See also
1.3 OTSM Triz

5 Techniques to Resolve Contradictions / Resources / Effects

5.1 - Definition Contradictions

Definition

A contradiction literally means saying "No" but more generally refers to the proposition that assert apparently incompatible or opposite things.

Theory

TRIZ can be summarized as the result of a huge empirical study and can be presented as 3 main postulates – one of these postulates states the importance of "contradictions" in the field of problem solving and invention: These three postulates are:

- the existence of a set of Laws of evolution
- the concept of contradiction as the key barrier limiting system evolution until an invention appears
- the concept of the specific situation which determines the specific conditions and resources impacting the evolution of a technical system

The most effective inventive solution of a problem, according to TRIZ, is the one that overcomes some contradictions.

Instruments

A contradiction shows where (in the TRIZ so-called operative zone) and when (in the TRIZ so-called operative time) a conflict happens.

Contradictions occur when improving one parameter or characteristic of a technique negatively affects the same or other characteristics or parameters of the technique.

Examples

Presence of contradictions / dialectics can be shown in various fields:

- Mathematics: plus and minus, differential and integral
- Physics: mechanic action and reaction, positive and negative electrical charges
- Chemistry: combination and dissociation of atoms

5.1.1 – Types of Contradictions

Definition

Altshuller and his coworkers distinguished the following three types of contradictions:

- Administrative Contradiction - we speak about administrative contradiction when it is necessary to do something, but we do not know how to do it.
- Technical Contradiction - we speak about a technical contradiction when we improve one part (an evaluation parameter) of the technical system with the help of known methods, but that entails the worsening of other part (another evaluation parameter) of the technical system.
- Physical Contradiction - we speak about a physical contradiction when we impose mutually opposed requirements on the same control parameter of the system.

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Further definitions of these 3 types are given in the following paragraphs

Theory
According to Altshuller, an inventive situation typically hides a number of contradictions. Identifying the contradictions which prevent the achievement of the Most Desirable Result is the first step from an inventive situation to the beginning of problem solution.
Usually, a successful formulation of the physical contradiction shows the problems nucleus. When the contradiction is extremely intensified, often the problems solution will be straightforward.

Instruments
See Chapter 2 "Techniques to resolve Technical Contradiction" & Chapter 3 "Techniques to resolve a Physical Contradiction"

Examples
Administrative Contradiction:

- It is necessary to detect the number of small particles in a liquid with very high optical purity.
- The particles reflect light poorly even if we use a laser.
- What to do?

Technical Contradiction:
- If the particles are very small the liquid stays optically pure, BUT the particles are invisible.
- OR if the particles are very big they are detected, BUT the liquid is not optically pure.

Physical Contradiction:
- The particle size must increase to be viewed AND-NOT increase to keep the optical purity of the liquid.

5.1.1.1 – Administrative Contradiction
Definition

The Administrative Contradiction states that there is a problem with an unknown solution.

Model
Something is required to make or receive some result, to avoid the undesirable phenomenon, but it is not known how to achieve the result.

Example

We want to increase quality of production and decrease the cost of raw materials.
Such a form of a problem recalls an inventive situation.
The administrative contradiction itself is provisional, has no heuristic value, and does not show a direction to the answer.

Notes
Most TRIZ practitioners completely ignore the Administrative Contradiction due to its lack of tangible meaning.

5.1.1.2 – Technical Contradiction

Definition

A technical contradiction occurs when two different Evaluation Parameters are in conflict with each other.
An Evaluation Parameter represent the desired domain for solutions.
The Evaluation Parameters and their required values define the objective of resolutions.
That means that these parameters represent what the customer or problem owner wants from the solution. That can be a better performance, an increased use of resources, a decreased amount of harmful effects, etc … (see OTSM model of a contradiction)

Theory

The technical contradiction represents a conflict between "two subsystems" or between a subsystem and the external environment.
Such technical contradictions occur if:

- Creating or intensifying the useful function in one subsystem creates a new harmful or intensifies an existing harmful function in another subsystem (or in the environment)
- Eliminating or reducing the harmful function in one subsystem deteriorates the useful function in another subsystem
- Intensifying the useful function or reducing the harmful function in one subsystem causes the unacceptable complication of other subsystems or the whole technique. Or even „just“ a not acceptable consumption of resources.

Model

There are different models for defining a technical contradiction:

- The OTSM model of a contradiction (described subsequently – Section Physical Contradiction)
- An action is simultaneously useful and harmful
- An action causes useful and harmful functions
- The introduction of the useful action or the recession of the harmful effect leads to deterioration of some subsystems or the whole system

Instruments

See Chapter 2 "Techniques to resolve Technical Contradiction"

Example

As a container becomes stronger it becomes heavier.
We want high strength and low weight.
We want to increase the penetration depth of ions into a semiconductor and decrease the electrical power (energy source) that is necessary for the ion implanter operation.

5.1.1.3 – Physical Contradiction

Definition

A physical contradiction defines a situation where there are conflicting values of one "Control Parameter".
Control Parameters impact a system and so represent the possible domain of variables. Control Parameters and their values define means to act on the problem.
That means that these parameters represent what we are able to change within the system.

Theory
Such physical contradictions occur if:

- Intensifying the useful function in a subsystem simultaneously intensifies the existing harmful function in the same key subsystem
- Reducing the harmful function in a subsystem simultaneously reduces the useful function in the same key subsystem
- it could be also useful against another useful function, harmful against harmful etc

See also "The OTSM Model of a contradiction"

Model

- See "The OTSM Model of a contradiction" (described subsequently)
- A given subsystem (element) should have property A to execute a necessary function and property non-A or anti-A to satisfy the condition of a problem.

A physical contradiction implies inconsistent requirements to a physical condition of the same subsystem (element) of the technical system.

Instruments
See Chapter 3 "Techniques to resolve a Physical Contradiction"

Example
We want high weight and low weight.
We want the insulator in semiconductor chips to have low dielectric constant k in order to reduce parasitic capacities – and we want that insulator also to have high dielectric constant k in order to store information better.

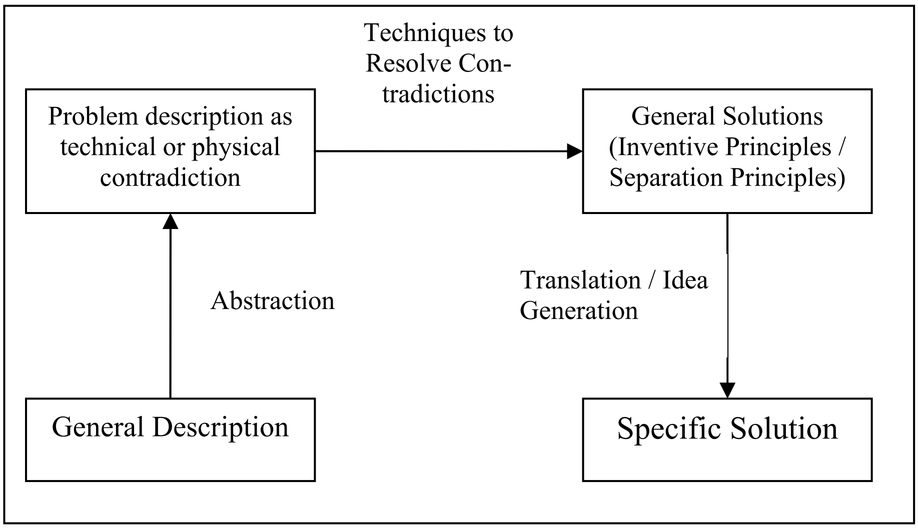
5.1.1.4 – TRIZ & Technical & Physical Contradictions

Definition

TRIZ states that inventive solutions eliminate contradictions rather than looking for tradeoffs , and that there is a defined set of inventive principles to help eliminate such contradictions.
The research of Altshuller discovered that not only it is possible to resolve contradictions, but there are a finite number of ways to resolve them.
Engineering solutions are mostly found by searching 'randomly' for the answer (trial-and-error problem solving) or drawing on personal knowledge and analogies. TRIZ offers a systematic process based on the concept of abstraction in which a problem-solver maps a specific problem to a generic framework out of which comes a generic solution requiring translation back to the specific.
Identifying, understanding and resolving contradictions within a system is a powerful way to improve that system. The way how to identify **and resolve technical and physical contradictions** and within a system will be described subsequently.

Theory & Model
The "Hill"-Model illustrates very well the overall steps of the application process:

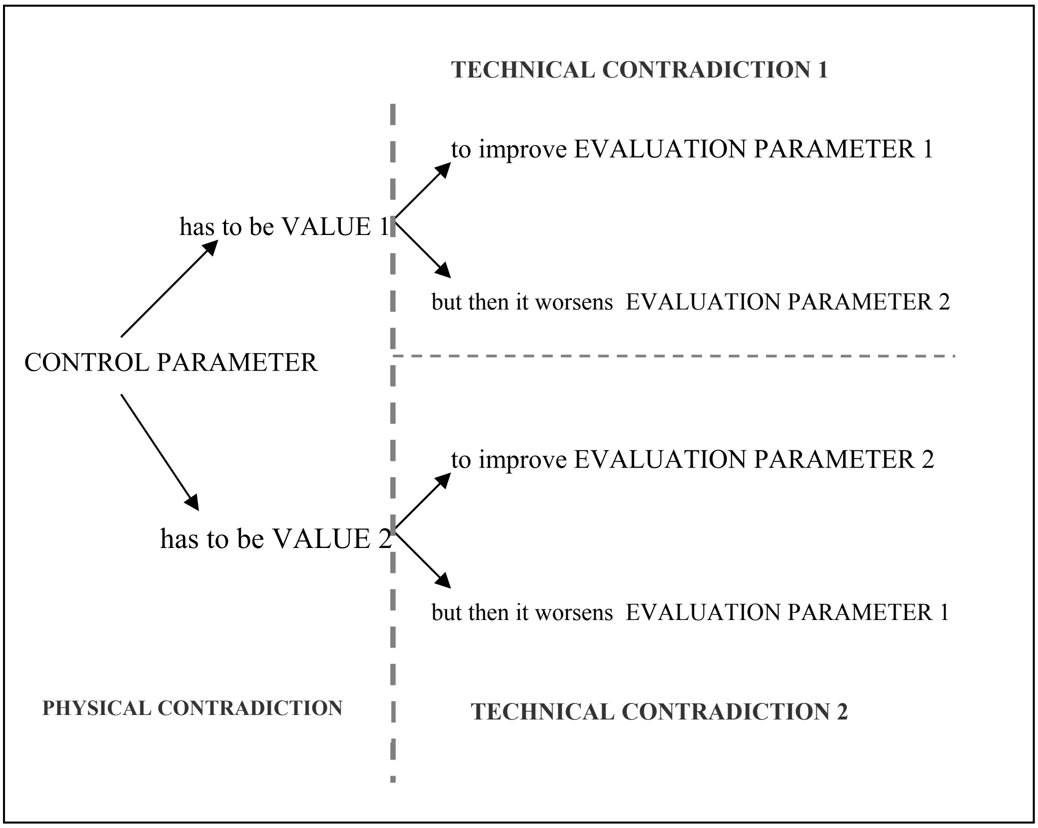
- General description of the problem
- Abstraction the problem – problem definition as a technical or physical contradiction
- Application of the TRIZ techniques to resolve (technical or physical) contradictions - general solutions
- Idea generation for specific solutions of the specific problem



Instruments
See Chapter 2 & 3

5.1.2 The OTSM model of a contradiction:

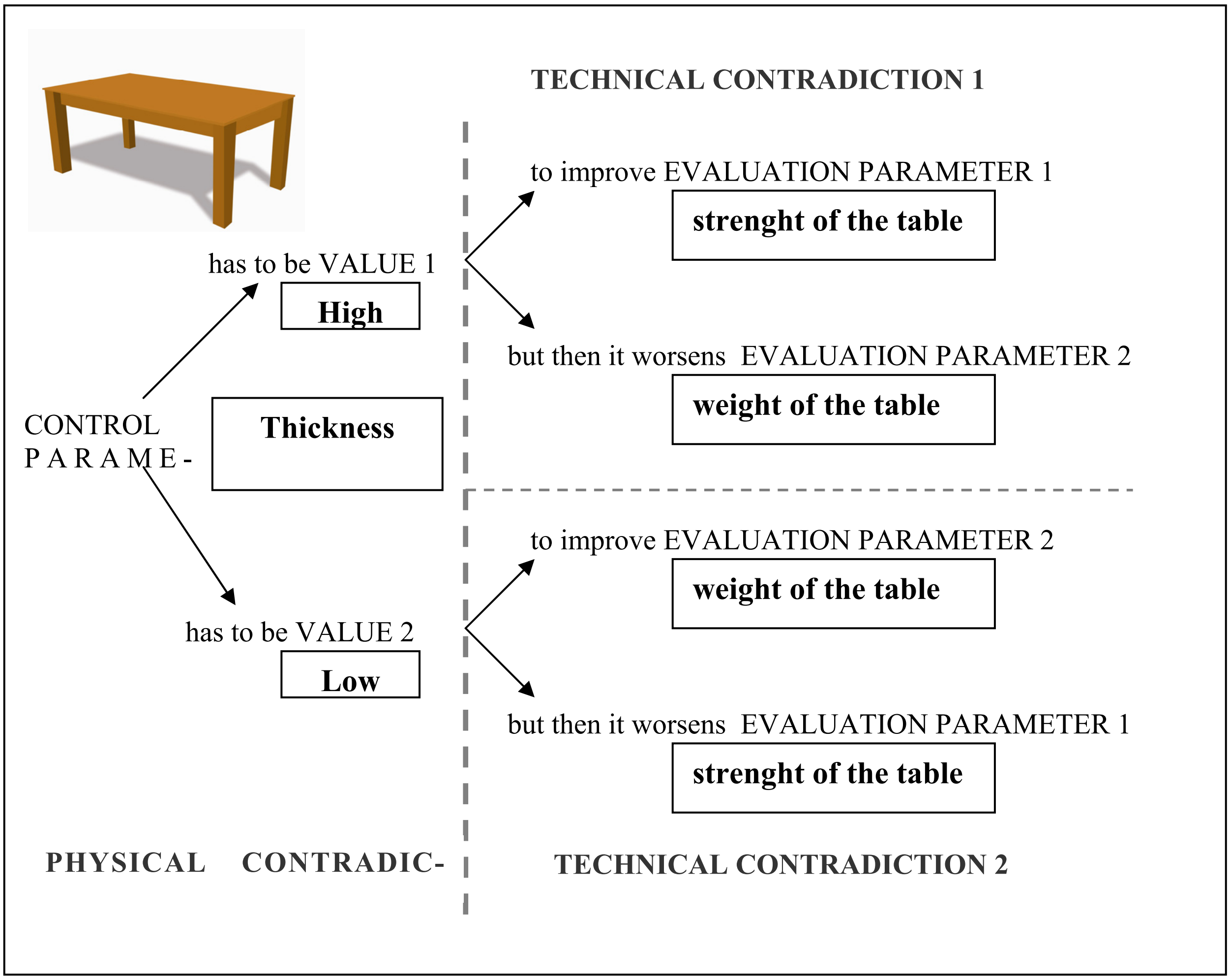
This system of contradictions is based on the existence of a physical contradiction and two technical contradictions. These technical contradictions justify the need of the two different states of the physical contradiction.
The two technical contradictions are complementary as they correspond to the increasing of the first evaluation parameter that implies the decreasing of the second evaluation parameter. And of the increasing of the second that implies the decreasing of the first.
The two evaluation parameters of the technical contradictions are defined as taking part in describing the objective, whereas the control parameter of the physical contradiction is a mean to make the situation change.



