TOMSK POLYTECHNIC UNIVERSITY

# INVENTIVE PROBLEM SOLVING

*Recommended for publishing as a study aid*
*by the Editorial Board of Tomsk Polytechnic University*

*Draftsman* **O.B. Shamina**

Tomsk Polytechnic University Publishing House
2013

UDC 62:001.895(075.8)
BBC Ю251.20я73
S53

**Shamina O.B.**

S53 Inventive Problem Solving: study aid / O.B. Shamina; Tomsk Polytechnic University. – Tomsk: TPU Publishing House, 2013. – 98 p.

How to find new ideas? How to make the best and optimal decision? In this tutorial there are described different methods to enhance way of thinking when you try to find the solution in technical (design and manufacturing) and economical tasks.

The most important thing is to understand how the Inventive Problem Solving Theory (TRIZ) is working and now you can use specialized software when you need to leverage the total sum of human innovation knowledge.

Tutorial is intended for students who are interested in learning of innovation problem solving.

**UDC 62:001.895 (075.8)**
**BBC Ю251.20я73**

*Reviewers*

Doctor of Psychology, Professor of TSU

*O.M. Krasnoryadtseva*

Candidate of Technical Sciences
Director of OOO «Siberian machine building company»

*E.N. Pankratov*

# CONTENTS

## Preface

Contemporary engineer must have the competencies system set while working and making out decisions. The most important parts of his\her work are the following [1]:

- finding and assessing new technical and technological tasks,
- understanding the ways how people will use the devices, which he\she constructed, developed and made,
- foresighting the new device appearance in the market for the sales.

Thus, the activity of engineer depends on society needs, recognition of usefulness of inventions and understanding how these inventions can help people. In usual understanding the main engineering goal is design and manufacturing of technical system (TS), but it is very important to reduce the atonement factor such as defects, accidents, environmental contamination. Now the atonement factor foreknowledge prevails under the design significance.

Attainments and skills which make us possible to connect manufacturing and marketing, economic, psychology, and sociology are of great value in the engineer qualification. In the nearest future a specialist will be helpless without knowing analysis and prediction methods. Moreover in a world which is full of competition and opportunity, the people who are able to create their thinking are the ones who will succeed. This approach presupposes the up-to-date methods use that are of the great importance for the engineering education development and are entirely consistent with the update statements of CDIO (Conceive – Design – Implement – Operate) goals for engineering education [2].

This tutorial represents my rewritten and translated into English book "*Методы научно-технического творчества: синтез новых технических решений*", published in 2010.

Many thanks to my colleagues for their inventive tasks and articles about TRIZ, published in books and on the Internet sites. Special thanks to my students for their interest and enthusiastic work.

## Introduction

*The skill of the engineer is to know the moment when it is necessary to stop phenomena's learning and to begin their mastering.*

*Nortcot Parkinson*

Every day we face with necessity to solve different tasks – household, manufacturing, scientific, etc. These tasks may be simulating and real, simple and complex, typical and innovative. Some of them we are ready to understand and do because we know what method could be used. If we don't know we can find typical way in educational books and the Internet. On the other hand we can determine how this task has been done before us. We will have success if we have the method and an analogy.

Another situation when the task is not typical, creative and inventive. There is so much of unclearance, indefinitely – we don't have a clear statement of the problem, we don't have a method to solve this task, we don't have any examples and the result could be polysemantic. Often we can't see the problem itself. When everybody finds unconventional approach and does outstanding invention or discovery we exclaim – genius! Edward de Bono wrote: "There is no doubt that creativity is the most important human resource. Without creativity, there would be no progress, and we would be forever repeating the same patterns."

The idea to find effective methods for inventive problem solving appeared in ancient times. Firstly the term "evristica" can be met in works of the old Greek mathematician Pappus of Alexandria. The productions developed slowly and there would be time enough to think over inventions. The inventor could do mistakes and could loop through the potential query solutions assortment in order to select the best one. Everybody thought that invention is equal to the inspiration flash and for a long time the solutions could be found by trial and error. Ideas generated slowly and psychological inertia prevented to find the best way. It is psychological inertia that is guilty of trivial, unoriginal ideas. “It should come to us without surprise that the people who tend to be highly successful and rise above mediocrity, are often those who break the rules and restrictions that society has placed on us.”[1]

Of course, there can’t be without science-fiction writers. There were science-fiction writers who described discoveries in their books for a long time before discoveries. They catch inventor’s ideas which seem to be crazy. For example, stimulated emission amplifier, which was invented by soviet physicists N. Basov and A. Prochorov in 1955, was in details described in A. Tolstoy’s novel in 1927. Moreover, the first attempt to get laser light was in 1927.

On the other hand successful and safety regulator mechanism (scuba) was adapted to diving in 1864 with the help of French Navy officer Auguste Denayrouze. Even though it was independent from the surface for a very short duration, the Rouquayrol-Denayrouze apparatus reached worldwide celebrity after having been mentioned by Jules Verne in his adventure book *Twenty Thousand Leagues Under the Sea*; but Jules Verne wildly exaggerated its dive duration without external air supply.

The first part of this tutorial gives up the short story of invention.

XX century has changed not only the techno-sphere but also demanded new techniques to find and solve technical and management tasks. In the middle of the XX century a number of publications about several methods appeared in Europe and the USA. It is necessary to say about brainstorming (Alex Faickney Osborn), focal objects method, synectics (George M. Prince and William J.J. Gordon), and morphological analysis (Fritz Zwicky). For the first time techniques creators improved the possibility to control and manage via inventions. Today more than 200 different methods are used for engineering tasks solving.

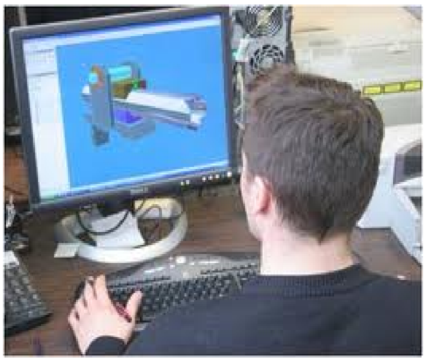
The second part is devoted to the most popular heuristic methods.

---

[1] Exforsys Inc. How to Enhance Your Way of Thinking. Published on 8th Mar 2009

In 1956 the magazine “The Question of Psychology” published the article devoted to the “invention’s technique”. The article authors were Raphael B. Shapiro and Genrikh S. Altshuller, a Soviet engineers, inventors, scientists, journalists and writers. G. Altshuller [3] analyzed the number inventions and understood that many ideas were several years late because their inventors used the trial and error method. G. Altshuller created the Theory of Inventive Problem Solving, better known by its Russia acronym TRIZ. For a long time G. Altshuller published articles about TRIZ, with examples and exercises, in the Soviet popular science magazine *Izobretatel i Ratsionalizator* (*Inventor and Innovator*). Altshuller played the intellectual leader role for the Soviet engineers and other technically inclined people in the 1970s. A number of his close friends and students have become the most prominent thinkers and teachers of the movement, popularizing TRIZ in Russia and abroad.

The third part of this tutorial is devoted to TRIZ.



At the end of the XX century scientists and engineers began actively use information technology (IT) in their practical work and the idea to create artificial intelligence for the new inventions generation has been extensively debated. There were made intelligence programs to help the developers to find new technical decisions [4]. You can find the analysis description with the IT help at the end of this tutorial in the fourth part and also you can find in the Internet the article called “IT-Focused Case Studies for I-TRIZ” by Chad Camara (University of South Carolina Upstate).

# Part 1. «Engineering»

## 1.1. Historical Reference

*Those who devoted their lives to the mystery of the History only they comprehend the present and begin to see clearly the future.*

*Pavel Cherevin,*
*Russian historian, XIX century*

The civilization history is the inventions history – not only of the new implementations, not only of the new devices or new building methods, but also, sad to say, mass destruction instruments.

Invention is the ancient human occupation. The process of shifting to a human itself is connected with the first implements invention such as pulley, lever, and wheel.

*Fig. 1.1. Pyramids in Egypt and Teotihuacán*

The precision forms of the pyramids in Egypt and Teotihuacán, the Mayan, Inca and Aztec Empires cities and pyramids affect the contemporary man imagination. In Giza, not far from modern Cairo, there are three huge geometrical objects – perfectly right four-sides pyramids known as the Great Pyramid of Giza (the Pyramid of Cheops or Khufu), the somewhat smaller Pyramid of Khafre (or Chephren), and the relatively modest-sized Pyramid of Menkaure (or Mykerinos). The most famous, is the Pyramid of Cheops (XXVII B.C.), still overtops any equal construction among stone buildings in the world: its height is 147 m; the founding length is 233 m. The pyramid consists of light golden limestone blocks. The blocks weight varies from 2.5 to 30 tons. Even today it is difficult to explain the accuracy of treatment and putting of these blocks[2].

The Great Pyramid is just the one of the Ancient World's Seven Wonders remained relatively intact. Wonders or "things to be seen" – like this the ancient travelers named the various lands landmarks and marvels, impressed by their view.

*Table 1.1. Seven Wonders of the Ancient World*[3]

| **Wonder** | **Date of construction** | **Builder** | **Date of destruction** |
|---|---|---|---|
| Great Pyramid of Giza | 2584–2561 BC | Egyptians | *Still in existence* |
| Babylon Hanging Gardens | Around 600 BC (evident) | Chaldeans | After 1st century BC |
| Artemis Temple at Ephesus | c. 550 BC | Lydians, Greeks | 356 BC (by Herostratus)<br>AD 262 (by the Goths) |
| Statue of Zeus at Olympia | 466–456 BC (Temple)<br>435 BC (Statue) | Greeks | 5th–6th centuries AD |
| Mausoleum at Halicarnassus | 351 BC | Carians, Greeks | by AD 1494 |
| Colossus of Rhodes | 292–280 BC | Greeks | 226 BC |
| Alexandria Light-house (Pharos of Alexandria) | c. 280 BC | Ptolemaic Egypt,Greeks | AD 1303–1480 |

You may find in different references that the Acropolis and the Parthenon in Greece, the Roman aqueducts, Via Apia and the Coliseum in Italy, the Great Wall of China are the Wonders too.

