The TRIZ Method

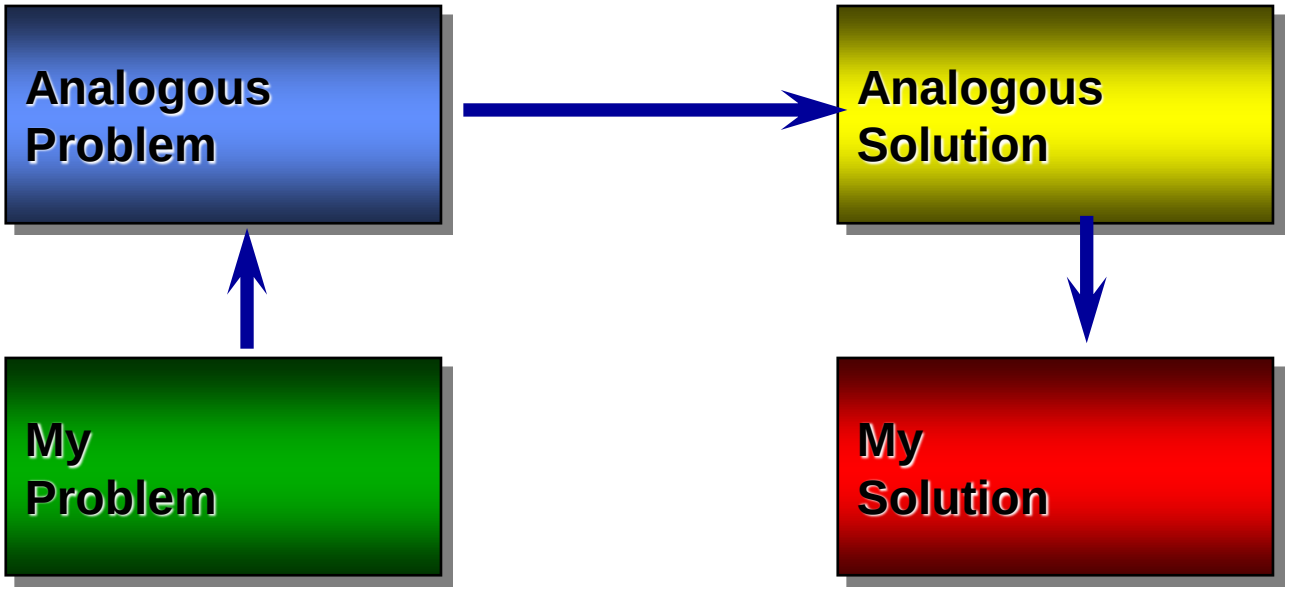
in

Engineering Design

TRIZ

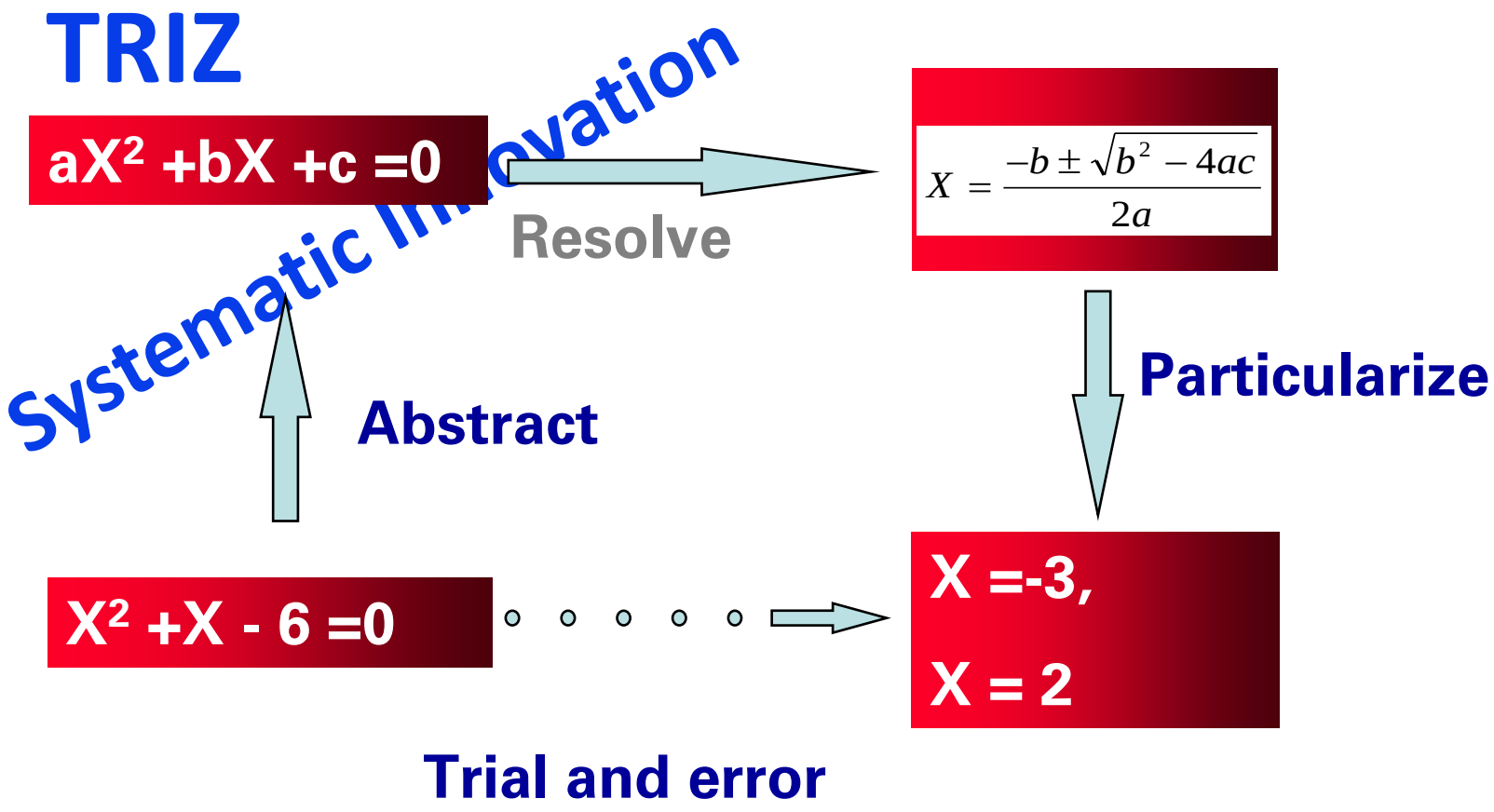
- *Teoriya Resheniya Izobreatatelskikh Zadatch*
- Theory of inventive problem solving (TIPS)
- Started with Altshuller's (Genrich Saulovich Altshuller) interest in invention and work in Soviet Navy patent office.

GENERAL APPROACH TO PROBLEM SOLVING



Example: Measuring cables with a normal rule

“Simply” a matter of finding the previously well-solved problem analogous to the problem at hand


TRIZ
aX² +bX +c =0
Systematic Innovation
Resolve
$X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
Particularize
Abstract
X² +X - 6 =0
X =-3,
X = 2
Trial and error

What is TRIZ?

TRIZ is an evolving, open-ended system for enhancing human inventiveness through

- Systematic identification of problems and attaining ideal solutions
- Overcoming various blocks through heuristics and approaches that have performed in other disciplines

Context and Issues:

Levels of inventive solutions

Regularities in the evolution of technological systems

Technical contradictions, the matrix

Substance-Field (SU-Field) theory

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). eg: developing a completely new methodology challenging the existing one
- Level 5: Discovery, essentially new system, new science? (lasers, aircraft, computers).

Regularities in Evolution of Technological Systems

8 Laws of Development of Engineered Systems

1. Law of completeness of parts of a system
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

CRISP EMF

Completeness Rhythm Ideal Supersystem Parts - Energy Macro Field

Technical Contradictions & the Matrix

- Parameter A improves, but parameter B deteriorates, strength v. weight.
  - Usually involves tradeoff or compromise
  - TRIZ seeks to outdo contradiction.