The graphical representation of the OTSM model of contradiction makes it much more clear. We have to define / find one Control Parameter and two Evaluation Parameters of the system. The graphic representation is an easy to use template where on the "right part" we have the two Technical Contradictions, and on the "left part" there is the Physical Contradiction.

Model:
A certain Control Parameter should have a Value1 in order to improve a certain Evaluation Parameter1, but this worsens a certain Evaluation Parameter2, and the Control Parameter should have a Value2 in order to improve a certain Evaluation Parameter2, but this worsens a certain Evaluation Parameter1;
It is clear that V1 and V2 can assume also extremely opposite values like “present”/”absent”, or “true”/”false”, …..

<u>Example for Contradictions - OTSM Model</u>



Technical Contradiction 1: We want to improve the strength of a table but normally than the weight of the table worsens,
Technical Contradiction 2: If we improve the weight (make it lighter) the will worsens,

So we can define two Evaluation Paameters:
EP1: strength of the table
EP2: weight of the table

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The next step is to look for a Control Parameter: Thickness of the table
Value of thickness can be "big" or "small"
If the thickness is big then the strength will be high (good) but the weight will also be high (bad).
If the thickness is small then the weight will be little (good) but the strength will also be low (bad).

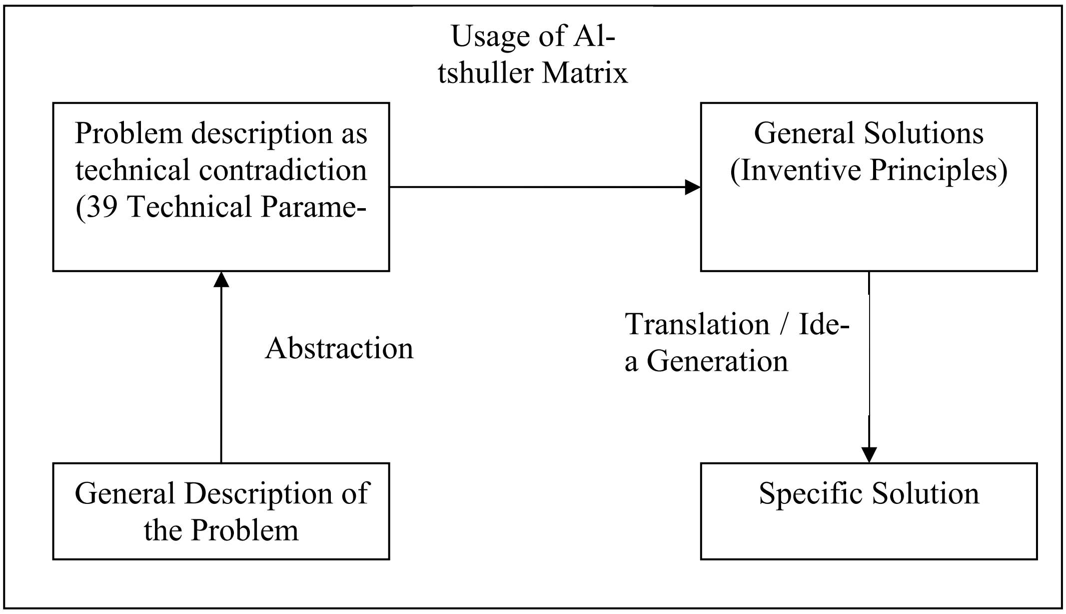
So we are looking for solutions to get a "big" AND "small" thickness!

5.2 – Techniques to resolve Technical Contradictions

Definition

A technical Contradiction is a conflict between characteristics within a system when improving one parameter of the system causes the deterioration of other parameter.
Altshuller identified 40 Principles that could be used to eliminate technical contradictions. He also identified 39 characteristics of Technical Systems – so called Technical Parameters - that can be used to develop and describe a technical contradiction.
How to structure the problem as a contradiction is an essential step of the analysis of the problem. The formulation of the technical contradiction helps to understand the root of the problem better and to find out the right solutions faster. TRIZ states that if there is no (technical) contradiction then it is not an inventive problem. (see 2.2.3.1 Description of the Problem)

Model



Example:
Increasing the power of the motor (a desired effect) may cause the weight of the motor to increase (a negative effect).

5.2.1 – The 40 Inventive Principles

Definition

The Inventive Principles are a very simple tool within TRIZ to look for ideas and resolve technical contradictions.
The application of the 40 Inventive principles does not require any special knowledge and children as well as professionals may use them.
The Altshuller Matrix was designed to formalize and to facilitate the usage of this TRIZ tool in practical activity. So the usage of the Inventive principles in combination with the Altshuller Matrix (contradiction table) requires some practical skills.

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Theory
Genrich S. Altshuller offered an approach to the development of inventive principles in the late 50's. He selected the most often occurring strong principles based on the analysis of a large number of the patents. Each of these principles efficiently "worked" at least in 80-100 inventions. As a result, 40 most often used inventor's Principles were published.

Model
The 40 Inventive Principles:
1. Segmentation
2. Extraction (Extracting, Retrieving, Removing, Taking out)
3. Local Quality
4. Asymmetry
5. Consolidation (Merging)
6. Universality
7. Nesting (Matrioshka, "Nested doll")
8. Counterweight (Anti-weight)
9. Prior Counteraction (Preliminary anti-action)
10. Prior Action (Preliminary action)
11. Cushion in Advance (Beforehand cushioning)
12. Equipotentiality
13. Do it in Reverse ("The other way round")
14. Spheroidality (Curvature)
15. Dynamics
16. Partial or Excessive Action
17. Transition into a New Dimension (Another Dimension)
18. Mechanical Vibration
19. Periodic Action
20. Continuity of Useful Action
21. Rushing Through (Skipping)
22. Convert Harm into Benefit ("Blessing in disguise" or "Turn Lemons into Lemonade")
23. Feedback
24. Mediator („Intermediary")
25. Self-service
26. Copying
27. Dispose (Cheap Short-living Objects)
28. Replacement of Mechanical System (Mechanics Substitution)
29. Pneumatic or Hydraulic Constructions (Pneumatics and Hydraulics)
30. Flexible Membranes or Thin Films (Flexible Shells and Thin Films)
31. Porous Material
32. Changing the Color (Color Changes)
33. Homogeneity
34. Rejecting and Regenerating Parts (Discarding and Recovering)
35. Transformation of Properties (Parameter Changes)
36. Phase Transition
37. Thermal Expansion
38. Accelerated Oxidation (Strong Oxidants)
39. Inert Environment (Inert Atmosphere)
40. Composite Materials

Instruments

For each of the 40 Inventive Principles a detailed description was provided by Altshuller and his colleagues. (see Annex).

The model of each Principle is constituted by:

1. a title
2. a number of guidelines
3. (possibly) a number of examples

Inventive Principle 01 - Segmentation

A. Divide an object into independent parts.
B. Make an object easy to disassemble.
C. Increase the degree of fragmentation or segmentation.

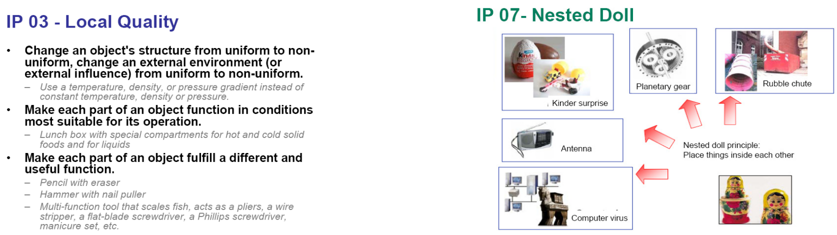
Several exemplified descriptions have been published afterwards. During the last years also exemplified descriptions for an application of the Inventive Principles in a lot of different fields (architecture, biology, chemistry, construction, busineness & management / finance, ..) are available.

Example

Principle 1. Segmentation

A. Divide an object into independent parts.

- *Replace mainframe computer by personal computers.*
- *Replace a large truck by a truck and trailer.*
- *Use a work breakdown structure for a large project.*
- Make an object easy to disassemble.
- *Modular furniture*
- *Quick disconnect joints in plumbing*
- Increase the degree of fragmentation or segmentation.
- *Replace solid shades with Venetian blinds.*
  1. *Use powdered welding metal instead of foil or rod to get better penetration of the joint.*Rejecting and Regenerating Parts (Discarding and Recovering) = Scarto e rigen-erazione delle parti (scartare e ricuperare)
  2. Transformation of Properties (Parameter Changes) = Trasformazione di proprietà
  3. Phase Transition = Transizione di fase
  4. Thermal Expansion = Espansione termica
  5. Accelerated Oxidation (Strong Oxidants) = Ossidazione accelerate (elevata ossidazio-ne)
  6. Inert Environment (Inert Atmosphere) = Ambiente inerte (atmosfera inerte)
  7. Composite Materials = Materiali composite



Examples for TRIZ – Playing Cards: (Text and Illustrations)

The Usage of the Inventive Principles

In general there are two methods to apply the 40 Inventive Principles during the problem solving process:

- The simplest method is what we can call familiarization of the principles. Here we are trying to apply each of the principles or their combinations to solving the technical contradiction in the specific problem.
(Note: this is just a suggestion for getting acquaintance with the inventive principles, because it doesn't fit with the main purpose of Altshullers work , i.e. avoiding trial and errors)
- The second way is the formulation of a technical contradiction and utilization of Altshuller's Matrix in order to get a set of recommended principles for solving your problem. (see 2.2.)

Another suggestion is to browse the Inventive principles more strictly related to separation in space strategies, because they enlarge the view on possible resources to adopt (moreover they start reducing the generalization level from the ideal solution to the technical solution)

Familarization / Brainstorming with the Principles
Instrument

The simplest method is what we can call familiarization of the principles. Here we are trying to find applications of each of the principles or their combinations to see where they are used in products and processes.
The more ones become familiar with these principles, the more ones will see them in action everywhere around us and can apply them in a problem solution process.
The second step is that we are using principles and/or their combinations as catchwords for successive brainstorming sessions. A good and helpful suggestion for a previous step is the definition of the so called "operational space" and "operational time", that means where and when exactly is the problem.

The Contradiction or Altshuller Matrix
(see 2.2 The Altshuller Matrix)
Definition

The contradiction matrix was one of the first outcomes of the work of Altshuller and his colleagues.
Altshuller abstracted and classified inventive solutions (inventive principles) and also identified 39 technical parameters that can describe all the different contradictions solved. (see 2.2.2. the 39 technical parameters)
These technical parameters were laid out in a 39x39 matrix where the x-axis is the parameter that worsens in the contradiction, whilst the parameter described on the y-axis is the one that improves.

Model

↓ Useful Parameter / Feature to improve / Characteristics to be improved
→ Harmful Parameter / Undesired Result / Characteristic that is getting worse

	harmful parameter → / useful parameter ↓	1 weight of mobile object	2 weight of stationary object	3 length of mobile object	4 length of stationary object	5 area of mobile object	6 area of stationary object	7 volume of mobile object	8 volume of stationary object	9 velocity	10 force	11 tension/ pressure	12 shape	13 stability of composition	14 strength	15 durabilty of mobile object	16 durability of stationary object	17 temperature	18 lumination
1	weight of mobile 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	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35	-	6, 29, 4, 38	19, 1, 32
2	weight of stationary 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	26, 39, 1, 40	28, 2, 10, 27	-	2, 27, 19, 6	28, 19, 32, 22	19, 32, 35
3	length of mobile 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	1, 8, 15, 34	8, 35, 29, 34	19	-	10, 15, 19	32
4	length of stationary object		35, 28, 40, 29	-	+	-	17, 7, 10, 40	-	35, 8, 2,14	-	28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26	-	1, 10, 35	3, 35, 38, 18	3, 25
5	area of mobile object	2, 17, 29, 4	-	14, 15, 18, 4	-	+	-	7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3	-	2, 15, 16	15, 32, 19, 13
6	area of stationary object	-	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	
7	volume of mobile object	2, 26, 29, 40	-	1, 7, 4, 35	-	1, 7, 4, 17	-	+	-	29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4	-	34, 39, 10, 18	2, 13, 10
8	volume of stationary object	-	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	
9	velocity	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

Extract of the Altshuller Matrix

Example
Usage of the Altshuller Matrix: see 2.2.

Other Selection Approaches of the Inventive Principles
Some other selection approaches of the Inventive Principles appeared during the last years:
Selection regarding the frequency of occurrence on the Altshuller Matrix
Selection regarding the approach from S. Fayer

Selection regarding the frequency of occurrence on the Altshuller Matrix
Inventive Principles listed according to their frequency of occurrence (FoO) on the Altshuller Matrix (starting with the most often listed principle)

Inventive Principles FoO 1- 10	**Inventive Principles FoO 11-20**	**Inventive Principles FoO 21-30**	**Inventive Principles FoO 31-40**
35	*26*	*14*	*38*
10	*03*	*22*	*08*
01	*27*	*39*	*05*
28	*29*	*04*	*07*
02	*34*	*30*	*21*
15	*16*	*37*	*23*
19	*40*	*36*	*12*
18	*24*	*25*	*33*
32	*17*	*11*	*09*
13	*06*	*31*	*20*

Selection regarding the approach from Mr. S. Fayer

S. Fayer recommends 4 groups of problems, where the inventive principles can be related to:

Group 1: Changing something about substances (quantity, quality, structure, shape) Inventive Principles: 1, 2, 3, 4, 7, 14, 17, 30, 31, 40

Group 2: How to deal with harmful factors Inventive Principles: 9, 10, 11, 12, 13, 19, 21, 23, 24, 26, 33, 39

Group 3: How to increase effectiveness and ideality Inventive Principles: 5, 6, 15, 16, 20, 25, 26, 34

Group 4: Using scientific effects, special fields and substances Inventive Principles: 8, 18, 28, 29, 32, 35, 36, 37, 38, 30, 31, 40

5.2.2. – The Altshuller Matrix / Contradiction Matrix

5.2.2.1. – The Design of the Altshuller Matrix

Definition

The Contradiction Matrix or Altshuller Matrix, developed by G. S. Altshuller, suggests Inventive Principles to solve contradictions arising while trying to improve a feature or a characteristic of any product, process or system. The contradiction matrix was one of the first outcomes of the work of Altshuller and his colleagues. Though this is one of the oldest components of TRIZ, it is still useful in preliminary problem solving.

