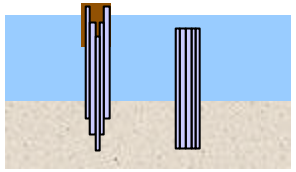
First Crystal

Then In Solution

Rearranging / Unfolding

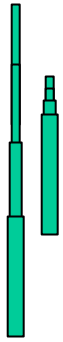


- Multiply or segment elements
  - Hinged and allow unfolding
  - Guided by each other
  - Interact through field
  - Rearrange on condition if possible
  - Consider Nesting

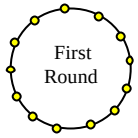


First Sharp Then Blunt

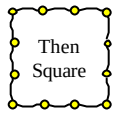
Expandable Cup



Pointer Or Antenna

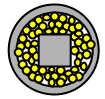


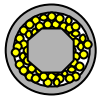
First Round



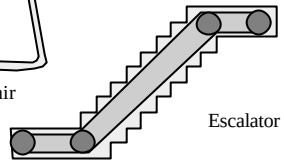
Then Square

Folding Chair



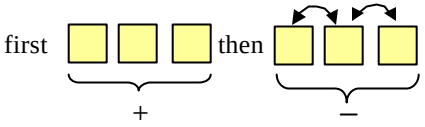


Self-Adjusting Nut Driver

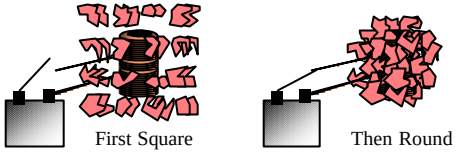


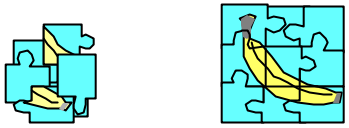
Escalator

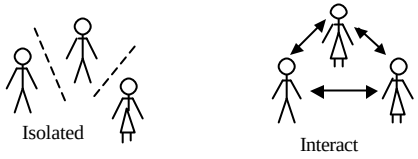
Interacting

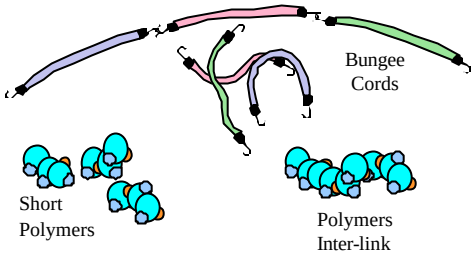


- Identify existing or easily added fields
- Begin with separate parts and then make individual pieces interact.
  - •Parts Adhere
  - •Parts nestle into each other
  - •Parts shaped to interact
  - •Parts shaped to inter-link
  - •Linked by transmission
  - •Interact through field
  - •Hinged

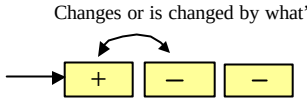




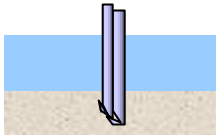




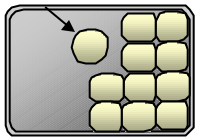
Merged Interaction



- How can the added part change the parts already in place or be changed to have the conflicting property? (At least a little with each addition until the whole has the conflicting property).
- All or all but the last one added have the conflicting property
- 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

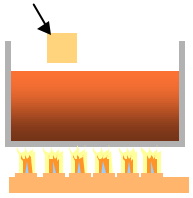


Added sharp piles push on lip of previous pile making it blunt



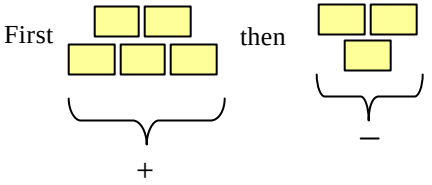
Each round roll is pushed against the previous rolls to make them square

Each trainee that is added is educated by the rest of the trained group



Each piece of solid metal is made liquid by the prior pieces added

Adding / Subtracting Parts



- Make the number of parts adjustable