Innovation and the Theory of Inventive Problem Solving (TRIZ)

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Innovation and TRIZ

- Definition of Innovation
- What is TRIZ?
- Basic Concepts
- Standard Solutions and Innovative Principles
- Levels of inventive solutions
- Evolution of technological systems
- Patterns in Inventive Systems
- Contradictions => matrix of technical parameters
- Trimming

Innovation and TRIZ

Questions to Reflect on

- Can innovation be taught and learned?
- Are there systematic and structured ways towards innovation?

Innovation and TRIZ

…more questions…

- Can you carry water in a basket?
- Can a child lift a grown man in the air and hold him up for a long time?
- How to seal a bottle of champagne or sparkling wine? Old solution – put a wire cage on top of the cork that covers the bottle
- How to make a coffee cup so that it is strong enough not to break, light enough to carry around, and does not occupy a lot of space when transported from one place to the other.

Innovation and TRIZ

…additional Questions

- Why is there no lack of organ donors in Spain?
- How to eliminate the drag caused by airplane wheels during flight?
- How to reduce the drag due to the wings of a fighter jet?

What is Innovation?

- introduction of something new;
- a new idea, method or device;
- transformation => useful; commercial application
- creation and delivery of customer value to the marketplace

What is TRIZ?

- Russian Acronym for *Teoriya Resheniya Izobreatatelskikh Zadatch*
- Theory of inventive problem solving (TIPS) in English
- started with Altshuller's interest in invention and work in Soviet Navy patent office.
- Results of over 50 years of research analyzing over 2 million worldwide patents within all engineering disciplines

TRIZ

- Systematic, structured way of thinking
- Science
- A tool set: it is the only innovation tool which uses the patterns of innovation OUTSIDE of the room!
- an evolving, open-ended system or methodology for enhancing human inventiveness and creativity through
  - Systematic identification of problems and ideal solutions
  - Overcoming various blocks through heuristics and approaches that have worked in other disciplines

  => ARIZ, TRIZICS, I-TRIZ, …

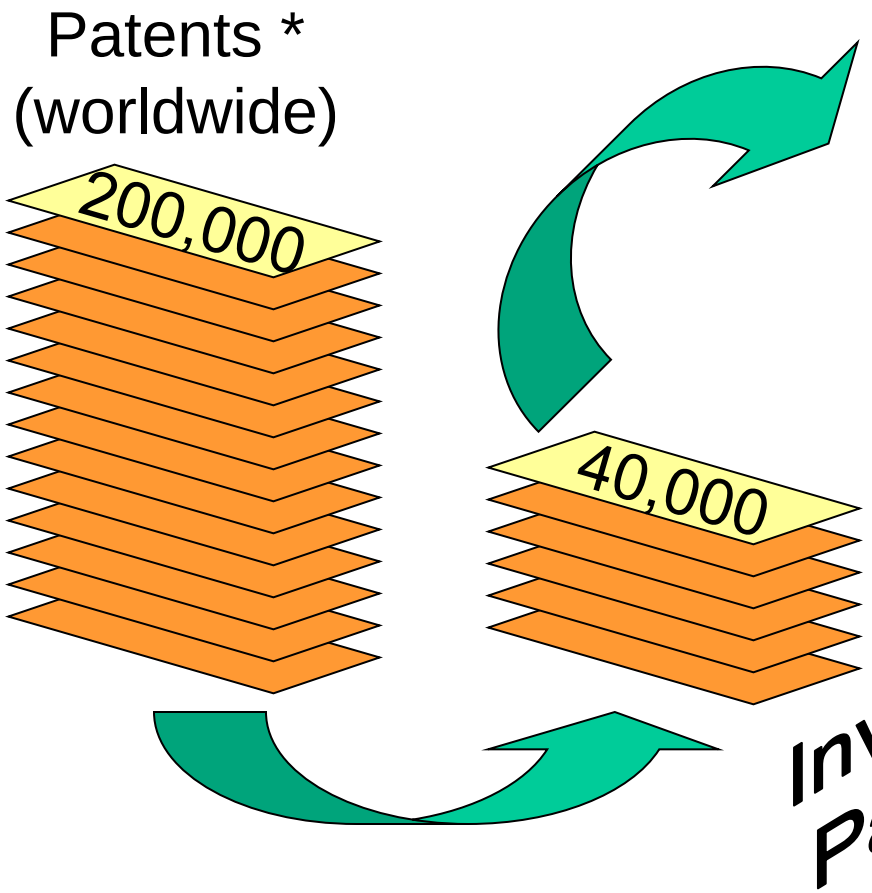
- born 15 October 1926
- grew up in the city of Baku, Azerbaijan in the former USSR
- over a dozen patented devices, the first one at age 14 for an underwater breathing device
- an engineering degree
- 1946 worked in Soviet Navy patent office as consultant – assist inventors in filling out patent details
- 1948 wrote a letter to Comrade Stalin wishing to help the motherland do better invention
- 1950 arrested for “investor’s sabotage” sent to the Gulag
- 1956 wrote his first paper
- searched for simple way of classifying inventions and discovered that there are only 5 levels of inventiveness

Genrich Saulovich Altshuller (1926-1998)

History

- He recognized that the development of technological systems follows predictable patterns that cut across ALL areas of technology--the *speed* of technical evolution can be accelerated
- Also recognized that problem solving principles are also predictable and repeatable--***anyone can invent!***
- Established schools to teach after a Stalin 7 yr. prison term--deceased in 1999 at age 71

TRIZ is Based on Abstraction of Knowledge Rather than Guesswork



Key Findings

- Inventive problem
- Levels of invention
- Patterns of evolution
- Patterns of invention

* Today over 2,500,000 patents have been investigated.

BASIC CONCEPTS

- Systems evolve toward IDEALITY irreversibly
- Using RESOURCES within the system
- Resolving CONTRADICTIONS
- EVOLUTION of TECHNOLOGICAL SYSTEMS, PATTERNS of INVENTIONS, and OPERATORS, are constantly recognized and used
- INNOVATIVE PRINCIPLES AND STANDARD SOLUTIONS

40 Inventive Principles and 76 Standard Solutions

The "76 Standard Solutions" of TRIZ were compiled by GENRICH S. Altshuller and his associates between 1975 and1985. These are grouped into 5 large categories:

1.	Improving the system with no or little change	13
2.	Improving the system by changing the system	23
3.	System transitions	6
4.	Detection and measurement	17
5.	Strategies for simplification and improvement	17

Total:		76 standard Solutions

Ref: http://www.triz-journal.com/archives/1999/05/e/index.htm

40 Inventive Principles

The 76 standard solutions can be distilled into
40 Inventive Principles

…40 Inventive Principles (1-3)

1. Segmentation
   - Divide the element into smaller units
   - Use particles instead of the whole object
   - Divide the object into parts, then make it flexible by linking the parts
   - Transition to the micro-level

2. Extraction (Take out)

3. Local Quality
   - Protect certain regions from the full impact of an action
   - Turn a magnetic field on or off according to the local need.
   - Change from uniform structure to a structure that is specific to the situation
   - Concentrate an additive in one location

…40 Inventive Principles (4-8)…

4. Asymmetry
   - Change from uniform structure to a structure that is specific to the situation
5. Combining/Merging
   - Additive, temporary or permanent, internal or external, from the environment or from changing the environment
   - Simplification of Bi- and Poly-systems
6. Universality
7. Nesting
8. Counterweight/Anti-weight

…40 Inventive Principles (9-14)…

9. Preliminary anti-action (Prior counter-action)
10. Preliminary action
11. Cushion in advance
12. Equipotentiality
13. Other way around (Inversion)
    - Introduce magnetic materials in the environment, instead of into the object
14. Spheroidality or use of curves

40 Inventive Principles (15-17)…

15. Dynamism
- Make the system flexible Use dynamic magnetic fields

16. Partial or overdone (excessive) action
- Control small quantities by applying and removing a surplus
- Simulate the introduction of more than is acceptable

17. Another dimension

…40 Inventive Principles (18-20)…

18. Mechanical vibration

- Match the natural frequencies of the field with the substance
- Use vibration in conjunction with magnetic fields
- Measure changes in a system by means of changes in its resonant frequency

19. Periodic action

20. Continue useful action (Continuity of action)

- Do one operation during the downtime of another

…40 Inventive Principles (21-24)…

21. Skipping (do fast)
22. Blessing in disguise (Eliminate harmful effects)
23. Feedback
- Self-controlled changes
- Use dynamic magnetic fields

24. Intermediary (Mediator)
- Use one object to make the actions of another possible.
- Create structures by use of magnetic particles
- Introduce a ferromagnetic additive, temporarily
- Use a temporary additive, internal or external
- Introduce an additive temporarily

…40 Inventive Principles (25-27) …

25. Self-service
- Self-controlled changes
- Use dynamic magnetic fields

26. Copying
- Measure a copy
- Apply additives to a copy instead of the original

Substitute throwaway

27. Cheap short life

…40 Inventive Principles (28-29) …

28. Replace Mechanical System with Fields

- Replace or supplement a poorly controlled field with a more easily controlled field
- Use of ferromagnetism and ferromagnetic materials
- Use electric current instead of magnetic particles
- Create a field that can be detected or measured
- Use a field instead of a substance

29. Pneumatic/Hydraulic

- Use magnetic liquids
- Use "nothing“
- Use "nothing" to simulate structures

…40 Inventive Principles (30-32) …

30. Flexible film or thin membranes
    - Change from a uniform structure to a structure that is specific to the situation

31. Porous material
- Use porous or capillary materials
- Change a uniform structure to a non-uniform one
- Use capillary or porous structures in a magnetic material, or to contain magnetic fluid

32. Change color
    - Use detection instead of measurement
    - Measure the system by means of natural phenomena
    - Use detection instead of measurement
    - Measure the system by means of natural phenomena Transform physical-chemical states

…40 Inventive Principles (33-35) …

33. Homogeneity
34. Discard/Recover
    - The additive disappears after use
35. Change Parameters

Phase change

- Additive, temporary or permanent, internal or external, from the environment or changing the environment

Use rheological liquids

…40 Inventive Principles (36-40)

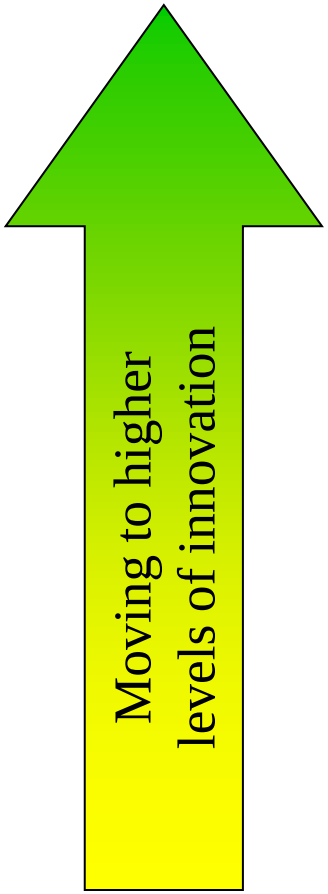
36. Thermal expansion
    - Control a system by means of thermal expansion, instead of measuring temperature
    - Measure expansion instead of temperature
37. Use oxidizers
    - Getting needed ions, molecules, etc. Includes 5.51, 5.52, and 5.53
    - Use small amounts of very active additives
38. Inert environment
    - Additive, temporary or permanent, external
    - Change the environment of the system
40. Composite material
    - Add "nothing"—foam, honeycomb, etc.

Levels of Inventive Solution

- Level 1: Standard, routine methods within specialty.
- Level 2: Improvement, new features.
- Level 3: Invention inside paradigm, essential improvement of existing system (automatic transmission).
- Level 4: Invention outside paradigm, new system (use of little known phenomena).
- Level 5: Discovery, essentially new system, new science? (lasers, aircraft, computers).

Classification of Solutions: We need to raise innovation skills via methods and tools.

Levels of Invention (Solution)



- **Level 5: Discovery**
  - Pioneering of an essentially new system
    - Laser, radio, airplane
- **Level 4: Invention outside the paradigm**
  - A concept for a new generation of an existing system, based on changing the principle by which the primary function is performed
    - Jet aircraft, integrated circuit
- **Level 3: Invention inside the paradigm**
  - Essential improvement of an existing system
    - Automatic transmission, radio telephone
- **Level 2: Improvement**
  - Small improvements of an existing system, usually with compromise
    - Bifocal glasses, beeper
- **Level 1: Apparent solution (no invention)**
  - Established solutions; well-known and readily accessible

WHAT TO USE TRIZ FOR

- Level 2-4 problems
  - 1--straightforward engineering design
  - **2--simple contradictions**
  - **3--difficult design and manufacturing contradictions**
  - **4--extremely difficult system design problems (“intestine problems**”)
  - 5--invention of new science
- Level 4 can require looking at hundreds of thousands of potential solutions and take many years of effort within an organization

What is an Inventive Problem?

- Involves one or more contradictions
- Suggests no known ways or means of solution

Contradictions/Separation Principles- One of the premises and the Most Powerful Parts of the TRIZ Methodology

Physical Contradiction

- A characteristic must be higher and lower (self-opposing)
  - Example: An organization must be large so it has resources but must be small so it has agility.
- A characteristic must be present and absent
  - Example: A purchasing department must be present to provide a function that is vital to the company but should not be present because it increases the cost of overhead.

Physical Contradiction

- Single parameter that we want to both increase and decrease.
- Do not compromise: Invent.
- Separation principles for overcoming:
  - Separation in time
  - Separation in space
  - Separation in scale

Technical Contradiction

- An improvement in one system characteristic results in the deterioration of another
  - Example: Cost of service vs. accuracy of work
  - Example: Size of company and ease of change
- Traditionally, technical contradictions are resolved by trade-off or compromise
- TRIZ seeks to eliminate the contradiction without the use of trade-offs

Altshuller's 39 Parameters (1-20)…

1. Weight of moving object
2. Weight of nonmoving object
3. Length of moving object
4. Length of nonmoving object
5. Area of moving object
6. Area of nonmoving object
7. Volume of moving object
8. Volume of nonmoving object
9. Speed
10. Force
11. Tension, pressure
12. Shape
13. Stability of object
14. Strength
15. Durability of moving object
16. Durability of nonmoving object
17. Temperature
18. Brightness
19. .Energy spent by moving object
20. Energy spent by nonmoving object

…39 Parameters (21-39)

21. Power
22. Waste of energy
23. Waste of substance
24. Loss of information
25. Waste of time
26. Amount of substance
27. Reliability
28. Accuracy of measurement
29. Accuracy of manufacturing
30. Harmful factors acting on object
31. Harmful side effects
32. Manufacturability
33. Convenience of use
34. Repairability
35. Adaptability
36. Complexity of device
37. Complexity of control
38. Level of automation
39. Productivity

Sample Contradiction

- Weight of moving object vs force
- Use 8, 10, 18, 37
  - Counterweight
  - Prior action
  - Mechanical vibration
  - Thermal expansion
- Amounts to an expert system depending upon technical blocks.