Altshuller abstracted and classified inventive solutions (inventive principles) and also created 39 technical parameters that can describe all the different contradictions solved. (see 2.2.2. the 39 technical parameters)

These technical parameters were laid out in a 39x39 matrix where the x-axis is the parameter that worsens in the contradiction, whilst the parameter described on the y-axis is the one that improves.

The Altshuller Matrix (contradiction table) was designed to formalize and to facilitate the usage of this TRIZ tool in practical activity. The Matrix presents you with 39 system characteristics or "technical parameters", which represent the cionflicting Evaluation Parameters (OTSM).

The pairs of contradictory characteristics form a Matrix. The first item in the pair is located in the left column of Matrix and called Useful Parameter (or Feature to improve, Improving Feature, ..) . The other item of the pair is placed in the top row of the Matrix and called the Harmful Pasrameter (or Worsening Feature, Undesired Result, ..) . Not every contradictory pair of features has a set of principles associated with them.

Model

↓ Useful Parameter / Feature to improve / Characteristics to be improved
→ Harmful Parameter / Undesired Result / Characteristic that is getting worse

	harmful parameter → / useful parameter ↓	1 weight of mobile object	2 weight of stationary object	3 length of mobile object	4 length of stationary object	5 area of mobile object	6 area of stationary object	7 volume of mobile object	8 volume of stationary object	9 velocity	10 force	11 tension/ pressure	12 shape	13 stability of composition	14 strength	15 durabilty of mobile object	16 durability of stationary object	17 temperature	18 lumination
1	weight of mobile 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	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35	-	6, 29, 4, 38	19, 1, 32
2	weight of stationary 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	26, 39, 1, 40	28, 2, 10, 27	-	2, 27, 19, 6	28, 19, 32, 22	19, 32, 35
3	length of mobile 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	1, 8, 15, 34	8, 35, 29, 34	19	-	10, 15, 19	32
4	length of stationary object		35, 28, 40, 29	-	+	-	17, 7, 10, 40	-	35, 8, 2,14	-	28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26	-	1, 10, 35	3, 35, 38, 18	3, 25
5	area of mobile object	2, 17, 29, 4	-	14, 15, 18, 4	-	+	-	7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3	-	2, 15, 16	15, 32, 19, 13
6	area of stationary object	-	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	
7	volume of mobile object	2, 26, 29, 40	-	1, 7, 4, 35	-	1, 7, 4, 17	-	+	-	29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4	-	34, 39, 10, 18	2, 13, 10
8	volume of stationary object	-	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	
9	velocity	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

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5.2.2.2. – The 39 Technical Parameters

Definition

In order to find a descriptive and clearly arranged tool for the application of the Inventive Principles Altshuller also has to define and abstract characterictics of technical systems. In TRIZ these abstracted characteristics are called 39 Technical Parameters or 39 Characteristics (sometimes also Features).
For each of the 39 technical parameters a more detailed description was provided by Altshuller (Annex).
One of the questions behind was to find out if there are several Inventive Principles that have been used more often than others solving specific inventive problems.

Instruments

The 39 Technical Parameters

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

Examples

TP 01 - Weight of moving object
The measurable force, resulting from gravity, that a moving body exerts on the surface which prevents it from falling.
A moving object is one which changes position on its own or as a result of some external force.

TP 02 - Weight of non-moving object
The measurable force, resulting from gravity, that a stationary object exerts on the surface on which it rests.
A stationary is one which cannot change position on its own or as a result of some external force

TP 17 -Temperature
The loss or addition of heat to an object or system during required functions, which may cause potentially undesirable changes to objects, system or productions.

TP 18-Brightness
The ratio of light energy to heat the area which is being lit by or in a system. Brightness includes the quality of light, degree of illumination, and other characteristics of light.

5.2.2.3. – Usage of the Altshuller Matrix

Theory

The usage of the Matrix requires a proper analysis of the problem, because a (technical) contradiction - there could be some more than one - has to be defined within the system.
The main steps using the Altshuller Matrix are:

- Description of the Problem
- Defining the Technical Contradiction
  (Ways of Modelling the Problem - Finding technical contradictions)
- Translation into Technical Parameter (improving & worsening features)
- Identifying Inventive Principles from the Altshuller-Matrix
- Idea Generation with the Inventive Principles

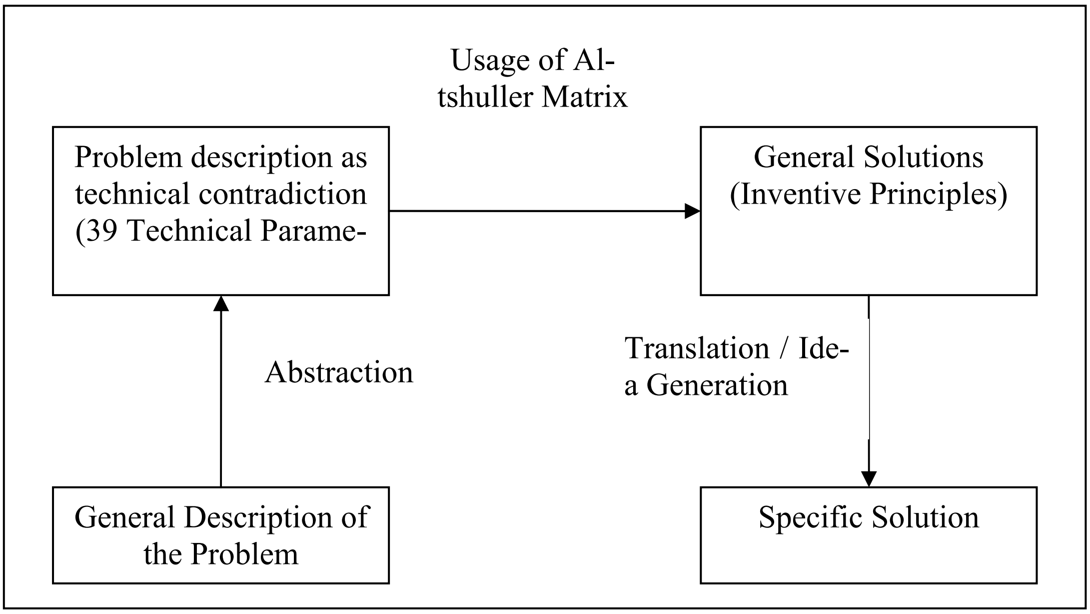
The first step here is to summarise the problem to be solved and the problem context.
During this stage it may be helpful to note your problem and keep asking yourself what is stopping you from solving it. Either you will come up against a constraint to be evaluated or you will discover a contradiction that needs to be solved.
Then translate your problem analysis into separate contradiction statements. The desired state can't be reached because something else in the system prevents it. In other words, when something gets better, something else gets worse.

For example:
The bandwidth increases (good) but requires more power (bad).
The service is customized to each customer (good) but the service delivery system gets complicated (bad)

The next step is to translate the statement into a technical contradiction by matching the features to the particular Technical Parameters.
Note: This step may not be that easy initially, it is important to become familiar with the parameters, this means studying the parameters and beginning to collect your own examples of them.

Then look up your improving features to the worsening features on the Altshuller Matrix. Identify the numbers for the Inventive Principles that may help solve this technical contradiction. The numbers are contained in the cell at the intersection of that row and column
Look up the principles and use each principle to generate and record some solution ideas. The description of each Principle and additional hints will gives you a clue to a possible solution.

Model



Example
Usage of the Altshuller Matrix: see 2.2

Usage Matrix: Description of the Problem
Theory
Professional problem solvers say that a well defined problem is half solved.
There should be a good understanding of the system around the problem. Accordingly, different aspects related to the problem should be systematically documented.
For a detailed description of the problem and the problem surroundings TRIZ offers the so called "Innovation-Situation-Questionnaire®" (ISQ) or innovation checklist. The ISQ was developed by the Kishinev School of TRIZ in Moldova. (owned by Ideation International Inc.)
The ISQ is not an imperatively necessary when working with the Altshuller Matrix. However it assists by the findings and definition of important contradictions in the system.

Important Note:
ARIZ includes and defines a step-by-step process to work out technical contradictions and translate them into a physical contradiction (see Chapter ARIZ)

Instruments
"Innovation-Situation-Questionnaire®" – Structure:

Information about the system you would like to improve / create and its environment
- Systems name
- System´s primary useful function
- Current or desired system structure

Functioning of the system
System environment
Available resources (see Substance-Field-Resources)
Information about the problem situation
desired improvement to the system or a drawback you would like to eliminate
Mechanism which causes the drawback to occur, if it is clear
Other problems to be solved
Changing the system
Allowable changes to the system
Limitations to changing the system
Criteria for selecting solution concepts
Desired technological characteristics
Desired economic characteristics
Desired timetable
Expected degree of novelty
other criteria
History of attempted solutions to the problem
Previous attempts to solve the problem
Other system(s) in which a similar problem exists

Examples for ISQ: In "Systematic Innovation – an Introduction to TRIZ", John Terninko, Allo Zusman, Boris Zlotin, (also available on books.google.com)

Usage Matrix: Defining the Technical Contradiction (Ways of Modelling the Problem - Finding technical contradictions)

There are several ways and models described in TRIZ how to find out contradictions in the system.
Defining "What gets better – what gets worse"
OTSM Model of Contradictions (see Chapter 1.1.4)
ARIZ (see chapter ARIZ)

Theory & Instruments

Defining "What gets better – what gets worse" or "if-then-but"

The simplest way to look for contradicting parameters in a system is – after a one-sentence - summary of the problem - to answer the following two questions:

Summarise the problem to be solved and the problem context

What gets better (what is "good")	What gets worse (What is "bad")
this aspect of the system gets better….	at the expense of this aspect…
	‘

OTSM Model of Contradictions

See Chapter 1.1.4

Example

Ex 1: "Increase the durability of a product"

Defining "What gets better – what gets worse" or "if-then-but"

Summarise the problem to be solved and the problem context
Most design strategies for durability involve over-specifying the material type or its quantity. The most common durability solution is to add material to make something stronger.

What gets better (what is "good")	What gets worse (What is "bad")
this aspect of the system gets better….	at the expense of this aspect…
A product gets stronger…	*…but its weight increases*

Result:
If I want to get the product "stronger" the "weight" would get worse. (technical contradiction)

Translation into Technical Parameter
Model
The next step is to translate the general contradiction statement into a technical contradiction using the defined 39 Technical Parameters.
This step may not be that easy initially, it is important to become familiar with the parameters, this means studying the parameters and beginning to collect your own examples of them.
(see Annex)

Instruments
List of 39 Technical Parameters (with explanations)

Example
Ex 1: "Increase the durability of a product"

Summarise the problem to be solved and the problem context
Most design strategies for durability involve over-specifying the material type or its quantity. The most common durability solution is to add material to make something stronger.

What gets better (what is "good")	What gets worse (What is "bad")
that aspect of the system gets better….	at the expense of this aspect…
A product gets stronger…	*…but its weight increases*

Technical Parameter - Improving Feature	Technical Parameter - Improving Feature
A product gets stronger…	*…but its weight increases*
Strength – TP 14	***Weight of a non-moving object – TP 02***

Identifying Inventive Principles from the Altshuller Matrix
Look up the improving parameters to the worsening parameters on the Altshuller Matrix provided. Identify numbers for the Inventive Principles that may help solve this technical contradiction. The numbers are contained in the cell at the intersection of that row and column.
If the Altshuller Matrix contains a blank box at that intersection, try out the reversed contradiction or redefining your parameters.

Instruments
Altshuller Matrix (Annex)

Example
Ex 1: "Increase the durability of a product"

Summarise the problem to be solved and the problem context
Most design strategies for durability involve over-specifying the material type or its quantity. The most common durability solution is to add material to make something stronger.

What gets better (what is "good")	What gets worse (What is "bad")
that aspect of the system gets better….	at the expense of this aspect…
A product gets stronger…	*…but its weight increases*

Technical Parameter - Improving Feature	Technical Parameter - Improving Feature
A product gets stronger…	*…but its weight increases*
Strength – TP 14	***Weight of a non-moving object – TP 02***

Inventive Principle Numbers from intersection of the Technical Parameters on the Altshuller Matrix:
(row 14) vs. (column 2 à)Inventive Principles: 40, 26, 27, 1

harmful parameter → / useful parameter ↓		1 weight of mobile object	2 weight of stationary object	…
1	weight of mobile object	+	-	1… 2…
2	weight of stationary object	-	+	
3	length of mobile object	8, 15, 29, 34	-	
4	length of stationary object		35, 28, 40, 29	
5	area of mobile object	2, 17, 29, 4	-	14 1
6	area of stationary object	-	30, 2, 14, 18	
7	volume of mobile object	2, 26, 29, 40	-	1,
8	volume of stationary object	-	35, 10, 19, 14	19
9	velocity	2, 28, 13, 38	-	13
10	force	8, 1, 37, 18	18, 13, 1, 28	17 9
11	tension/ pressure	10, 36, 37, 40	13, 29, 10, 18	35
12	shape	8, 10, 29, 40	15, 10, 26, 3	29
13	stability of composition	21, 35, 2, 39	26, 39, 1, 40	13
14	strength	1, 8, 40, 15	40, 26, 27, 1	1, 8
		19, 5		

Idea Generation with the Inventive Principles
In the last step ideas have to be generated with the identified Innovative Principles.
Notes:
The inventive principle must be used as a precise direction to overcome the corresponding technical contradiction.

> **Typical mistake:** often it happens that beginners apply the Inventive Principles to the whole system (and not to the specific elements where the technical contradiction occurs).

The interpretation of the inventive principle guidelines should be as literal as possible in order to avoid their usage just as a confirmation of an ideal already conceived by the user.
The directions suggested by the different principles proposed by the same cell of the matrix can be combined, because they sometimes provide complementary suggestions.

Instruments & Example

Ex 1: "Increase the durability of a product"

Summarise the problem to be solved and the problem context
Most design strategies for durability involve over-specifying the material type or its quantity. The most common durability solution is to add material to make something stronger.