[2] The contemporary developers disagree about what are these three pyramids – the marks of humanity or the result of extra terrestrial life activity

[3] http://en.wikipedia.org/wiki/Seven_Wonders_of_the_Ancient_World

Now the World's Eighth Wonder was called the Sydney Opera House. There is a multi-venue performing arts centre in Sydney, New South Wales, Australia. It was conceived and largely built by Danish architect Jørn Utzon with using of unique technology.

*Fig. 1.2.*
*The Antikythera mechanism*

Ancient Greece developed machines in both in the civilian and military domains. The Antikythera mechanism, the earliest known model of a mechanical computer in history, and Archimedes mechanical inventions are early mechanical engineering examples. Some Archimedes' inventions as well as the Antikythera mechanism required sophisticated knowledge of differential gearing or epicyclical gearing, two key principles in machine theory that helped design the Industrial revolution gear trains and which are still widely used today in diverse fields such as robotics and automotive engineering.[4]

According to Wiki the term "engineering" itself has a much more recent etymology, derived from the word "engineer", which dates back to 1325, when an engine'er (literally, one who operates an engine) originally referred to "a constructor of military engines"[5]. In this context, now obsolete, an "engine" referred to a military machine. But the word "engine" itself is of even older origin, ultimately deriving from the Latin *ingenium*, and meaning "innate quality, especially mental power, hence a clever invention"[6].

With the word "ingenieur" is very similar another word in French – "ingénue", that means: naïve, simple-minded, sincere. Very similar, but how different translation is give and what is the new understanding about engineering – imagine how to do simply and clever!

In Russian there is another now obsolete word – "rozmusel". There were the town builders and guns foundry workers and bells name when Ivan the Terrible was the Tsar in Rus [5].

---

[4] Wright, M T. (2005). "Epicyclic Gearing and the Antikythera Mechanism, part 2". *Antiquarian Horology* **29** (1 (September 2005)): 54–60.

[5] Oxford English Dictionary

[6] Random House Unabridged Dictionary, © Random House, Inc. 2006.

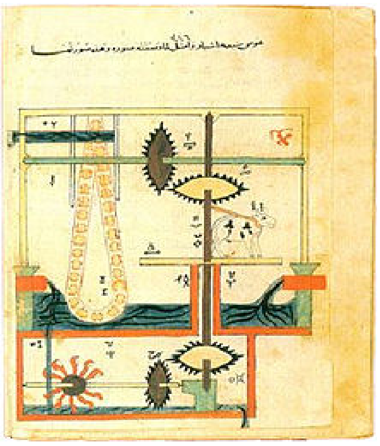


*Fig. 1.3. Al-Jazari's hudropowered chain pump device*

In different countries there were their own inventors, some of them are obscure, but several are famous and respected in time. Such as Al-Jazari, an Arab, who lived during the Islamic Golden Age and is the author of *The Book of Knowledge of Ingenious Mechanical Devices* (1206), where he described fifty mechanical devices along with instructions on how to construct them.

China has been a source of many inventions, including the four Great Inventions, such as papermaking, the compass, gunpowder and printing. Also the Chinese invented technologies involving mechanics, hydraulics and mathematics applied to horology, metallurgy, astronomy, agriculture, craftsmanship, warfare and so on. By the Warring States Period (403–221 BC), Chinese had advanced metallurgic technology, including the blast furnace and cupola furnace. A sophisticated economic system in China gave birth to inventions such as paper money. The gunpowder invention at the 10th century led to an inventions array such as the fire lance, land and naval mine, exploding cannonballs, multistage rocket.

*Fig. 1.4. A model in Kaifeng of a Chinese ladle-and-bowl type compass*

In Russia, Peter the Great, inspired and advised by Gottfried Leibniz, founded the Academy that was originally called The Saint Petersburg Academy of Sciences. Peter the First was concerned about the technical sciences development when founded the Academy. Among the foreign scholars invited to work at the academy there were the mathematicians Leonhard Euler, Nicolas and Daniel Bernoulli, physicist Georg Wolfgang Kraft and others.

*Fig. 1.5. Leonhard Euler, 1707–1783*

Leonhard Euler made important discoveries in fields as diverse as infinitesimal calculus and graph theory. He was also renowned for his work in mechanics, fluid dynamics, optics and astronomy. Euler was interested in such practice questions as the best ships' rigging and, by the way, at one time he purposed to be the Russian Fleet lieutenant. A statement attributed to Pierre-Simon Laplace expresses Euler's influence on mathematics: "*Read Euler, read Euler, he is the master of us all*."

In general, it must to be said, that the story of inventions is the human relations story.

## 1.2. The Inventions' Description

*...it seems to be that a genius is not so divine rare talent, it is a destiny of everyone who is not fully idiot.*

*Peter K. Engelmeier*

Psychologists made huge efforts to analyze inventiveness and creativity. Ability to create shall be seen as depending on

heritage,
environment,
overall development,
technical training level.

*Fig. 1.6. Théodule-Armand Ribot (1839–1916), French psychologist*

In XIX c. the French psychologist T. Ribot who did much to advance the subject in both its experimental and its clinical aspects, investigated the dependence between the imagination and the age levels. In accordance with the Ribots' observation the imagination peak fits to the interval between 12 and 15 years (picture 1.7).

The question about inventiveness is the question about the intellect – does intellect innate characteristic or acquired properties. Hans J. Eysenck, the author of the book "Know you own IQ" [6], best remembered for his work on intelligence and personality though he worked in a wide range of areas.

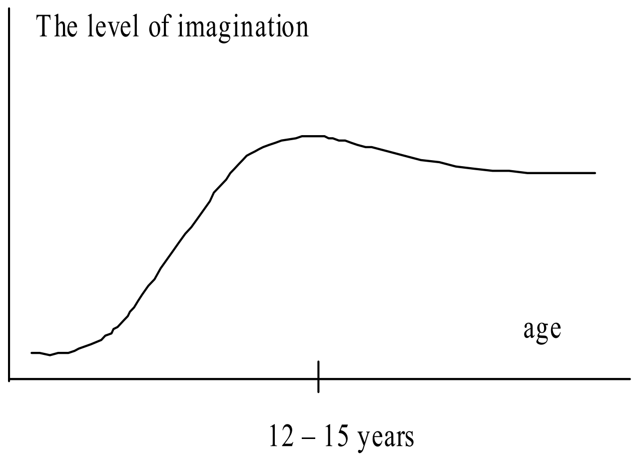



*Fig. 1.7. The dependance between the imagination and ages level*

Eysencks' investigations are the argument that innate characteristic influences more on inventiveness. During experiments with twins the heredity was identical, but surrounding environment changed. When investigating the children from orphan's home, whom life was the same, monitoring indicated different intelligence as usual children intelligence with different living conditions.

Psychologists have done different investigations to determine the most inventors peculiarities. There were found the following regularities:

- *There is meaningful dependence between an intelligence quotient, or IQ*[7] *and inventiveness, but the intellectual advance scope does not obligatory limit capability to create (it is necessary that* $IQ>IQ_{min,\ after}$ *that there is not proportional dependence).*

- *In accordance with the "rationality – feeling" scale by Carl Gustav Jung (USA) perceptional people are more inventiveness than the rational people. A rational person in new situation decides "how it should be" and "is it well or bad". What is this thing or phenomenon? How does it work All this is not interesting for rational person [7]. Jung concludes that people, trusting intuition, prone to be more inventiveness.*

---

[7] When modern IQ tests are devised, the mean (average) score within an age group is set to 100 and the standard deviation (SD) almost always to 15, although this was not always so historically. Thus the intention is that approximately 95% of the population scores within two SDs of the mean i.e. have an IQ between 70 and 130.

*Fig. 1.8. War and Peace by Jim Warren*

Perception is connected with observation and visual viewing which can be developed via arts lessons. To train observation means to sight on things, to understand their work, to find hidden components and functions.

Some ways to develop imagination are to describe environment on far fantastic planet, to paint fantastic animal, to read popular science books and so on.

## Part 2. Creative Approach Techniques

*The idea is genius only if it contains some sort of craziness.*

*Niles Bohr*

For a long time engineering way was an experimental way. When Charles A. Parsons[8], a British engineer, was asked by his friend about the Theory of relativity, Parsons answered: “I do not understand the Theory of relativity, but I don’t think that I’ve lost much by not understanding it. I find my decisions by the tips of my fingers”.

*Fig. 2.1.*
*Charles Algernon Parsons*

George Stephenson[9], the steam locomotives inventor and Michael Faraday, a British scientist, chemist, physicist and philosopher, behaved and thought the same way. M. Faraday had been walking with a magnet in his pocket for nine years before he found the way to turn magnetism to electricity.

It is necessary to say about Thomas Alva Edison (1847 – 1931), famous American inventor and businessman. He developed many devices that greatly influenced the life all over the world, including the phonograph, the motion picture camera and a long-lasting, practical electric light bulb. He was the one of the first inventors to apply the principles of mass production and large-scale teamwork to the invention process, and because of that, he is often credited with the creation of the first industrial research laboratory[10]. But Edison founded ideas on a base of practice: before he founded the charred bamboo

---

[8] Sir Charles Algernon Parsons (1854 –1931), a British engineer, best known for his invention of the steam turbine, worked as an engineer on dynamo and turbine design, and power generation, with great influence on the naval and electrical engineering fields. He also developed optical equipment, for searchlights and telescopes. (http://en.wikipedia.org/wiki/Charles_Algernon_Parsons)

[9] George Stephenson (1781 –1848), an English civil engineer and mechanical engineer who built the first public railway line in the world to use steam locomotives. Renowned as being the "Father of Railways". (http://en.wikipedia.org/wiki/George_Stephenson)

[10] http://en.wikipedia.org/wiki/Thomas_Edison

linen he looked over one thousand different materials when designing electric light bulb.