- In patent study, Altshuler identified 39 engineering parameters and 40 operators (or Inventive Principles)

- 39 x 39 matrix of parameter contradictions

39 System Parameters

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
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

40 Inventive Principles (operators)

1. Segmentation
2. Extraction
3. Local quality
4. Asymmetry
5. Combining
6. Universality
7. Nesting
8. Counterweight
9. Prior counter-action
10. Prior action
11. Cushion in advance
12. Equipotentiality
13. Inversion
14. Spheroidality
15. Dynamicity
16. Partial or overdone action
17. Move to new dimension
18. Mechanical vibration
19. Periodic action
20. Continue useful action
21. Rushing through
22. Convert harm to benefit

Contd……40 Inventive Principles

23. Feedback
24. Mediator
25. Self-service
26. Copying
27. Substitute throwaway
28. Replace mechanical system
29. Use pneumatic-hydraulic system
30. Flexible film or thin membranes
31. Use porous material
32. Change color
33. Make homogeneous
34. Rejecting or regenerating parts
35. Transform physical-chemical states
36. Phase transition
37. Thermal expansion
38. Use oxidizers
39. Inert environment
40. Composite material

Undesired Result (Conflict) / Feature to Improve		Weight of moving object	Weight of non-moving object	Length of moving object	Length of non-moving object	Area of moving object	Area of non-moving object	Volume of moving object	Volume of non-moving object	Speed	Force (Intensity)	Stress or pressure	Shape
No		1	2	3	4	5	6	7	8	9	10	11	12
1	Weight of moving object	+		15, 8, 29,34		29, 17, 38, 34		29, 2, 40, 28		2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40
2	Weight of non-moving object		+		10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2		8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14
3	Length of moving object	8, 15, 29, 34		+		15, 17, 4		7, 17, 4, 35		13, 4, 8	17, 10, 4	1, 8, 35	1, 8, 10, 29
4	Length of non-moving object		35, 28, 40, 29		+		17, 7, 10, 40		35, 8, 2,14		28, 10	**1, 14, 35**	13, 14, 15, 7

Sample Contradiction

- Length of non-moving object vs. stress (or pressure)
- Use 1, 14, 35

  Segmentation

  Spherodiality

  Transform physical-Chemical States

- Amounts to an expert system depending upon technical blocks.

Another Sample Contradiction

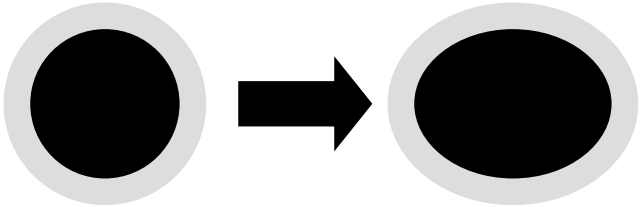
- Weight of moving object vs force
- Use 8, 10, 18, 37
  - Counterweight
  - Prior action
  - Mechanical vibration
  - Thermal expansion
- Amounts to an expert system depending upon technical blocks.

Resolve the Contradiction

Resolve the contradiction:
Lager engine diameter should produce Increases air intake, and should not produce Decreases ground clearance.

Separate in Space by the Inventive Principle "Different locations"

Idea: make the radius of the air intake large in one direction



Frequently Used Inventive Principles

Transform Physical State

- 35. **Parameter changes** (*Transport oxygen or nitrogen or petroleum gas as a liquid, instead of a gas, to reduce volume*)

Prior Action

- 10. **Preliminary action** (*Pre-pasted wall paper*)
- 1. **Segmentation** (*Modular furniture*)

transfers a complex task into a number of simpler tasks that are easier to solve

- 28. **Mechanics substitution** (*electronic voting*)

extraction

- 2. **Taking out** (*Locate a noisy compressor outside the building where compressed air is used*
- 15. **Dynamics** (*Adjustable seat*)
- 19. **Periodic action** (*Replace a continuous siren with a pulsed sound*)
- 18. **Mechanical vibration** (*Destroy gall stones or kidney stones using ultrasonic resonance)*
- 32. **Color changes** (*Colormatic lenses*)
- 13. **'The other way round'** (*Walking stairs*)

40 Inventive Principles

1. Segmentation

1.Divide an object into independent parts: bicycle chain,

2.Make an object sectional: telescopic pointer, 'plug able' computer boards

3.Increase the degree of an object's segmentation: ball bearing Vs bushing

2. Extraction, Separation, Removal, Segregation

1.Extract (remove or separate) a disturbing part or property from an object: I-beam Vs solid beam

2.Extract only the necessary part or property: Polaroid sun grasses

3. Local Quality

1.Transition from a homogeneous structure of an object to a heterogeneous structure, change an external environment or influence from uniform to non-uniform: plywood/anisotropic materials, temperature gradients for evaporation/condensation

2.Have different parts of the object carry out different functions: Swiss army knife, small and large teeth on a saw blade, p-n-p or n-p-n transistors

3.Place each part of the object under conditions most favorable for its operation: fridge's, cool Vs frozen sections

4. Asymmetry

1.Replace a symmetrical form with an asymmetrical form: component shapes for foolproof assembly

2.Change the properties of an object to suit external asymmetries: use liquid instead of solid materials to make contact with an odd-shaped solid

3.If an object is already asymmetrical, increase the degree of asymmetry: small front Vs very large rear tires for a dragster

5. Combining, Integration, Merging

1.Combine in space identical or similar objects, assemble identical or similar parts to perform parallel operations: honey cone, zero and one (off/on function) i.e. transistors

2.Combine in time homogeneous or contiguous operations: synchronize manufacturing operations, parallel manufacturing operations

3.Agglomerate objects to Bi- and Poly-systems: One power supply for multiple applications, Electro-chemical polishing

6. Universality, Multi-functionality

1.Have the object perform multiple functions, thereby eliminating the need for other object(s): hand for holding, pointing, sensing, etc. laser for cutting, fusing, cleaning

2.Use standardized attributes: Specifications, measurement master reference, communication protocol

7. Nesting

1.Contain the object inside another which, in turn, is placed inside a third object: paper cups, packaging of electronic devices, e.g. chip/module/card/board/computer housing

2.Pass an object through a cavity of another object: telescopic pointer, laser pointer

8. Counterweight, Levitation

1.Compensate for the object's weight by joining with another object that has a lifting force: outriggers/pontoons

2.Compensate for the weight of an object by interaction with an environment providing aerodynamic or hydrodynamic forces: sail, wings, ocean tides for lifting, capillary action, e.g. solder wick

9. Preliminary anti-action, Prior counteraction

1.Perform a counter-action in advance: annealed steel

2.If the object is (or will be) under tension, provide anti-tension in advance: pre-stressed concrete

10. Prior action

1.Carry out all or part of the required action in advance: pre-tinned electronic components,

2.Arrange objects so they can go into action in a timely matter and from a convenient position: SMDE, Single Minute Die Exchange

11. Cushion in advance, compensate before

1.Compensate for the relatively low reliability of an object by countermeasures taken in advance: plating, painting surfaces, redundancy, tolerances, screening failure prone devices, e.g. Stress Screening, Burn-in

12. Equipotentiality, remove stress

1.Change the working conditions so that an object need not be modified, raised, or lowered: pit for oil change, flexible coupling, continuous discharge to eliminate catastrophic ESD

13. Inversion, The other way around

1.Instead of an action dictated by the specifications of the problem, implement an opposite action: move the part instead of the tool, use negatives instead of positives

2.Make a moving part of the object or the outside environment immovable and the non-moving part movable: escalator

3.Turn the object upside-down: Hour glass. Mobius Band for increases length

14. Spheroidality, Curvilinearity

1.Replace linear parts or flat surfaces with curved ones; replace cubical shapes with spherical shapes: use rollers instead of skids to move parts, replace typewriter keys with one IBM print "ball", rounded instead of pointed objects to minimize stress concentrations, Ball Grid Arrays, BGA's