What gets better (what is "good")	What gets worse (What is "bad")
that aspect of the system gets better….	at the expense of this aspect…
A product gets stronger…	*…but its weight increases*

Technical Parameter - Improving Feature	Technical Parameter - Improving Feature
A product gets stronger…	*…but its weight increases*
Strength – TP 14	***Weight of a non-moving object – TP 02***

Inventive Principle Numbers from intersection of the Technical Parameters on the Altshuller Matrix:
(row 14) vs. (column 2 à)Inventive Principles: 40, 26, 27, 1

Solution ideas	
IP 40 - Composite materials	***Use lightweight composite materials in products that are likely to have a long-life and benefit from being very lightweight or create new composite materials from waste.***
IP 26 – Copying	***Dematerialize the mechanical parts of electronic interfaces by using screen prompts and fewer keys or use software only with robust touch screens.***
IP 27 - Cheap short lived products	***Evaluate whether products should be long lived. Use existing logistics and incentives to enhance product take-back, then design products and components for re-use, upgrade or recycling.***
IP 1 – Segmentation	***Make the object sectional for easy assembly and disassembly at the end of its life. almost all end-of-life strategies rely on easy separation of components and materials.***

5.3. Techniques to resolve Physical Contradictions

Definition

A physical contradiction is a conflict between two mutually exclusive physical requirements to the same parameter of an element of the system. More precisely, according to the ENV model (see chapter 1c) a physical contradiction occurs when different values are required for a given control parameter.

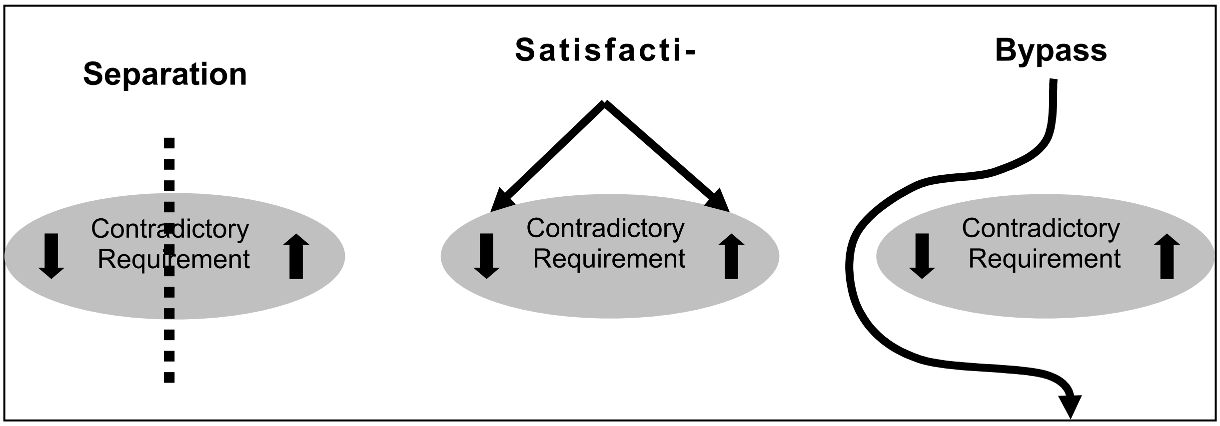
For problem solving, Contradiction formulation has the format: "A given element of the system should have characteristic A in order to realize a required function (to solve problem) AND this element should have characteristic NON-A in order to satisfy existent limitations and requirements".

Example: Element should be hot and cold...
Element should be hard and soft...

As a matter of principle a physical contradiction can be resolved by three concepts:

- Separation of the contradictory requirements (see 4 Separation Principles)
- Satisfaction of the contradictory requirements
- Bypass the contradictory requirements

Model



5.3.1. – The 4 Separation Principles

Definition

When dealing with a known Physical Contradiction – and the concepts of satisfaction and by-pass are not working - one can use one of the 4 Separation Principles for overcoming this type of contradiction:

- Separation in Time
- Separation in Space
- Separation on Condition / in Relation
- Separation in System Level

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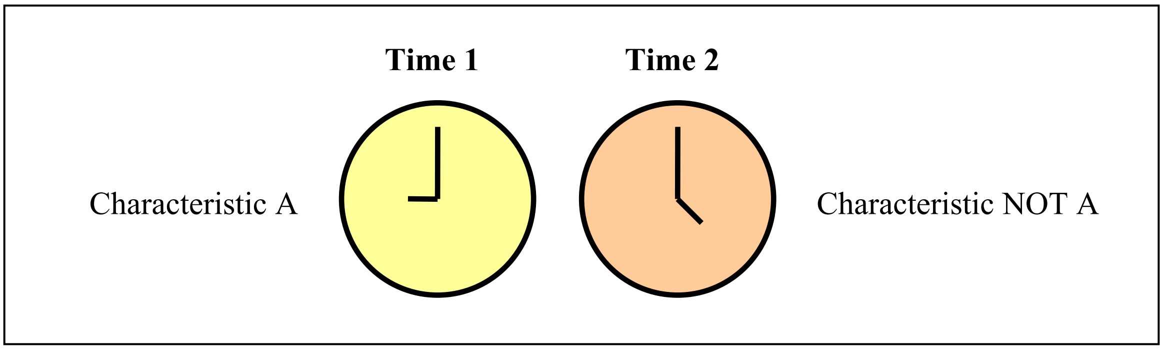
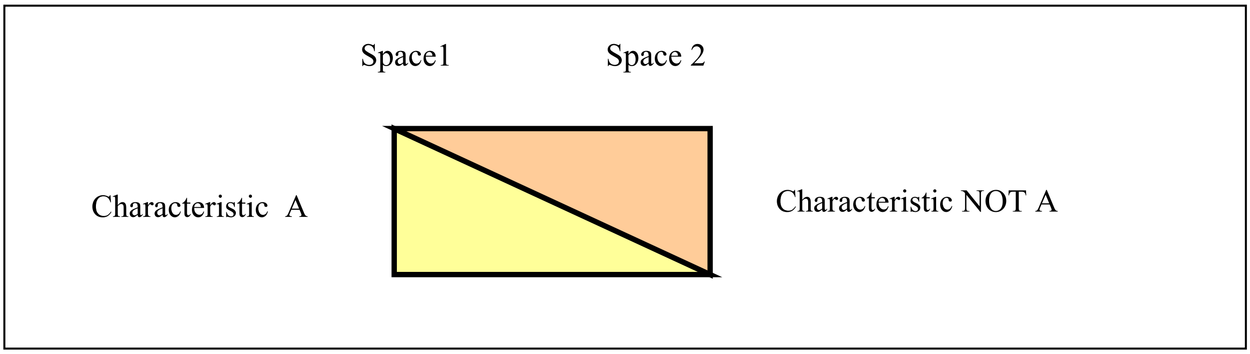
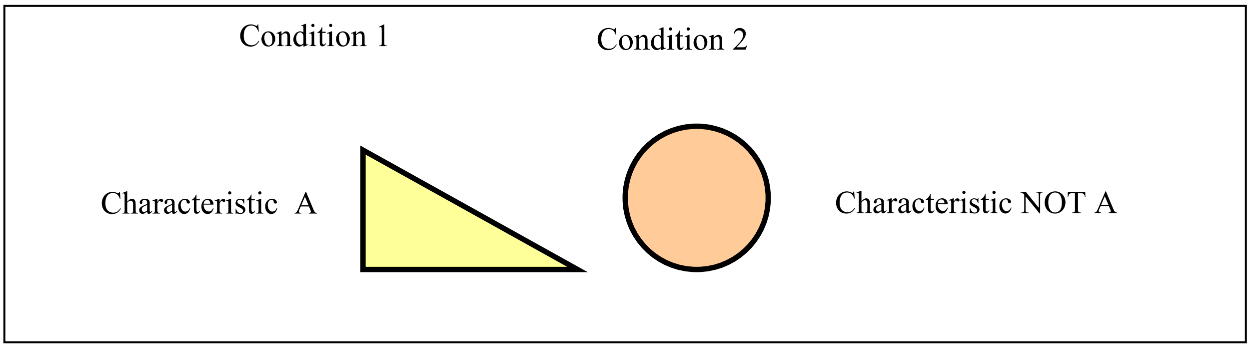
Model



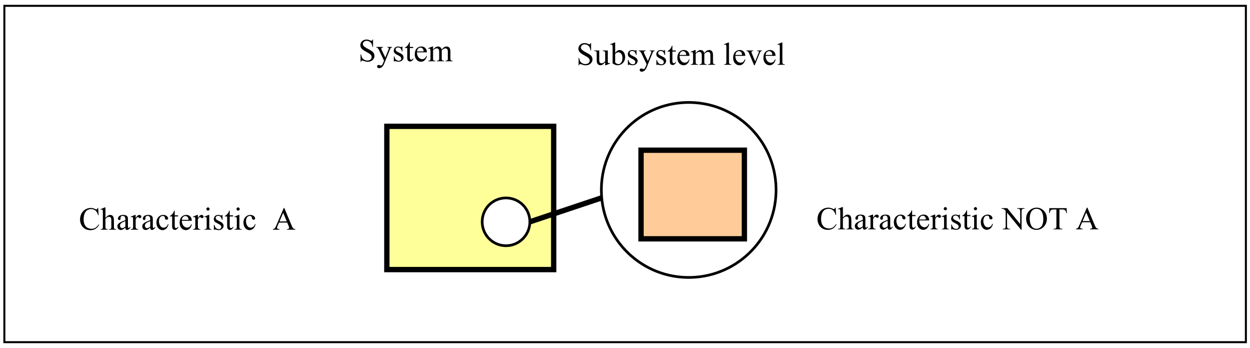
Separation in Time



Separation in Space



Separation on Condition / in Relation

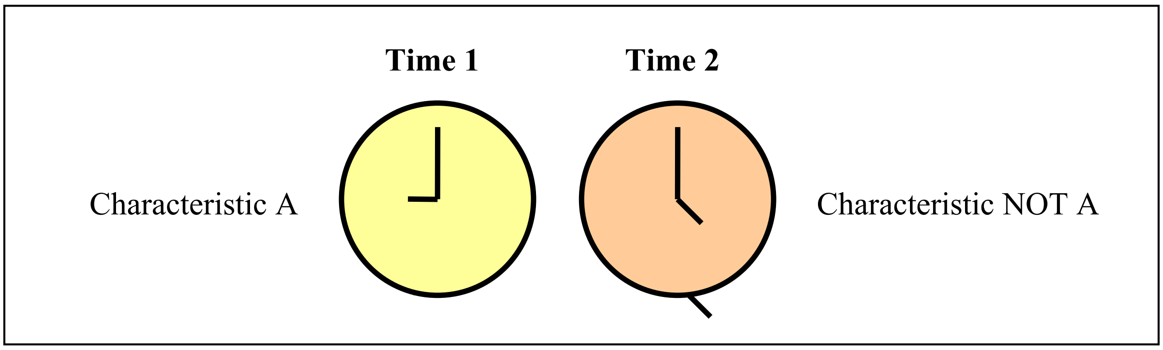


Separation in System Level

5.3.1.1 – Separation in Time

Definition

The concept is to separate the opposite requirements in time.
If a system or process must satisfy contradictory requirements, perform contradictory functions or operate contradictory conditions, try to schedule the system operation in such a way that requirements, functions or operations that conflict take effect at different times.
The concept of the "separation in time" is based on the definition on the so called "operational time":
That means when – at which time - exactly to we need the opposite requirements.



The question we have to ask is:
Do we need characteristic A anytime or is it only needed at a certain time?
If the characteristic A is not needed always, we can try to separate it in time.

Instruments

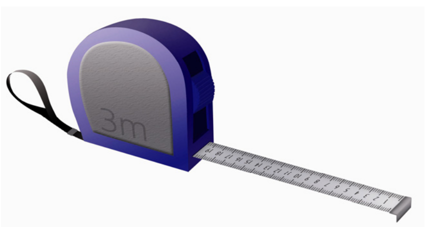
Inventive Principles supporting Separation in Time (This list is not exhaustive.)

- IP 15 – Dynamics
- IP 34 – Rejecting and Regenerating Parts
- IP 10 – Prior Action
- IP 9 – Prior Counteraction

IP 11 – Cushion in advance

Example – Product

A ruler should be long to have a wide range for measuring distances and a ruler should also be small in order to easily be taken away.
Inventive Principle 15 recommends to “dynamize”, i.e. to increase the internal degees of freedom of the ruler.
One product using this principle is the "roll ruler".



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Example

Problem formulation:

During a battle, cannons have to be loaded always very quickly. When rapid introducing the blackpowder into the cannon barrel, the powder can still glowing in particles or by radio shock ignite. Therefore a fast reloading of the gun is very dangerous. The task was to develop of a fast firing gun.

(Photo: R. Adunka)

That can be translated in a physical contradiction:

- The loading time of the gun should short to have a fast firing gun

AND

- The loading time of the gun should long to be more safety when loading the gun.

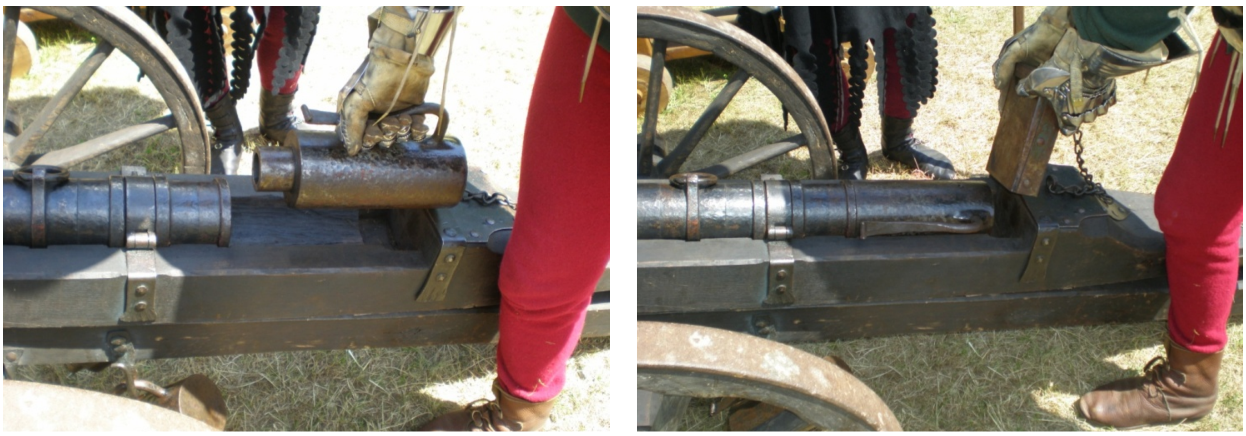
The operational time of the function “fast firing” can clearly separated from the operational time of the function “loading the gun”.
We can use the concept of Separation in Time to find ideas.
One of the recommended Inventive Principles supporting Separation in Space is IP 10 – Prior Action.