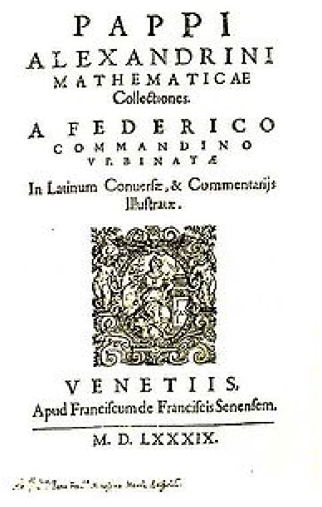
∢ *Nikola Tesla*[11] *worked in Edison laboratory and wrote "If Edison should find a needle in a hay stack, he did not lost time to determine the most probable place where a needle could be. He immediately with feverish assiduousness of bee should inspect a straw by straw before he found his search object. His techniques are ineffective: he can spend significant amounts of time and achieve nothing, if a chance did not help him. Firstly I watched him with sadness. I understood that a bit of creative knowledge and calculations could have saved him 30% of his labor. But how bitter was his scorn to the education and mathematician knowledge book! He wholly trusted his own inventor's flair and American's common sense" [8].*

∇ Such creativity technique (or "trial and error" technique) not only leads to huge loss of time and force, but is ineffective in contemporary situation.

## 2.1. Heuristic

Many years ago it was observed that the way is clear when the task is solved. Accordingly there appeared a thought about regulation of searching and science making about creative tasks solving.

Firstly the term *Evristica* appeared in *Collection* of the old Greek mathematician Pappus of Alexandria[12]. Pappus lived in the 3rd century and was one of the last great Greek mathematicians of Antiquity, known for his *Collection*, and for Pappus's Theorem in projective geometry. Moreover he was a teacher in Alexandria. *Collection*, his best-known work, is a compendium of mathematics in eight volumes, the bulk of which sur-


PAPPI
ALEXANDRINI
MATHEMATICAE
Collectiones.
A FEDERICO
COMMANDINO
VRBINATE
In Latinum Conuersæ, & Commentarijs
Illustratæ.

VENETIIS.
Apud Franciscum de Franciscis Senensem.
M. D. LXXXIX.

*Fig. 2.2. Title page of Pappus's Mathematicae Collectiones*

---
11 Nikola Tesla (1856 – 1943), a Serbian inventor, physicist, mechanical engineer, electrical engineer and futurist. He is the best known for developing the modern alternating current electrical supply system. (http://en.wikipedia.org/wiki/Nikola_Tesla)

12 http://en.wikipedia.org/wiki/Pappus_of_Alexandria

vived. It covers a wide topics range, including geometry, recreational mathematics, doubling the cube, polygons and polyhedra. Heuristic was a scientific term about inventions and discovery's making. Rene Descartes, Gottfried W. Leibniz, Bernhard Bolzano, Jules H. Poincaré made their own contribution in Heuristic creation. It was Peter K. Engelmaier, an engineer and engineering philosopher, who made serious contribution to the engineering science development.

*Fig. 2.3. Vercingetorix Surrenders to Caesar, by Lionel Royer*

Heuristic's developers and followers had a goal to find universal regulations for different kinds of creativity. Meanwhile the goal was general, and then it was a halting making of inventions but keeping up with demand. Moreover technicians did not want to take into account creativity's psychological features and psychologists did not take into consideration science and engineering development laws. All attempts to create anyone sketches were as Julius Caesar's expression: "Veni.Vedi.Vici."

A Hungarian Jewish mathematician G. Pólya[13] spent considerable effort on trying to characterize the methods that people use to solve problems, and to describe how problem-solving should be taught and learned. He wrote about heuristic in 1944: "…so was called not clearly described investigation area that was concerned or logics or philosophy or psychology. Heuristic was often characterized generally, was rarely described in detail and is off the map now." In 1945 in his book "How to solve it", Pólya provides general heuristics for solving all kinds of problems, not only the mathematical ones. The book includes advice for teaching students mathematics and a heuristic terms mini-encyclopedia. Here are a few commonly used heuristics, from book "How to solve it":

---

[13] George Pólya (1888 –1985) a professor of mathematics at Stanford University. He made fundamental contributions to combinatorics, number theory, numerical analysis and probability theory. He is noted for his work in heuristics and mathematics education.

If you are having difficulty understanding a problem, try to draw a picture.

If you can't find a solution, try to assume that you have a solution and see what you can derive from that ("working backward").

If the problem is abstract, try to examine a concrete example.

Try to solve a more general problem first (the "inventor's paradox": the more ambitious plan may have more chances of success).

Heuristic was forgotten when cybernetics and computer allowed to realize possibilities enumeration but then necessity to choose variants in accordance with attributes forced to remember about heuristic. Today the heuristics fund consists of 140 different modifications. Table 2.1 contains the heuristics' groups classifications example.

*Table 2.1*

*Fund of heuristics*

| № of group | Name of group | Number of heuristics |
|---|---|---|
| 1. | Object form and structure transformation | 17 |
| 2. | Transformation in space | 17 |
| 3. | Transformation in time | 8 |
| 4. | Force and moving transformation | 14 |
| 5. | Material and substance transformation | 18 |
| 6. | Differential ways | 12 |
| 7. | Integration ways | 8 |
| 8. | Using of prophylactic actions | 16 |
| 9. | Reserve using | 10 |
| 10. | Transformation with analogy | 11 |

A.I. Polovinkin provides illustration for working with fund of heuristics in his book[14] "The Laws of Technics Structure and Development" [9].

[14] in Russian it sounds as "Zakony stroenia i razvitia techniki"

## 2.2. Questions' Technique Control

*In order to ask correctly, it is necessary to know majority of answers.*

*Robert Sheckley*

Questions' Technique Control may be considered to be the one of the heuristics directions. The most ancient and famous Control Questions' Technique is the Socratic Method or *elenchus*. This technique remains a commonly used tool in a wide discussions range and is a pedagogy type in which a series of questions are asked not only to draw individual answers, but also to encourage fundamental insight into the issue at hand. Socrates could ask so smartly during dialog that the speaker got the truth answering the question.

Questions' Technique Control allows searching task in the earnest. A goal is to find task solution with the leading questions help. Inventor answers the questions and analyses his\her task. It helps him\her to understand the system problem. A. Osborn, T. Eiloart, G. Pólya compiled universal question lists. There are notes for inventors, the ways for thoughts may be used. Master of brainstorming can use those question lists.

In 1965 American magazine "Product engineering" edited the next list of questions for inventors:

1. How was this problem solved in the past? Was it in the ancient engineering era? Is it possible to solve this problem in the future?
2. Was there anything created in anyone's engineering field in the past?
3. Can we divide an object on detail? To change the operations sequence?
4. How could we solve this problem under the water? In space?

The famous questions list by A. Osborn consists of nine questions groups:

1. What new technical object application you can request? Are there any possibilities to use new ways of application? How can we modify the known application method?
2. Can we decide an inventive task via adaptation, simplification, reduction? What does this object resemble to you? Can there appear smth. new e.g. analogical idea? Did you have the analogical problem in past? What can you copy? What technical object is it necessary to outstrip?

3. Which modification possibilities there can be? Can it be modified by turning, bending, stranding, and swerving? Is it possible to change purpose, function, color, movement, shape, smell? Are there any other changes applicable?
4. What can be increased? What parts can be joined? Is it possible to increase durability? When does the increase of frequency, strength, and quality make sense? Is it possible to multiply operating devices, other elements?
5. What can be decreased or changed? Can one join, press, thick, miniaturize, short, narrow, break, and separate?
6. What can be changed? What parts and to what extend could be changed? – is it possible to use another material, another process, another generation, another color, sound, illumination?
7. What can be transformed in technical object? Can we reverse reason and effect, change velocity, conditions?
8. What can be rearranged? Can we interchange elements, back to front or turn around them? Can we invert polarity?
9. Which new elements combination is possible? Can we create new mixture, allow, composition, variety? Is it possible to combine sections, blocks, aggregates? Can we get new ideas, shows?

At the end of the 20-th century the Department of the Interior in the USA recommended to corporations to use the improved techniques system. It was suggested to answer on the following questions: Can we make this operation simpler? Can we improve the work?

An English inventor T. Eiloart[15] made the most full and successful question list [10]:

1. To enumerate all qualities and invention definitions. To transform it.
2. To formulate the task clearly. To attempt to reformulate the task. To mark out the main tasks. To determine secondary and accessory tasks.
3. To enumerate real solving imitations.
4. To find fantastic, biological, economical and others analogies.

---

[15] Tim Eiloart (1936 - 2009) was unwittingly crucial in driving the so-called "Cambridge phenomenon", manifested by the dozens of hi-tech companies. In 1960, he founded Cambridge Consultants Ltd (CCL), the first independent UK contract research and development company

5. To construct a mathematician, hydraulic, electronic, mechanical and others models (model more expresses an idea than analogy).
6. Try to use:
   different materials: a gas, a liquid, a solid, a foam, a paste and so on;
   different types of energy: warm, magnet energy, light, impact value;
   Various wave lengths, surface's quality;
   transient conditions: freezing, condensation, Curie peak and so on;
   Joule-Thomson, Faraday's effects etc.
7. To establish relations variants, possible connections, logical coincidence.
8. To know under-briefed people' opinion.
9. To make group discussion, listen to all ideas without critics.
10. To use "national" decisions: sly Scottish, comprehensive German, extravagant American, complex Chinese etc.
11. To sleep with problem, go to work, walk, take bath, drink, eat, play tennis – all with this task!
12. To ramble among create incentives (scrap damp, technical museum, low-price things store), to look through magazines, comics.
13. To construct a price table, volumes, materials, shifts, various problem solving, try to find the problem in decisions, to search after new combinations.
14. To determine ideal decision.
15. To change decision in time (faster – slower), in length (greater – smaller) etc.
16. To situate inside mechanism in imagination.
17. To determine alternative problems and systems, that delete link of chain and create new one.
18. Whose is the problem? Why him?
19. Who was the first? The history of the question. What were the false problem interpretations?
20. Who solved this problem? What did he do?
21. To determine conventional restrictions and restrictions' establishment causes.