Technical Contradictions & the Matrix

- Parameter A improves, but parameter B deteriorates, strength v. weight.
  - Usually involves tradeoff or compromise
  - TRIZ seeks to surmount contradiction.
- In patent study, Altshuler identified 39 engineering parameters and 40 operators
- 39 x 39 matrix of parameter contradictions

THE CONTRADICTION TABLE

- The first organized form of TRIZ
- A little bulky and unwieldy without computerization, but still useful in quick and dirty screening for solutions
- Computerized in software products, available on line at various web sites, in many publications
- Applies to technical contradictions

CONTRADICTION TABLE

Undesired Result (Degraded Feature) / Feature to Improve		1 Weight of Moving Object	2 Weight of Nonmoving Object	• •	14 Strength	• •	38 Level of Automation	39 Productivity
1	Weight of Moving Object				28, 27, 18, 40			
2	Weight of Nonmoving Object							
	• •							
	• •							
38	Level of Automation							
39	Productivity							

- **Possible contradictions represented in 39 x 39 table**
- **Intersections of contradicting rows and columns are references to 40 inventive principles for contradiction elimination**

28 Replace a mechanical system with a non mechanical system
27 An inexpensive short-life object instead of an expensive durable one
18 Mechanical vibration
40 Composite materials

Proposed Solution Pathways:

Altshuller

The Parameter(s) that gets degraded
Length of an Object
Speed
Force
Stress
Weight of Object
Strength
Temperature
Power
Waste of Time
Reliability
Meas. Accuracy
Ease of Manuf.
Complexity
Etc.
Etc.
The Parameter(s) you want to Improve
Length of an Object
Speed
Force
Stress
Weight of Object
Strength
Temperature
Power
Waste of Time
Reliability
Measurement Accuracy
Ease of Manufacturing
Complexity
Etc.
Etc.
01 26
27 40
01 - Segmentation
26 - Copying
27 - Cheap Short Living
40 - Composites

An invention happens only when a contradiction is resolved.

When something is improved, something else gets deteriorated. Most improvements allow this and they compromise. This is NOT invention.

An improvement in one aspect, without deteriorating any other aspect, is Invention. This is actually Resolving Contradictions.

So, unless a contradiction is resolved, there is no Invention.

One of the steps in TRIZ is to identify the contradictions.

Example: If an automobile has to withstand impact, it has to be strong-if strengthened by increasing the thickness of metal, it consumes more fuel to move. How to strengthen without losing fuel efficiency becomes a contradiction.

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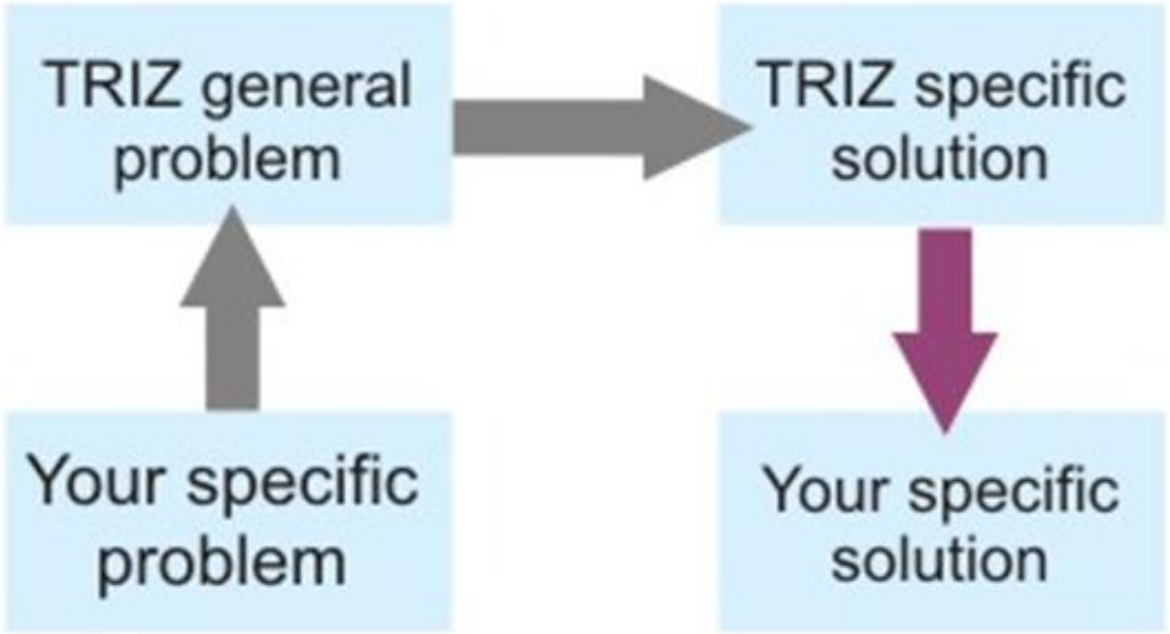
How are they most commonly used?

- Use the list as a structured Brain storming tool
- Best used to help resolve Contradiction
  - When two different parameters in a system are in conflict with each other
  - I want to increase strength by using a more dense material but my system is now too heavy to move
  - I want to increase output from a chemical reaction by using a higher a temperature but the catalyst becomes unstable
  - I want to improve air flow by increasing the speed of my fan but the fan motor gets too hot

The TRIZ Problem-solving Method



The arrows represent transformation from one formulation of the problem or solution to another. The gray arrows represent analysis of the problems and analytic use of the TRIZ databases. The purple arrow represents thinking by analogy to develop the specific solution.

An Operator Example

Specific problem

$3x^2+5x+2 = 0$

Specialized solution

$x = ?$

An Operator Example

Specific problem Specialized solution

$x^2+3x+2 = 0$ $x= -1, -2$

The solution can be obtained by:

- Trial and error
- Completing the squares
- Quadratic formula

The Basic Principle of TRIZ

Abstract problem

Abstract solution

$ax^2+bx+c = 0$ → **$x= (-b+/-\sqrt{b^2-4ac})/2a$ (operator)**

↑ (abstraction)