Principle 10 – Prior Action (Preliminary action)

A. Perform required changes to an object completely or partially in advance.
Place objects in advance so that they can go into action immediately from the most convenient location.

Solution:

"Cans chamber" have the blackpowder and the propellant in separated chambers. These chambers were set in for each shot extra. A number of these chambers can be prepared for a battle with blackpowder load and can be used during the battle. The bullet was introduced continually from the front. The risk of ignition of the blackpowder when introducing into the gun was reduced.



(Photo R. Adunka)

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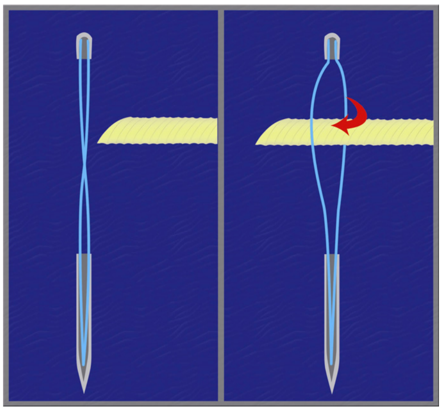


Example: Needle with dynamic eye

It is difficult to pass a thick thread through the small eye of a needle. We can formulate the following physical contradiction to represent this situation: A needle must have a large eye to facilitate insertion of the thread, and must have a small eye for convenient sewing.

By separating the contradiction in time this problem can be formulated as follows: **the eye must be large while the thread is inserted, and must be small during sewing, as follows:**

R. Pace of Britain designed a needle made of two thin, spring-like wires of identical length. The wires are welded together at one end, twisted three quarters of a turn, then welded at the opposite end. The resulting needle looks like an ordinary needle, but when slightly unwound, a large slot appears through which a thread can easily pass. When released, the needle returns to its initial shape and grips the thread.

(Source: Ideation, TRIZ Tutorial)

5.3.1.2 – Separation in Space

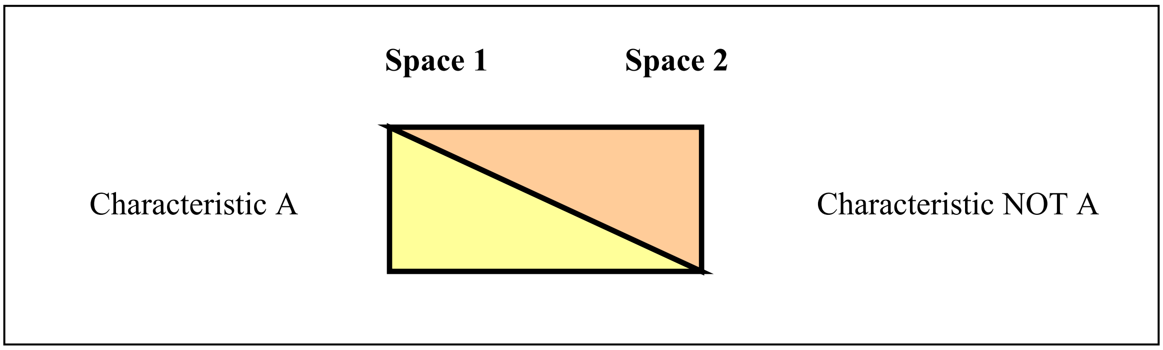
Definition

The concept is to separate the opposite requirements in space.

If a system must perform contradictory functions or operate under contradictory conditions, try to partition the system into subsystems. Then assign each contradictory function or condition to a different subsystem.

The concept of the "separation in space" is based on the definition on the so called "operational space": That means when – on which place - exactly to we need the opposite requirements.

Model



The question we have to ask is:

Do we need characteristic A everywhere or is it only needed in certain places?

If the characteristic A is not needed everywhere, we can try to separate it in space.

Instruments

Inventive Principles supporting Separation in Space (This list is not exhaustive.)

- IP 1 – Segmentation
- IP 2 – Extraction
- IP 3 – Local Quality
- IP 7 – Nesting
- IP 4 – Asymmetry
- IP 17 – Transition into an other Dimension
- IP 13 – The other way round

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Example – Product

A coffee cup should be hot to hold the coffee warm for a certain time and the cup should be not hot in order to not burn once fingers.
Inventive Principle 7 recommends to use the idea of nesting.
Starbucks is using this principle:

www.jeremyadamdavis.com

Example

Problem formulation:
At tournaments in the Middle Ages knight´s armor has to protect the knight against body injuries. In order to please the audience the clothing (armor) should also look nice.
So the task was to develop a "charming armor"

(Photo R. Adunka)

That can be translated in a physical contradiction:

- The armor should be out of metal to protect the knight AND
- The armor should NOT be out of metal (fabric, ..) to look charming.

The operational space of the function “protect the knight” (inside) is clearly separable from the operational space of the function “provide a charming look”
We can use the concept of Separation in Space to find ideas.
One of the recommended Inventive Principles supporting Separation in Space is IP 3 – Local Quality.

Principle 03 - Local Quality

A.Transition from homogenous to heterogeneous structure of an object or outside environment (action).
B.Different parts of an object should carry out different functions.
Each part of an object should be placed under conditions that are most favourable for its operation.

Solution:
The so called "Brigandine" is an armor that consists on the inner side out of metal plates and on the outside out of fibre or leather. It was a kind of "bulletproof vest" of the 15th century.

(Photo R. Adunka)

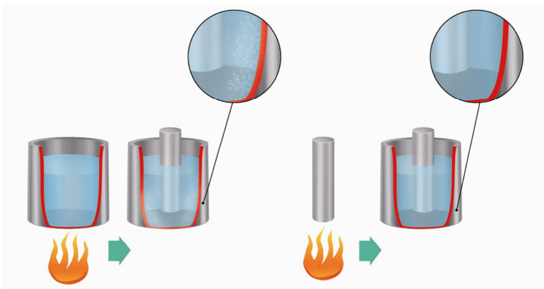
Example: Coating metal workpieces

Metal surfaces are chemically coated as follows: the metal workpiece is placed in a bath filled with a metal salt solution (e.g. nickel, cobalt, etc.). During the ensuing reduction reaction, metal from the solution precipitates onto the surface of the workpiece. The higher the temperature, the faster the process takes place; however, at high temperatures the solution decomposes, and up to 75% of the chemicals are lost by settling on the bottom and sides of the bath. Adding stabilizers is not effective, and conducting the process at a low temperature sharply decreases production.

To apply the principle of separation in space, for example, we should ask ourselves the following question: Do we need this parameter -- temperature, in this case -- to be high (and low) everywhere, or is it necessary in certain places only? If the temperature need not be both high and low everywhere, we can try to separate these opposite requirements in space.

In this case, we need the temperature to be high only near the parts rather than everywhere in the bath. How can this be achieved?

The answer is as follows: The workpiece is heated to a high temperature before it is immersed in the solution, and the process itself is conducted at a low temperature. The solution is therefore hot near the workpiece but cold everywhere else. (One way to accomplish this is to apply an electric current to the workpiece during the coating process.)



(Source: Ideation, TRIZ Tutorial)

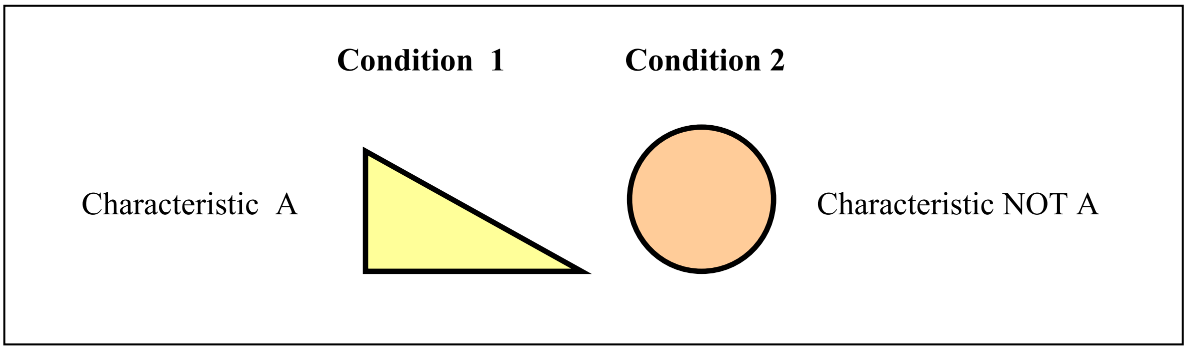
5.3.1.3 – Separation on Conditions // in Relation

Definition

The concept of separating opposing requirements of a condition can resolve contradictions in which a helpful process takes place when special conditions exist. Consider changing the system or the environment so that only the helpful process can take place.

Example: In the kitchen – A sieve will stop the pasta but not the water.

Model



The question we have to ask is:
Can we change or modify the conditions of the system or its surrounding so that both characteristic A and NOT A are fulfilled.

Instruments

Inventive Principles supporting Separation on Condition (This list is not exhaustive.)
- IP 40 – Composite Materials
- IP 31 – Porous Material
- IP 32 – Changimg the Color
- IP 3 – Local Quality
- IP 19 – Periodic Action
- IP 17 – Transition into an other Dimension

Note: In this case the relationship between the separation concept and the inventive principle is not so evident

Example

Problem formulation:
One customer of a sawmill wants to buy pure saw dust. Vacuum is used to suck the surrounding area of the saw blade. The saw dust is then directed through a metal suction pipe to the collecting tank. Unfortunately also small wooden staffs are sucked by the vacuum and so the content of the tank is contaminated.

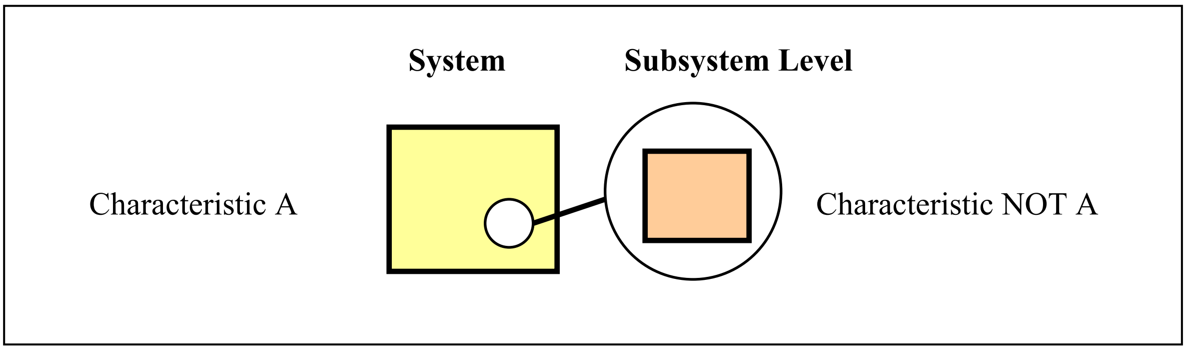
The contradiction can be formulated:
The suction (vacuum) should be strong to collect all the saw dust (but also the wooden staffs) and the suction should be rather weak in order not to collect the wooden staffs.

Solution:
By increasing the cross section diameter of the suction pipe within a certain length (convexity) the flow conditions can be changed in a way that larger parts – the wooden staffs – will accumulate there and will not be flow into the collection pipe.

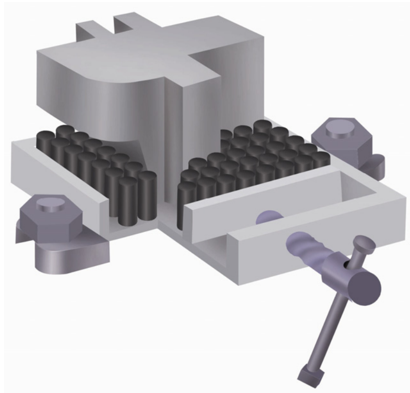
5.3.1.4 – Separation in System Level // by Transition to Sub- or Supersystem

Definition

The concept is to separate the opposite requirements within a whole object or its parts.
If a system must perform contradictory functions or operate under contradictory conditions, try to partition the system and assign one of the contradictory functions or conditions to a subsystem (or several subsystems). Let the system as a whole retain the remaining functions and conditions.



Model
The question we have to ask is:
Can we satisfy characteristic A and NOT-A by s assign one of them to the whole system and the other to its parts?



Example: Gripping workpieces of complex shape
To grip workpieces of complex shape, vice jaws must have a corresponding shape. It is expensive to produce a unique tool for every workpiece, however. Besides, a deformable gripper would be able to adjust its shape to the workpiece to be held, but the supporting capability would be worsened (the gripper would result not stiff enough).
The physical contradiction is thus the following: the gripper should be stiff in order to support the workpiece properly, and the stiffness should be soft in order to modify its geometry to match the complex shape of the workpiece itself.
The answer is as follows: Use a vise with ordinary jaws, but add multiple hard bushings around the workpiece that move horizontally to conform to the workpiece shape (high deformability at system level and low deformability at subsystem level).

(Source: Ideation, TRIZ Tutorial)

5.3.2. – Satisfaction (Effects) & Bypass (Redesign)
Satisfaction:
If the physical contradiction can not be solved by one of the separation principles it might be possible to meet both requirements simultaneously by using a new effect.
In most cases this is a radical change of the system structure.
TRIZ Laws of evolution help identifying the direction to overcome the contradiction with such a paradigm shift:

Transition to Supersystem: including
the Trend mono-bi-poly
the Trend towards Increased Difference between the integrated systems
→ Reference to Laws of Evolution 6 and 7

Transition to Microlevel or Subsystem: i.e. transition to alternative systems
→ Reference to physical, chemical and geometrical effects

Inventive Principles supporting Separation by Transition to Sub- or Supersystem (This list is not exhaustive.)
- IP 1 – Segmentation
- IP 5 – Merging
- IP 33 – Homogeneity
- IP 12 – Equipotentiality

Note: In this case the relationship between the separation concept and the inventive principle is not so evident

Bypass:

If the physical contradiction can not be solved by one of the separation principles, it might be possible to bypass both requirements. This new solution could cause the contradiction gets irrelevant.

This can be done by looking at different screens of the system operator. The screens can help to find alternative bypass problems still related to the same overall goal.

	PAST	PRESENT	FUTURE
SUPERSYSTEM	What should <any resource of the supersystem> do to prevent the appearance of problem in order achieve the Most Desirable Result?	What should <any resource of the supersystem> do in order to make the <system> deliver the useful function properly without undesirable harmful side effects in order achieve the Most Desirable Result?	If the problem has not been solved, what should <any resource of the supersystem > do in order to make the <system> achieve the Most Desirable Result as well?
SYSTEM	What should the <system> do to prevent the appearance of problem in order achieve the Most Desirable Result?	What should the <system> do to deliver the useful function properly without undesirable harmful side effects in order achieve the Most Desirable Result?	If the problem has not been solved, what should the <system> do to achieve the Most Desirable Result as well?
SUBSYSTEM	What should <any of the subsystems> do to prevent the appearance of problem in order achieve the Most Desirable Result?	What should <any of the subsystems> do in order to make the <system> deliver the useful function properly without undesirable harmful side effects in order achieve the Most Desirable Result?	If the problem has not been solved, what should <any of the subsystems> do in order to make the <system> achieve the Most Desirable Result as well?