---

(http://www.guardian.co.uk/education/2009/may/28/obituary-tim-eiloart)

There also exists the G. Pólya's question list. Question lists compose such a determine system, where questions cannot be changed. Pólya's list can be used mainly for solving mathematician tasks [11].

S. I. Churumov and E. S. Dgarikov [12] created their own selfstorming technique**,** where questions are different "operators": for example, common operator, particular case operator, fantastic operator, practice operator (where it is necessary to determine idea use practical sphere) and so on.

∇ In accordance with their own inventive experience authors choose the strongest questions and Control Questions'. This Technique is a better "trial and error" technique improvement. Then it is more preferable to use this technique for tasks solving, when any idea has come to your mind.

## 2.3. Brainstorming

For a long time "trial and error" technique was considered the single inventions technique. In 1953 A. Osborn made an attempt to improve "trial and error" technique and created brainstorming. He divided ideas' generation and analysis processes. Today there are more than ten such techniques types.

Brainstorming – psychological technique, but the author A. Osborn was not a psychologist. His top achievement was a work in advertising firm and he tried to find new ideas for advertising campaign. He created brainstorming and used it in advertising field. Understanding that it is necessary to divide ideas' generation process from reviewing process is such a technique milestone. Under ideas' discussion many people do not dare to express new ideas because of the sneers fear. If unexpected supply is expressed, other participants attack it and the idea dies without development.

Certainly the division on groups is of relative nature since it depends to a very large extent on the critics' behavior, but it is possible to re-collect ideas generators and "nearly dreamer". Such selection plus prohibition on criticism, then an arrangement to support and to develop any suggestions set up a facility for courageous and uncommon ideas. Osborn requested to generate ideas under conditions without critics and to encourage any suggestion.

A little and motley "ideas generators" group is chosen to organize brainstorming. Top-managers are not included in this group. All ideas are written and after that materials are handed over to experts group for further valuation and selection.

"Craft council" is the brainstorming predecessor and it is known from the Age of Discovery. Under complex conditions a captain put together his team and gave the floor to everyone. The first was a sailor boy. It was the best way to provide captain by ideas before he took the floor.

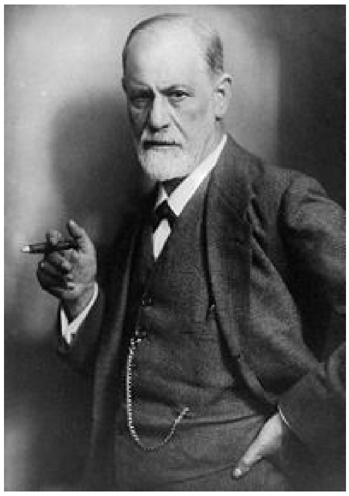


*Fig. 2.4.*
*Sigmund Freud,*
*by Max Halberstadt, 1921*

Another brainstorming source is the Sigmund Freud[16] philosophy concept. He developed therapeutic techniques such as the free association use in which patients report their thoughts without reservation and make no attempt to concentrate while doing so. Also in his later work, Freud proposed that the human psyche could be divided into three parts: Id, ego, and super-ego. The super-ego is the psyche moral component, which takes into account no special circumstances in which the morally right thing may not be right for a given situation. The rational ego attempts to exact a balance between the Id and the super-ego; it is a psyche part that is usually reflected most directly in a person's actions. This model represents the roles the Id, Ego, and Super Ego play in relation to conscious and unconscious thoughts. Freud compared the relationship between the ego and the id to that between a charioteer and his horses: the horses provide the energy and drive, while the charioteer provides direction.[17]

In accordance with Freud consciousness is thin and weak layer over sub consciousness chasm. Spontaneous forces and sub consciousness instinct burst the thin consciousness bounder and instigate man to illogical actions, and taboos breaking. For successful ideas generation it is necessary to overcome psychological inertia and create conditions for irrational ideas break from sub consciousness.

[16] Sigmund Freud (1856 –1939), a Jewish Austrian neurologist, who founded the discipline of psychoanalysis.

[17] http://en.wikipedia.org/wiki/Sigmund_Freud

Imagine the search field as plane. The "trial and error" technique will be as in Fig. 2.5 and brainstorming – as in Fig. 2.6. Here VI is a psychological inertia vector[18], and as a rule this vector directs opposite with a solution.

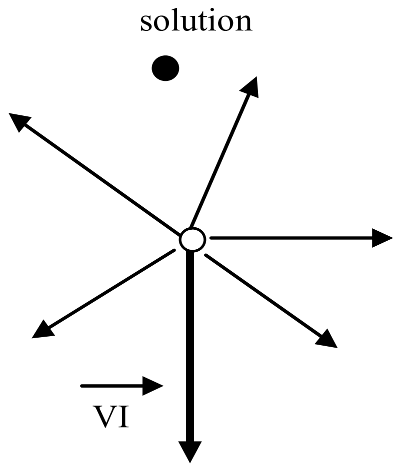



*Fig. 2.5. The searching field – trial and error technique*

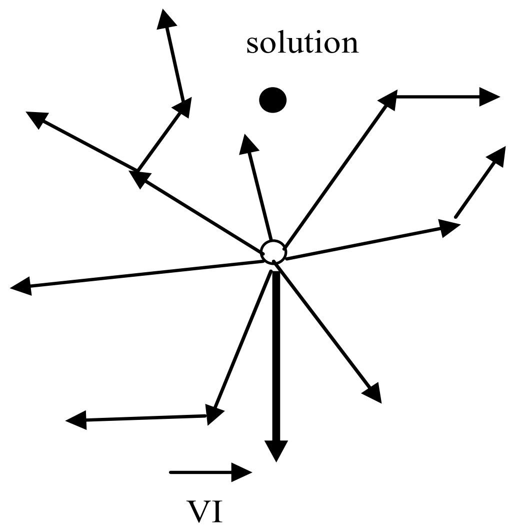



*Fig. 2.6. The searching field – brainstorming*

∇ As it is seen from the pattern, brainstorming doesn't not significantly different from trial and error technique because of the unsystematic searching.

[18] About psychological inertia see 3.4 in this tutorial

## 2.4. Synectics

*It is necessary to have a great ability for being a metaphor master.*

*Aristotle*

The brainstorming force is in the criticism prohibition. On the other hand it is necessary to find out all shortcomings for idea's development. It means that in any case we do need criticism. George M. Prince and William J.J. Gordon[19] overcame this contradiction by forming and teaching special groups. Groups' participants gradually began to enjoy working together, without having a fear of criticism. Within time the problem solving experience increases. Gordon managed to streamline the task solving process and save brainstorming spontaneity [13–15].

Gordon supposed that creativity could be perceived and improved. It is necessary to study, to organize the creativity' process and to use special methods.

According to Gordon there exist two creativity mechanisms:

- uncontrolled processes – intuition, inspiration etc.;
- operating processes (different analogies use).

Operating processes use provides the creative efficiency increase and creates uncontrolled processes facility. It is important to understand task because primary conditions may be unclear.

The term *synectics* is of the Greek origin and it means "different elements joining together and even apparently irrelevant elements". The thing is to solve a new problem via usual and already known way. On the other hand it is important to have fresh view on usual things. Synectics is brainstorming with the analogies use, i.e. solving task by analogy finding way in different knowledge fields or object behavior investigation under other conditions up to the fantastic ones [16].

The synectics procedure[20] (Fig. 2.7) is a comprehensive creative procedure, containing problem analysis techniques, ideas generation and the selec-

[19] Method was developed by George M. Prince (1918–2009) and William J.J. Gordon (1919–2003), originating in the Arthur D. Little Invention Design Unit in the 1950s. They set up Synectics Inc. (now Synecticsworld) in 1960 and the methodology has evolved substantially in the ensuing 50 years. (http://en.wikipedia.org/wiki/Synectics)

[20] http://www.wikid.eu/index.php/Synectics

tion stage. Synectics concentrates on the idea's generation steps with the analogy use. Analogies allow us to move away from the original problem statement and make a forced fit to further development solutions on these analogies basis. The synectics procedure is also based on the (1) preparation, (2) incubation, (3) illumination and (4) verification (Wallas, 1926) processes. The incubation and illumination stages are now brought about through the analogies use: 'To make the strange familiar and the familiar strange'. Ability to make the strange familiar and on the contrary the familiar strange is very important for creativity.

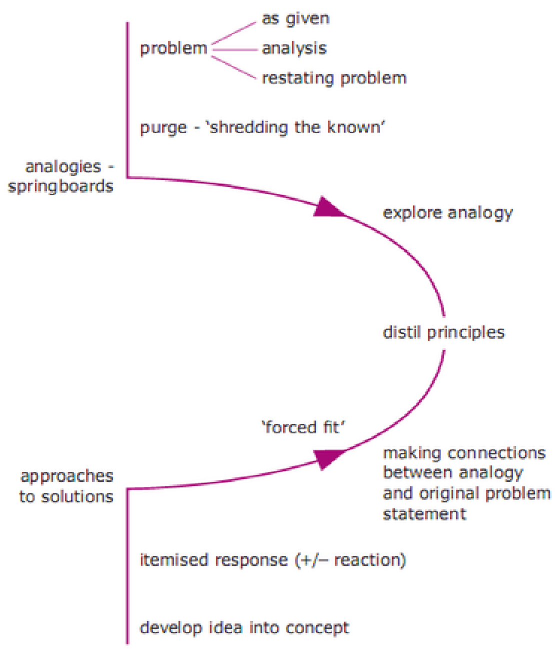



*Fig. 2.7. The Synectics process (Tassoul, 2006)*

In the preparatory stages, there is a problem briefing by the problem owner, an extensive problem analysis phase through questioning the participants, and definition of a problem statement into 'one single concrete target'. After this, a purging phase takes place in which known and immediate ideas are collected and recorded. This phase is also called 'Shredding the Known'. From this point on, the analogies are used to estrange you from the original problem statement and come up with inspirations for the new solutions and approaches. These analogies take a number of forms that are presented in table 2.2.