2.Use rollers, balls spirals: ball bearings

3.Replace a linear motion with rotating movement: carousel conveyor instead of straight conveyor

4.utilize a centrifugal force: spin coatings, rotating water sprinkler, turbine Vs reciprocating engine

15. Dynamicity, Optimization

1.Make an object or its environment automatically adjust for optimal performance at each stage of operation: self-adjusting tinted glasses

2.Divide an object into elements which can change position relative to each other: adjustable wrench, variable pitch screw, MEMS

3.If an object is immovable, make it movable or interchangeable: water faucet

4.Increase degree of free motion: ball joints or universal joints

16. Partial or excessive action

1.If it is difficult to obtain 100% of a desired effect, achieve somewhat more or less to greatly simplify the problem: to apply coatings dip and then skim or spin off the excess, allow for safety margins by using robust designs that enable generous tolerances e.g. large Cpk

17. Moving to a new dimension

1.Remove problems associated with moving an object linearly by using two or three-dimensional movement: in machining use Z-axis motion to avoid obstacles, solve problems by using time Vs space

2.Use a multi-layered assembly of objects instead of a single layer: thermal clothing is layered, multi-layer printed circuit boards, stacked or brick-walled electronic components

3.Tilt the object or turn it on its side: skidoo or boat trailers that tilt for easy load/unload

4.Use another side: Mobius strip, double sided printed circuit boards (PCB)

18. Mechanical vibration/oscillation

1.Set an object into oscillation: hammer drill, mixing by using shaking
2.If oscillation exists, increase its frequency, even as far as ultrasonic: vibratory part feeders, ultrasonic cleaning, ultrasonic and thermo-sonic bonding
3.Use the resonant frequency: violin, kidney stone removal
4.Instead of mechanical vibrations, use piezoelectric vibrators: crystal oscillators, piezoelectric vibrators for spray coating
5.Use ultrasonic vibrations in conjunction with an electromagnetic field:

19. Periodic action

1.Replace a continuous action with a periodic (pulsed) one: DC Vs AC, quality sampling, High Mix Low Volume Manufacturing,
2.If an action is already periodic, change its frequency: Micro-processor frequency (ever increasing frequency of Pentium chips), pulsed laser cutting
3.Use pauses between impulses to provide additional action: remove or insert parts in die press during reciprocating die punch motion, perform machine setups during slack periods

20. Continuity of a useful action

1.Carry out an action continuously (i.e. without pauses), where all parts of an object operate at full capacity: Hydro-electric generators pump water into reservoirs during low electricity consumption periods, use 24/7 operation

2.Remove idle and intermediate motions: rotary cutters for cutting in any direction, during burn-in or stress screening perform other diagnostic tests

21. Rushing through

1.Perform harmful or hazardous operations at very high speed: inoculation "gun" instead of syringe, seal glass ampoules very quickly by using high temperature thus eliminating thermal damage to the contents

22. Convert harm into benefit, "Blessing in disguise"

1.Utilize harmful factors or environmental effects to obtain a positive effect: friction rotates tire, gas from manure, waste recycling

2.Remove a harmful factor by combining it with another harmful factor: explosions to put out oil well fires, reduce the drag on airplane wings caused by linear air over the wing by creating a rotating micro-layer of air turbulence between the wing and the linear air flow

3.Increase the amount of harmful action until it ceases to be harmful: increase vibration to stop resonance, increase the frequency until it becomes inaudible

23. Feedback

1.Introduce feedback: cursor on computer screen, inspection, Statistical Process Control (SPC)

2.If feedback already exists, reverse or change it: part inspection: sampling Vs 100% inspection, Stop the manufacturing line if SPC data is unsatisfactory

24. Mediator, intermediary

1.Use an intermediary object to transfer or carry out an action: chisel plus hammer instead of just using the hammer, primers for paint adhesion, Nickel or Tin coatings on electronic components to facilitate soldering, multi-layer substrates in electronics to achieve high wirability (minimize area)

2.Temporarily connect an object to another one that is easy to remove: magnet to hold photo onto fridge, air in air mattress, dry ice for cooling

25. Self-service, self-organization

1.Make the object service itself and carry out supplementary and/or repair operations: boomerang, knife holder that sharpens, use the surface tension of solder to fine tune the positioning of electronic components

2.Make use of wasted material and energy: use scrap parts for setups, use both sides of paper for writing, use excess heat to cool e.g. evaporation

26. Copying

1.Use a simple and inexpensive copy instead of an object which is complex, expensive, fragile or inconvenient to operate: mock-ups, printed circuits instead of wired interconnections, modeling, simulations, spread sheets instead of actual counts

2.Replace an object by its optical copy or image: drawings, computer animation, optical inspection, projection lithography

3.If visible optical copies are used, replace them with infrared or ultraviolet copies: use ultraviolet markings so they're hidden from human vision, infrared interferometry, X-ray laminography, photoluminescence, polarized light

27. Substitute throwaway

1.Inexpensive, short-lived object instead of expensive, durable one Replace an expensive object by a collection of inexpensive ones, forgoing certain properties (e.g. longevity): paper/plastic bags, plastic eye lenses, disposable gloves, slippers, masks, cameras

28. Replacement of a mechanical system with 'fields'

1.Replace a mechanical system with a sensory (optical, acoustic, taste or smell) system: optical sensors, bar code readers,

2.Use an electrical, magnetic or electromagnetic field for interaction with the object: solenoid, magnets, eddy current,

3.Replace fields:

a.Stationary fields with moving fields: Microwave drying, curing, cleaning

b.Fixed fields with those changing in time: replace DC with AC, pulse vacuum cleaner suction

c.Random fields with structured fields: random vibration rock drill with a resonance induced drill

4.Use a field in conjunction with field-activated (e.g. ferromagnetic) particles: ferromagnetic particles in electrorheological materials for controlling substance stiffness, use of lumiphores

29. Pneumatics or hydraulics:

1.Use gaseous or fluidic objects instead of solid objects: air bearings, shock absorbers, vacuum pick-and-place, pneumatics

30. Flexible membranes or thin film

1.Replace traditional constructions with those made from flexible membranes or thin film: beer can, plastic bags, foam for heat of sound insulation, car air bag

2.Isolate an object from its environment using flexible membranes or thin film: paint, surfactants on ponds to minimize evaporation, tape for holding tape-and-reel electronic components, thin oil films for lubrication

31. Use of porous material

1.Make an object porous or add porous elements: sintered metal, bricks, air or liquid filters, strainers

2.If an object is already porous, use pores to induce a useful substance or function: capillaries for suction, heat pipes, photo-mask for etching

32. Changing color or optical properties

1.Change the color of an object or its surroundings: traffic light, RGB color mixing, polarizing of light

2.Change the transparency of an object or its environment: X-rays, optical lens coatings,

3.Use colored additives to observe objects or processes which are difficult to see: Luminescent strips, LEDs, magna fluxes for detection of cracks in steel parts

33. Homogeneity

1.Make those objects which interact with a primary object out of the same material or material that is close to the primary object in behavior: tooth fillings, allow ice to build up on bridge columns to minimize damage from ice flows, to minimize stress in mechanical assemblies use at high temperatures use components having the same coefficient of thermal expansion

34. Rejection and regeneration, Discarding and recovering

1.Make portions of an object that have fulfilled their functions disappear (discard, dissolve, evaporate) or modify these directly during operation: digestible medicine capsules, space shuttle booster rockets, skeet shooting disks made from ice that melts

2.Immediately restore any part of an object which is exhausted or depleted: water in toilette basin, condensation of evaporated refrigeration coolant

35. Transformation of the physical and chemical states of an object, parameter change, changing properties

1.Change an object's physical state (to solid, gas, or liquid): use ice bergs to transport water, transport feather pillows as a vacuum pack, use dry ice to cool

2.Change the concentration, consistency, rheology: magnetorheoligal materials, thicksotropic materials like ketchup

3.Change the degree of flexibility: rod Vs chain VS belt, spring, shock absorber

4.Change temperature: Change temperature of Curie materials to affect electrical conductivity,