→ Reference to Systems Operator and

→ Reference to Transition to Supersystem & Microlevel

5.4. – Effects

Definition

Utilization of scientific effects and phenomena helps an inventor to develop solutions of the highest innovation level, since formulated problem contradiction is being resolved on its physical level.

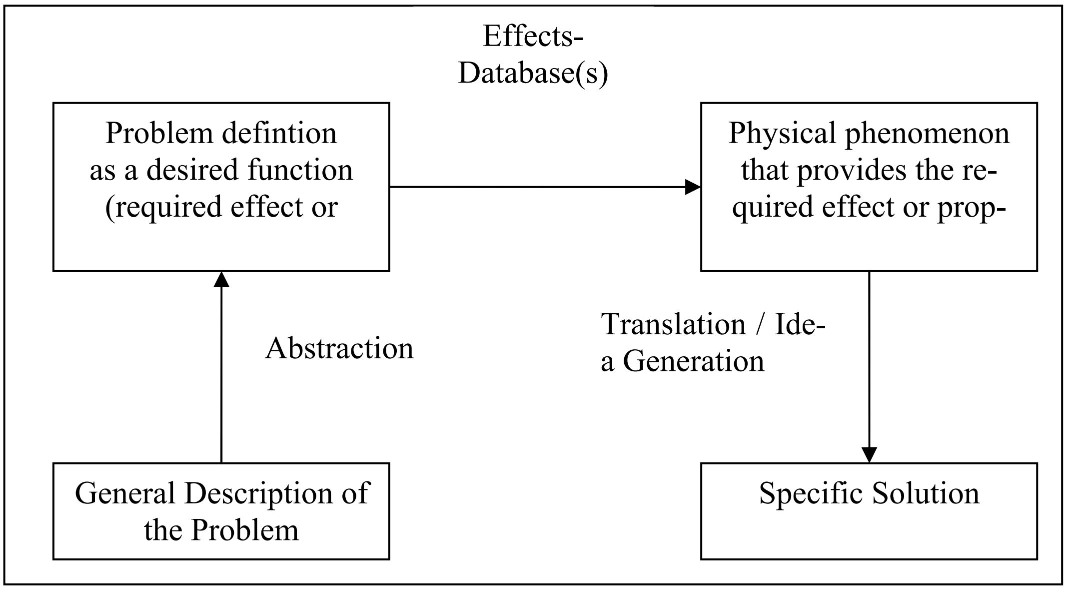
In order to find the right effects Altshuller started to collect physical phenomena and structured them regarding the required effect or property. So a special knowledge database was born. Out of these several software tools and online services developed over the years.

The traditional classification of effects in TRIZ is the differentiation of physical, chemical and gemoetrical effects.

✦ Physical Effects: enable to transform one form of energy into another
✦ Chemical Effects: enable to obtain some substances from others by the absorption or the emission of energy
Geometrical Effects: organize and redistribute flows of energy and substances that are already available in the system
Geometrical Effects start where Physical and Chemical Effects end.

Note: Within the TRIZ literature the most comprehensive and acknowledged studies about Geometrical Effects (GE) have been published by Vikentiev.

Model



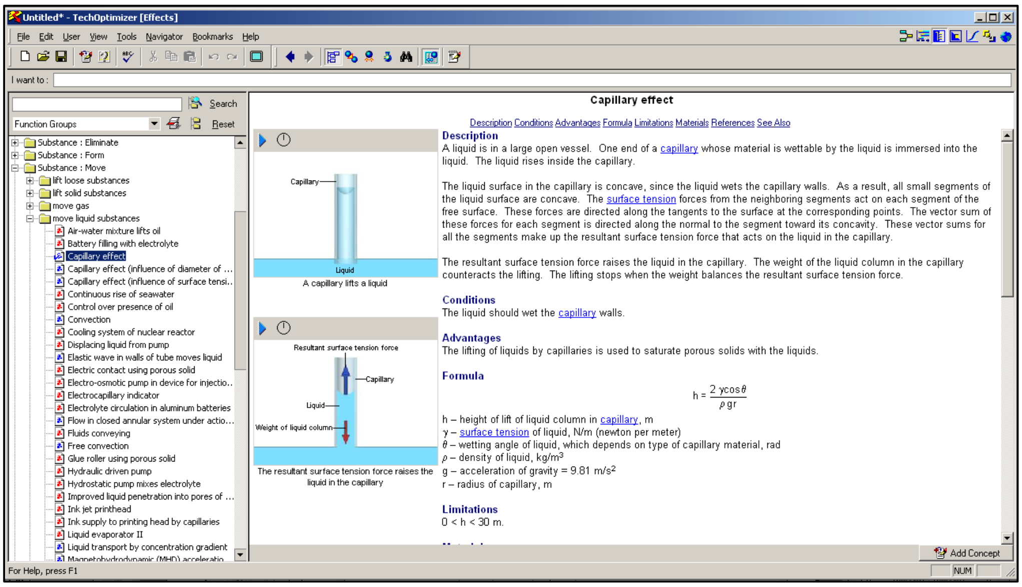
Instruments
Physical phenomenon that provide the following "required effect or property" have been collected:

1. Measure temperature
2. Reducing temperature
3. Increasing temperature
4. Temperature stabilization
5. Object location
6. Moving an object
7. Moving a liquid or gas
8. Moving an aerosol (dust particles, smoke, mist, etc.)
9. Formation of mixtures
10. Separating mixtures
11. Stabilizating object position
12. Generating and/or manipulating force
13. Changing friction
14. Crashing objects
15. Accumulating mechanical and thermal energy
16. Transferring energy through mechanical, thermal, radiation, or electric deformation
17. Influencing moving object
18. Measuring dimensions
19. Varying dimensions

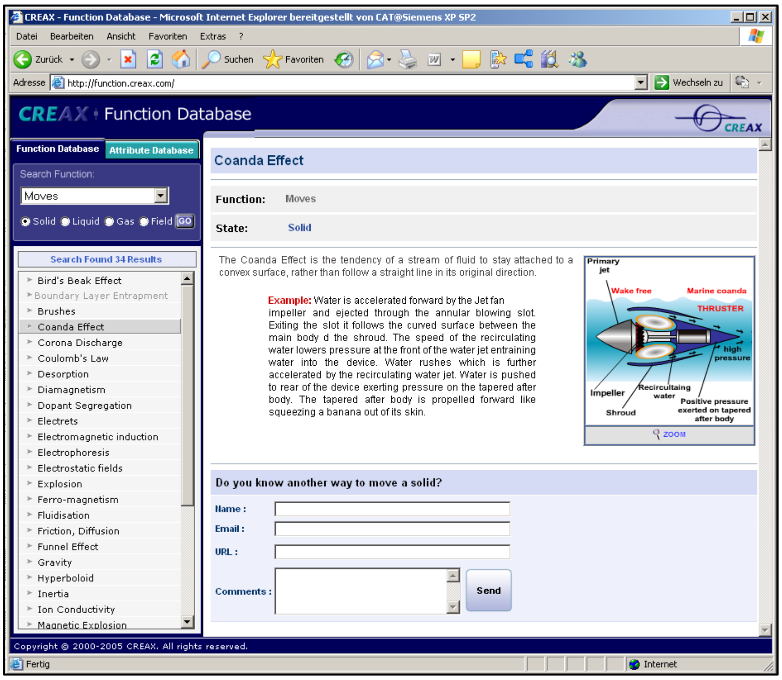
20. Detecting surface properties and/or conditions
21. Varying surface properties
22. Detecting volume properties and/or conditions
23. Varying volume properties
24. Developing certain structures, structure stabilization
25. Detecting electric and magnetic fields
26. Detecting radiation
27. Generating electromagnetic radiation
28. Controlling electromagnetic fields
29. Controlling light, light modulation
30. Initiating and intensification of chemical reactions

<u>Several Software and Online tools have been developed in this field:</u>

<u>Software Invention Machince Inc.: TechOptimizer / Goldfire Innovator</u>



<u>Function Database CREAX : http://fuction.creax.com</u>



5.5. – Substance and-Field- Resources

Definition

TRIZ recommends using the internal, external, by-product and complex substance-field resources of the existing system during problem solving. This meets the requirements of an ideal system and leads to strong solutions with minimal reconstructions as the best result.
Once you have identified your technical system and defined your contradiction, you should evaluate what resources are available to overcome the contradiction. To solve the contradiction, TRIZ recommends using the substance-field resources of the existing system. This meets the requirements of an ideal system.
In TRIZ a resource is everything that can be applied for a solving problem and improving the system without any big expenses. Resources should be easily attainable, free or low cost. Resources can be internal or external to the system or supersystem. Resources can be substances or fields. Other resources include space and time or even other nearby systems.
The identification of these resources provides abundant opportunities for solution concepts to be readily developed. Each resource is a potential solution to your problem. The more resources that are available for use, the greater the solution space to generate more solution concepts.
Resources of an existing system and its elements are the base of the strongest and most efficient solutions. The identification of these resources provides abundant opportunities for solution concepts to be developed. Each resource is a potential solution to the problem. The more resources that are available for use, the greater the solution space is to generate more solution concepts. By using resources we don't need to add "something" from outside the system and can reach very good results.
Resources are also playing an important part in two more concepts of TRIZ:

- the use of the System Operator to guide/improve the search for resources
- the search for resources as a means to reformulate a physical contradiction (see ARIZ part 3)

Model
What kinds of resources are being used in problem solving? The resources can be classified as substances, energy, space, time, functions, information, and combined resources.

The substance resources are all substances and properties of substances (e.g. phase transitions, curie points, thermal/electrical/optical…conductivity etc) used in the analyzed system and in an external environment.

The energy resources are all known kinds of energies and fields (electrical, electromagnetic, thermal fields and etc.). These resources are already present in the improved system or in the external environment where the system resides.

The space resources, we shall perceive an unoccupied space or "hollow", which can be used for changing of the initial system for increasing its efficiency and functionality.

The time resources are, at first, the time prior to the beginning of some main production process, and, secondly, it could be the time between separate stages of the production process. Both of those intervals can be used for improving the basic operation of the system.

The information resources are usually used in solving problems on measuring, detection and separation. Therefore, information resources are data on parameters of substance, fields, change of properties or of object. Thus, the more we shall detect of differences of one substance from other, the more efficiently there can be their measuring or detection.

The functional resources are an opportunity to use known functions of the object on a diverse purpose, or the detection of a new function in the system. A possibility to carry out any additional functions after some changes is also a functional resource. It is a very valuable point of resource utilization because the knowledge and application of the different features or a characteristic property with a new function of the same substance can give a very strong invention.
Note: The search for "functional resources" sometimes causes confusion, because mostly they are already listed.

The **combined resources** are the combination of the above prime resources. Sometimes, there is no resource in the system with required property for solving the problem. We can easily fix this by changing existing substances in the system. We know that a liquid can become a solid substance and vice versa under temperature (water-ice, ice-water), iron can become a magnet, and solid substance can change size under heating or cooling.

<u>How do use resources for problem solving?</u>
This is a short workflow that can be recommended for utilization of the resources and example:

- Formulation of the problem
- Composition of a list of resources in the next order: internal, external, of by-product and complex
- Definition what kind of resources are needed for solving this problem
- Estimation of each of the existing resources and effect from its utilization
- Proposition how to use founded resource

Instruments
See Annex Substance-Field-Resources
The System Operator is a useful tool to search for resources through a systematic scan of the system, its parts and its environment within its whole lifecycle.

5.6 Annexes

5.6.1 The 40 Inventive Principles

Source:
G. Altshuller – Lev Shulyak, Steven Rodman, The Innovation Algorithm, TRIZ, Systematic Innovation and Technical Creativity, Technical Innovation Center, 2000)

Principle 01 - Segmentation
A. Divide an object into independent parts.
B. Make an object easy to disassemble.
C. Increase the degree of fragmentation or segmentation.

Principle 02 - Extraction (Extracting, Retrieving, Removing, Taking out)
A. Extract the “disturbing” part or property from the object.
B. Extract only the necessary part or property from an object.

Principle 03 - Local Quality
A. Transition from homogenous to heterogeneous structure of an object or outside environment (action).
B. Different parts of an object should carry out different functions.
C. Each part of an object should be placed under conditions that are most favourable for its operation.

Principle 04 - Asymmetry
A. Replace symmetrical form(s) with asymmetrical form(s).
B. If an object is already asymmetrical, increase its degree of asymmetry.

Principle 05 – Consolidation (Merging)
A. Consolidate in space homogeneous objects, or objects destined for contiguous operations.
B. Consolidate in time homogeneous or contiguous operations.

Principle 06 - Universality
A. An object can perform several functions; therefore, other elements can be removed.

Principle 07 - Nesting (Matrioshka, "Nested doll”)
A. One object is placed inside another. That object is placed inside a third one. And so on …
B. An object passes through a cavity in another object.

Principle 08 – Counterweight (Anti-weight)
A. Compensate for the weight of an object by combining it with another object that provides a lifting force.
B. Compensate for the weight of an object with aerodynamic or hydrodynamic forces influenced by the outside environment.

Principle 09 – Prior Counteraction (Preliminary anti-action)
A. Preload countertension to an object to compensate excessive and undesirable stress.

Principle 10 – Prior Action (Preliminary action)
Perform required changes to an object completely or partially in advance.
Place objects in advance so that they can go into action immediately from the most convenient location.

Principle 11 – Cushion in Advance (Beforehand cushioning)
A. Compensate for the relatively low reliability of an object with emergency measures prepared in advance.

Principle 12 - Equipotentiality
A. Change the condition of the work in such a way that it will not require lifting or lowering an object.

Principle 13 – Do it in Reverse ("The other way round")
A. Instead of the direct action dictated by a problem, implement an opposite action (i.e., cooling instead of heating).
B. Make the movable part of an object, or outside environment, stationary – and the stationary part moveable.
C. Turn the object "upside down".

Principle 14 - Spheroidality (Curvature)
A. Replace linear parts with curved parts, flat surfaces with spherical surfaces, and cube shapes with ball shapes.
B. Use rollers, balls, spirals.
C. Replace linear motion with rotational motion; utilize centrifugal force.

Principle 15 - Dynamics
A. Characteristics of an object or outside environment, must be altered to provide optimal performance at each stage of an operation.
B. If an object is immobile, make it mobile. Make it interchangeable.
C. Divide an object into elements capable of changing their position relative to each other.