*Table 2.2*

*Type of analogies that can be used in Synectics (Tassoul, 2006)*

| **Types of analogies** | **Comments** | **Example** |
|---|---|---|
| **Direct Analogy** | Starting from some aspect in the problem, one looks for comparable or analogous situations | For a time pressure problem, take for example 'ships in a busy harbor'. How do they maneuver without incidents? |

*End of Table 2.2*

| Types of analogies | Comments | Example |
|---|---|---|
| **Personal Analogy** | What if you were an element in the problem, e.g. a planning problem? | Imagine you are the time. How would you feel? Maybe pressed. How would you influence the situation from such a perspecive? |
| **Nature Analogy** | What kind of situations in nature does this remind me about? | E.g. an anthill, or the jungle with all the animals closely together, lungs and blood stream and all the gaseous matter that needs to be transported through the body. |
| **Fantastic Analogy** | Can you place the problem in a fairytale or other mythical situation and develop it from there? | How does the Nautilus withstand the pressure at 2000 miles under the sea, and what did the people aboard the Nautilus do? (thinking of Jules Verne's "20.000 miles under the seas") |
| **Paradoxical Analogy** | Characterize the issue in two words which are each other's opposites. | For example: blind open-mindedness, or overwhelming silence. |

**Direct Analogy** means any analogy search– technical, natural, cultural etc. Decision appears as a result of real technical matching of the object or similarity finding between different objects.

Technical analogies searching can be at:

- similar engineering fields,
- engineering leading branch– in accordance with the task conditions,
- in engineering branches where there are great solving similar tasks experience,
- in engineering branches where similar tasks are solving under more stringent conditions.

The next Pólya questions are used for rational analogs search:

- Have we ever seen such task in another form? Do we know any related tasks?
- Is it necessary to understand what is unknown in task and try to remember the task with similar unknown items?
- We have the similarly solved task. Can we use this task or the result of this task?

- If we cannot solve this task it is necessary to solve similar task. Can we give an idea of another similar task?

There can be used direct analogy different forms.

*Exterior form analogy* – it is necessary to find object analog on exterior form or new object is making similar to another object on exterior form. For example usual table and PC table.

*Structure analogy* – it is necessary to find analog objects' structure in surrounded world, this structure have to repeat components interaction by the best way. For example, the Universe atomic structure.

*Functional analogy* – it should determine the object functions and find who or what performs such functions (in engineering, in nature, in art etc.).

*Situation analogy* – searching of different objects phases. For example, water could be soft – as liquid and hard – as ice.

*Properties analogy* – it should answer on questions *which?* For example, a ball – which is? Rubber. Analogy: teat, bathing cap. A ball – which is? Flexible. Analogy: umbrella, wind, stream.

*Associative garlands analogy* – garlands are formed as words list: new word is formed as the previous word analog.

**Personal analogy (PeA)** is the strongest analogy type. The researcher tries to identify it with an object and analyses any arising sensations. The main idea is to become someone or something for understanding inner communications, interaction between system parts and system connection with surrounding objects.

PeA particular case is *modeling with little men* (MLM). MLM allows to see and to sense obvious system elements interaction, cooperation and its objects. It is necessary to imagine that system consists of little men which can think, move, act, have different characters and habits and can obey to different orders. Put yourself in the place of these little men in order to sense and understand the object's structure threw actions, sensitive and interaction between little men.

**Nature Analogy (NA)** means that it is necessary to search the shape, principles of operation and so on in the Nature. Today such science as bionics has become wide spread.

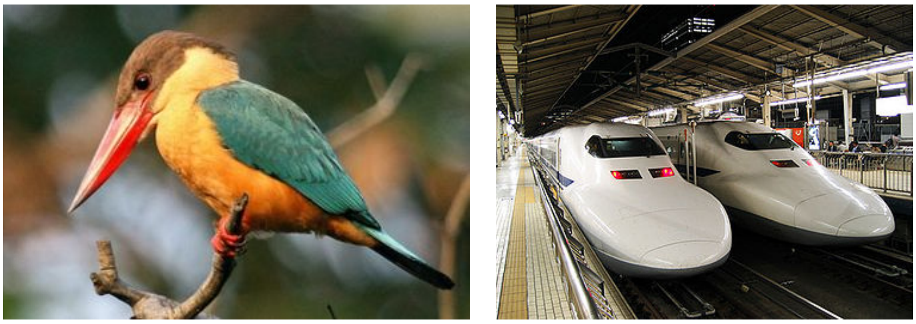


*Fig. 2.8. Example of a nature analogy[21]:*
*King Fisher and Shinkansen Bullet Train*

**Fantastic Analogy (FA)** presupposes task formulation in the terms of tales, myths, legends. It is necessary to imagine ideal object without possibilities and validities (lack of human and financial resources, lack of power sources etc.). FA use permits to overcome psychological inertia and find a new way for task solving.

**Paradoxical Analogy (PaA)** is the object poetic imagery, metaphor, which uncovers object properties. PaA is the technique for "unfreezing of understanding words and ways". Object in this case is determined through metaphor paradoxical form. Skill to determine the real object as image, symbol and mark permits us to identify real and cover object properties, its advantages and disadvantages.

An *oxymoron*[22] is the PaA elder brother. Oxymoron is a speech figure that combines contradictory terms. Oxymorons appear in a variety of contexts, including inadvertent errors such as *ground pilot* and literary oxymorons crafted to reveal a paradox.

The most common oxymoron form involves an adjective-noun two words combination. For example, the following line from Tennyson's *Idylls of the King* contains two oxymora:
*"And faith unfaithful kept him falsely true."*

---

[21] http://www.wikid.eu/index.php/Synectics
[22] An **oxymoron** (plural **oxymorons** or **oxymora**) - from Greek ὀξύμωρον, "sharp dull"

Other kinds of oxymora examples are

- Dark light,
- Living dead,
- Open secret,
- Original copy,
- Guest host (also: Permanent guest host),

or such types of definition as

- marble – hard inconstancy;
- cloud – light gravity, air water, opaque vacuum.

One case where many oxymora are strung together can be found in Shakespeare's *Romeo and Juliet*, where Romeo declares:

*"O heavy lightness! Serious vanity!*
*Mis-shapen chaos of well-seeming forms!*
*Feather of lead, bright smoke, cold fire, sick health!"*

For the new solution possibilities assessment, the synectics approach introduces another special technique: 'itemized response'. For every idea there are both good sides (the pluses) and poor or bad sides (the minuses). By breaking down the idea into pluses and minuses and then trying to turn the minuses into pluses (for example, through a creativity method), the original idea may be – systematically – transformed into a better one.

- *The above mentioned variation is visual synectics: quiet images and music are introduced to induce an incubation phase. Music and images let people quietly simmer away, daydream on the images and on the music. This is done for some length of time after which there comes a switch to much more active music and images on the basis of which the participants now have to generate ideas, similar to the brainstorming or brain writing.*

**Possible Synectic Procedure:**

1. Start with the original problem statement. Invite the problem owner to briefly present and discuss the problem.
2. Analyze the problem. Restate the problem. Formulate the problem as one single concrete target.
3. Generate, collect and record the first ideas that come to mind (shredding the known).
4. Find a relevant analogy in one of the listed analogies categories (personal, nature, fantastic, etc.).
   Ask yourself questions in order to explore the analogy. What problem type occurs in the analogous situation? What solutions types are there to be found?
   Force the appropriate various solutions to the reformulated problem statement.
   Generate, collect and record the ideas.
   Test, and evaluate the ideas. Use the itemized response method to select among the ideas.
   Develop the selected ideas into concepts.
   Present your concepts in a manner that is close to the point.

∇ It is better to apply Synectics for extremely complex and intricate problems. Synectics can be used in groups as well as individually. With an untrained group, the facilitator will have to work in small steps at a time; he or she must have enough experience to inspire the group through such a process.

## 2.5. Morphological Analysis

It is “Arc magna” that is considered as the morphological analysis prototype for problem solving. Raymond Llull[23] (1232-1315) Ars Magna (or Ars Generalis Ultima) is an astonishing attempt to systematise all possible knowledge using a rigorous computational procedure.

*Fig. 2.9.*
*Raymond Lull*

Around 1275, Llull designed a method, which he first published (in full) in his *Ars generalis ulti-*

[23] http://en.wikipedia.org/wiki/Ramon_Llull

*ma* or *Ars magna*, combining religious and philosophical attributes selected from the lists number. It is believed that Llull's inspiration for the *Ars magna* came from observing Arab astrologers's device called zairja.

It was designed as a debating tool for Muslims victory over the Christian faith via logic and reason. As his detailed analytical efforts result, Llull built an in-depth theological reference by which a reader could enter in an argument or question about the Christian faith. The reader would then turn to the appropriate index and page to find the correct answer.

For this purpose Llull also invented numerous 'machines'. One method is now called the *Lullian Circle*[24], which consisted of two or more paper discs inscribed with alphabetical letters or symbols which referred to the attribute lists. The discs could be rotated individually to generate a large number of ideas combinations. A number of terms, or symbols relating to those terms, were laid around the full circle circumference. They were then repeated on the inner circle which could be rotated. These combinations were said to show all possible truth about the circle subject. Llull based this on the notion that there were a limited number of basic, undeniable truths in all knowledge fields and that we could understand everything about these knowledge fields by studying these elemental truths combinations.

*Fig. 2.10. Arc magna. Figure 1*

The method was an early attempt to use logical means to produce knowledge. Llull hoped to show that Christian doctrines could be obtained artificially from the fixed preliminary ideas set. For example, one of the tables listed the God attributes: goodness, greatness, eternity, power, wisdom, will, virtue, truth and glory. Llull knew that all believers in the monotheistic religions – whether Jews, Muslims or Christians – would agree with these attributes, giving him a firm platform from which he could start to argue.