↓

Specific problem

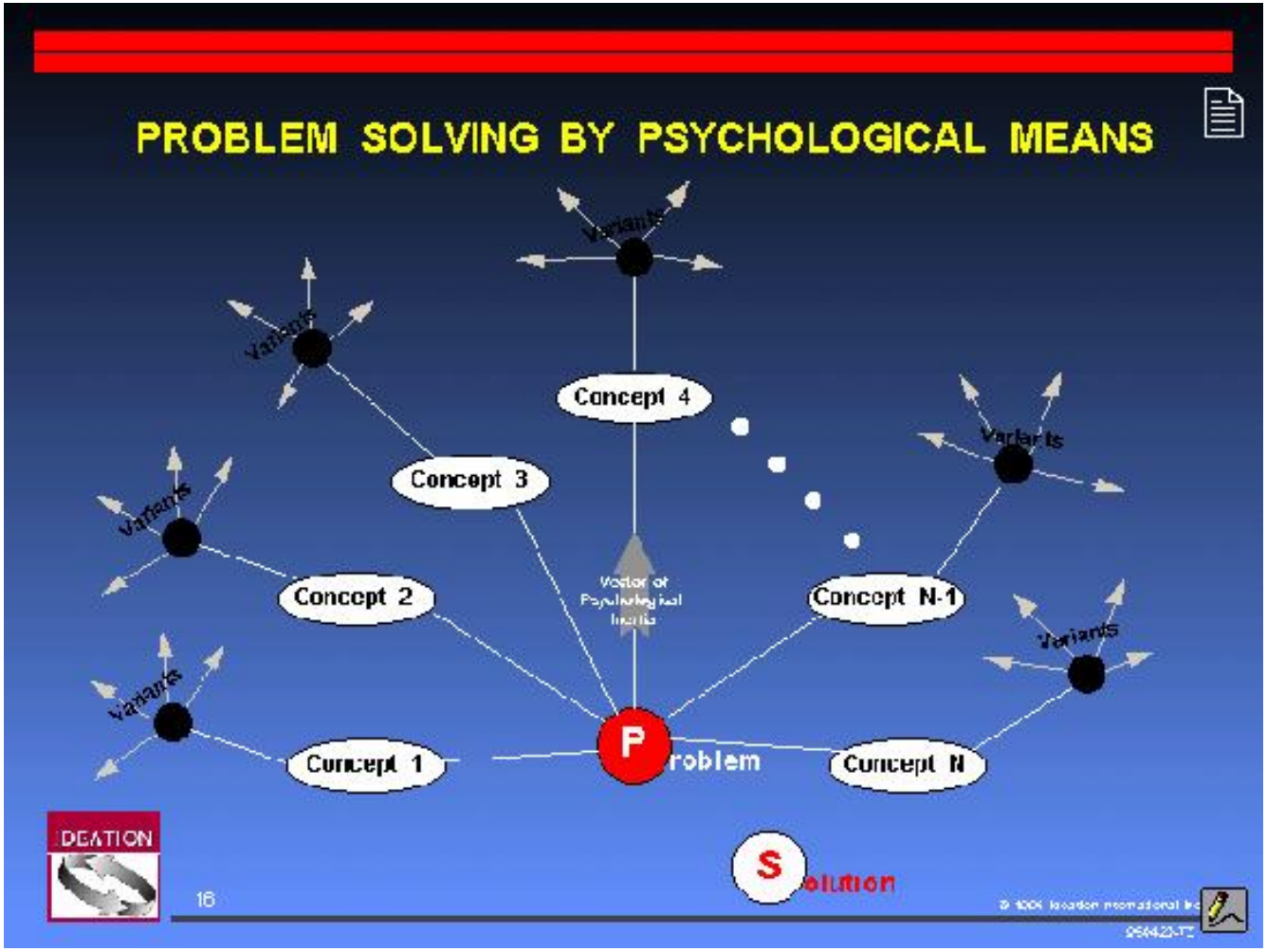
$x^2+3x+2 = 0$

Solution to specific problem

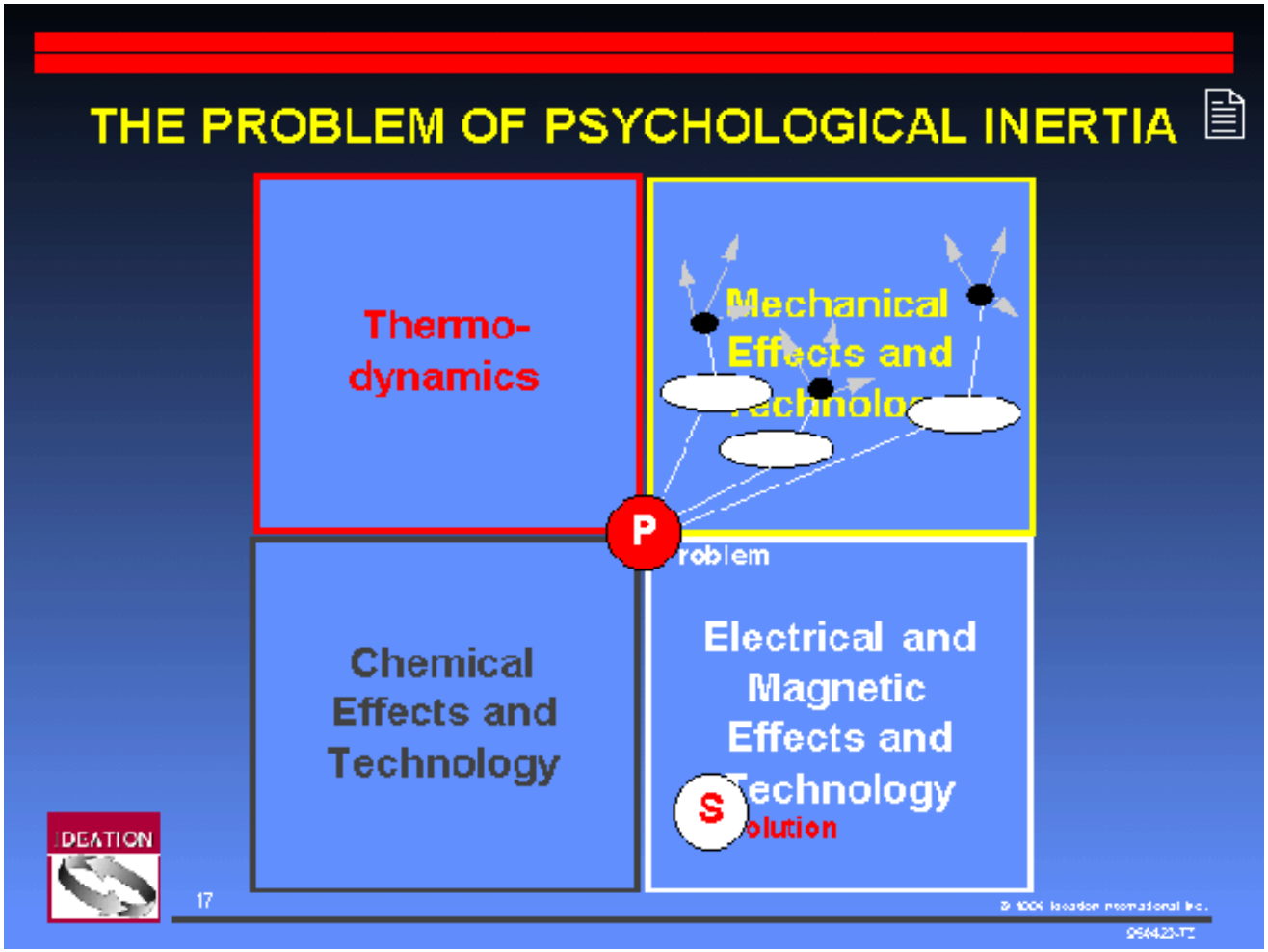
$x= -1, -2$

Barrier to Innovation : Psychological Inertia

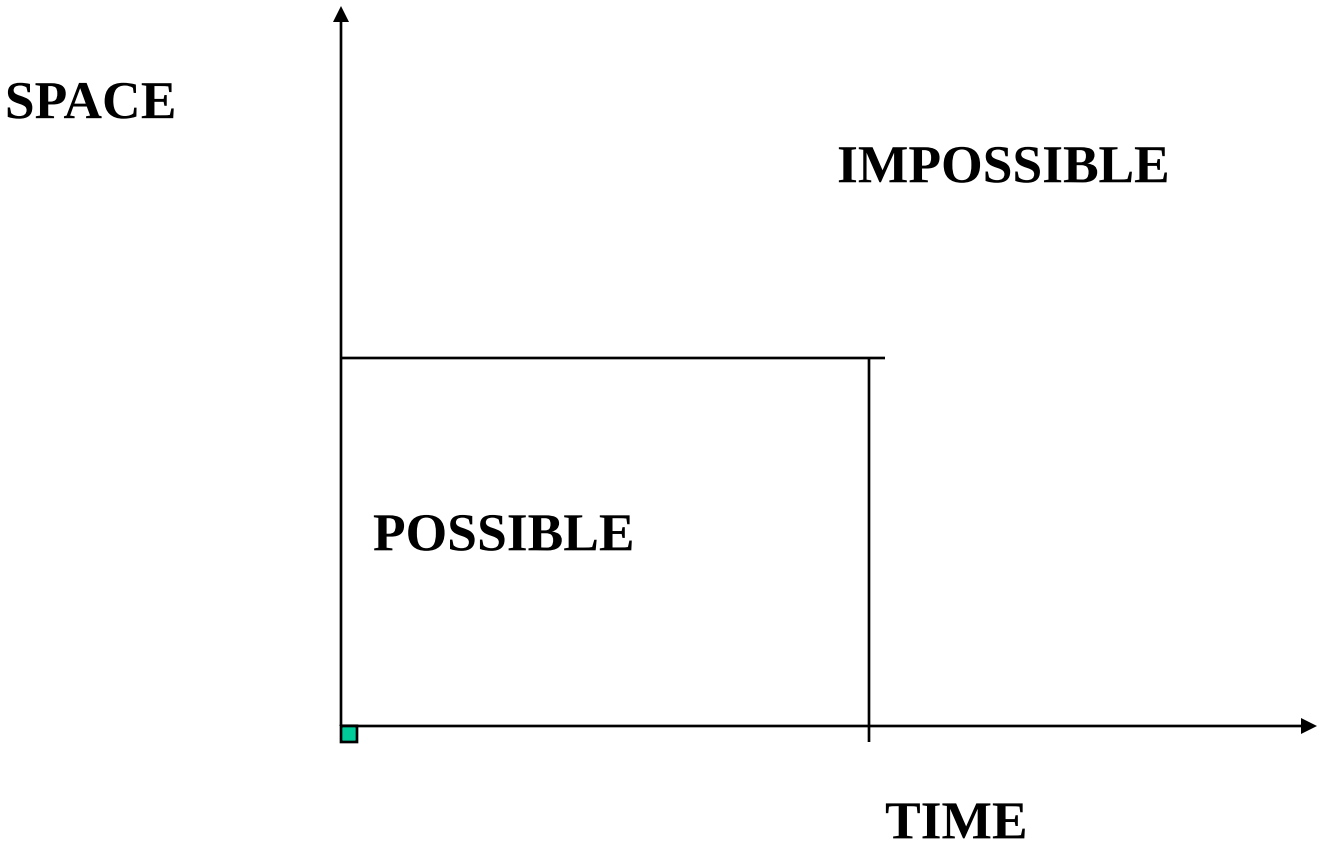
Solutions being considered are not within one's field of expertise



Experience, prescriptive regulations, normative laws
=> Resistance to change

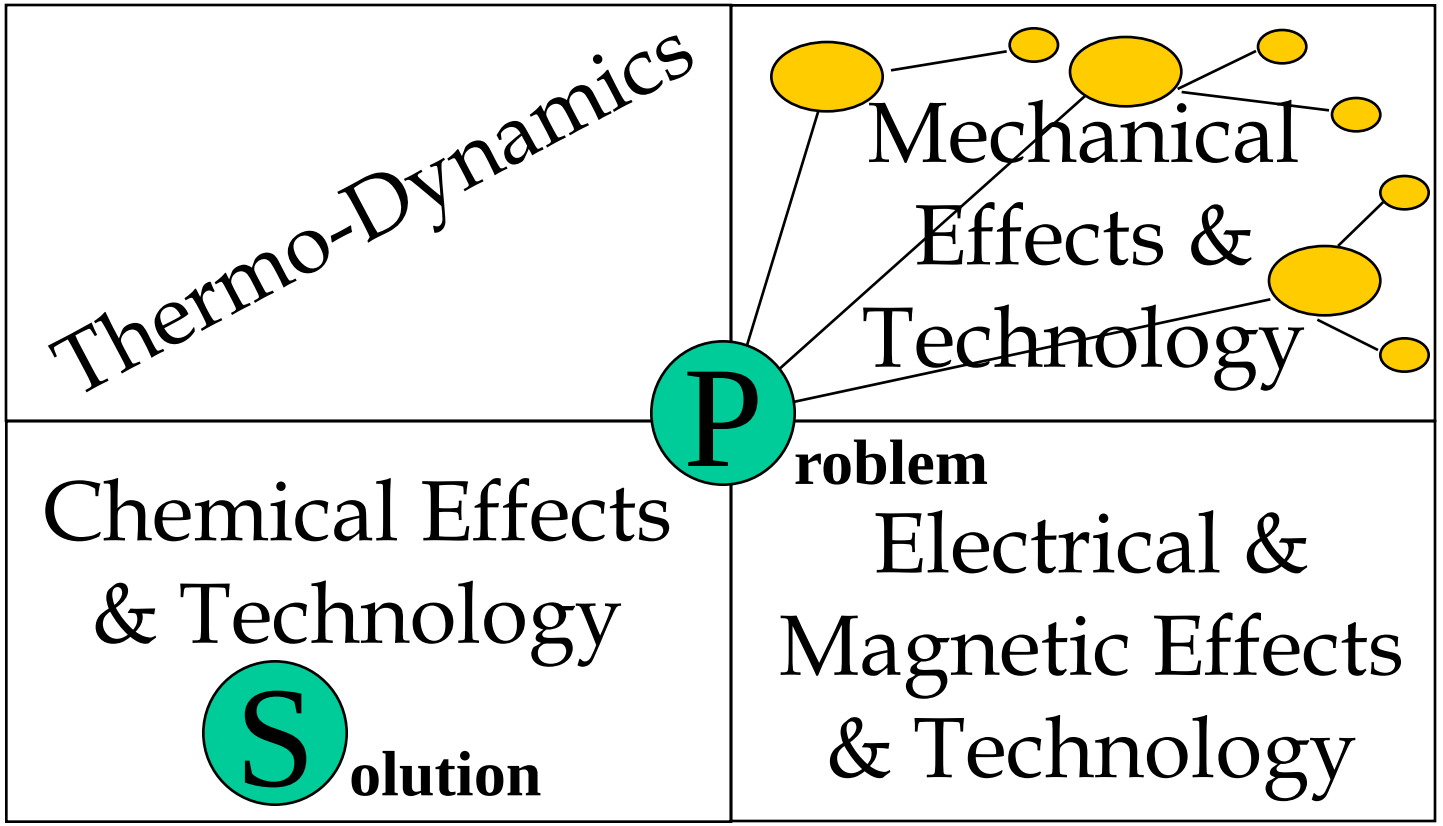


THINKING OUTSIDE YOUR PARADIGM



EVENTS AND EXPERIENCES SHAPE OUR BELIEF SYSTEM!!!

THE SOLUTION SPACE



PARALLEL UNIVERSES

- Many other industries or technologies face the same type of problems in a generic sense
- It’s almost impossible to follow all areas of technology, read all literature, go to all meetings
- Accidents or alerts sometimes change this, but it is normally not proactive in most organizations
- In the most efficient problem solving, it is helpful to be aware of problem solving principles used by everyone

Patterns of Evolution: The Primary TRIZ Postulate

- Systems evolve not randomly, but according to objective patterns
- These patterns can be revealed from the patent fund and purposefully used for systems development without numerous blind trials

Patterns of Evolution: Common threads between evolving systems.

Evolution of Technological Systems

8 Laws of Development of Engineered Systems

1. Law of completeness of parts of a system – towards more complete synthesis of its parts
2. Law of energy conductivity of a system
3. Law of harmonization of rhythms
4. Law of increasing ideality
5. Law of uneven development of parts
6. Law of transition to a supersystem
7. Law ot transition from macro to mirco level
8. Law of increasing substance-field involvement

Energy Conductivity

- Systems evolve toward increasing efficiency in the transfer of energy
- From engine to working organ.
- Transfer through a substance or a field
  - Substance: material items
  - Field: magnetic field
  - Substance-field: stream of charged particles

Harmonization

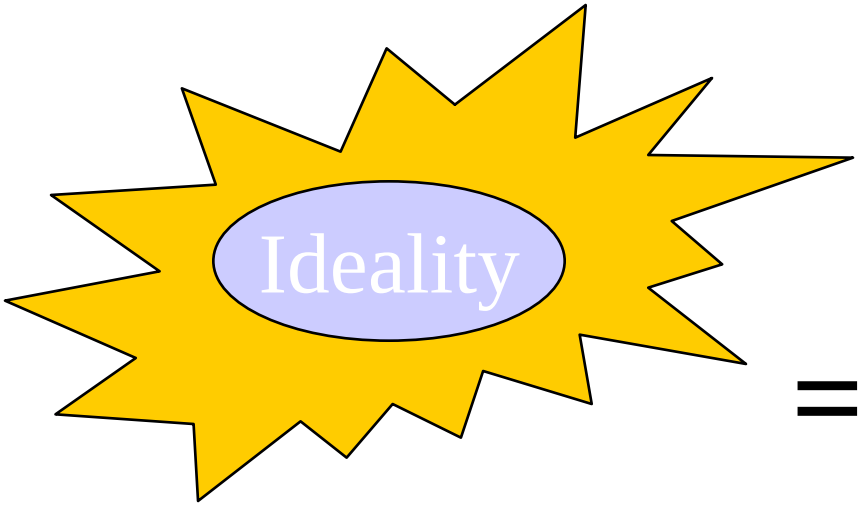
- System evolves toward harmony of its rhythms and natural frequencies of its parts.
- Coal boring method example. 2-steps, 7-year delay avoided.

Ideality

- IFR = ideal final result
- Function exists but machine does not.
- Ideality is the useful effects divided by the harmful.

$$I = \frac{\sum U_i}{\sum H_j}$$

WHAT IS IDEALITY?



$$\text{Ideality} = \frac{\text{All } \textit{Useful} \text{ Functions}}{\text{All } \textit{Harmful} \text{ Functions}}$$

The ideal system **performs a required function without actually existing**. The function is often performed using existing resources. **ALL** systems evolve in this direction over time by resolving contradictions.

HOW DO WE GET TO IDEALITY?

- TRIZ provides two general approaches for achieving close-to-ideal solutions (that is, solutions which do not increase system complexity):
  - Use of resources
  - Use of physical, chemical, geometrical and other effects (remember the Waissenberg effect?)

Uneven Development of Parts

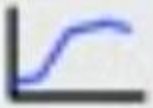
- Development proceeds monotonically
- Parts evolve in fits and starts
- See this in GAs
- Cargo ship example: capacity and engine size exceed braking capacity.

Evolution of Technological Systems

- Transition to Supersystem
  - Reach limits of development
  - System becomes subsystem of larger system
- Transition from Macro to Micro
  - Stuff gets smaller
- Increasing substance-field involvement

PATTERNS/TRENDS OF EVOLUTION OF TECHNICAL SYSTEMS

1. Stages of Evolution
2. Evolution Toward Increased Ideality
3. Non-Uniform Development of Systems Elements
4. Evolution Toward Increased Dynamism and Controllability
5. Increased Complexity then Simplification (Reduction)
6. Evolution with Matching and Mismatching Components
7. Evolution Toward Micro-level and Increased Use of Fields
8. Evolution Toward Decreased Human Involvement



Trend 1: The Stages of Evolution *(S-Curves)*

Trend 2: Increasing Ideality

Trend 3: Uneven Development of Elements

Trend 4: Increasing Dynamicity & Control

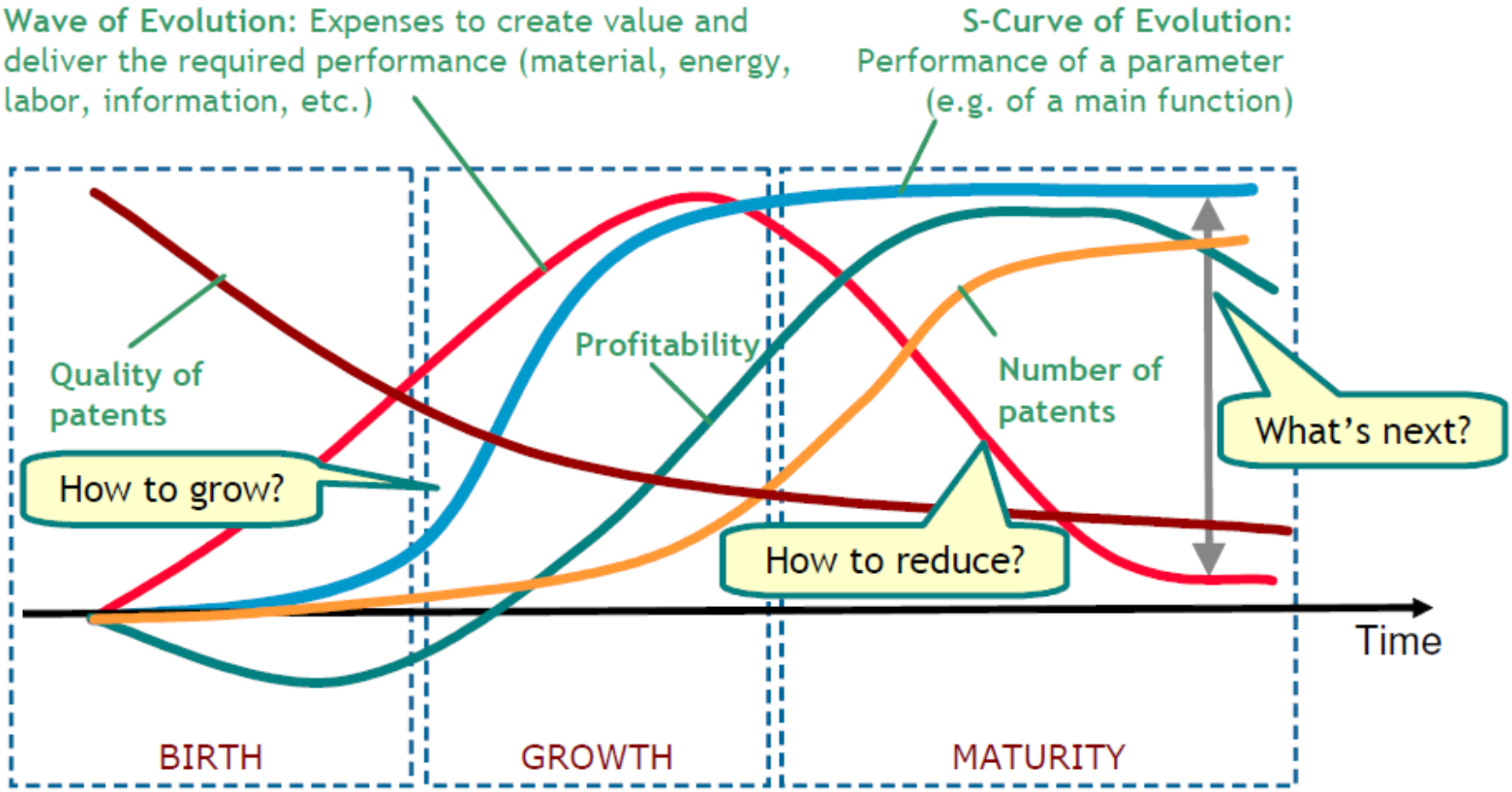
Trend 5: Increasing Complexity, then Simplification

Trend 6: Harmonization of Rhythms

Trend 7: Transition to Micro-levels, Increased use & Efficiency of Energy

Trend 8: Increasing levels of Automation

S curve?