5.Change pressure: Vacuum deposition, friction welding

36. Phase transformation

1.Use phenomena that occur during phase transitions of a substance: use boiling water to maintain a constant temperature of 100 deg. C., use evaporation to cool, freeze water to increase its volume

37. Thermal expansion

1.Use a material which expands or contracts with heat: use heat shrink tubing to hold separate items, thermal compression assembly

2.Use various materials with different coefficients of heat expansion: fuses, bimetallic on-off heat sensor, leaf spring sensors

38. Use strong oxidizers, enriched atmospheres, accelerated oxidation

1.Replace normal air with enriched air: breathing apparatus,

2.Replace enriched air with oxygen: oxy-acetylene torch

3.Treat an object in air or in oxygen with ionizing radiation:

4.Use ionized oxygen: anodic arc plasma oxidation

5.Replace ionized oxygen with ozone: UV-Ozone cleaning

39. Inert environment or atmosphere

1.Replace the normal environment with an inert one: Use Nitrogen during soldering to minimize oxidation of solder joints, hermetic enclosures, Nitrogen atmospheres material storage, clean rooms, deionized water

2.Add neutral or inert components to an object: add air to materials for improved thermal insulation, vacuum bonding

40. Composite materials

1.Replace a homogeneous material with a composite (multiple) material: alloys, fertilizer, plastics with fillers: glass, metal, etc., laminated structures for flexibility, fiber glass, steel belted tires, Si-on-Si, Silicon-on -ceramic

The Trends of Technological System Evolution

1. INCREASING IDEALITY:

- Technological systems tend toward ever increasing functionality, while reducing their unwanted or not needed functions: The computer has progressed from a computational system to one that is in addition a radio, a fax, a printer, a video projector, while at the same time reducing its cost, size, and weight.

Parts

2. CONSTRAINT GENESIS DUE TO UNEVEN SUBSYSTEM DEVELOPMENT:

- As technological systems improve, certain sub-systems can't keep up with required performance improvements. This causes conflicts or contradictions. For example, although engines had the capability to produce high speed of racing cars, these speeds were unattainable until the aerodynamic property of the car itself was improved.

3. DYNAMIZATION OF STRUCTURE:

- Structures tend to evolve from rigid to hinged to multi-jointed to flexible to hydraulic to pneumatic to field-like(e.g. electro-magnetic) to non-existent structures. An example would be wire printer, inkjet, laser printer, to a non-existent printer, the computer monitor.

4. TRANSITION TO A HIGHER LEVEL:

Supersystem

- Systems tend to evolve from mono to bi to poly-systems: Examples are razors (1, 2, 3 blades), screwdrivers, one to multi-head.

5. TRANSITION FROM MACRO TO MICRO TO MACRO LEVEL:

- To eliminate contradictions systems may fragment and later convolute. Examples: to increase/reduce heat transfer a system may fragment/coalesce.

6. DECREASING HUMAN INVOLVEMENT/INCREASING AUTOMATION:

- Technological systems first take over the primary function, then the control function and ultimately, in the future, the planning function. For instance, the sewing machine performs the primary function of sewing, plus the functions of pattern and thread color selection via computer control.

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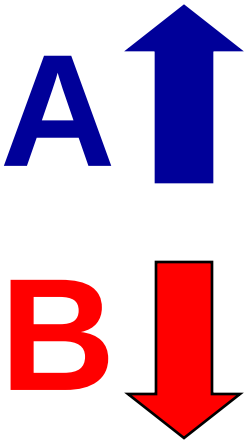
Technical Contradiction



- Parameter A improves
- Parameter B deteriorates
- Temperature vs. Waste of Energy
- Amount of Substance vs. Reliability, etc.