Principle 16 - Partial or Excessive Action
A. If it is difficult to obtain 100% of a desired effect, achieve more or less of the desired effect.

Principle 17 – Transition into a New Dimension (Another Dimension)
A. Transition one-dimensional movement or placement of objects into two-dimensional or three-dimensional, etc.
B. Utilize multi-level composition of objects.
C. Incline an object, or place it on its side.
D. Utilize the opposite side of a given surface.
E. Project optical lines onto neighboring areas or onto the reverse side of an object.

Principle 18 - Mechanical Vibration
A. Utilize oscillation.
B. If oscillation exists, increase its frequency to the ultrasonic.
C. Use the frequency of resonance.
D. Replace mechanical vibrations with piezo-vibrations.
E. Use ultrasonic vibrations in conjunction with electromagnetic field.

Principle 19 - Periodic Action
A. Replace a continuous action with a periodic one (impulse).
B. If an action is already periodic, change its frequency.
C. Use pauses between impulses to provide additional action.

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Principle 20 - Continuity of Useful Action
A. Carry out an action without a break. All parts of the object should constantly operate at full capacity.
B. Remove idle and intermediate motion.
C. Replace “back-and-forth” motion with rotating one.

Principle 21 – Rushing Through (Skipping)
A. Perform harmful and hazardous operations at a high speed.

Principle 22 – Convert Harm into Benefit (“Blessing in disguise" or "Turn Lemons into Lemonade")
A. Utilize harmful factors – especially environment – to obtain a positive effect.
B. Remove one harmful factor by combining it with another harmful factor.
C. Increase the degree of harmful action to such an extent that it ceases to be harmful.

Principle 23 - Feedback
A. Introduce feedback.
B. If feedback already exists change it.

Principle 24 – Mediator („Intermediary“)
A. Use an intermediary object to transfer or carry out an action.
B. Temporarily connect the original object to one that is easily removed.

Principle 25 - Self-service
A. An object must service itself and carry out supplementary and repair operations.
B. Make use of waste material and energy.

Principle 26. Copying
A. A simplified and inexpensive copy should be used in place of a fragile original or an object that is inconvenient to operate.
B. If visible optical copy is used, replace it with infrared or ultraviolet copies.
C. Replace an object (or system of objects) with their optical image. The image can then be reduced or enlarged.

Principle 27 – Dispose (Cheap Short-living Objects)
A. Replace an expensive object with a cheap one, compromising other properties (i.e. longevity).

Principle 28 – Replacement of Mechanical System (Mechanics Substitution)
A. Replace a mechanical system with an optical, acoustical, thermal or olfactory system.
B. Use an electric, magnetic and electromagnetic field to interact with an object.
C. Replace fields that are:
- Stationary with mobile
- Fixed with changing in time
- Random with structured
- Use fields in conjunction with ferromagnetic particles.

Principle 29 – Pneumatic or Hydraulic Constructions (Pneumatics and Hydraulics)
A. Replace solid parts of an object with gas or liquid. These parts can now use air or water for inflation, or use pneumatic or hydrostatic cushions.

Principle 30 – Flexible Membranes or Thin Films (Flexible Shells and Thin Films)
A. Replace customary constructions with flexibe membranes or thin films.
B. Isolate an object from its outside environment with flexible membranes or thin films..

Principle 31 - Porous Material
A. Make an object porous, or use supplementary porous elements (inserts, covers, etc.).
B. If an object is already porous, fill pores in advance with some substance.

Principle 32 – Changing the Color (Color Changes)
A. Change the color of an object or its environment.
B. Change the degree of translucency of an object or its environment.
C. Use color additives to observe an object or process which is difficult to see.
D. If such additives are already used, employ luminescent traces or trace atoms.

Principle 33 - Homogeneity
A. Objects interacting with the main object should be made out of the same material (or material with similar properties) as the main object.

Principle 34 – Rejecting and Regenerating Parts (Discarding and Recovering)
A. After completing its function, or becoming useless, an element of an object is rejected (discarded, dissolved, evaporated, etc.) or modified during its work process.
B. Used-up parts of an object should be restored during its work.

Principle 35 – Transformation of Properties (Parameter Changes)
A. Change the physical state of the system.
B. Change the concentration or density.
C. Change the degree of flexibility.
D. Change the temperature or volume.

Principle 36 - Phase Transition
A. Using the phenomena of phase change (i.e. a change in volume, the liberation or absorption of heat, etc.).

Principle 37 - Thermal Expansion
A. Use expansion or contraction of material by changing its temperature.
B. Use various materials with different coefficients of thermal expansion.

Principle 38 – Accelerated Oxidation (Strong Oxidants)
A. Make transition from one level of oxidation to the next higher level:
- Ambient air to oxygenated
- Oxygenated to oxygen
- Oxygen to ionized oxygen
- Ionized oxygen to ozoned oxygen
- Ozoned oxygen to ozone
- Ozone to singlet oxygen

Principle 39 - Inert Environment (Inert Atmosphere)
A. Replace a normal environment with an inert one.
B. Introduce a neutral substance or additives into an object.
C. Carry out the process in a vacuum.

Principle 40 - Composite Materials
Replace homogeneous materials with composite ones.

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5.6.2. – The 39 Technical Parameters

The 39 Technical Parameters / Characteristics
Source:
G. Altshuller – Lev Shulyak, Steven Rodman, The Innovation Algorithm, TRIZ, Systematic Innovation and Technical Creativity, Technical Innovation Center, 2000)

TP 01 - Weight of moving object
The measurable force, resulting from gravity, that a moving body exerts on the surface which prevents it from falling. A moving object is one which changes position on its own or as a result of some external force.

TP 02 - Weight of non-moving object
The measurable force, resulting from gravity, that a stationary object exerts on the surface on which it rests. A stationary is one which cannot change position on its own or as a result of some external force
Length of moving object

TP 03 - Length of moving object
The linear measure of an object's length, height or width in the direction of observed movement of that object. Movement may be caused by inernal or external forces.

TP 04 - Length of non-moving object
The linear measure of an object`s length, height or width in the direction for which no observed movement occurs.

TP 05 - Area of moving object
the square measure of any plane or portion of a plane of an object which, when acted on by internal or external forces, cannot change its position in space

TP 06-Area of non-moving object
The square measure of any plane or portion of a plane of an object which, when acted on by internal or external forces, cannot change its position in space.

TP07-Volume of moving object
the cubic measure of an object which can change its position in space when acted on by internal or external forces.

TP08-Volume of non-moving object
the cubic measure of an object which cannot change its position in space when acted on by internal or external forces.

TP09-Speed
the rate at which an action or process is completed over time.

TP10-Force
the capacity to cause physical change in an object or system. The change may be full or partial, and permanent or temporary.

TP11-Tension/ Pressure
The intensity of forces acting on an object or system, measured as the force of compression or tension per unit of area.

TP12-Shape
The outward appearance or contour of an object or system. Shape may full or partial and permanent or temporary changes due to forces acting on the object or system.

TP13-Stability of object
The resistance of a whole object or system to change caused by the interactions of its associated objects or systems.

TP 14-Strength
Under definable conditions and limits, the ability of an object or system to absorb the effects of force, speed, stress etc. without breaking.

TP 15-Durability of moving object
The length of time over which an object that changes position in space is able to successfully fulfil its function.

TP 16-Durability of non-moving object
The length of time over which an object that does not change position in space is able to successfully fulfil its function.

TP 17 -Temperature
The loss or addition of heat to an object or system during required functions, which may cause potentially undesirable changes to objects, system or productions.

TP 18-Brightness
The ratio of light energy to heat the area which is being lit by or in a system. Brightness includes the quality of light, degree of illumination, and other characteristics of light.

TP 19-Energy spent by moving object
The energy requirements of an object or system which changes position in space by its own means or by external forces.

TP 20-Energy spent by non-moving object
The energy requirements of an object or system which does not change position in space in the presence of external forces.

TP 21-Power
The ratio of work to the time required to perform that work. Used to measure the time required but potentially undesirable changes in power evident in an objector system under given conditions.

TP 22-Waste of energy
Increased inability of an object or system to exert force, especially when no work or product is produced.

TP 23-Waste of substance
Decrease or elimination of material from an object or system, especially when no work or product is produced.

TP 24-Loss of information
Decrease or elimination of data or input from a system.

T25-Waste of time
Increase in the amount of time needed to complete a given action.

TP26-Amount of substance
The number of elements or the quantity of an element used to create an object or system.

TP27-Reliability
The ability of an object or system to adequately perform its required function during some period of time or cycles.

TP28-Accuracy of measurement
The degree to which a measurement is close to the actual value of the quantity being measured.

TP29-Accuracy of manufacturing
The degree of correspondence between elements of an object or system to its design specification.

TP30-Harmful factors acting on object
Externally produced influences acting on an object or system which reduce efficiency or quality.

TP31-Harmful side effects
Internally produced influences acting on an object or system which reduce efficiency or quality.

TP32-Manufacturability
The convenience and facility with which an object or system is produced.

TP33-Convenience of use
Convenience and facility with which an object or system is operated.

TP34-Repairability
Convenience and facility with which an object or system is restored to operating condition after damage or extensive use.

TP35-Adaptability
The ability of an object or system to reshape or reorder itself as external conditions (environment, function, etc.) change.

TP36-Complexity of device
The quantity and diversity of elements forming the object or system, including the relationship between elements. Complexity may also describe the difficulty of mastering the use of an object or system.

TP37-Complexity of control
The quantity and diversity of elements used in measuring and monitoring an object or system, as well as the cost of measuring to an acceptable error.

TP38-Level of automation
The ability of an object or system to perform operations without human interaction.

TP39-Productivity
The relationship between the number of times an operation is completed and the amount of time it takes to do it.

5.6..3. – The Altshuller Matrix

Part 1/2

↓ Useful Parameter / Feature to improve / Characteristics to be improved

→ Harmful Parameter / Undesired Result / Characteristic that is getting worse

	harmful parameter → / useful parameter ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		weight of mobile object	weight of stationary object	length of mobile object	length of stationary object	area of mobile object	area of stationary object	volume of mobile object	volume of stationary object	velocity	force	tension/ pressure	shape	stability of composition	strength	durability of mobile object	durability of stationary object	temperature	lumination	energy consumption of mobile object	energy consumption of stationary object
1	weight of mobile 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	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35	-	6, 29, 4, 38	19, 1, 32	35, 12, 34, 31	-
2	weight of stationary 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	26, 39, 1, 40	28, 2, 10, 27	-	2, 27, 19, 6	28, 19, 32, 22	19, 32, 35	-	18, 19, 28, 1
3	length of mobile 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	1, 8, 15, 34	8, 35, 29, 34	19	-	10, 15, 19	32	8, 35, 24	-
4	length of stationary object		35, 28, 40, 29	-	+	-	17, 7, 10, 40	-	35, 8, 2,14	-	28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26	-	1, 10, 35	3, 35, 38, 18	3, 25	-	
5	area of mobile object	2, 17, 29, 4	-	14, 15, 18, 4	-	+	-	7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3	-	2, 15, 16	15, 32, 19, 13	19, 32	-
6	area of stationary object	-	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		-	
7	volume of mobile object	2, 26, 29, 40	-	1, 7, 4, 35	-	1, 7, 4, 17	-	+	-	29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4	-	34, 39, 10, 18	2, 13, 10	35	-
8	volume of stationary object	-	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		-	
9	velocity	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	-
10	force	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	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
11	tension/ pressure	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, 24	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	
12	shape	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, 18, 4	30, 14, 10, 40	14, 26, 9, 25		22, 14, 19, 32	13, 15, 32	2, 6, 34, 14	
13	stability of composition	21, 35, 2, 39	26, 39, 1, 40	13, 15, 1, 28	37	2, 11, 13	39	28, 10, 19, 39	34, 28, 35, 40	33, 15, 28, 18	10, 35, 21, 16	2, 35, 40	22, 1, 18, 4	+	17, 9, 15	13, 27, 10, 35	39, 3, 35, 23	35, 1, 32	32, 3, 27, 16	13, 19	27, 4, 29, 18
14	strength	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
15	durabilty of mobile object	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	
16	durability of stationary object	-	6, 27, 19, 16	-	1, 40, 35	-		-	35, 34, 38	-				39, 3, 35, 23		-	+	19, 18, 36, 40		-	
17	temperature	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	
18	lumination	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	energy consumption of mobile object	12,18,28,31	-	12, 28	-	15, 19, 25	-	35, 13, 18	-	8, 35, 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	+	-
20	energy consumption of stationary object	-	19, 9, 6, 27	-		-		-		-	36, 37			27, 4, 29, 18	35				19, 2, 35, 32	-	+
21	power	8, 36, 38, 31	19, 26, 17, 27	1, 10, 35, 37		19, 38	17, 32, 13, 38	35, 6, 38	30, 6, 25	15, 35, 2	26, 2, 36, 35	22, 10, 35	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	
22	waste of energy	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		
23	waste of substance	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
24	loss of information	10, 24, 35	10, 35, 5	1, 26	26	30, 26	30, 16		2, 22	26, 32						10	10		19		
25	waste of time	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, 26, 17	35, 38, 19, 18	1
26	amount of substance	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
27	reliability	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
28	accuracy of measurement	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	10, 26, 24	6, 19, 28, 24	6, 1, 32	3, 6, 32	
29	manufacturing precision	28, 32, 13, 18	28, 35, 27, 9	10, 28, 29, 37	2, 32, 10	28, 33, 29, 32	2, 29, 18, 36	32, 23, 2	25, 10, 35	10, 28, 32	28, 19, 34, 36	3, 35	32, 30, 40	30, 18	3, 27	3, 27, 40		19, 26	3, 32	32, 2	
30	harmful factors acting on object	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, 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
31	harmful side effects of the object	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
32	manufacturability	28, 29, 15, 16	1, 27, 36, 13	1, 29, 13, 17	15, 17, 27	13, 1, 26, 12	16, 40	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
33	operation convenience	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, 39, 31	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	26, 27, 13	13, 17, 1, 24	1, 13, 24	
34	repairability	2, 27 35, 11	2, 27, 35, 11	1, 28, 10, 25	3, 18, 31	15, 13, 32	16, 25	25, 2, 35, 11	1	34, 9	1, 11, 10	13	1, 13, 2, 4	2, 35	11, 1, 2, 9	11, 29, 28, 27	1	4, 10	15, 1, 13	15, 1, 28, 16	
35	adaptabilty	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	35, 16	15, 37, 1, 8	35, 30, 14	35, 3, 32, 6	13, 1, 35	2, 16	27, 2, 3, 35	6, 22, 26, 1	19, 35, 29, 13	
36	complexity of device	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, 13	27, 2, 29, 28	
37	complexity of control	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	30, 28, 40, 19	35, 36, 37, 32	27, 13, 1, 39	11, 22, 39, 30	27, 3, 15, 28	19, 29, 39, 25	25, 34, 6, 35	3, 27, 35, 16	2, 24, 26	35, 38	19, 35, 16
38	level of automation	28, 26, 18, 35	28, 26, 35, 10	14, 13, 17, 28	23	17, 14, 13		35, 13, 16		28, 10	2, 35	13, 35	15, 32, 1, 13	18, 1	25, 13	6, 9		26, 2, 19	8, 32, 19	2, 32, 13	
39	productivity	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