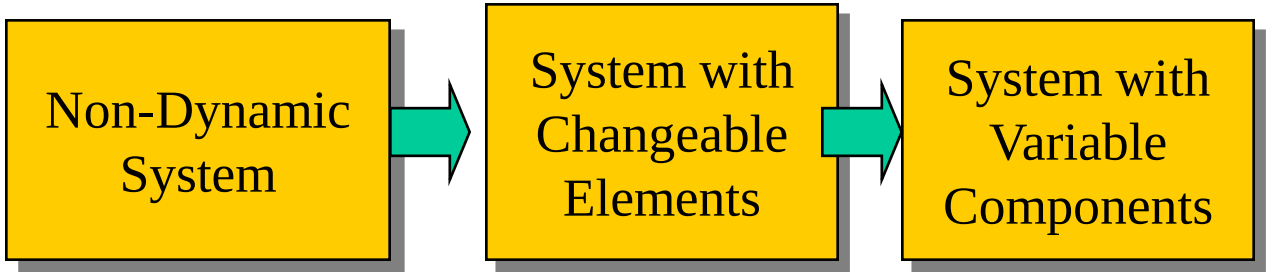

Wave of Evolution: Expenses to create value and deliver the required performance (material, energy, labor, information, etc.)
S-Curve of Evolution: Performance of a parameter (e.g. of a main function)
Quality of patents
Profitability
Number of patents
How to grow?
How to reduce?
What's next?
Time
BIRTH
GROWTH
MATURITY

To Increase Dynamicity Consider

- Provide more than one stable state
  - Bi-stable membrane
  - Over center clamp
- Make a fixed component movable
- Make parts movable relative to each other
  - Hinge
  - Flexible materials as links
- Introduce a mobile object
- NOTE: All of these have different ergonomic implications

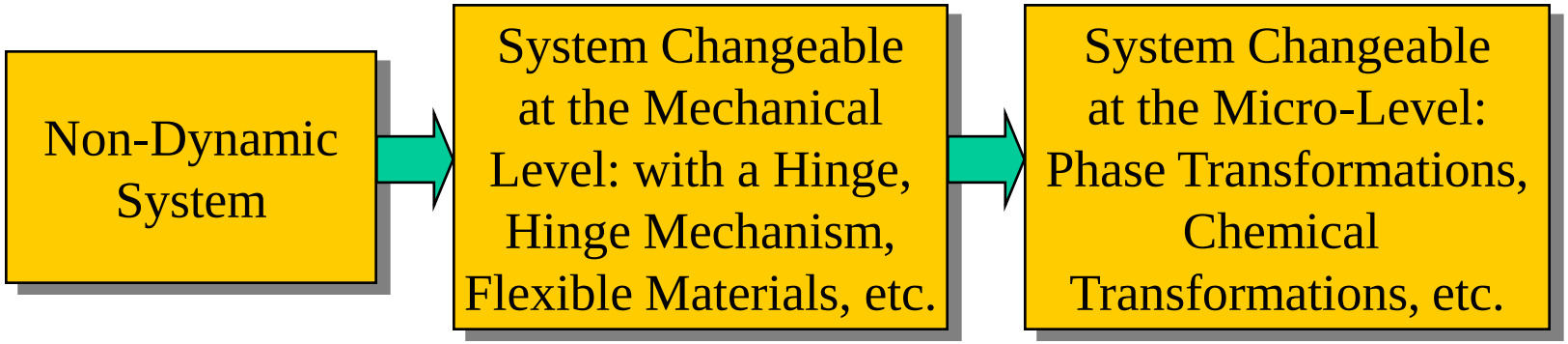
4. EVOLUTION TOWARD INCREASED DYNAMICS AND CONTROL

Transition to Multifunctional Performance



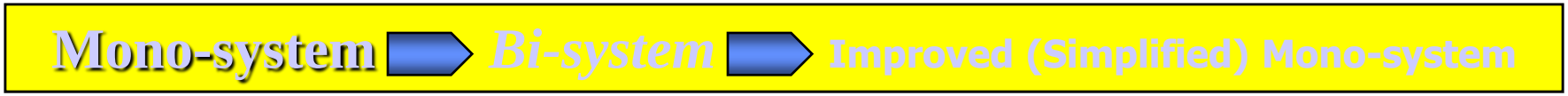
Increasing system dynamism allows functions to be performed with greater flexibility or variety

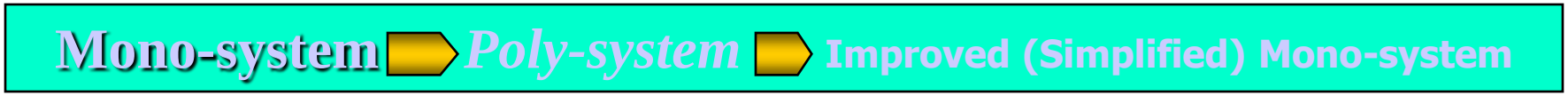
Increasing Degrees of Freedom



5. INCREASED COMPLEXITY AND THEN SIMPLIFICATION

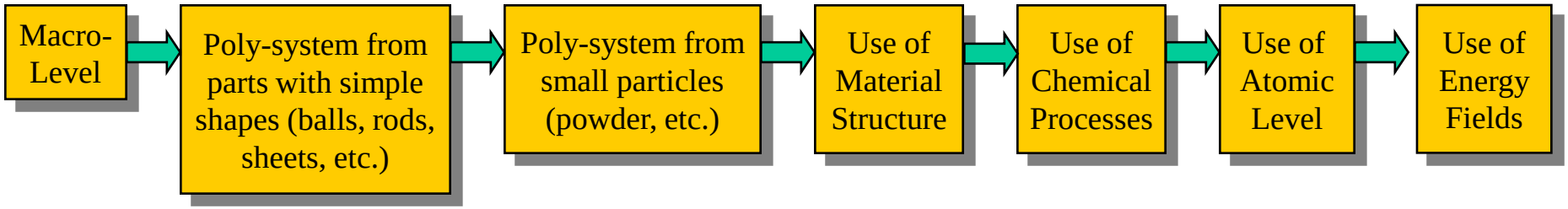
- **Technological systems tend to develop first toward increased complexity (i.e., increased quantity and quality of systems functions), and then toward simplification (where the same or better performance is provided by a less complex system). This may be accomplished by transforming the system into a bi- or poly-system, as shown here in two of the lines of evolution related to this pattern.**





7. EVOLUTION TOWARD THE MICROLEVEL AND INCREASED USE OF FIELDS

- **Technological systems tend to transition from macro systems to micro systems. During this transition, different types of energy fields are used to achieve better performance or control**
- **Example: Cooking oven development**
  - Large cast iron wood stove
  - Smaller stove fired by natural gas
  - Electrically-heated oven
  - Microwave oven



8. EVOLUTION TOWARD DECREASED HUMAN INVOLVEMENT

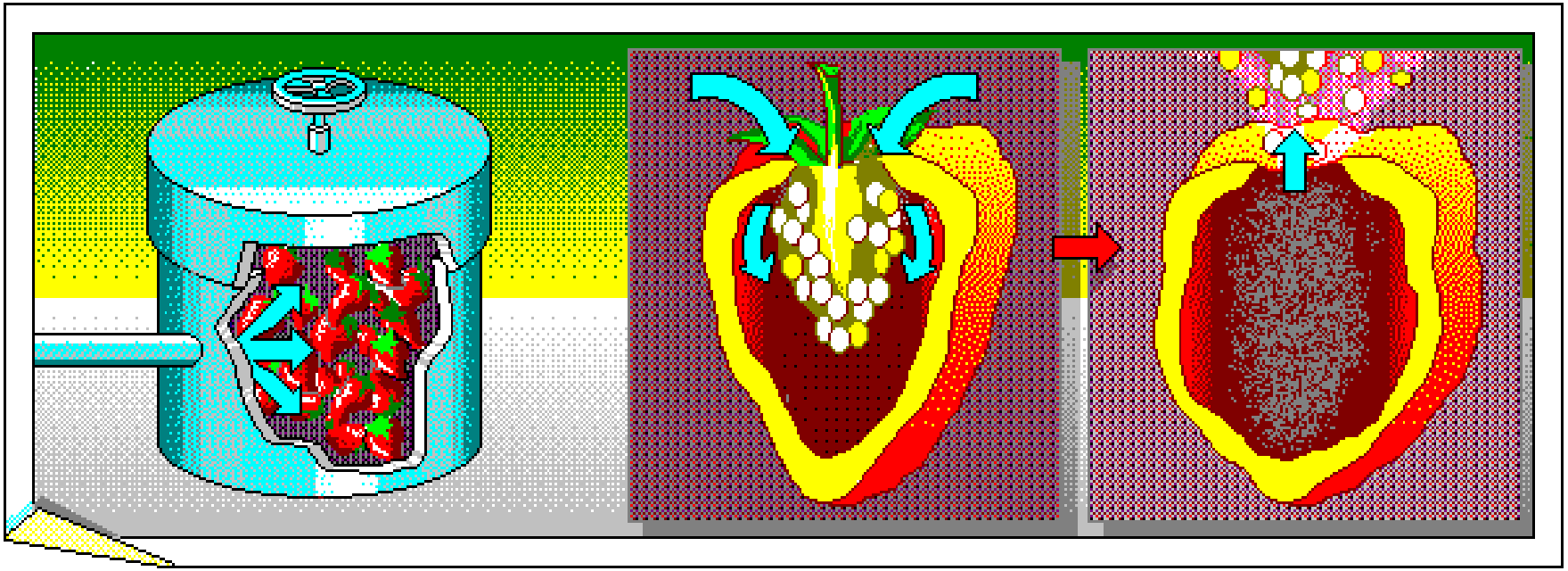
- **Systems develop to perform tedious functions that free people to do more intellectual work**
- **Example: Clothes washing**
  - Tub and washboard
  - Ringer washing machine
  - Automatic washing machine
  - Automatic washing machine with automatic dispensing of bleach and fabric softener
- REMEMBER THE NEW MACHINE AND PILL???

PATTERNS OF INVENTION

- Removing stems from bell peppers
- Removing shells form sunflower seeds
- Cleaning filters
- Unpacking parts wrapped in protective paper
- Splitting diamonds along micro-cracks
- Producing sugar powder from sugar crystals
- Explosive depulping

PATTERNS OF INVENTION

Processing Sweet Peppers



WHAT IS THE OPERATOR?

"Slowly raise pressure and suddenly reduce it"
OR "accumulate energy and release it"

- A path to a solution
- An approach to solving a problem
- A direction towards an answer

THE TOOLS IN THE TOOL KIT

- *Ideal Final Result/Ideality (IFR)*
- *Resources*
- *Contradictions, contradiction table, and separation principles*
- *Lines and patterns of evolution*
- *Reverse TRIZ*
- ARIZ
- Software

IDEALITY AND RESOURCES

THE BASIC TRIZ PRINCIPLES THAT UNDERLIE SYSTEM EVOLUTION AND PATTERNS OF PROBLEM SOLVING

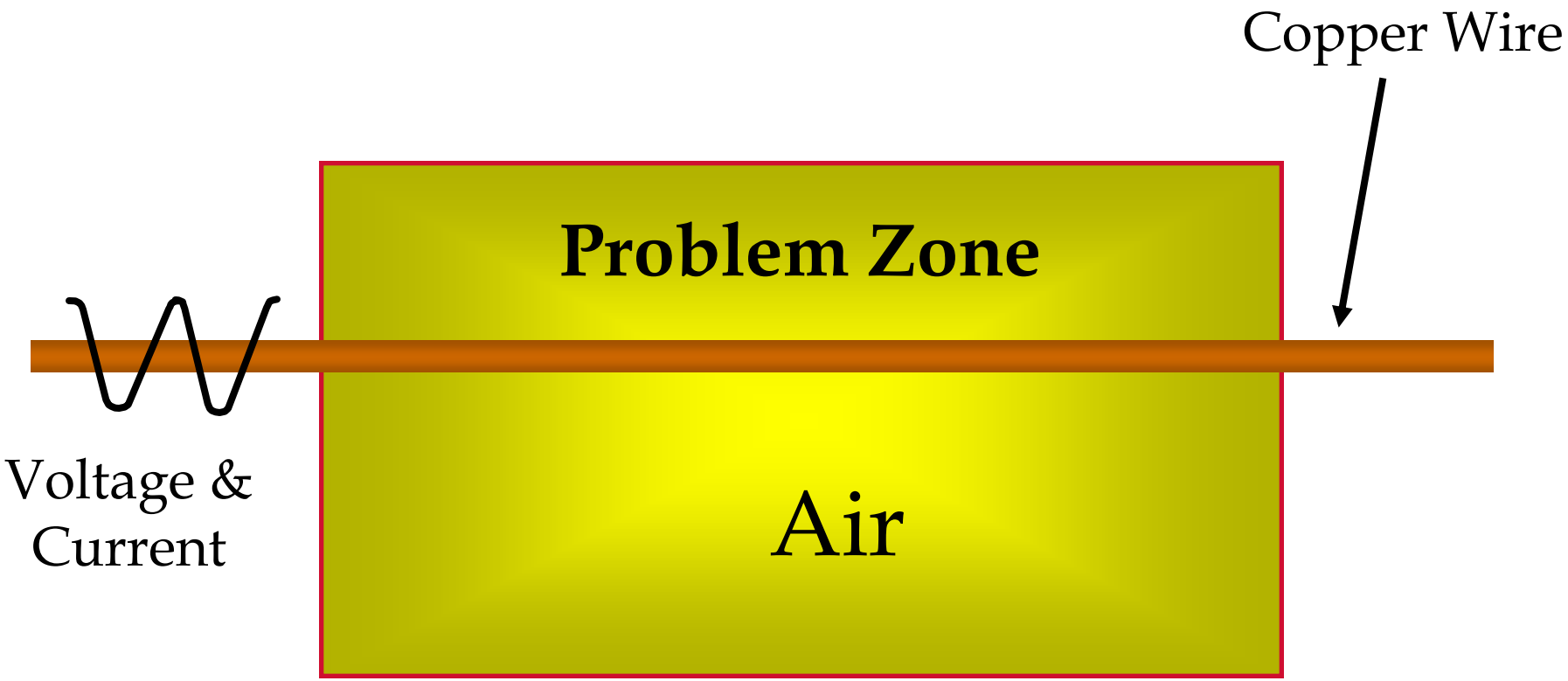
SYSTEM RESOURCES

- When a system's resources are depleted, it will probably be replaced
- Tracking system resources is a good way to predict when a system may be replaced, challenged, or significantly modified
- Sometimes it's a matter of just *seeing* the resource, other times it's a matter of figuring out how to use it (ex: field and information generation, Navy example)

WHAT'S A RESOURCE FROM A TRIZ PERSPECTIVE?