- Invention surmounts the contradiction, achieving both

Contradictions Matrix

GSA-1969	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
1			15. 8. 29. 34		29. 17. 38. 34		29. 2. 40. 28		2. 8. 15. 38	8. 10. 18. 37	10. 36. 37. 40	10. 14. 35. 40	1. 35. 19. 39	28. 27. 18. 40	5. 34. 31. 35		6. 29. 4. 38	19. 1. 32	35. 12. 34. 31		12. 36. 18. 31	6. 2. 34. 19	5. 35. 3. 31	10. 24. 35	10. 35. 20. 28	3. 26. 18. 31	3. 11. 1. 27	28. 27. 35. 26	28. 35. 26. 18	22. 21. 18. 27	22. 35. 31. 39	27. 28. 1. 36	35. 3. 2. 24	2. 27. 28. 11	29. 5. 15. 8	26. 30. 36. 34	28. 29. 26. 32	26. 35. 18. 19	35. 3. 24. 37
2			10. 1. 29. 35		35. 30. 13. 2		5. 35. 14. 2		8. 10. 19. 35	13. 29. 10. 18	13. 10. 29. 14	26. 39. 1. 40	28. 2. 10. 27		2. 27. 19. 6	28. 19. 32. 22	35. 19. 32			18. 19. 28. 1	15. 19. 18. 22	18. 19. 28. 15	5. 8. 13. 30	10. 15. 35	10. 20. 35. 26	19. 6. 18. 26	10. 28. 8. 3	18. 26. 28	10. 1. 35. 17	2. 19. 22. 37	35. 22. 1. 39	28. 1. 9	6. 13. 1. 32	2. 27. 28. 11	19. 15. 29	1. 10. 26. 39	25. 28. 17. 15	2. 26. 35	1. 28. 15. 35
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6		30. 2. 14. 18		26. 7. 9. 39						1. 18. 35. 36	10. 15. 36. 37		2. 38	40		2. 10. 19. 30	35. 39. 38				17. 32	17. 7. 30	10. 14. 18. 39	30. 16	10. 35. 4. 18	2. 18. 40. 4	32. 35. 40. 4	26. 28. 32. 3	2. 29. 18. 36	27. 2. 39. 35	22. 1. 40	40. 16	16. 4	16	15. 16	1. 18. 36	2. 35. 30. 18	23	10. 156. 17. 7
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8		35. 10. 19. 14	19. 14	35. 8. 2. 14						2. 18. 37	24. 35	7. 2. 35	34. 28. 35. 40	9. 14. 17. 15		35. 34. 38	35. 6. 4				30. 6		10. 39. 35. 34		35. 16. 32. 18	35. 3	2. 35. 16		35. 10. 25	34. 39. 19. 27	30. 18. 35. 4	35		1		1. 31	2. 17. 26		35. 37. 10. 2
9	2. 28. 13. 38		13. 14. 8		29. 30. 34		7. 29. 34			13. 28. 15. 19	6. 18. 38. 40	35. 15. 18. 34	28. 33. 1. 18	8. 3. 26. 14	3. 19. 35. 5		28. 30. 36. 2	10. 13. 19	8. 15. 35. 38		19. 35. 38. 2	14. 20. 19. 35	10. 13. 28. 38	13. 26		10. 19. 29. 38	11. 35. 27. 28	28. 32. 1. 24	10. 28. 32. 25	1. 28. 35. 23	2. 24. 32. 21	32. 13. 8. 1	32. 28. 13. 12	34. 2. 28. 27	15. 10. 26	10. 28. 4. 34	3. 34. 27. 16	10. 18	
10	8. 1. 37. 18	18. 13. 1. 28	17. 19. 9. 36	28. 1	19. 10. 15	1. 18. 36. 37	15. 9. 12. 37	2. 36. 18. 37	13. 28. 15. 12		18. 21. 11	10. 35. 40. 34	35. 10. 21	35. 10. 14. 27	19. 2		35. 10. 21		19. 17. 10	1. 16. 36. 37	19. 35. 18. 37	18. 15	8. 35. 40. 5		10. 37. 36	14. 29. 18. 36	3. 35. 13. 21	35. 10. 23. 24	28. 29. 37. 36	1. 35. 40. 18	13. 3. 36. 24	15. 37. 18. 1	1. 28. 3. 25	15. 1. 11	15. 17. 18. 20	26. 35. 10. 18	36. 37. 10. 19	2. 35	3. 28. 35. 37
11	10. 36. 37. 40	13. 29. 10. 18	35. 10. 36	35. 1. 14. 16	10. 15. 36. 28	10. 15. 36. 37	6. 35. 10	35. 34	6. 35. 36	36. 35. 21		35. 4. 15. 10	35. 33. 2. 40	9. 18. 3. 40	19. 3. 27		35. 39. 19. 2		14. 24. 10. 37		10. 35. 14	2. 36. 25	10. 36. 37		37. 36. 4	10. 14. 36	10. 13. 19. 35	6. 28. 25	3. 35	22. 2. 37	2. 33. 27. 18	1. 35. 16	11	2	35	19. 1. 35	2. 36. 37	35. 24	10. 14. 35. 37
12	8. 10. 29. 40	15. 10. 26. 3	29. 34. 5. 4	13. 14. 10. 7	5. 34. 4. 10		14. 4. 15. 22	7. 2. 35	35. 15. 34. 18	35. 10. 37. 40	34. 15. 10. 14		33. 1. 1. 18	30. 14. 10. 40	14. 26. 9. 25		22. 14. 19. 32	13. 15. 32	2. 6. 34. 14		4. 6. 2	14	35. 29. 3. 5		14. 10. 34. 17	36. 22	22. 1. 2. 35	28. 32. 1	32. 30. 40	1. 32. 17. 28	32. 15. 26	2. 13. 1	1. 15. 29	16. 29. 1. 28	15. 13. 39	15. 1. 32	17. 26. 34. 10
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14	1. 8. 40. 15	40. 26. 27. 1	1. 15. 8. 35	15. 14. 28. 26	3. 34. 40. 29	9. 40. 28	10. 15. 14. 7	9. 14. 17. 15	8. 13. 26. 14	10. 18. 3. 14	10. 3. 18. 40	10. 30. 35. 40	13. 17. 35		27. 3. 26		30. 10. 40	35. 19	19. 35. 10	35	10. 26. 35. 28	35	35. 28. 31. 40		29. 3. 28. 10	29. 10. 27	11. 3	3. 27. 16	3. 27	18. 35. 37. 1	15. 35. 22. 2	11. 3. 10. 32	32. 40. 28. 2	27. 11. 3	15. 3. 32	2. 13. 28	27. 3. 15. 40	15	29. 35. 10. 14
15	19. 5. 34. 31		2. 19. 9		3. 17. 19		10. 2. 19. 30		3. 35. 5	19. 2. 16	19. 3. 27	14. 26. 28. 25	13. 3. 35	27. 3. 10			19. 35. 39	2. 19. 4. 35	28. 6. 35. 18		19. 10. 35. 38		28. 27. 3. 18	10	20. 10. 28. 18	3. 35. 10. 40	11. 2. 13	3	3. 27. 16. 40	22. 15. 33. 28	21. 39. 16. 22	27. 1. 4	12. 27	29. 1. 27	13	10. 4. 29. 15	19. 29. 39. 35	6. 10	35. 17. 14. 19
16		6. 27. 19. 16		1. 40. 35				35. 34. 38					39. 3. 35. 23				19. 18. 36. 40				16		27. 16. 18. 38	10	28. 20. 10. 16	3. 35. 31	34. 27. 6. 40	10. 26. 24		17. 1. 40. 33	22	35. 10	1	1	2		25. 34. 6. 35	1	20. 10. 16. 38
17	36. 22. 6. 38	22. 35. 32	15. 19. 9	15. 19. 9	3. 35. 39. 18	35. 38	34. 39. 40. 18	35. 6. 4	2. 28. 36. 30	35. 10. 3. 21	35. 39. 19. 2	14. 22. 19. 32	1. 35. 32	10. 30. 22. 40	19. 13. 39	19. 18. 36. 40	32. 30. 21. 16		19. 15. 3. 17		2. 14. 17. 25	21. 17. 35. 38	21. 36. 29. 31		35. 28. 21. 18	3. 17. 30. 39	19. 35. 3. 10	32. 19. 24	24	22. 33. 35. 2	22. 35. 2. 24	26. 27	26. 27	4. 10. 16	2. 18. 27	2. 17. 16	3. 27. 35. 31	23. 2. 19. 16	15. 28. 35
18	19. 1. 32	2. 35. 32	19. 32. 16		19. 32. 26		2. 13. 10		10. 13. 19	26. 19. 6		32. 30	32. 3. 27	35. 19	2. 19. 6		32. 35. 19		32. 1. 19	32. 35. 1. 15	19. 16. 1. 6	13. 1	1. 6	19. 1. 26. 17	1. 19		11. 15. 32	3. 32	15. 19	35. 19. 32. 39	19. 35. 28. 26	28. 26. 19	15. 17. 13. 16	15. 1. 19	6. 32. 13	32. 15	2. 26. 2. 10	2. 25. 16
19	12. 18. 28. 31		12. 28		15. 19. 25		35. 13. 18		8. 15. 35	16. 26. 21. 2	23. 14. 25	12. 2. 29	19. 13. 17. 24	5. 19. 9. 35	28. 35. 6. 18		19. 24. 3. 14	2. 15. 19			6. 19. 37. 18	34. 23. 15. 24	35. 24. 18. 5		35. 38. 19. 18	34. 23. 16. 18	19. 21. 11. 27	3. 1. 32		1. 35. 6. 27	2. 35. 6	28. 26. 30	19. 35	1. 15. 17. 28	15. 17. 13. 16	2. 29. 27. 28	35. 38	32. 2	12. 28. 35
20		19. 9. 6. 27								36. 37			27. 4. 29. 18	35			19. 2. 35. 32						28. 27. 18. 31			3. 35. 31	10. 36. 23			10. 2. 22. 37	19. 22. 18. 1. 4					19. 35. 16. 25		1. 6
21	8. 36. 38. 31	19. 26. 17. 27	1. 10. 35. 37			17. 32. 13. 38	35. 6. 38	30. 6. 25	15. 35. 2. 36. 35	26. 2. 35	22. 10.	29. 14. 2. 40	35. 32. 15. 31	26. 10. 28	19. 35. 10. 38	16	2. 14. 17. 25	16. 6. 19	16. 6. 19. 37			10. 35. 38	28. 27. 18. 38	10. 19	35. 20. 10. 6	4. 34. 19	19. 24. 26. 31	32. 15. 2	32. 2	19. 22. 31. 2	2. 35. 18	26. 10. 34	26. 35. 10	35. 2. 10. 34	19. 17. 34	20. 19. 30. 34	19. 35. 16	28. 2. 17	28. 35. 34
22	15. 6. 19. 28	19. 6. 18. 9	7. 2. 6. 13	6. 38. 7	15. 26. 17. 30	17. 7. 30. 18	7. 18. 23	7	16. 35. 38	36. 38			14. 2. 39. 6	26			19. 38. 7	1. 13. 32. 15			3. 38		35. 27. 2. 37	19. 10	10. 18. 32. 7	7. 18. 25	11. 10. 35	32		21. 22. 35. 2	21. 35. 2. 22		35. 32. 1	2. 19		7. 23	35. 3. 15. 23	2	28. 10. 29. 35
23	35. 6. 23. 40	35. 6. 22. 32	14. 29. 10. 39	10. 28. 24	35. 2. 10. 31	10. 18. 39. 31	1. 29. 30. 36	3. 39. 18. 31	10. 13. 28. 38	14. 15. 18. 40	3. 36. 37. 10	29. 35. 3. 5	2. 14. 30. 40	35. 28. 31. 40	28. 27. 3. 18	27. 16. 18. 38	21. 36. 39. 31	1. 6. 13	35. 18. 24. 5	28. 27. 12. 31	28. 27. 18. 38	35. 27. 2. 31			15. 18. 35. 10	6. 3. 10. 24	10. 29. 39. 35	16. 34. 31. 28	35. 10. 24. 31	33. 22. 30. 10	10. 1. 34. 29	15. 34. 32. 24	32. 28. 2. 34	2. 35. 34. 27	15. 10. 2	35. 10. 28. 24	35. 18. 10. 13	35. 10. 18	28. 35. 10. 23