Part 2/2 (Altshuller Matrix)

↓ Useful Parameter / Feature to improve / Characteristics to be improved
→ Harmful Parameter / Undesired Result / Characteristic that is getting worse

	harmful parameter → / useful parameter ↓	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
		power	waste of energy	waste of substance	loss of information	waste of time	amount of substance	reliability	accuracy of measurement	manufacturing precision	harmful factors acting on object	harmful side effects of the object	manufacturability	operation convenience	repairability	adaptability	complexity of device	complexity of control	level of automation	productivity
1	weight of mobile object	12, 36, 18, 31	6, 2, 34, 19	5, 35, 3, 31	10, 24, 35	10, 35, 20, 28	3, 26, 18, 31	1, 3, 11, 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	weight of stationary object	15, 19, 18, 15	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
3	length of mobile object	1, 35	7, 2, 35, 39	4, 29, 23, 10	1, 24	15, 2, 29	29, 35	10, 14, 29, 40	28, 32, 4	10, 28, 29, 37	1, 15, 17, 24	17, 15	1, 29, 17	15, 29, 35, 4	1, 28, 10	14, 15, 1, 16	1, 19, 26, 24	35, 1, 26, 24	17, 24, 26, 16	14, 4, 28, 29
4	length of stationary object	12, 8	6, 28	10, 28, 24, 35	24, 26,	30, 29, 14		15, 29, 28	32, 28, 3	2, 32, 10	1, 18		15, 17, 27	2, 25	3	1, 35	1, 26	26		30, 14, 7, 26
5	area of mobile object	19, 10, 32, 18	15, 17, 30, 26	10, 35, 2, 39	30, 26	26, 4	29, 30, 6, 13	29, 9	26, 28, 32, 3	2, 32	22, 33, 28, 1	17, 2, 18, 39	13, 1, 26, 24	15, 17, 13, 16	15, 13, 10, 1	15, 30	14, 1, 13	2, 36, 26, 18	14, 30, 28, 23	10, 26, 34, 2
6	area of stationary object	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, 15, 17, 7
7	volume of mobile object	35, 6, 13, 18	7, 15, 13, 16	36, 39, 34, 10	2, 22	2, 6, 34, 10	29, 30, 7	14, 1, 40, 11	26, 26, 28	25, 28, 2, 16	22, 21, 27, 35	17, 2, 40, 1	29, 1, 40	15, 13, 30, 12	10	15, 29	26, 1	29, 26, 4	35, 34, 16, 24	10, 6, 2, 34
8	volume of stationary object	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	velocity	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, 35, 21	35, 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	force	19, 35, 18, 37	14, 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	tension/ pressure	10, 35, 14	2, 36, 25	10, 36, 3, 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	shape	4, 6, 2	14	35, 29, 3, 5		14, 10, 34, 17	36, 22	10, 40, 16	28, 32, 1	32, 30, 40	22, 1, 2, 35	35, 1	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
13	stability of composition	32, 35, 27, 31	14, 2, 39, 6	2, 14, 30, 40		35, 27	15, 32, 35		13	18	35, 24, 30, 18	35, 40, 27, 39	35, 19	32, 35, 30	2, 35, 10, 16	35, 30, 34, 2	2, 35, 22, 26	35, 22, 39, 23	1, 8, 35	23, 35, 40, 3
14	strength	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, 25, 2	27, 11, 3	15, 3, 32	2, 13, 25, 28	27, 3, 15, 40	15	29, 35, 10, 14
15	durabilty of mobile object	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, 10, 27	1, 35, 13	10, 4, 29, 15	19, 29, 39, 35	6, 10	35, 17, 14, 19
16	durability of stationary object	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	temperature	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	26, 2, 19, 16	15, 28, 35
18	lumination	32	13, 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, 1, 19	6, 32, 13	32, 15	2, 26, 10	2, 25, 16
19	energy consumption of mobile object	6, 19, 37, 18	12, 22, 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	energy consumption of stationary object			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	power	+	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	waste of energy	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	waste of substance	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, 40	10, 1, 34, 29	15, 34, 33	32, 28, 2, 24	2, 35, 34, 27	15, 10, 2	35, 10, 28, 24	35, 18, 10, 13	35, 10, 18	28, 35, 10, 23
24	loss of information	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	waste of time	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	35, 28	6, 29	18, 28, 32, 10	24, 28, 35, 30	
26	amount of substance	35	7, 18, 25	6, 3, 10, 24	24, 28, 35	35, 38, 18, 16	+	18, 3, 28, 40	13, 2, 28	33, 30	35, 33, 29, 31	3, 35, 40, 39	29, 1, 35, 27	35, 29, 25, 10	2, 32, 10, 25	15, 3, 29	3, 13, 27, 10	3, 27, 29, 18	8, 35	13, 29, 3, 27
27	reliability	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, 1	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	accuracy of measurement	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	manufacturing precision	32, 2	13, 32, 2	35, 31, 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, 18, 23	10, 18, 32, 39
30	harmful factors acting on object	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, 3, 34	22, 35, 13, 24
31	harmful side effects of the object	2, 35, 18	21, 35, 2, 22	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	manufacturability	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	operation convenience	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	25, 13, 2, 34	1, 32, 35, 23	2, 25, 28, 39		2, 5, 12	+	12, 26, 1, 32	15, 34, 1, 16	32, 26, 12, 17		1, 34, 12, 3	15, 1, 28
34	repairability	15, 10, 32, 2	15, 1, 32, 19	2, 35, 34, 27		32, 1, 10, 25	2, 28, 10, 25	11, 10, 1, 16	10, 2, 13	25, 10	35, 10, 2, 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	adaptabilty	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	complexity of device	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	complexity of control	18, 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	level of automation	28, 2, 27	23, 28	35, 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	productivity	35, 20, 10	28, 10, 29, 35	28, 10, 35, 23	13, 15, 23		35, 38	1, 35, 10, 38	1, 10, 34, 28	18, 10, 32, 1	22, 35, 13, 24	35, 22, 18, 39	35, 28, 2, 24	1, 28, 7, 10	1, 32, 10, 25	1, 35, 28, 37	12, 17, 28, 24	35, 18, 27, 2	5, 12, 35, 26	+

Education and Culture DG
Lifelong Learning Programme

5.6.4 Effects

Source:

G. Altshuller – Lev Shulyak, Steven Rodman, The Innovation Algorithm, TRIZ, Systematic Innovation and Technical Creativity, Technical Innovation Center, 2000)

Required effect or property	Physical phenomenon that provides the required effect or property
Measure temperature	Thermal expansion and its influence on the natural frequency of oscillations Thermoelectric phenomena Radiation spectrum Changes in optical. electrical and magnetic properties of substances Transition over the Curie point Hopkins, Barkhausen and Seebeck effects
Reducing temperature	Phase transitions Joule-Thomson effect Rank effect Magnetic calorie effect Thermoelectric phenomena
Increasing temperature	Electromagnetic induction Eddy current Surface effect Dielectric heating Electronic heating Electrical discharge Absorption of radiation by substances Thermoelectric phenomena
Temperature stabilization	Phase transitions, including transition over the Curie point
Object location	Introduction of makers; that is, substances that are able to transform existing fields (like luminophores) or generate their own fields (like ferromagnetic materials) and therefore are easy to detect Reflection and emission of light Photo effect Deformation Radioactive and X-ray radiation Luminescence Changes in electric or magnetic field Electrical discharge Doppler effect
Moving an object	Magnetic field applied to influence an object or magnet attached to the object Magnetic field applied to influence a conductor with direct current passing through it Electric field applied to influence an electrically charged object Pressure transfer in a liquid or gas Mechanical oscillations Centrifugal force Thermal expansion Pressure of light

Moving a liquid or gas	Capillary force Osmosis Toms effect Waves Bernoulli effect Weissenberg effect
Moving an aerosol (dust particles, smoke, mist, etc.)	Electrization Applied electric or magnetic field Pressure of light
Formation of mixtures	Ultrasonics Cavitation Diffusion Applied electric field Magnetic field applied in combination with magnetic material Electrophoresis Solubilization
Separating mixtures	Electric and magnetic separation Electric and magnetic field applied to change the pseudo viscosity of a liquid Centrifugal force Sorption Diffusion Osmosis
Stabilizating object position	Applied electric or magnetic field Holding a liquid by hardening through the influence of an electric or magnetic field Gyroscope effect Reactive force
Generating and/or manipulating force	Generating high pressure Applying a magnetic field through magnetic material Phase transition Thermal expansion Centrifugal force Changing hydrostatic forces by influencing the pseudoviscosity of an electroconductive or magnetic liquid in a magnetic field Use of explosives Electrohydraulic effect Optical hydraulic effect Osmosis
Changing friction	Johnson-Rabeck effect Radiation effect Abnormally low friction effect No-wear friction effect
Crashing objects	Electrical discharge Electrohydraulic effect Resonance Ultrasonics Cavitation Use of lasers

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Accumulating mechanical and thermal energy	Elastic deformation Gyroscope Phase transitions
Transferring energy through mechanical, thermal, radiation, or electric deformation	Oscillations Alexandrov effect Waves, including shock waves Radiation Thermal conductivity Convection Light reflection Fiber optics Lasers Electromagnetic induction Superconductivity
Influencing moving object	Applied electric or magnetic fields, with no influence through physical contact
Measuring dimensions	Measuring the natural frequency of oscillations Applying and detecting magnetic or electric makers
Varying dimensions	Thermal expansion Deformation Magnetostriction Piezoelectric
Detecting surface properties and/or conditions	Electrical discharge Reflection of light Electronic emission Moiré effect Radiation
Varying surface properties	Friction Absorption Diffusion Bauschinger effect Electrical discharge Mechanical or acoustic oscillation Ultraviolet radiation
Detecting volume properties and/or conditions	Introduction of markers; that is, substances that are able to transform existing fields (like luminophores) or generate their own fields (like ferromagnetic materials), depending on the properties of a material Changing electric resistance, which depend on structure and/or propertie variations Interaction with light Electro- and/or magneto-optic phenomena Polarized light Radioactive and x-ray radiation Electronic paramagnetic or nuclear magnetic resonance Magneto-elastic effect Transition over the Curie point Hopkins and Barkhausen effect Ultrasonics Moessbauer effect Hall effect

Varying volume properties	Electric or magnetic applied to vary the properties of a liquid (pseudoviscosity, fluidity) Influencing by magnetic field via introduced magnetic material Heating Phase transition Ionization by electric field Ultraviolet, X-ray or radioactive radiation Deformation Diffusion Electric or magnetic field Bauschinger effect Thermoelectric, thermomagnetic or magneto-optic effect Cavitation Photochromatic effect Internal photo effect
Developing certain structures, structure stabilization	Interference Standing waves Moiré effect Magnetic waves Phase transitions Mechanical and acoustic oscillation Cavitation
Detecting electric and magnetic fields	Osmosis Electrization Electrical discharge Piezo-and segneto-electrical effects Electrets Electronic emission Electro-optical phenomena Hopkins and Barkhausen effect Hall effect Nuclear magnetic resonance Gyromagnetic and magneto-optical phenomena
Detecting radiation	Optical acoustic effect Thermal expansion Photo effect Luminescence Photoplastic effect
Generating electromagnetic radiation	Josephson effect Induction of radiation Tunnel effect Luminescence Hann effect Cherenkov effect
Controlling electromagnetic fields	Use of screens Changing properties (for example, varying electrical conductivity) Changing objects shapes

Controlling light, light modulation	Refraction and reflection of light Electro- and magneto-optical phenomena Photo elasticity Kerr and faraday effects Hann effect Franz-Keldysh effect
Initiating and intensification of chemical reactions	Ultrasonics Cavitation Ultraviolet, X-ray and radioactive radiation Electric discharge Shock waves

5.6.5 Substance-and-Field Resources

Source:
G. Altshuller – Lev Shulyak, Steven Rodman, The Innovation Algorithm, TRIZ, Systematic Innovation and Technical Creativity, Technical Innovation Center, 2000)

Substance Resources

Waste
Raw materials and products
System elements
Inexpensive substance
Substance flow
Substance properties

Field Fesources

Energy in the system
Energy from the environment
Build upon possible energy platforms
System waste becomes system energy

Space Resources

Empty space
Another dimension
Vertical arrangement
Nesting

Time Resources

Pre-work
Scheduling
Parallel operations
Post work

Informational Resources

Sent by substance
Inherent properties
Moving information
Transient information
Change of state information

Functional Resources

Resources space within primary function
Using harmful effects
Using secondary generated functions

5.6.6 Glossary: Contradictions / Effects / Resources

Contradiction
One of the main TRIZ postulates and a decisive factor of an inventive task.
In general, opposed requirements to one and the same object.
Contradictions are divided into Administrative, Technical and Physical Contradictions.

Administrative Contradiction:
We speak about administrative contradiction when it is necessary to do something, but we do not know how to do it.
(contradiction between the needs and abilities)

Technical Contradiction:
We speak about a technical contradiction when we improve one part (or one parameter) of the technical system with the help of known methods, but that entails the worsening of other part (or the other parameter) of the technical system.
This contradiction is a conflict between characteristics within a system: improvement of one parameter of the system leads to worsening of another parameter
(an inverse dependence between parameters/characteristics of a machine or technology)

Physical Contradiction:
We speak about a physical contradiction when we impose mutually opposed requirements to the same parameter on one and the same part of the system.
(opposite/contradictory physical requirements to an object)

Inventive Principles / 40 Principles:
Altshuller identified 40 Principles that could be used to eliminate technical contradictions.

Separation Principles:
For overcoming a physical contradiction, there are four "physical" principles and a database of physical phenomenon and effects.

Contradiction Matrix / Altshuller Matrix
Developed by G. Altshuller.
The matrix suggests Inventive Principles to solve contradictions arising while trying to improve a feature or a characteristic of any product, process or system.

Technical Parameters / Characteristics
Altshuller also identified 39 parameters or characteristics of technical systems that can be used to develop and describe a technical contradiction. With these parameters we can use the Contradiction Matrix.

5.6.7 References - Contradictions / Effects / Resources

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