The idea was developed further by Giordano Bruno in the 16th century and by Gottfried Leibniz in the 17th century for investigations into the science philosophy. Leibniz gave Llull's idea the name *Ars Combinatoria*, by which it is now often known. Some computer scientists have adopted Llull as

[24] http://lullianarts.net/downloads.htm

a sort of founding father, claiming that his logic system was the information science beginning.

In contemporary form General Morphology[25] was developed by Fritz Zwicky[26], Among others, Zwicky applied Morphological Analysis (MA) to astronomical studies and the development of jet and rocket propulsion systems.

- *Zwicky created tens variants of new jet and rocket propulsion systems, among them there were decision, reiterated such German rocket systems as the V–1 and V–2 flying bombs.*

As problem-structuring and problem-solving technique, MA was designed for multi-dimensional, non-quantifiable problems where causal modeling and simulation do not function well, or at all. Zwicky developed this approach to address seemingly non-reducible complexity: using the cross-consistency assessment (CCA) (Ritchey, 1998) technique, the system allows reduction by identifying the possible solutions that actually exist, eliminating the illogical solution combinations in a grid box rather than reducing the number of involved variables.

The conventional approach here would be used to break the system down into parts, isolate the vital parts (dropping the 'trivial' components) for their contributions to the output and solve the simplified system for creating desired models or scenarios. This method disadvantage is that real-world scenarios do not behave rationally: more often than not, a simplified model will break down when the 'trivial' components contribution becomes significant. Also, importantly, many components behavior will be governed by the states and their relations with other components – those that can be seen as the minor ones before the analysis.

---

[25] http://en.wikipedia.org/wiki/Morphological_analysis_(problem-solving)

[26] **Fritz Zwicky** (1898 –1974) was a Swiss astronomer. He worked most of his life at the California Institute of Technology in the United States of America, where he made many important contributions in theoretical and observational astronomy. (http://en.wikipedia.org/wiki/Fritz_Zwicky)

In a simple case, there can be built two dimensional morphological maps with two main system characteristics. Then there should be made the forms and types list of these characteristics and the table with axes. The new system variants are the table cells meaning.

For example, there should be offered a new products package. One table axis is 20 types of materials (metal, wood, carton, plastic etc.), another axis is 20 shapes (solid, flexible, reticular etc.). The result is the table with 400 package variants.

The MA examples are: Mendeleev's Periodic Table, different databases, Multiplication table.

At Ufa State Aviation Technical University (USATU) was created the metalworking processing morphological model (table 2.3).

*Table 2.3*

*The Metalworking Processing Morphological Model*

| **№ of sign** | **Sign** | **№ meaning of sign** | **Alternative meaning of signs** |
|---|---|---|---|
| 01 | product matter change (transformation)type | 01<br>02<br>03<br>04<br>05<br>06 | form change<br>volume change<br>property change<br>form and volume change<br>form and property change<br>form & volume & property change |
| 02 | product's matter aggregate state type, that is deleted during manufacturing process | 01<br>02<br>03<br>04<br>05<br>06 | solid<br>fluxed<br>ionized<br>fluid<br>chemically coherent<br>matter is absent |
| 03 | physical & chemical effect in transformation base | 01<br>02<br>03<br>04<br>05<br>06 | diffusion<br>erosion<br>anode dissolution<br>water hammering<br>sintering<br>electrolysis of solution/liquid |

*End of Table 2.3*

| № of sign | Sign | № meaning of sign | Alternative meaning of signs |
|---|---|---|---|
| 04 | power type for physical & chemical effect | 01<br>02<br>03<br>04<br>05<br>06<br>07 | thermal<br>mechanical<br>proof resilience<br>electrical<br>chemical<br>nuclear<br>electromagnetic |
| 05 | power admission and distribution character during transformation | 01<br>02<br>03 | point<br>linear<br>surface |
| 06 | power character in time | 01<br>02 | continuous<br>pulse |
| 07 | workspace physical state type | 01<br>02<br>03<br>04<br>05 | liquid<br>gaseous<br>solid<br>viscous / fluid<br>vacuum |
| 08 | tool physical state type | 01<br>02<br>03<br>04 | solid<br>liquid<br>gaseous<br>viscous / fluid |
| 09 | tool movement during transformation | 01<br>02<br>03<br>04 | rotation<br>progressive<br>rotation & progressive<br>motionless |

∇ Morphological Analysis does not drop any of the components from the system itself, but it works backwards from the output towards the system internals. Again, the interactions and relations get to play their parts in MA and their effects are accounted for the analysis. Morphological Analysis enables us to get various elements, signs, properties combinations mass.

## Part 3. Inventive-Problem Solving Theory

*Everything should be made as simple as possible, but not simpler…*

*A. Einstein*

There are a lot of Heuristic techniques but they saved within the trial and error technology. This is a reason why it is difficult to choose *optimal* decision when we are dealing with a challenging task.

Inventive-Problem Solving Theory (better known by its Russian acronym TRIZ) was created by the Russian inventor G.S. Altshuller[27]. In the TRIZ foundation there are 3 main principles: system's approach and system development objective mechanism. This system's "living" and development mechanism was described after several thousand inventions analysis.

*Fig. 3.1. Genrikh Saulovich Altshuller*

The system' parts development is connected with contradictions inside the system. There were worked out the methods, techniques, standards and later algorithm of the invention problem solving.

Teaching practice has shown that magnificent inventions are frequently connected with the use of the effects which are outside of the inventor's specialty. Therefore within the TRIZ limits there were created various physical, chemical and geometrical effects indexes.

When a challenging task has to be solved and system contradiction is not clear there should be applied *The technical system development* (LTSD) *laws* and Inventive-Problem Solving Algorithm (ARIZ in Russian abbreviation).

When inventor is working with ARIZ he or she analyzes and simplifies his\her task step by step, formulates the *ideal desired result* (IDR), obtains key contradiction, investigates this contradiction, determines the cause lead-

[27] Genrikh Saulovich Altshuller (1926 – 1998), Soviet engineer, inventor, scientist, journalist and writer. He is well-known for the Theory of Inventive Problem Solving creation. He found the Azerbaijan Public Institute for Inventive Creation, and was the first President of the TRIZ Association.

ing to contradiction and solved it via TRIZ tools. Moreover ARIZ includes parts for solution check, derived result development, ARIZ improvement and so on.

*Creative imagination development* is the TRIZ special and important part. It is very important to shatter usual preconceptions, to break down hard stereotypes while inventive task is being solved.

TRIZ is the engineer, inventor, and scientist tool. This tool doesn't only help to forecast any problem situation and to direct optimal decision search but it is the challenging intellect operations instrument.

## 3.1. Technical System Development

*No matter what sort of pose do naturalists take, the philosophy still prevails over them.*

*Friedrich Engels*

### 3.1.1. Base Notions

Charles Bonnet[28], Swiss XVIII Century naturalist wrote: "All parts, from which body consists, are so directly, so closely connected via their functions, that they cannot be separated, their utmost kinship is out of the question and it's clear that they appeared simultaneously. Arteries assume the veins occurrence, arteries and veins functions assume the nerves occurrence; the latter meant the brain occurrence, its occurrence – heart occurrence, each separate condition – a row conditions line …" [17]

Contemporary machineries and devices represent a set of elements (*'components'*), which are in special relationships and form complicated systems[29]. There are a lot of *system* definitions, including *meaningful* and *structural* [18].

*Meaningful definition Examples*:

- System is a complex of interacted components.
- System is a set of elements which are in specified relations between elements and surroundings.

[28] Charles Bonnet[28] (1720 –1793), Swiss naturalist and philosopher.

[29] A *system* (from Latin *systēma*, is from Greek *σύστημα* systēma, "the whole compounded of several parts or members, system") is a set of interacting or interdependent components forming an integrated whole (http://en.wikipedia.org/wiki/System).

*Example of Structural definition:*

- System is interacting elements combination that is organized for one or several goals achievement.

Fields that study the general systems properties include systems theory, cybernetics, dynamical systems, thermodynamics and complex systems [20]. They investigate the abstract systems' matter and organization properties, looking for concepts and principles that are independent of domain, substance, type, or temporal scale. The term *system* could also refer to a set of rules that governs structure and/or behavior.

TRIZ operates under the definition "technical system". *Technical system* (in accordance with TRIZ) is automat- or human- made real apparatus for the defined needs satisfaction. System's approach permits to choose optimal variant on the technical system design stage. In due time Vitruvius[30] affirmed: "Machine is a wooden adjustment which gives great assistance to heave to."

TRIZ defines common system characteristics including:

- Systems have structure, defined by components/elements.
- Components/elements are interconnected and organized in space and in time.
- Systems have interconnectivity: the various system parts have functional as well as structural relationships to each other.
- Systems have some useful functions or function groups.
- Systems have behavior, which involves inputs, processing and material, energy, information, or data outputs.
- Every system possesses by quality that is not equal to elements' behavior sum.

*Fig. 3.2. Vitruvian Man*
*By Leonardo da Vinci*

[30] Marcus Vitruvius Pollio (born c. 80–70 BC, died after c. 15 BC) - a Roman writer, architect and engineer, worked in the 1st century BC. He is widely known as the author of the multi-volume work De Architectura ("On Architecture").

The object cannot be considered as a technical system if it doesn't include any of the listed features[31].

### 3.1.2. Technical System Development Criteria

Any technical system development is determined by the following appropriate criteria [19]. These criteria can be divided into four groups:

- functional,
- technological,
- economical,
- anthropogenic.

*Functional criteria* are those which could give an answer to the purpose of the system. By the other words there are operating technical system performances: for example, velocity, flight altitude, positioning accuracy etc.