24	10. 24. 35	10. 35. 5	1. 26	26	30. 26	30. 16		2. 22	26. 32						10	10	19				10. 19	19. 10			24. 26. 28. 32	24. 28. 35	10. 28. 23			22. 10. 1	10. 21. 22	32	27. 22			35. 33	35	13. 23. 15
25	10. 20. 37. 35	10. 20. 26. 5	15. 2. 29	30. 24. 14. 5	26. 4. 5. 16	10. 35. 17. 4	2. 5. 34. 10	35. 16. 32. 18		10. 37. 36. 5	37. 36. 4	4. 10. 34. 17	35. 3. 22. 5	29. 3. 28. 18	20. 10. 28. 18	28. 20. 10. 16	35. 29. 21. 18	1. 19. 21. 17	35. 38. 19. 18	1	35. 20. 10. 6	10. 5. 18. 32	35. 18. 10. 39	24. 26. 28. 32		35. 38. 18. 16	10. 30. 4	24. 34. 28. 32	24. 26. 28. 18	35. 18. 34	35. 22. 18. 39	35. 28. 34. 4	4. 28. 10. 34	32. 1. 10		18. 28. 32. 10	24. 28. 35. 30	
26	35. 6. 18. 31	27. 26. 18. 35	29. 14. 35. 18		15. 14. 29	2. 18. 40. 4	15. 20. 29		35. 29. 34. 28	35. 14. 3	10. 36. 14. 3	35. 14	15. 2. 17. 40	14. 35. 34. 10	3. 35. 10. 40	3. 35. 31	3. 17. 39		34. 29. 16. 18	3. 35. 31	35	7. 18. 25	6. 3. 10. 24	24. 28. 35	38. 1831 6		18. 3. 28. 40	3. 2. 28	33. 30	35. 33. 29. 31	3. 35. 40. 39	29. 1. 35. 27	35. 29. 10. 25	2. 32. 10. 25	15. 3. 29	3. 13. 27. 10	3. 27. 29. 18	8. 35	13. 29. 3. 27
27	3. 8. 10. 40	3. 10. 8. 28	15. 9. 14. 4	15. 29. 28. 11	17. 10. 14. 16	32. 35. 40. 4	3. 10. 14. 24	2. 35. 24	21. 35. 11. 28	8. 28. 10. 3	10. 24. 35. 19	35. 1. 16. 11		11. 28	2. 35. 3. 25	34. 27. 6. 40	3. 35. 10	11. 32. 13	21. 11. 27. 19	36. 23	21. 11. 26. 31	10. 11. 35	10. 35. 29. 39	10. 28	10. 30. 4	21. 28. 40. 3		32. 3. 11. 23	11. 32	27. 35. 2. 40	35. 2. 40. 26		27. 17. 40	1. 11	13. 35. 8. 24	13. 35. 1	27. 40. 28	11. 13. 27	1. 35. 29. 38
28	32. 35. 26. 28	28. 35. 25. 26	28. 26. 5. 16	32. 28. 3. 16	26. 28. 32. 3	26. 28. 32. 3	32. 13. 6		28. 13. 32. 24	32. 2	6. 28. 32	6. 28. 32	32. 35. 13	28. 6. 32	28. 6. 32	20. 16. 24	6. 19. 28. 24	6. 1. 32	3. 6. 32		3. 6. 32	26. 32. 27	10. 16. 31. 28		24. 34. 28. 32	2. 6. 32	5. 11. 1. 23			28. 24. 22. 26	3. 33. 39. 10	6. 35. 25. 18	1. 13. 17. 34	1. 32. 13. 11	13. 35. 2	27. 35. 10. 34	26. 24. 32. 28	28. 2. 10. 34	10. 34. 28. 32
29	28. 32. 13. 18	28. 35. 27. 9	10. 28. 29. 37	2. 32. 10	28. 33. 29. 32	2. 29. 18. 36	32. 28. 2	25. 10. 35	10. 28. 32	28. 19. 34. 36	3. 35	30. 40	30. 18	3. 27	3. 27. 40		19. 26	3. 32	32. 2		32. 2	13. 32. 2	35. 11. 10. 24		32. 26. 28. 18	32. 30	11. 32. 1			26. 28. 10. 36	4. 17. 34. 26		1. 32. 35. 23	25. 10		26. 2. 18		26. 28. 10. 18. 18. 23	10. 18. 32. 39
30	22. 21. 27. 39	2. 22. 13. 24	17. 1. 39. 4	1. 18	22. 1. 33. 28	27. 2. 39. 35	22. 23. 37. 35	34. 39. 19. 27	21. 22. 35. 28	13. 35. 28. 39. 18	22. 2. 37	22. 1. 3. 35	35. 24. 30. 18	18. 35. 37. 1	22. 15. 33. 28	17. 1. 40. 33	22. 33. 35. 2	1. 19. 32. 13	1. 24. 6. 27	10. 2. 22. 37	19. 22. 31. 2	21. 22. 35. 2	33. 22. 19. 40	22. 10. 2	35. 18. 34	35. 33. 29. 31	27. 24. 2. 40	28. 33. 23. 26	26. 28. 10. 18		24. 35. 2	2. 25. 28. 39	35. 10. 2	35. 11. 22. 31	22. 19. 29. 40	22. 19. 29. 40	33. 22. 34	35. 13. 24
31	19. 22. 15. 39	35. 22. 1. 39	17. 15. 16. 22		17. 2. 18. 39	22. 1. 40	17. 2. 40	30. 18. 35. 4	35. 28. 3. 23	35. 28. 1. 40	2. 33. 27. 18	35. 1	35. 40. 27. 39	15. 35. 22. 2	15. 22. 33. 31	21. 39. 16. 22	22. 35. 2. 24	19. 24. 39. 32	2. 35. 6	19. 22. 18	2. 35. 22. 2	21. 35. 10. 1 34	10. 21. 29	1. 22	3. 24. 39. 1	24. 2. 40. 39	3. 33. 26	4. 17. 34. 26						19. 1. 31	2. 21. 27. 1	2	22. 35. 18. 39
32	28. 29. 15. 16	1. 27. 36. 13	1. 29. 13. 17	15. 17. 27	13. 1. 26. 12	16. 4	13. 29. 1. 40	35	35. 13. 8. 1	35. 12	35. 19. 1. 37	1. 28. 13. 27	11. 13. 1	1. 3. 10. 32	27. 1. 4	35. 16	27. 26. 18	28. 24. 27. 1	28. 26. 27. 1	1. 4	27. 1. 12. 24	19. 35	15. 34. 33	32. 24. 18. 16	35. 28. 34. 4	35. 23. 1. 24		1. 35. 12. 18		24. 2		2. 5. 13. 16	35. 1. 11. 9	2. 13. 15	27. 26. 1	6. 28. 11. 1	8. 28. 1	35. 1. 10. 28
33	25. 2. 13. 15	6. 13. 1. 25	1. 17. 13. 12		1. 17. 13. 16	18. 16. 15. 39	1. 16. 35. 15	4. 18. 31. 39	18. 13. 34	28. 13. 35	2. 32. 12	15. 34. 29. 28	32. 35. 30	32. 40. 3. 28	29. 3. 8. 25	1. 16. 25	26327. 13	13. 17. 1. 24	1. 13. 24		35. 34. 2. 10	2. 19. 13	28. 32. 2. 24	4. 10. 27. 22	4. 28. 10. 34	12. 35	17. 27. 8. 40	2. 34	35. 23	28. 39	2. 5. 12		12. 26. 1. 32	15. 34. 16. 12	32. 25. 17		1. 34. 12. 3	15. 1. 28
34	2. 27. 35. 11	2. 27. 35. 11	1. 28. 10. 25	3. 18. 31	15. 32. 13	16. 25	25. 2. 35. 11	1	34. 9	1. 11. 10	13	1. 13. 2. 4	2. 35	1. 11. 2. 9	11. 29. 28. 27	1	4. 10	15. 1. 28. 16	15. 1. 28. 16		15. 10. 32. 2	2. 35. 32. 19	2. 35. 34. 27	10. 25	2. 28. 10. 25	11. 10. 1. 16	1. 12. 26. 13	10. 2. 15	35. 102. 16	1. 35. 11. 10	1. 12. 26. 15	7. 1. 4. 16	35. 1. 13. 11		34. 35. 7. 13	1. 32. 10
35	1. 6. 15. 8	19. 15. 29. 16	35. 1. 29. 2	1. 35. 16	35. 30. 29. 7	15. 16	15. 35. 29		35. 10. 14	15. 17. 20	15. 37. 35. 16	1. 8	35. 30. 14	35. 3. 32. 6	13. 1. 35	2. 16	27. 2. 3. 35	6. 22. 26. 1	19. 35. 28. 13		19. 1. 29	18. 15. 1	15. 10. 2. 13		35. 28	3. 35. 15	35. 13. 8. 24	35. 5. 1. 10		35. 11. 32. 31		1. 13. 31	15. 34. 1. 16	1. 16. 7. 4		15. 29. 37. 28	1	27. 34. 35	35. 28. 6. 37
36	26. 30. 34. 36	2. 26. 35. 39	1. 19. 26. 24	26	14. 1. 13. 16	6. 36	34. 26. 6	1. 16	34. 10. 28	26. 16	19. 1. 35	29. 13. 28. 15	2. 22. 17. 19	2. 13. 28	10. 4. 28. 15		2. 17. 13	24. 17. 28. 13	27. 2. 29. 28		20. 19. 30. 34	10. 35. 13. 2	35. 10. 28. 29		6. 29	13. 3. 27. 10	13. 35. 1	2. 26. 10. 34	26. 24. 32	22. 19. 29. 40	19. 1	27. 26. 1. 13	27. 9. 26. 24	1. 13	29. 15. 28. 37		15. 10. 37. 28	15. 1. 24	12. 17. 28
37	27. 26. 28. 13	6. 13. 28. 1	16. 17. 26. 24	26	2. 13. 18. 17	2. 39. 30. 16	29. 1. 4. 16	2. 18. 26. 31	3. 4. 16. 35	36. 28. 40. 19	35. 36. 37. 32	27. 13. 1. 39	11. 22. 39. 30	27. 3. 15. 28	19. 29. 25. 39	25. 34. 6. 35	3. 27. 35. 16	2. 24. 26	35. 38	19. 35. 16	19. 1. 16. 10	35. 3. 15. 19	1. 18. 10. 24	35. 33. 27. 22	18. 28. 32. 9	3. 27. 29. 18	27. 40. 28. 8	26. 24. 32. 28		22. 19. 29. 28	2. 21	5. 28. 11. 29	2. 5	12. 26	1. 15	15. 10. 37. 28		34. 21	35. 18
38	28. 26. 18. 35	28. 26. 35. 10	14. 13. 28. 17	23	17. 14. 13		35. 13. 16		28. 10	2. 35	13. 35	15. 32. 1. 13	18. 1	25. 13	6. 9		19	8. 32. 19	2. 32. 13		28. 2. 27	23. 28	35. 10. 28. 10	18. 5	35. 33	24. 28. 35. 30	35. 13	11. 27. 32	28. 26. 10. 34	28. 26. 18. 23	2. 33	2	1. 26. 13	1. 12. 34. 3	1. 35. 13	27. 4. 1. 35	15. 24. 10	34. 27. 25		5. 12. 35. 26	
39	35. 26. 24. 37	28. 27. 15. 3	18. 4. 28. 38	30. 7. 14. 26	10. 26. 34. 31	10. 35. 17. 7	2. 6. 34. 10	35. 37. 10. 2		28. 15. 10. 36	10. 37. 14	14. 10. 34. 40	35. 3. 22. 39	29. 28. 10. 18	35. 10. 2. 18	20. 10. 16. 38	35. 21. 28. 10	26. 17. 19. 1	35. 10. 38. 19	1	35. 20. 10	28. 10. 29. 35	13. 15. 35. 23	23		35. 38	1. 35. 10. 38	1. 10. 34. 28	32. 1. 18. 10	22. 35. 13. 24	35. 22. 18. 39	35. 28. 2. 24	1. 28. 7. 19	1. 32. 10. 25	35. 18. 28. 37	5. 12. 27. 2	35. 26	