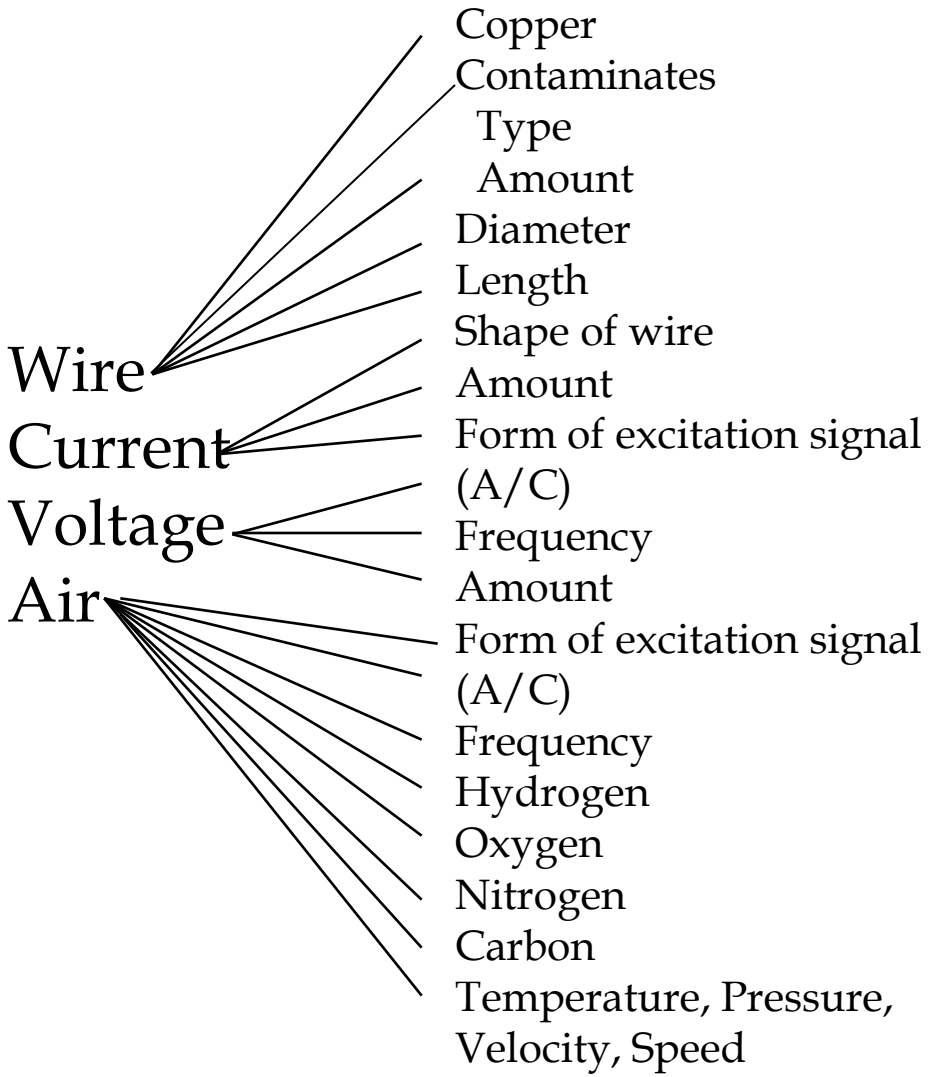
- A resource:
  - is any substance (including waste) available in the system or its environment
  - has the functional and technological ability to jointly perform additional functions
  - is an energy reserve, free time, unoccupied space, information, etc.

RESOURCES -- WIRE EXAMPLE



HANDOUT

IMMEDIATELY AVAILABLE RESOURCES



RESOURCE CHECKLIST

- Substances
- Fields
- Space
- Time
- Information
- Functional

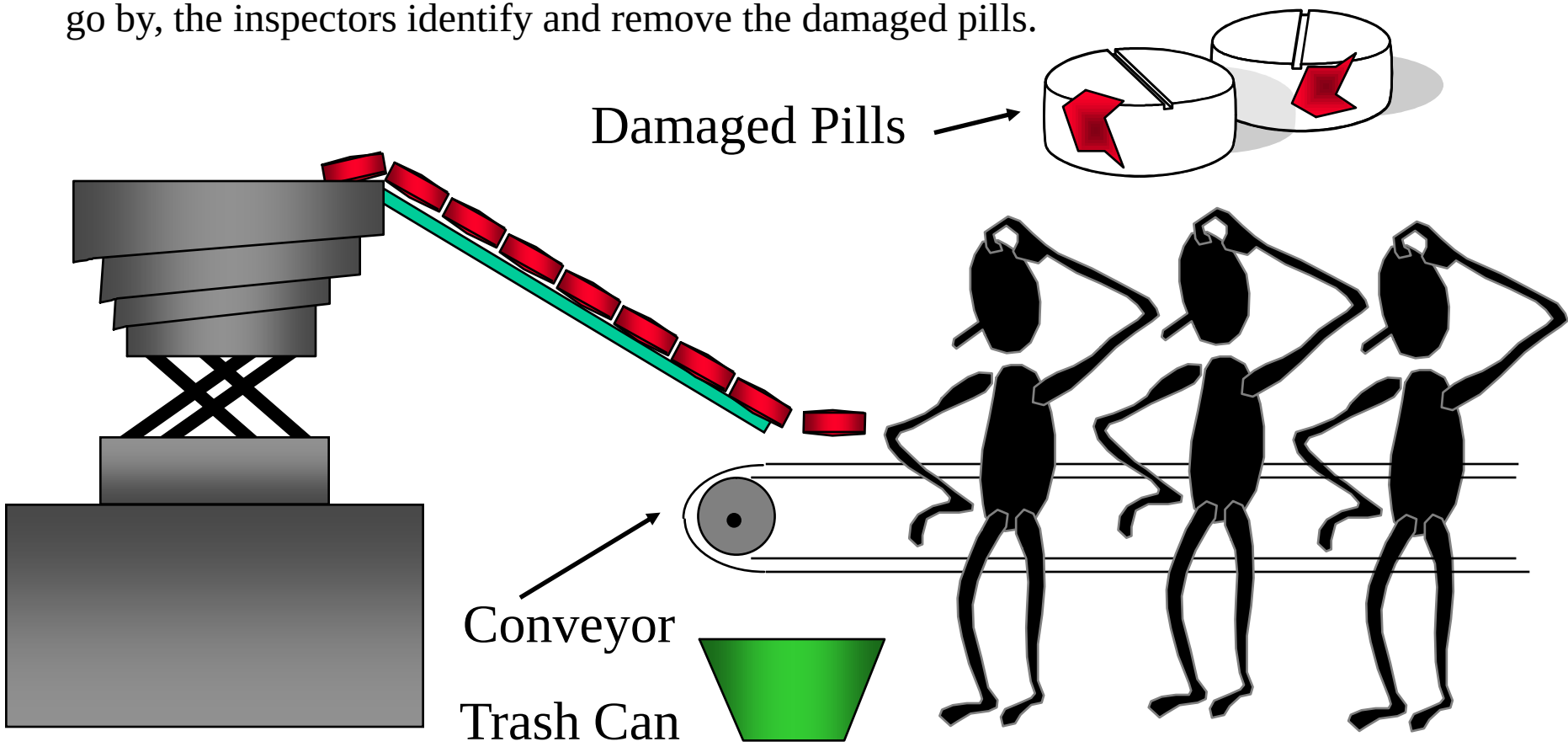
GOOD PILLS/BAD PILLS

- What is IDEALITY?

- What are the RESOURCES we have?

PILL INSPECTION WORKSTATION

Vibratory feed move pills around an internal spiral to top of vibratory bowl where the pills are discharge and slide down an incline plane onto a conveyor. As the pills go by, the inspectors identify and remove the damaged pills.

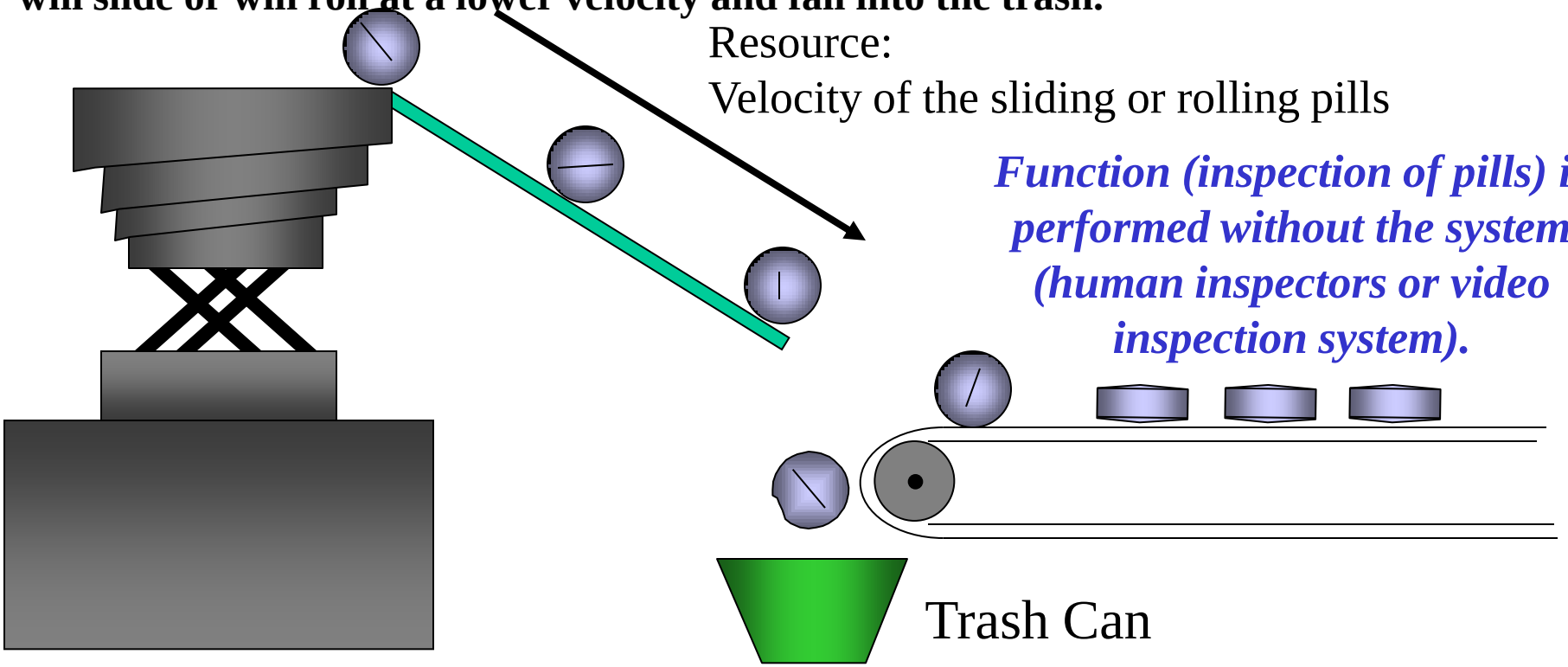


An Elegant Solution: The Pill Inspects Itself

Change the escapement for the vibratory bowl so that the pills are ejected standing on their edge. Move the conveyor 3 inches. Pills that are round will roll at a velocity that allows them to jump to the conveyor. The pills that are chipped will slide or will roll at a lower velocity and fall into the trash.

Resource:
Velocity of the sliding or rolling pills

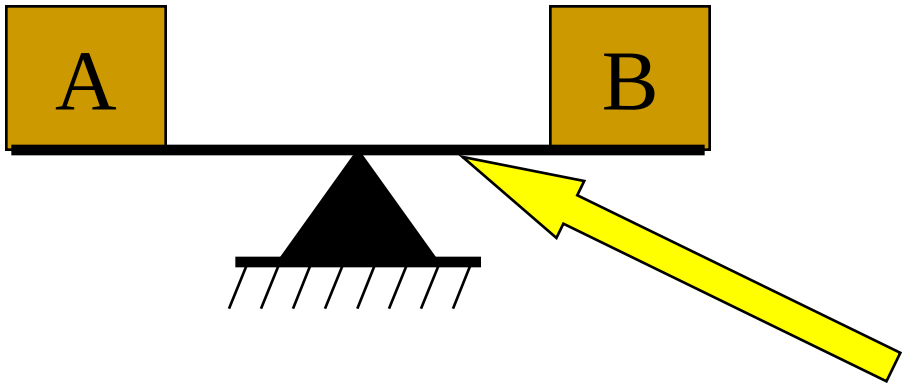
Function (inspection of pills) is performed without the system (human inspectors or video inspection system).