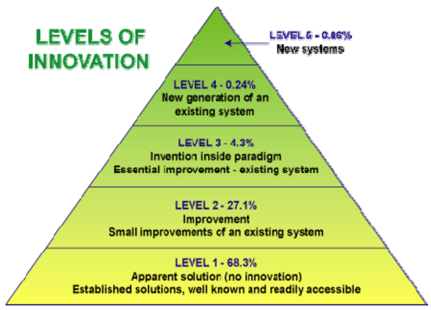



*Fig. 3.3.*
*Levels of Innovations*

*Technological criteria* allows us to estimate possibilities of technical system producing (materials consumption, energy intensity, degree of automation etc).

Technological criteria are closely connected with *economical criteria*. Economical criteria determine the costs for design, production, operation, maintenance.

*Anthropogenic criteria* provide the data connected with the system's operability for a man – surface appearance, ergonomics and ecological compatibility.

In accordance with TRIZ the main technical system development law is the Law of some criteria without worsening the others improvement [8, 9].

[31] In detail see [19].

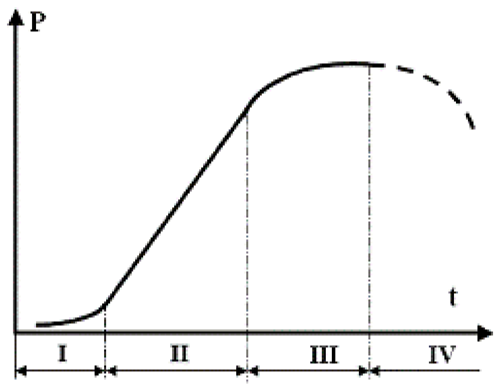


Fig. 3.4. S-Curve of technical system development

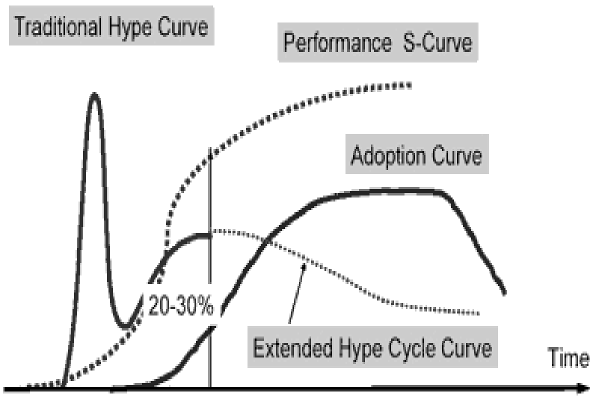


Fig. 3.5. Garthner' hypocycle

Technical system' ideal development can be depicted by classical S-Curve. S-Curve in TRIZ was named the curve that is plotted on Cartesian plane where y-axis is numerical value of the main system performance and x-axis is time or system age. Technical systems without their purpose depending pass the stages of system (picture 3.4):

I. *System or idea birth* – slow improvement one of the main performances,
II. *Development* – producing and improvement of a system, snowballing the main performances growth,
III. *Old age* – main performances stabilization,
IV. *Dying* – system performances worsening.

The *First stage* may be called as system "birth" and "childhood". On this stage we can observe a slow system' growth and formation.

The *Second stage* is a time of system intensive progress. This stage peculiarity is a new system active expansion – it ejects others from ecological niche and gives rise to modifications numbers that are adopted for different conditions.

The *Third stage* is an "old age" of a system. This is a system stabilization stage. There is a system performance improvement at the beginning, but then the performance does not improve in spite of the growing input. The complexity grows and there occurs a system crisis.

The *Fourth stage* is a system's "dying" stage. The previous stage system crisis creates necessary conditions for fundamental changes and a new system appearance (subsystem in TRIZ).

S-Curve may have unexpected variants. For example, two-humped S-curve investigation activity[32] (picture 3.5), when the beginning investigations have active surge, after that the period of lull sets in and then the period of growing sets in once again.

There are special laws on every stage of technical system development.

### 3.1.3. Technical System Evolution Laws [33]

In accordance with Oxford English Dictionary a *scientific law* is "a theoretical principle deduced from particular facts, applicable to a defined phenomena group or class and is expressible by the statement that a particular phenomenon always occurs under certain conditions". Physical laws are typical conclusions based on repeated scientific experiments and observations over many years and which are accepted universally within the scientific community.

Several general physical laws properties have been identified (see Davies (1992) and Feynman (1965) as noted, although each of the characterizations is not necessarily original). Physical laws are[34]:

*True,* at least within their regime of validity. By definition, there have never been repeatable contradicting observations.

*Universal*. They appear to apply everywhere in the universe. (Davies, 1992)

*Simple.* They are typically expressed in single mathematical equation terms. (Davies)

*Absolute.* Nothing in the universe appears to affect them. (Davies, 1992)

*Stable.* Unchanged since first discovered (although they may have been shown as more accurate laws approximations).

---

[32] http://www.metodolog.ru/01493/01493.html
[33] See in details [8, 9, 19, 21]
[34] http://en.wikipedia.org/wiki/Physical_laws

*Omnipotent.* Everything in the universe apparently must comply with them (according to observations). (Davies, 1992)

Generally *conservative of quantity*. (Feynman, 1965)

Often expressions of existing *homogeneities symmetries of space and time*. (Feynman)

Typically theoretical *reversible in time* (if non-quantum), although time itself is irreversible. (Feynman)

Physical laws are distinguished from scientific theories by their simplicity. Scientific theories are generally more complex than laws; they have got many component parts, and are more likely to be changed in the development of available experimental data and analysis. This is because a physical law is a summary observation of strictly empirical matters, whereas a theory is a model that deals with observation, explains it, relates it to other observations, and makes testable predictions based upon it. Simply stated, while a law notes *that* something happens, a theory explains *why* and *how* something happens.

Technical system evolution laws in accordance with the Theory of Invention problem solving were firstly formulated by G.S. Altshuller in his book "Creativity as Exact Science" [18]. In his pioneering work (dated 1975), Altshuller subdivided all technical systems evolution laws into 3 categories:

*Statics* – describes viability criteria of newly created technical systems.

*Kinematics* – defines how technical systems evolve regardless of conditions.

*Dynamics* – defines how technical systems evolve under specific conditions.

**Static Laws**

*System parts completeness law*

Any working system must have 4 parts: engine, transmission, working unit (working organ) and control element (steering organ). Engine generates the needed energy, transmission guides this energy to working unit, which ensures contact with outside world (processed object), and control element makes the whole system adaptable.

*Energy conductivity system law*

As it is known, every technical system is an energy transformer, this energy should circulate freely and efficiently through its 4 main parts (engine, transmission, working element and control element). The energy transfer can be via substance, field or substance-field.

*System parts harmonizing rhythms law*

The vibration frequencies or the parts periodicity and system movements should be synchronized with each other.

**Kinematic Laws**

*System ideality increasing degree law*

System ideality is a qualitative ratio between all desirable system benefits and its cost or any other harmful effects. When trying to decide how to improve a given invention, one naturally would attempt to increase ideality, either to increase beneficial features or to decrease cost or reduce any harmful effects. The *ideal final result* would have all the benefits at zero cost. That cannot be achieved; the law states, however, that successive versions of a technical design usually increase ideality:

$$Ideality = benefits/(cost + harm)$$

*System parts uneven development law*

A technical system encompasses different parts, which will evolve differently, leading to the new technical and physical contradictions.

*Super-system transition law*

When a system exhausts the further significant improvement possibilities, it's included in a super-system as one of its parts. As a result a new system development becomes possible.

**Dynamic Laws**

*Transition from macro to micro level*

Working organs development proceeds at first on a macro and then a micro level. The transition from macro to micro level is one of the main (if not the main) modern technical systems development tendency. Therefore in studying the inventive problems solution, special attention should be paid to examining "macro to micro transition" and physical effects which have brought this transition about.

*Increasing the S-Field involvement*

Non-S-field systems evolve to S-field systems. Within the S-field systems class, the fields evolve from mechanical fields to electro-magnetic fields. The substances dispersion increases in the S-fields. The links number in the F-fields increases and the whole system responsiveness is also tend to increase.

Later there was formulated one more law – system dynamics increase [8]. There could be seen the relationship between these categories and the technical system "birth, development, old ages and dying model" – S-Curve, used by Altshuller for the engineering evolutional processes description. For example, at the system "birth" stage there are in force S*ystem parts completeness law* and S*ystem energy conductivity law.*

Every system is energy conductor and converter. If energy does not go through system and system elements don't get energy such system is unable to operate. The energy used for the system's work, for allowance, for waste, for system work control. Thus it is important to build system that is not only a good energy conductor but which provides minimum energy loss.

On the system development stage there should be taken into consideration the following laws: *System parts harmonizing rhythms* and *System ideality increasing degree* because those systems are well operating, where there are elements supply system operation frequencies with the best useful functions.

When we deal with more complicated system then there are more uneven system parts developments. In every system the elements life paces are differ and it is because the system gradually dies away. Then there appears a system crisis. On this stage the administrative, technical and physical contradictions become sharp and the result is such a problem situation, which can be determined as

- system elements unsatisfactory state,
- system elements unsatisfactory interaction,
- unsatisfactory interaction between system and environment elements.

If it is possible to overcome contradictions – the system evaluates, if contradiction is not possible to overcome– the system "dies away" because of the limited resource.

It is possible to overcome contradictions by different ways:

- by increasing the system dynamics,
- by increasing the S-Field involvement,
- by transition from macro to micro level,
- by transition to a super-system.

For example, for more effective work the so called “rigid” system[35] must become dynamic, we mean that it should change its structure and operating mode in accordance with the environment change.

Firstly technical systems have rigid internal connections; there are not subsystems for operating mode change, such systems are vulnerable, often they fall out and are of short duration. Transformations are connected with rigid elements to flexible change, using of pneumatic and hydraulic constructions and so on. On the next stages there is introduced a feedback, physical and chemical effects; systems and subsystems are changed by ideal systems.

System extensive evolution possibilities on the macro level are quickly reduced and mass increasing, outer dimensions, energy intensity is limited by physical bounds. Therefore the transition to micro-level is necessary: there are new energy reserves and possibility to use new substance properties. By the other words inside of wheels, shafts, gears their work molecules, atoms, ions, electrons etc., which are easy ruled by fields with the help of physical and chemical effects.