Improving Feature \ Worsening Feature		Weight of moving object	Weight of stationary object	Length of moving object	Length of stationary object	Area of moving object	Area of stationary object	Volume of moving object	Volume of stationary object
		1	2	3	4	5	6	7	8
1	Weight of moving object	+	-	15, 8, 29, 34	-	29, 17, 38, 34	-	29, 2, 40, 28	-
2	Weight of stationary object	-	+	-	10, 1, 29, 35	-	35, 30, 13, 2	-	5, 35, 14, 2
3	Length of moving object	8, 15, 29, 34	-	+	-	15, 17, 4	-	7, 17, 4, 35	-
4	Length of stationary object		35, 28, 40, 29	-	+	-	17, 7, 10, 40	-	35, 8, 2, 14
5	Area of moving object	2, 17, 29, 4	-	14, 15, 18, 4	-	+	-	7, 14, 17, 4	
6	Area of stationary object	-	30, 2, 14, 18	-	26, 7, 9, 39	-	+	-	

Contradictions Matrix – Another Example

- Possible contradictions 39 X 39

Feature to improve \ Deteriorated feature	1 Weight of moving object	2 Weight of stationary object	** **	14 Strength	** **	38 Level of automation	39 Productivity
1 Weight of moving object				28,27 18,40			
2 Weight of stationary object							
** **							
39 Level of automation							
39 Productivity							

Possible solutions:

28 Replacement of a mechanical pattern

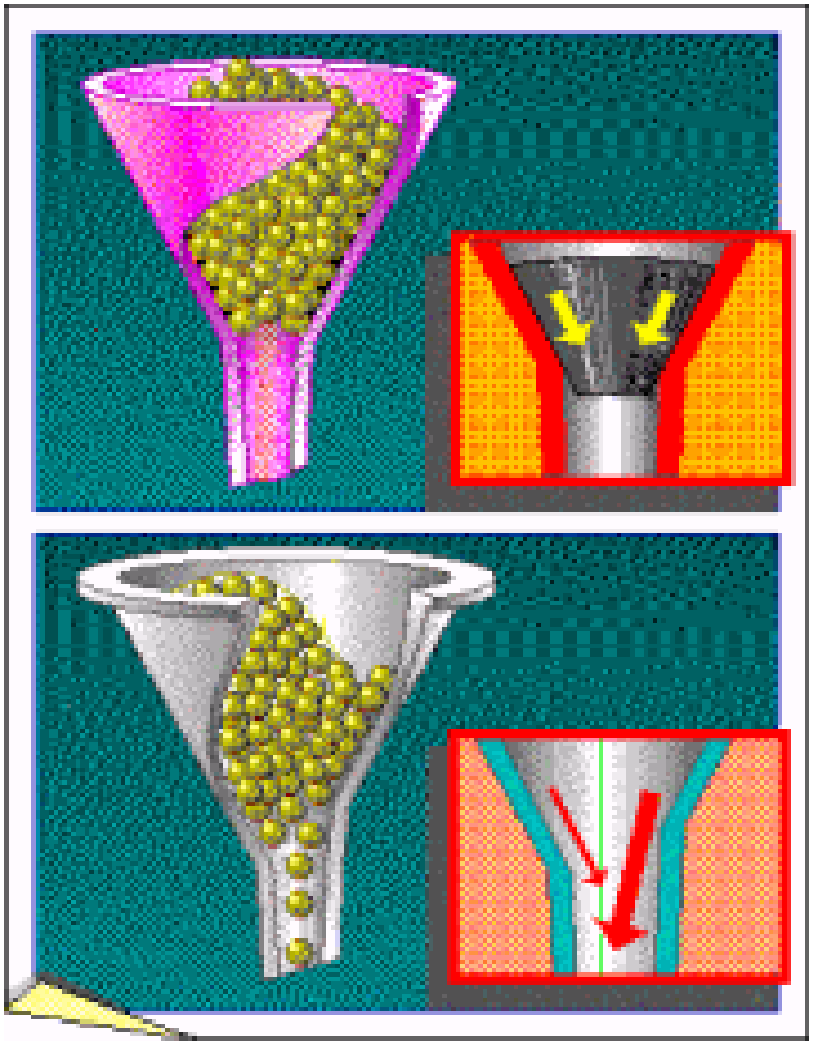
27 Cheap short life instead of expensive longevity