EXAMPLES OF CONTRADICTIONS

- Weight vs. strength
- Speed and weight vs. fuel economy
- Vision accuracy vs. distance
- Organizational structure vs. entrepreneurial climate
- Food that tastes good vs. good for you
- Open office space vs. quiet
- Accessibility vs. security and safety
- “Voice of the customer” vs. radical innovation
- Security vs. easy access

CONTRADICTIONS



Technical Contradiction

Control Parameter, **C**

So:

C should be high, and
C should be low

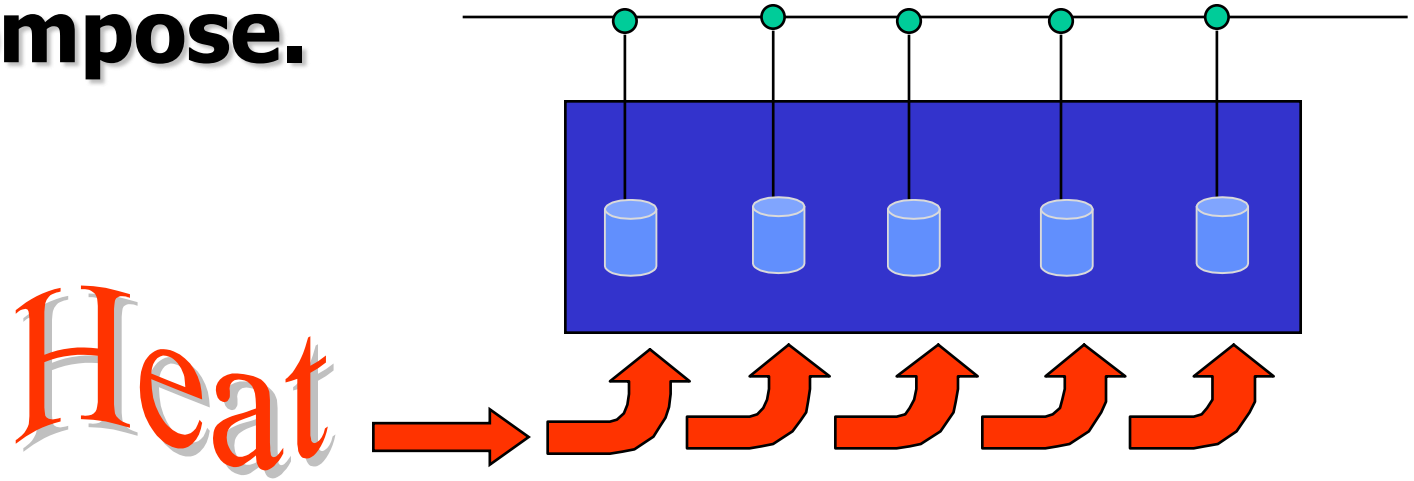
} **Physical Contradiction**

PHYSICAL CONTRADICTION

- **A characteristic must be higher <u>and</u> lower (self-opposing)**
  - Example: An airplane wing should have large area for easy takeoff but small area for higher speed
  - Example: A pen tip should be sharp to draw fine lines, but blunt to avoid tearing the paper
- **A characteristic must be present <u>and</u> absent**
  - Example: For sandblasting the abrasive must be present (to abrade) but is not wanted on (or in) the product
  - Example: Aircraft landing gear are needed for landing but undesired in flight

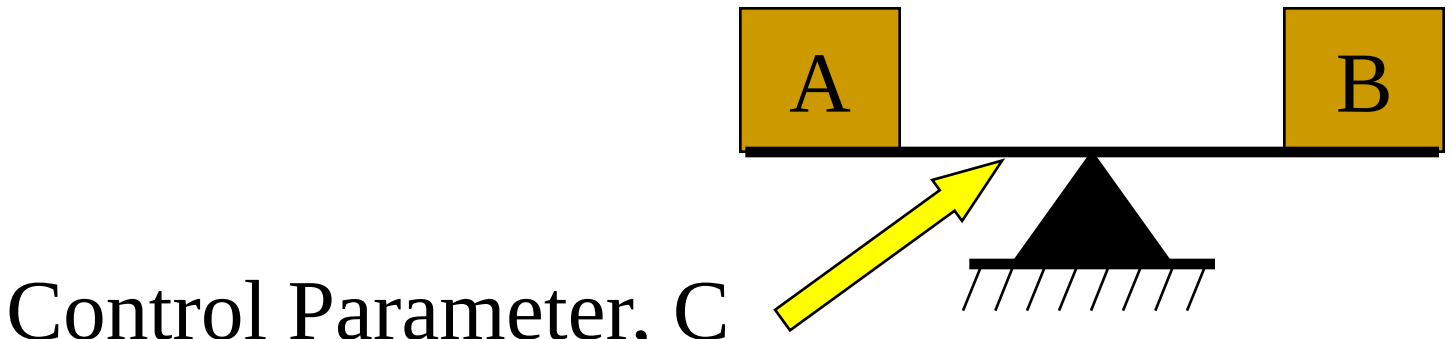
PLATING METAL PARTS

- To plate metal parts with nickel they were placed in a bath of nickel salt. The bath was heated to increase the productivity of the process. However, heating reduced the stability of the salt solution and it started to decompose.



CONVERTING TECHNICAL CONTRADICTIONS TO PHYSICAL CONTRADICTIONS

- **Technical Contradiction**
  - Heating increases productivity (A), but wastes material (B)
  - Control parameter is temperature
- **Physical Contradiction**
  - Temperature (C) should be high to increase productivity and low to avoid waste



PRINCIPLES OF SEPARATION

- **TRIZ seeks to eliminate the physical contradiction by separating the two contradictory requirements**

  - Separation in space
  - Separation in time
  - Separation between the parts and the whole
  - Separation upon condition

Step 2: Applying the 4 Principles

1. Separate in TIME:

2. Separate in SPACE:

3. Between the PARTS and the WHOLE:

4. Separate upon CONDITION:

SEPARATION IN TIME

- A characteristic is made larger at one time and smaller at another
- A characteristic is present at one time and absent at another
  - **Example: Aircraft wings are longer for takeoff, and then pivot back for high speed flight.**
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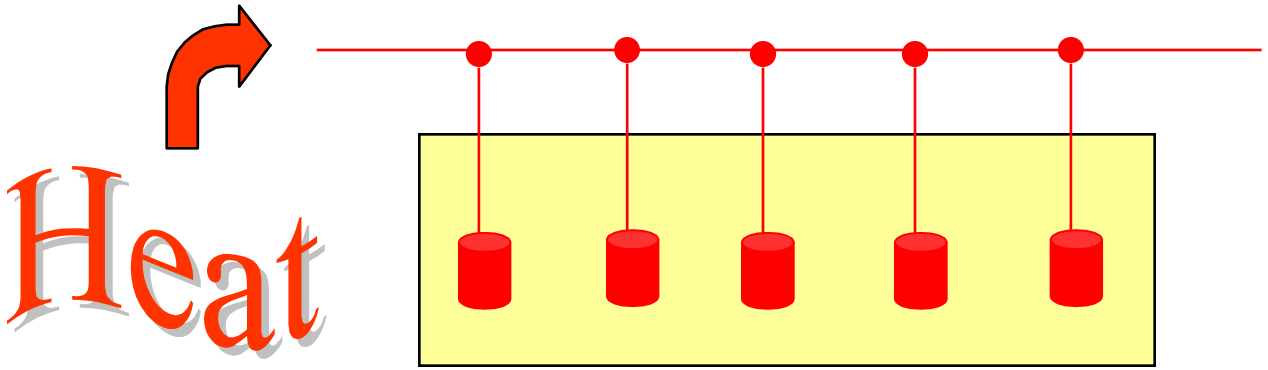
SEPARATION IN SPACE

- **A characteristic is made larger in one place and smaller in another**
- **A characteristic is present in one place and absent in another**
  - Example: Submarines which pull sonar detectors drag the detectors at the end of several thousand feet of cable to separate the detector from the noise of the submarine
  - Example: Bifocal glasses

SEPARATION IN SPACE

- **In the nickel plating of parts, increased temperature is necessary only in proximity to the parts. To accomplish this, the parts themselves may be heated, rather than the solution.**



SEPARATION BETWEEN PARTS AND THE WHOLE

- **A characteristic has one value at the system level and the opposite value at the component level**
- **A characteristic exists at the system level but not at the component level (or vice versa)**
  - Example: A bicycle chain is rigid at the micro-level for strength, and flexible at the macro-level.

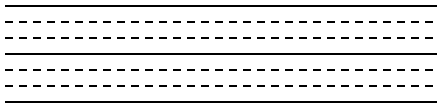
A "SOFT" EXAMPLE

- **Example: A business should be large and small**
  - Large for profits and resources
  - Small for flexibility
- **Solution: Formation of a conglomerate of small independent organizations under one umbrella**

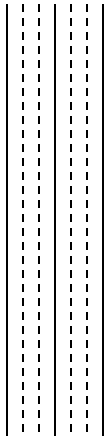
SEPARATION UPON CONDITION

- A characteristic is high under one condition and low under another
- A characteristic is present under one condition and absent under another
  - Example: A kitchen sieve is porous with regard to water and solid with regard to food.
  - Example: Water is "soft if entered at a low speed. However, it one jumps into the same water from a height of 10 meters, the water feels considerably harder. Thus, the speed of the body's interaction with the water is the condition to be considered when applying this principle.

Intersecting Highways



?



Two major highways are proposed to intersect. Traffic cannot flow on both highways without conflict.

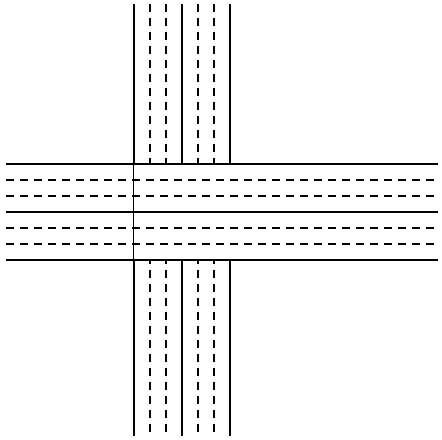
State the technical contradiction:

State as a physical contradiction:

Intersecting Highways

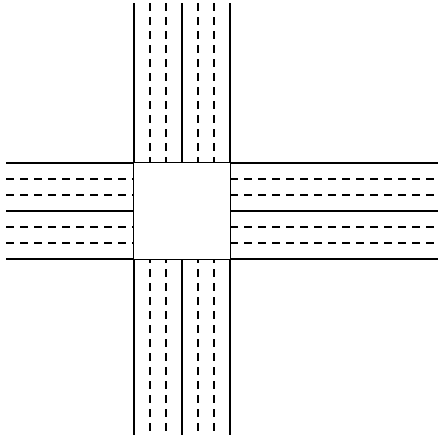
Separation in space:

Over/under pass



Separation in time:

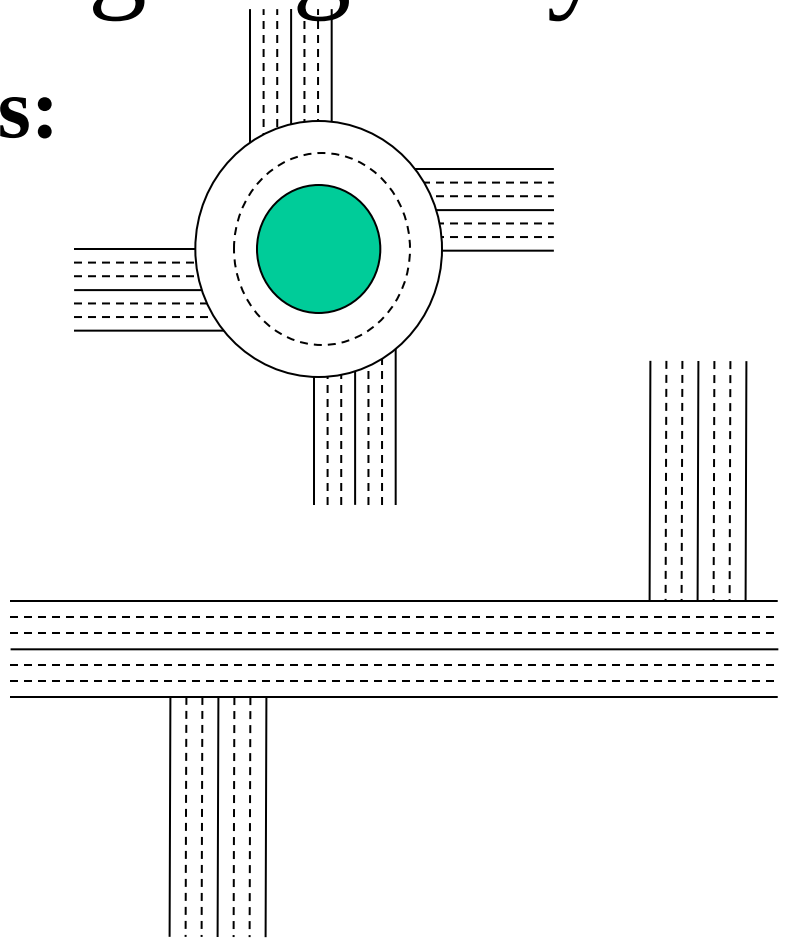
Stoplight or rush hour directional control



Intersecting Highways

Separation by Parts:

Rotary or highways merge and crossover



Intersecting Highways

Separation upon Condition:

Drawbridge or access control such as gates, or possibly stoplights.

OTHER EXAMPLES

- I want my children to be able to color, but I don't want them to color on the walls…….
- I want shorts in summer and jeans in winter--in the same piece of clothing
- Mattress design to accommodate different firmness preferences
- Water filled weight lifting bars which can be packaged and then filled with water later

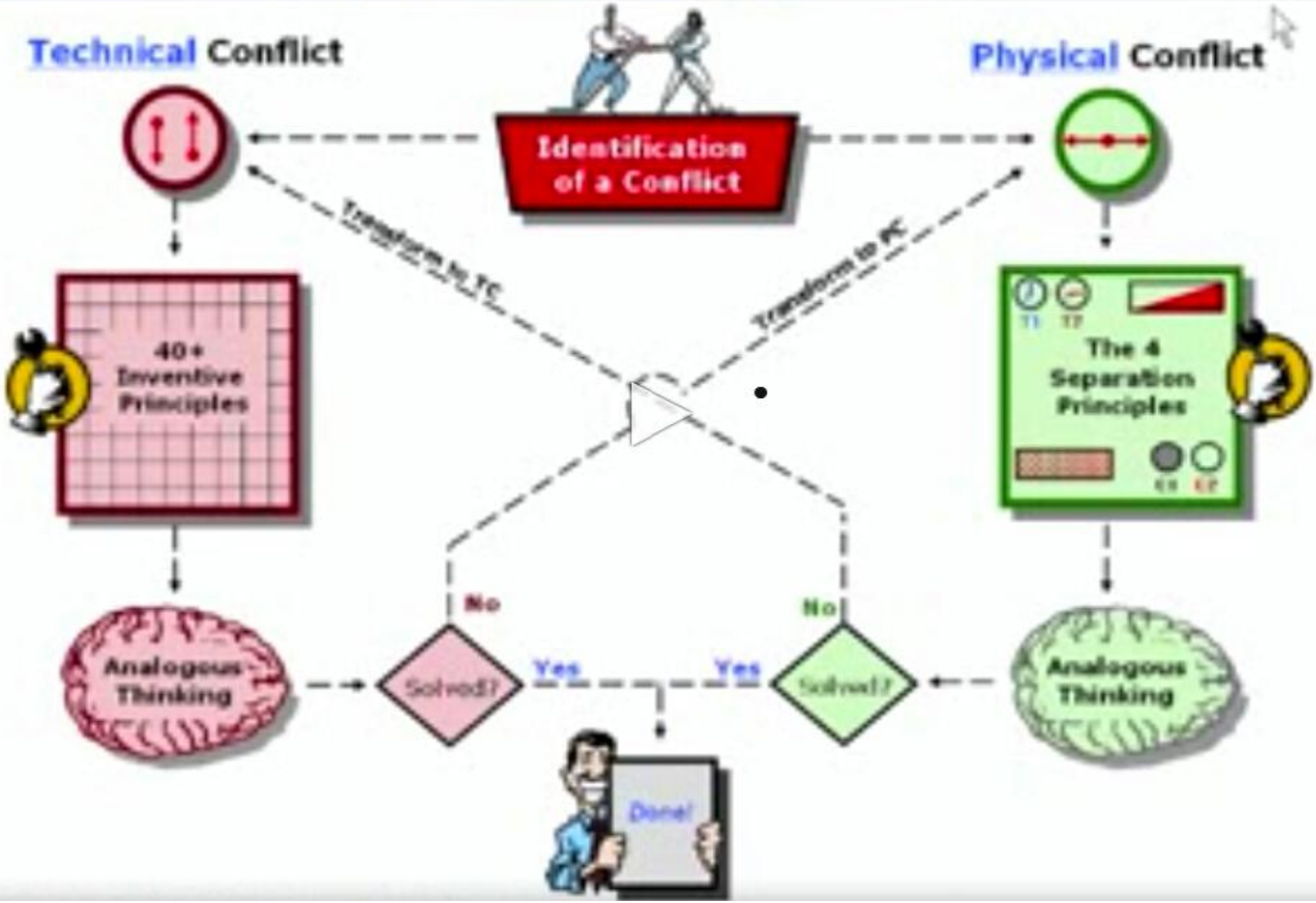
OTHER EXAMPLES

- Energy spent vs.----
  - weight, length, and area of non-moving object
  - force, tension/pressure
  - harmful factors
  - complexity of device
  - complexity of automation

More Examples

- Want bike transmission to be rigid for strength, but flexible for smooth drive
  - Separation in scale
  - Bike chain is rigid at small scale, but flexible at large scale.