18 Use of mechanical vibrations

40 Composite Materials

Inventive Principle

Reducing jamming with asymmetry



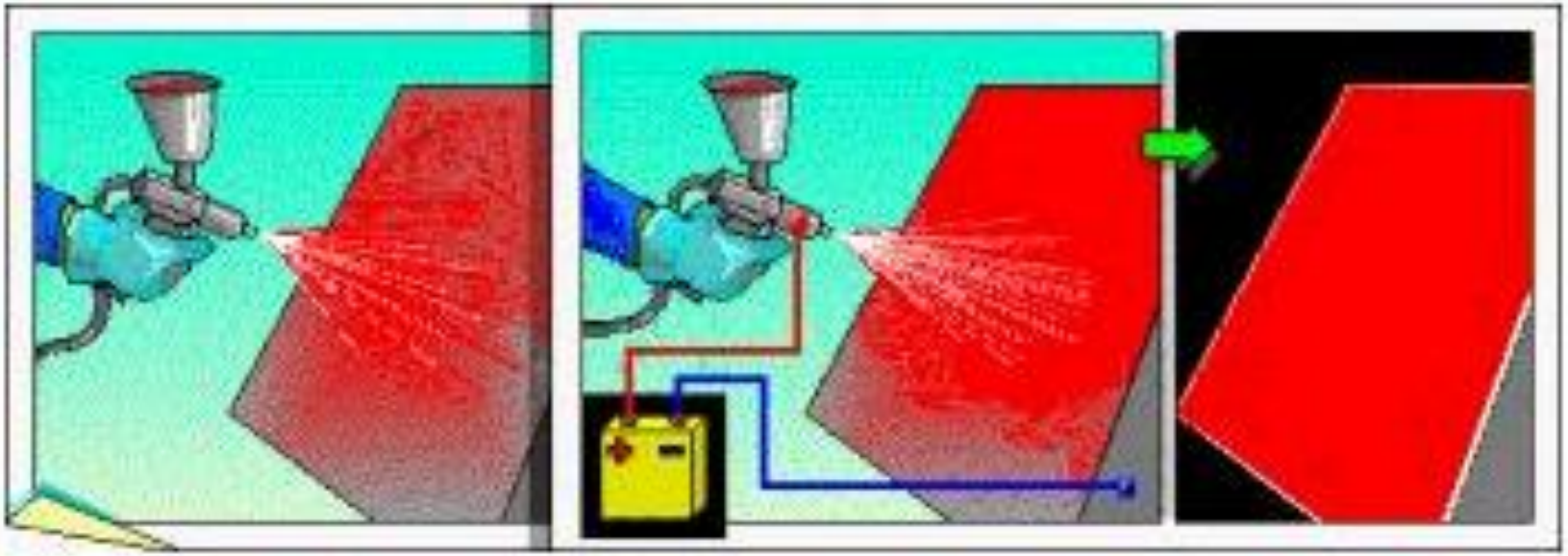
When an ordinary funnel is used, loose material tends to collect and block the outlet. This occurs because the funnel's cross-section is circular and material moves symmetrically about the funnel axis.

Obtain space resource using asymmetry. A funnel with an asymmetric cross-section (i.e., where the distance from the axis is 35-50 percent greater on one side) can be used.

The result: Loose material does not collect and jam the funnel, and the pouring rate is increased.

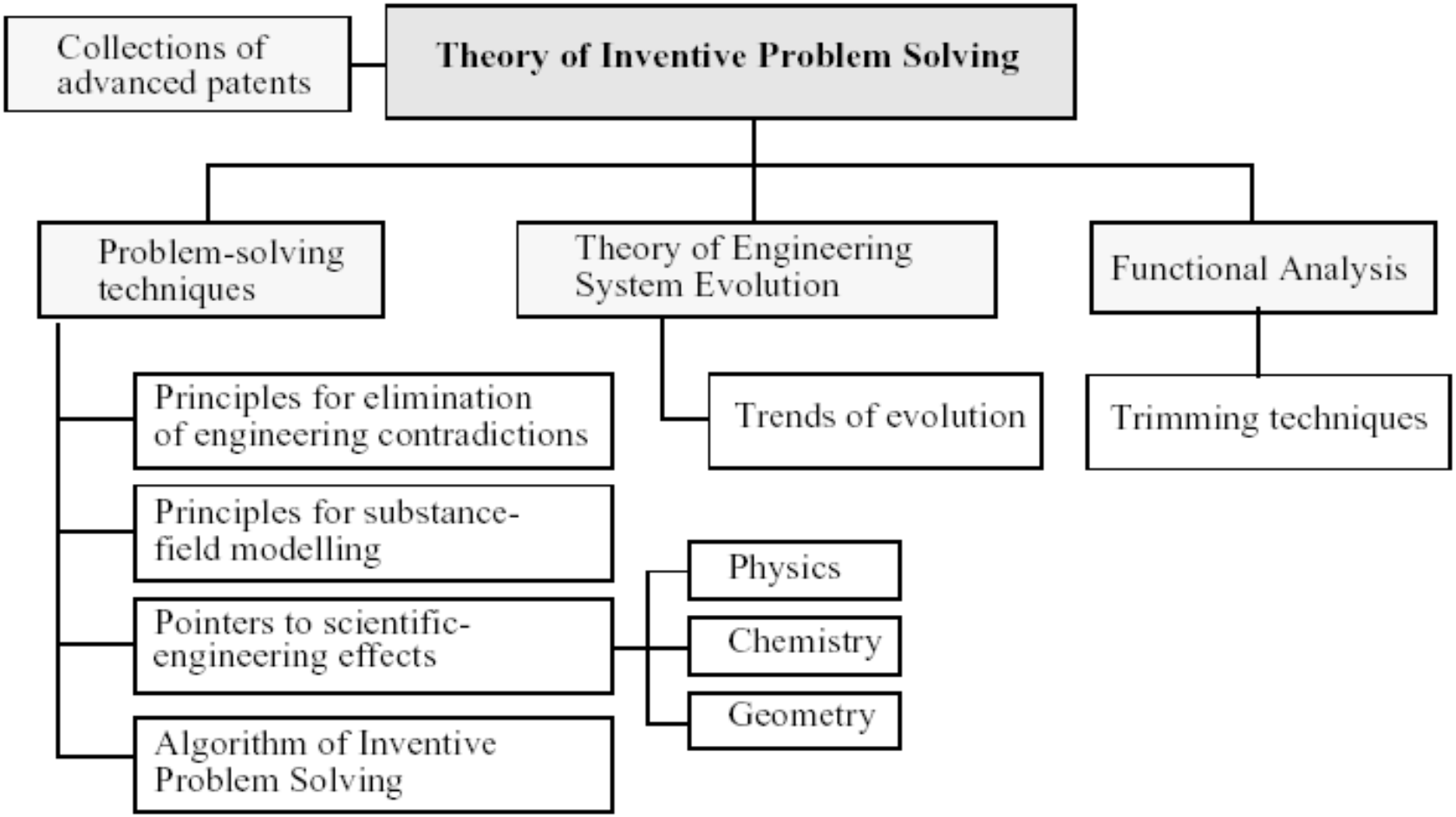
Inventive Principle Using physical principles

Economical painting of surfaces



Spray-painting results in a certain amount of waste which occurs when the paint misses the surface to be painted.

To prevent this waste, opposite electrical charges can be imparted to the paint and the surface to be painted, causing the latter to attract the paint drops.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