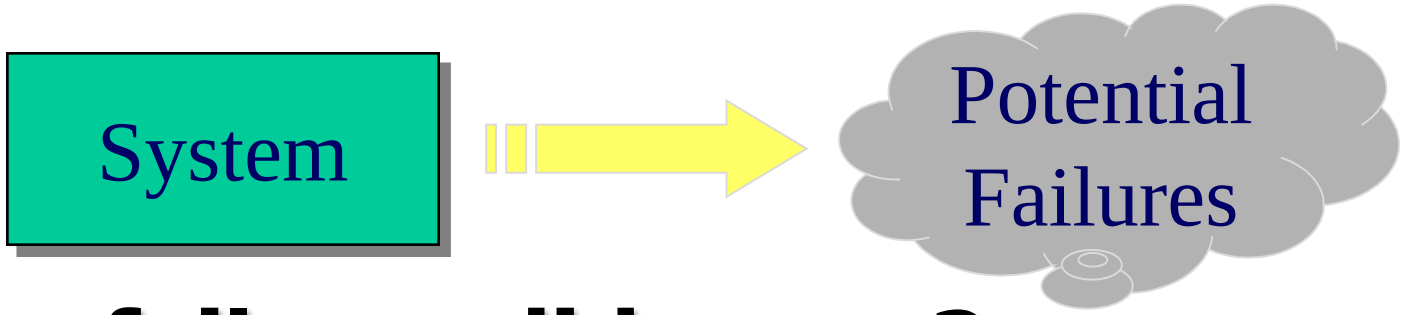
Conflict Resolution Algorithm



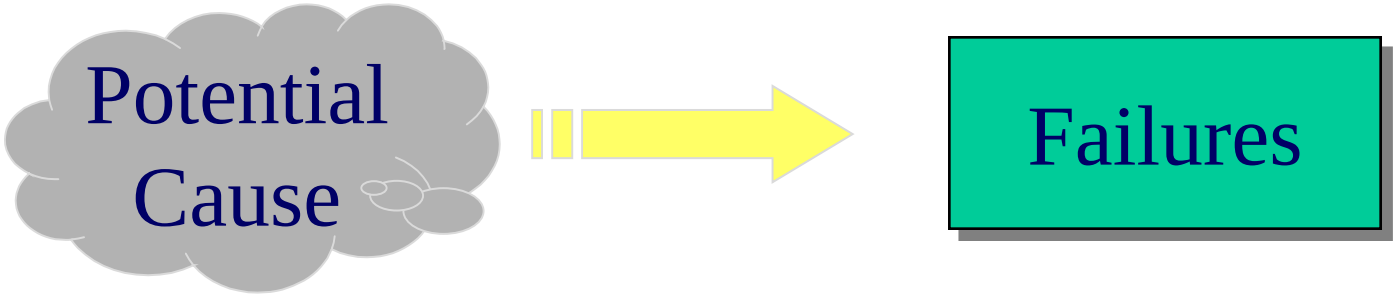
REVERSE TRIZ FOR FAILURE ANALYSIS AND PREDICTION

REVERSE TRIZ

- **What failures may occur?**



- **Why failures did occur?**



REVERSE TRIZ

- Formulate original problem
- Invert the original problem
- Amplify the inverted problem
- Search for information and resources
- Hypothesis, tests, and correction

THE REVERSE TRIZ APPROACH

- The problem: I want to prevent a leak
- Invert the problem: I WANT to have a leak
- Exaggerate/amplify the inverted problem: I WANT to have a CATASTROPHIC leak, causing MAJOR damage and public affairs impact
- What RESOURCES do I need to have/cause a leak?
- If I was a saboteur, how would I cause this system to leak? Hurt someone? Cause the town to be evacuated? Make our company famous in the national press?

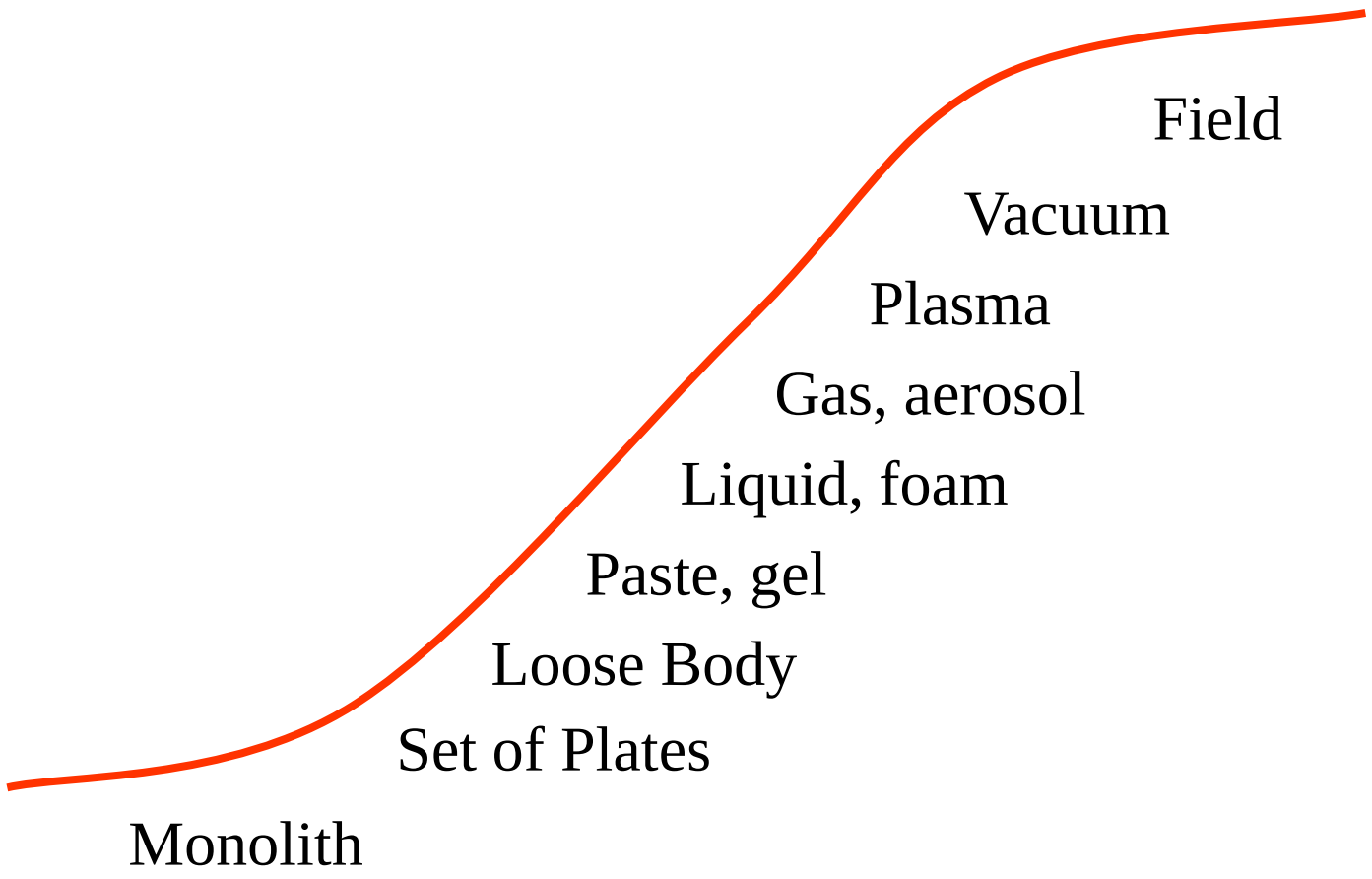
USES

- Failure prediction for projects
- Failure prediction and/or analysis for technology developments
- Failure prediction for technology adoption
- Failure analysis for product design/system failures
- Failure analysis for product use and application

APPLYING TRIZ AT DIFFERENT LEVELS

- The principles of TRIZ can be applied at different system levels from a competitive standpoint
- Need to understand what those levels are and how they might affect us
- What are potential solutions at DIFFERENT levels?
- Different definitions of ideality
- Different resources

THE LINE OF SEGMENTATION



40 Inventive Principles

Principle	Solution
Segmentation (Divide an object into independent parts)	Individually wrapped cheese slices
Local quality (Provide different packaging for different uses)	"Adult" editions of Harry Potter books
Universality (make an object perform multiple functions)	Chocolate spread sold in glasses (with a lid) that can be used for drinking afterwards
Nested Doll	Store within store (coffee shops in bookstores)
Another dimension (Tilt or re-orient object)	Squeezable ketchup bottles that sit on their lids

THE TRANSITION

MeThChEM

(Mechanical, Thermal, Chemical, Electronic, Magnetic, Electromagnetic)

Ex: Polymer Processing, Photography

EXAMPLES

- Toothbrushes
- Adhesives
- Pointers
- House construction
- Telephone
- Automobile steering, other systems
- Functional connections
- Writing instruments
- Software development
- Polymer processing
- Tools
- Flow of electricity
- Control systems (on/off, regulates, regulates vs. needs)
- Hydraulic pressure, synchronicity, matched frequency, away from resonant frequencies
- Sunglasses, compensating bysystems
- A/C systems
- Computer interfaces

EXAMPLE:
Clamping or Holding Methods

Macro level	By hand or flat vise
Poly - simple shapes	Cylinders between plates to grip irregular cylinders
Poly - small particles	Powder for 3 dimensional shapes
Material structure	Freeze material to permit clamping
Chemical process	Contain material in a foam
Field	Magnetic clamping

WHAT WOULD THE “NEXT” FIELD BE IN YOUR SYSTEM? COULD YOU USE IT? DO YOU UNDERSTAND IT? WHAT ARE THE ERGONOMIC CONSEQUENCES?

WHAT IS THE NEXT STEP IN AUTOMATION? WHAT TECHNOLOGY IS REQUIRED? WHAT ARE THE ERGONOMIC CONSEQUENCES? IN OPERATION? IN MAINTENANCE?

SEPARATION IN TIME

- A characteristic is made larger at one time and smaller at another
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  - Example: Concrete piles must be pointed for easy driving but not pointed to support a load. The piles are made with pointed tips which are destroyed after driving, via an embedded explosive.
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When something is improved, something else gets deteriorated. Most improvements allow this and they compromise. This is NOT invention.

An improvement in one aspect, without deteriorating any other aspect, is Invention. This is actually Resolving Contradictions.

So, unless a contradiction is resolved, there is no Invention.

One of the steps in TRIZ is to identify the contradictions.

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  - I want to increase output from a chemical reaction by using a higher a temperature but the catalyst becomes unstable
  - I want to improve air flow by increasing the speed of my fan but the fan motor gets too hot

Altshuller, along with dozens of coinvestigators, continued developing and teaching TRIZ throughout his life, eventually applying it to non-technical fields.

Even when Stalin rewarded Altshuller with imprisonment in a Siberian labor camp, Altshuller continued his work.

He formed a "University for One" where persecuted intellectuals, authors, and college professors taught him their subjects of expertise. He amassed an unprecedented knowledge base while motivating his teachers to survive the camp hardships.

After Stalin's death, Altshuller was released. Unable to openly teach TRIZ, he began writing science fiction.

4. Lateral Thinking "LT"

- "VT" is sticking with the current approach
- "LT" is coming at a problem from a non-standard direction. It separates imitators from innovators.
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- LT is Thinking outside the box, don't allow yourself to be tied down to a certain way of thinking.
- Example: Einstein unified his own Special relativity, Newton's law of universal gravitation, ... the effects of gravity can be described by 'space-time' curvature.

Critical Thinking	Creative Thinking
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vertical	lateral
probability	possibility
judgment	suspended judgment
focused	diffuse
objective	subjective
answer	an answer
left brain	right brain
verbal	visual
linear	associative
reasoning	richness, novelty
yes but	yes and

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- To provide a **systematic** step-by-step procedure
- To guide inventors through their solution space and direct them to the area with the best (**most ideal**) solutions
- To provide inventors with **reliable** and **repeatable** Objective results that do not depend on personal (psychological) issues
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- To **accumulate knowledge** of the human innovation experience

1.1. TRIZ Philosophy Cont.

2. Is The problem you are trying to solve unique and special?

No, Then: Don't reinvent the wheel

- Make the maximum use of resources.
- Get others experiences through the history around the Globe & Yours using:
  - TRIZ Inventive Principles
  - What do Millions of Patents Teach Us?

- Discovery of new science, scientific law will be generated based on our scientific thinking, logic, and methodology
- That's why Technology evolution trends follow highly predictable paths.

Factor of Innovation Success Depending on I-TRIZ

Level in I-TRIZ	Level characteristics	$C_{I\text{-}TRIZ}$
1	Minimal knowledge obtained via reading available books, Internet search or courses on simplified versions of TRIZ (like SIT).	0 - 3
2	Training in Classical TRIZ received from trainers without Russian background	1 - 5
3	• Two-week seminar on Classical TRIZ from educators with real Russian background, or • Three-day workshop with Ideation software	5 - 10
4	• Training from a TRIZ Master with Russian background and practical experience in utilizing TRIZ over 5 years, or • Ideation Boot camp (combination of training and intensive practice)	10 - 50
Master I-TRIZ	Complete I-TRIZ knowledge + substantial practical experience – over 100 problems solved (including at least 5 solutions of level 3 or higher.	>>100

$$\text{Innovation Success} = P_c \times P_{kn} \times P_m \times M_s \times (1+C_{I\text{-}TRIZ})$$

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TRIZ Method: Problem Solving

-DMASI methodology

Define The innovation problem/system (requirements, constraints, …) the Ideal Final Result

Model The system (how its elements interact; how its elements create contradictions; how to resolve contradictions)

Abstract The specific problem into a generic problem (es. Express the contradictions in terms of the 39 engineering parameters)

Solve For the specific solution using TRIZ tools (separation principles, inventive principles, standard solutions, …)

Implement solutions that eliminate problems or generate new revenues

This is Method #13: Self-Service.

Now we need to know some of the physical laws on how to use **Self-Service**. In order to develop the protective layer of the balls, we need to use a magnet. We will place the magnet on the outside of the bend. Some of the balls from the flow will stick to the wall inside the pipe as soon as they reach the magnetized area. The prob-
lem is solved! We should mention

SEPARATION BETWEEN PARTS AND THE WHOLE

- A characteristic has one value at the system level and the opposite value at the component level
- A characteristic exists at the system level but not at the component level (or vice versa)
  - Example: A bicycle chain is rigid at the micro-level for strength, and flexible at the macro-level.
  - Example: Epoxy resin and hardener are liquid until mixed, then they solidify.

SEPARATION IN TIME

- A characteristic is made larger at one time and smaller at another
- A characteristic is present at one time and absent at another

  - Example: Concrete piles must be pointed for easy driving but not pointed to support a load. The piles are made with pointed tips which are destroyed after driving, via an embedded explosive.
  - Example: Aircraft wings are longer for takeoff, and then pivot back for high speed flight.
  - Example: Consider the problem of sand accumulation with abrasive sandblasting. An effective solution is to use dry ice chips as the abrasive. After abrading, the chips will simply disappear by sublimation.

An invention happens only when a contradiction is resolved.

When something is improved, something else gets deteriorated. Most improvements allow this and they compromise. This is NOT invention.

An improvement in one aspect, without deteriorating any other aspect, is Invention. This is actually Resolving Contradictions.

So, unless a contradiction is resolved, there is no Invention.

One of the steps in TRIZ is to identify the contradictions.

Example: If an automobile has to withstand impact, it has to be strong-if strengthened by increasing the thickness of metal, it consumes more fuel to move. How to strengthen without losing fuel efficiency becomes a contradiction.

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How are they most commonly used?

- Use the list as a structured Brain storming tool
- Best used to help resolve Contradiction
  - When two different parameters in a system are in conflict with each other
  - I want to increase strength by using a more dense material but my system is now too heavy to move
  - I want to increase output from a chemical reaction by using a higher a temperature but the catalyst becomes unstable
  - I want to improve air flow by increasing the speed of my fan but the fan motor gets too hot

4. Lateral Thinking "LT"

- "VT" is sticking with the current approach
- "LT" is coming at a problem from a non-standard direction. It separates imitators from innovators.
- "Is exploring multiple possibilities and approaches instead of pursuing a single approach."
- LT is Thinking outside the box, don't allow yourself to be tied down to a certain way of thinking.
- Example: Einstein unified his own Special relativity, Newton's law of universal gravitation, ... the effects of gravity can be described by 'space-time' curvature.

Critical Thinking	Creative Thinking
analytic	generative
convergent	divergent
vertical	lateral
probability	possibility
judgment	suspended judgment
focused	diffuse
objective	subjective
answer	an answer
left brain	right brain
verbal	visual
linear	associative
reasoning	richness, novelty
yes but	yes and

1.1.1 Why TRIZ was created & How?

- To provide a **systematic** step-by-step procedure
- To guide inventors through their solution space and direct them to the area with the best (**most ideal**) solutions
- To provide inventors with **reliable** and **repeatable** Objective results that do not depend on personal (psychological) issues
- To provide a means to access **proven knowledge** (patent information)
- To **accumulate knowledge** of the human innovation experience

1.1. TRIZ Philosophy Cont.

2. Is The problem you are trying to solve unique and special?

No, Then: Don't reinvent the wheel

- Make the maximum use of resources.
- Get others experiences through the history around the Globe & Yours using:
  - TRIZ Inventive Principles
  - What do Millions of Patents Teach Us?

- Discovery of new science, scientific law will be generated based on our scientific thinking, logic, and methodology
- That's why Technology evolution trends follow highly predictable paths.

Factor of Innovation Success Depending on I-TRIZ

Level in I-TRIZ	Level characteristics	$C_{I\text{-}TRIZ}$
1	Minimal knowledge obtained via reading available books, Internet search or courses on simplified versions of TRIZ (like SIT).	0 - 3
2	Training in Classical TRIZ received from trainers without Russian background	1 - 5
3	• Two-week seminar on Classical TRIZ from educators with real Russian background, or • Three-day workshop with Ideation software	5 - 10
4	• Training from a TRIZ Master with Russian background and practical experience in utilizing TRIZ over 5 years, or • Ideation Boot camp (combination of training and intensive practice)	10 - 50
Master I-TRIZ	Complete I-TRIZ knowledge + substantial practical experience – over 100 problems solved (including at least 5 solutions of level 3 or higher.	>>100

$$\text{Innovation Success} = P_c \times P_{kn} \times P_m \times M_s \times (1+C_{I\text{-}TRIZ})$$

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Summary and Concluding Remarks

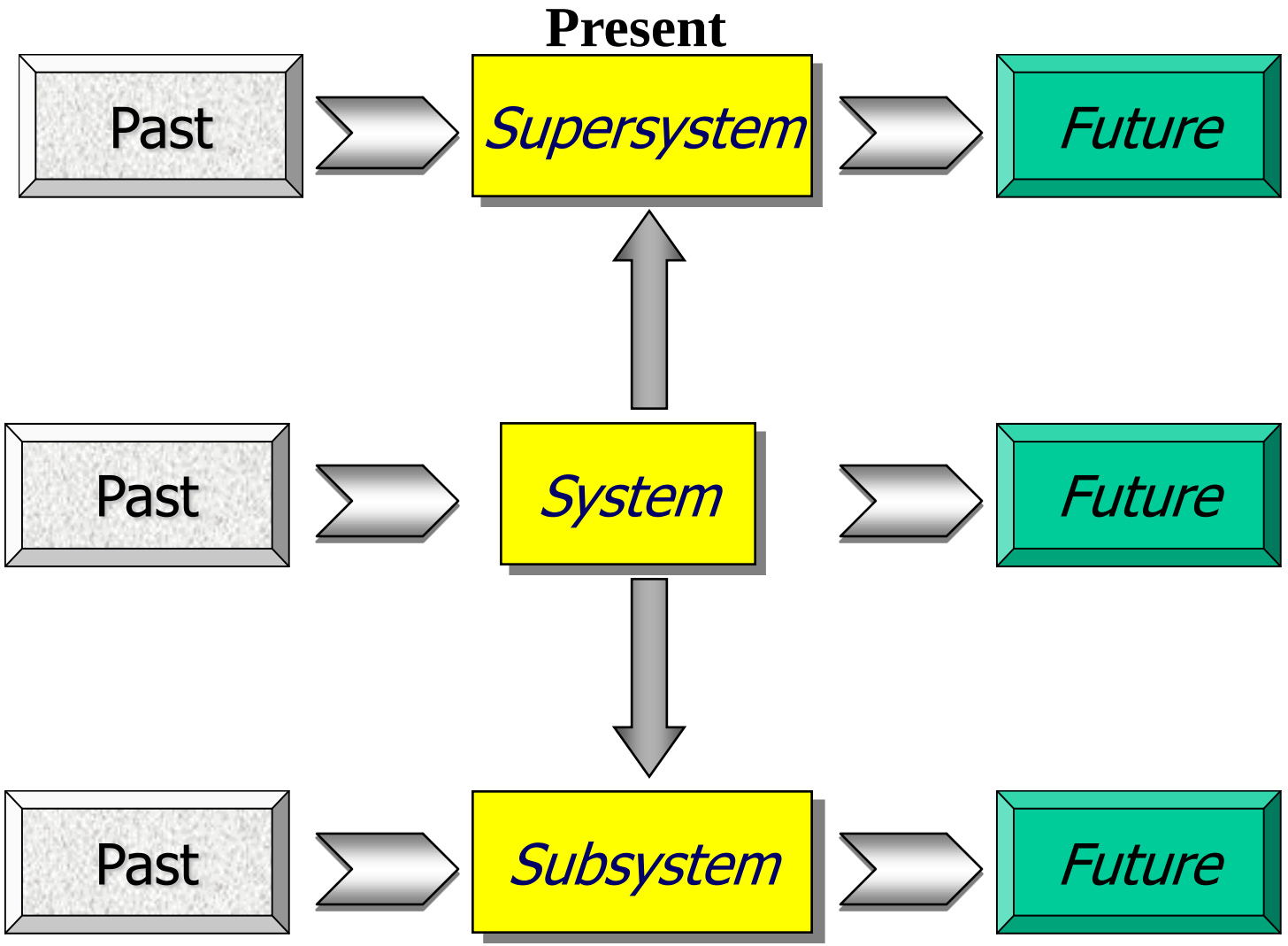
- Innovation is value creation + market delivery
  - different levels and types
  - Blue Ocean Strategy: market creation instead of market competition
- TRIZ
  - inventive problem solving with systematic approach
  - Millions of patents
  - Contradictions lead to high levels of innovation: physical and technical => 39 parameters
  - Evolution of Technological Systems
  - Patterns of Inventions
  - 40 inventive principles and 76 standard solutions
  - No need to reinvent the wheel

Innovation needs and requirements

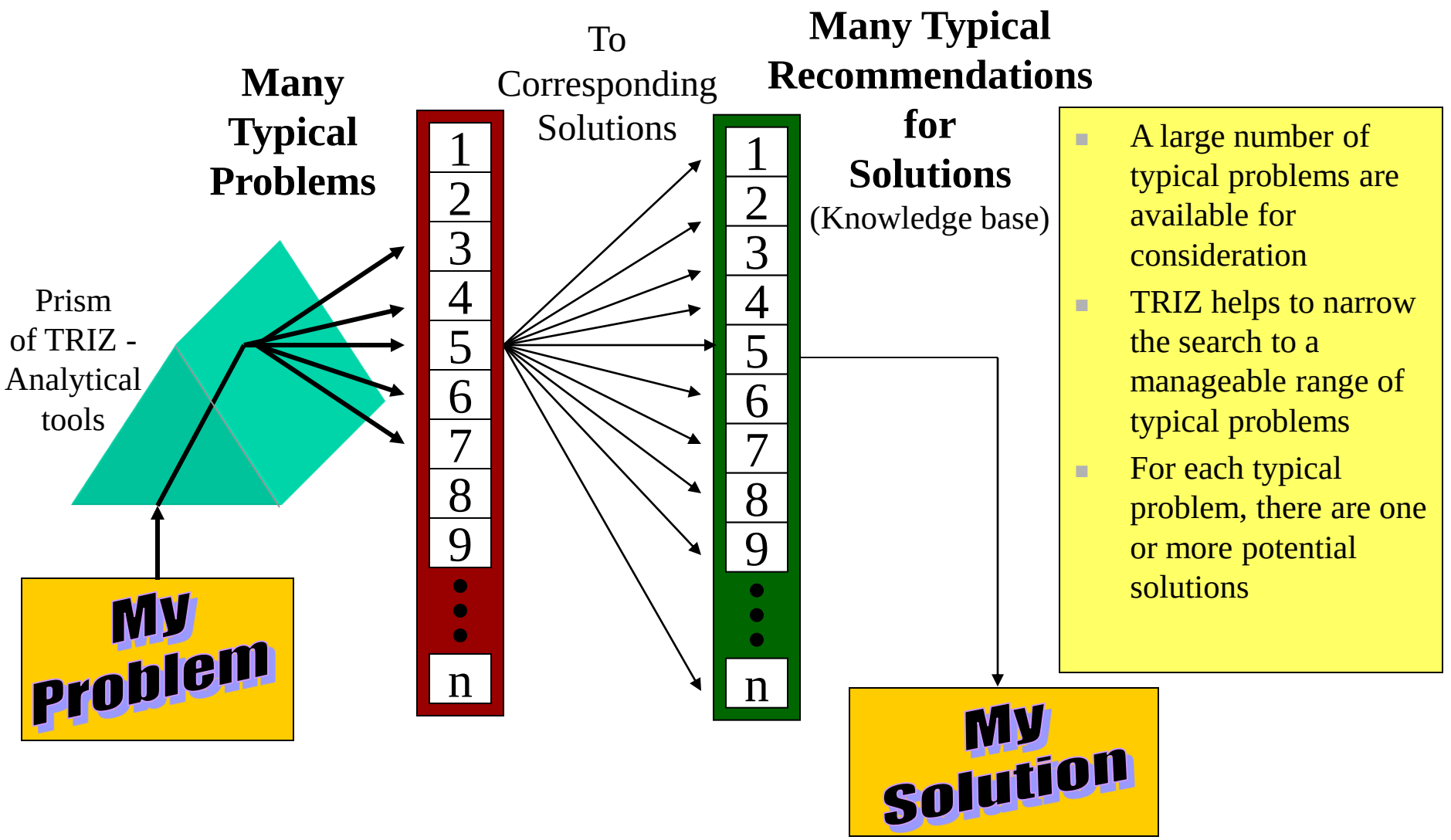
- critical thinking - application of reasoning in the determination whether something is good or bad;
  - diverse range of intellectual skills and activities (analyzing, conceptualizing, defining, examining, inferring, questioning, reasoning, synthesizing) concerned with evaluating information and our own thought in a disciplined way to help refine thought process to identify and reject false ideas and ideologies
- problem solving: define, model, abstract, solve, implement => no need to reinvent the wheel
- creativity: diverse points of view/perspectives
  - De Bono's 6 thinking hats, TRIZICS 9 windows, TRIZ 40 lenses, 76 standard solutions,
- intellectual property rights: trade mark, service mark, patent, utility model, logo, copyright, trade secret

LEVEL OF PROBLEM ATTACK

(NINE BOX LOOK)



How the Knowledge Wizard™ Works



- A large number of typical problems are available for consideration
- TRIZ helps to narrow the search to a manageable range of typical problems
- For each typical problem, there are one or more potential solutions

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THANK YOU!