Techniques evolution reminds the life evolution on the Earth [9]:

- organisms consolidation to super-system in accordance with line: cell – organism – population – ecosystem – biosphere,
- functions combinations (for example plant leaves combine the solar energy converter function to chemical energy, pump function, which pressurizes in capillaries, temperature regulator function,
- systems collapse with useful function to ideal substance (for example, the inherited information transfer system was firstly worked off on cells level and then was collapsed to genetic mechanism).

It is necessary to remember about the principal difference: only the ancient organisms are the most closed modern techniques prototypes. It is impossible to say about direct analogy, there are only separate factors, common for every system evolution.

[35] Rigid system in TRIZ is system with rigid link

*Fig. 3.6. Sagan with a model of the Viking Lander probes which would land on Mars.*

American biologist Carl Sagan[36] writes in his book The Dragons of Eden [22]: "Every Viking Lander – spaceship, which landed on Mars in 1976, had pre-programmed directions in its computers with up capacities to a few millions of bits. Hereby Viking possessed by genetic information, which is more than bacterium but considerably less than seaweeds". Vikings complexity, accuracy and effectiveness may be compared with bacterium but the Vikings assembly plant may be compared with living organism cell.

Designers can purposefully search optimal construction variants with cognition and technical evolution laws use and this helps to reduce costs on the idea generation and technical project realization.

For example, General Motors specialists worked out programs for turbine buckets where there was realized a self-perfection possibility in accordance with Darwins' evolution theory, such as genetic code mutation and different construction variants intraspecific competition [23].

---

[36] **Carl Edward Sagan** (1934 – 1996) - an American astronomer, astrophysicist, cosmologist, author, science popularizer, and science communicator in astronomy and natural sciences. He spent most of his career as an astronomy professor at Cornell University where he directed the Planetary Studies Laboratory. (http://en.wikipedia.org/wiki/Carl_Sagan).

### 3.1.4. Technical System Evolution Example

Technical system as a musician ensemble or a sport team is well when everyone plays coordinately. So the inventors firstly try to find “system formula” – fortunate parts combination. It is the first stage in system life. Each from four stages has its own tasks and features and on every stage their own practice is used.

*Fig. 3.7.*
*V. Vasnetsov. Flying-carpet. 1880*

Let’s have a good look at airplane history [24]. On the first stage the inventors were interested: What is it – an airplane? What parts airplane should include? What are these parts: wings plus engine or wings without engine? What wings type there must be – fixed or waved? What engine type there must be – muscular, steam, electrical, combustion? At last the airplane formula was founded: fixed wings and combustion engine.

The second system evolution stage began – “threes correction”. Inventors improved separate system parts, tried to find the best dimensions, shape etc. In the second stage end the airplane began to look familiar for us, but at the same time the airplane began to lose its patterns because the third stage is a system dynamic change: rigid parts transformed to flexible, there were invented retracted landing gears and wings, changing their shape and area, there appeared a moveable nose. Also there were invented vertical take-off airplanes with rotary engines. There were patented transformed airplanes.

*Fig. 3.8. Blended wing body*

The fourth stage is the self-steered systems stage. As example there are space vehicles, which can reform during work: to throw down worked off missile stages, to open wings with solar batteries etc.

Evolution from stage to stage is connected with object characteristics and construction change. Technical systems evolution analysis shows that the main transition reason to the next stage is the necessity to delete main defect/defects in existing technical objects generation. Meanwhile the principal defect is connected with the system progressive evolution criteria improving and this principal defect removal is realized via object construction consequent change.

## 3.2. Technical Systems Contradictions. Main Principles to Solve Contradictions

As it was mentioned above the contradictions appear as a result of system parts uneven development. In accordance with the contradictions formulation level there may be administrative, technical and physical [8].


Administrative contradictions establish fact that there exists a problem situation. It is necessary to do something but what and how to do – is quite unknown. If a problem situation analysis was done correctly one can work to technical contradiction. In TRIZ technical contradiction is a situation when the attempt to improve one characteristic provokes the another one worsening [16]. Technical contradictions are the conflict mirror between systems parts or systems properties.

Technical contradiction is the conflict between different system parts. To formulate physical contradiction it is necessary to find zone, where demands to physical condition interfere. For example a zone must have property A and at the same time it must not have property A. If such zone is detected then typical inventive principles and contradictions matrix to solve typical technical contradictions may be used [21, 25, 26].

Altshuller screened patents in order to find out what contradiction kinds were resolved or dissolved by the invention. From this he developed a 40 inventive principles set and later a contradictions matrix. Matrix rows indicate the 39 system features that one typically wants to improve, such as speed, weight, accuracy of measurement and so on. Columns refer to typical undesired results. Each matrix cell points to principles that have been most frequently used in patents in order to resolve the contradiction. Later there were worked out typical principles, standards, geometrical, physical and chemical effects and phenomena indexes to obviate contradictions [8, 25, 26].

It is necessary to overcome contradictions on a base of technical system evolution laws. Of course these laws cannot be used for concrete technical decision making. The laws only direct technical systems evolution and are the concrete mechanisms base for inventive problem solving. So inventive problem solving algorithm is published in different sources [8, 21, 25, 26].

### 3.2.1. Substance-Field Analysis

*Every thoughts movement must be precise and adjusted as those of a pilot who leads aircraft.*

*A. Yakovlev,*
*Soviet aeronautical engineer*

The modeling is one of the effective cognition techniques. The real object is replaced by ideal system, which has the main characteristics similar with real model. It is easier work with models but the investigation results are applicable to real system. There exists the huge number of models – from language description to designing model similar the real object in the proportionate scale.

One more technique that is frequently used by inventors involves the substances analysis, fields and other resources. Altshuller developed methods to analyze resources; several of his invention principles involve the different substances use and fields that help to resolve contradictions and increase technical system ideality. TRIZ uses non-standard definitions for substances and fields and such technical system model is named SuField (Su – substance and Field).

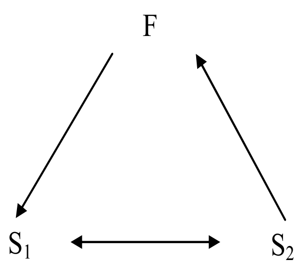



*Fig. 3.9. SuField model*

SuField analysis produces a structural model of the initial technological system, exposes its characteristics, and with the special laws help, transforms the problem model. Through this transformation the solution structure that eliminates the initial problem shortcomings is revealed. SuField analysis is a special formulas language with which it is possible easily describe any technological system in specific (structural) model terms. A model produced in this manner is transformed according to special laws and regularities, thereby revealing the problem structural solution.

SuField (picture 3.9) is the minimum structure model of working technical system, it includes

- substance-item $S_1$ (that it is necessary to change, work out, replace, control etc.),
- substance-tool $S_2$ (tool does necessary action and is the reason of technical contradiotion),
- external field F (interaction power or energy between $S_1$ and $S_2$).

Every technical system can be represented as structural model that includes one or several SuFields. This model allows checking shortcomings, initial system "diseases", which are connected with technical system evolution objective laws malfunction.

It is necessary to note that in TRIZ notion "field" distinguish from the same notion in physics. Today inventors do not use weak and strong nuclear interaction physical fields but broadly apply "technical fields": mechanical, acoustical, chemical interactions etc.

SuField transformation suggests to inventor what may be entered to the system for task solving – substance, field or both of them but it doesn't tell what are these fields and substances. To get technical answer it is necessary to select the proper ones. TRIZ recommends begin from fields because the fields number is less then substances.

In TRIS the term "substance" means any object – it does not depend on size or complexity. It may be ice or ice-breaker, cutting tool or lathe, half-product or complex object.

Term "field" means space every point of which is connected with some scalar or vector value. In TRIZ there are used both physical (gravitational, electromagnetic, weak and strong nuclear interaction fields) and "technical" fields. There is abbreviation in TRIZ ***"MAHCEM"*** to remember these fields:

***M*** – mechanical field (interaction). There is a wide manifesting variability and this field possibilities:

simple mechanical force and deformation in different directions,
pressure (increasing and reducing),
inertial, gravity and centrifugal forces,
vibration, blow, air and hydro dynamical effects etc.

***A*** – acoustic field. This field continues mechanical field action: acoustic vibrations, infra and ultrasound, stationary waves, resonance oscillations etc.

***H*** – heat field (heating and cooling).

***C*** – chemical field (interaction), using different chemical reactions.

***Э*** – electrical field including electrostatic and constant/alternating current field.

***M*** – magnetic field, generate by permanent magnet or constant/alternating current.

Last time there are so many invention solutions connected with the biochemistry, biotechnology, optical phenomena use. Possibly the fields list can be extended using optical and biological fields.

The above mentioned fields majority are connected with their "own' substances:

*chemical field* – with different catalysts, inhibitors, active or inert substances,
*electrical field* – with charged particles (electrons, ions),
*magnetic field* – with ferromagnetic materials.

The fields enumeration order is connected with abbreviation MAHCEM. This abbreviation reflects the technical systems evolution succession in direction from simple mechanical interaction to most effective magnetic field. One more tendency is observing in fields use. It is transition from constant fields to variable and impulse fields. It is effective to use several fields combination, especially of adjacent fields in abbreviation MAHCEM: heat and chemical, chemical and electrical, electrical and magnetic.

Patent information statistic analysis shows that there exist certain common SuField models conversation laws in accordance with technical systems evolution laws. These laws permit to solve most of the practical tasks.

**∢ It is difficult to control the substance (to find out, to measure, to change), it is necessary to provide with effective control**

Usually it is connected with absent in SuField one or two elements (such model is called not full SuField). It is necessary to complete – to introduce missing elements (substances or fields). If task is on measurement or detection it is necessary to introduce second substance (for example, luminophor, ferromagnetic etc.), which is interacting with external field.

If task is on travel, crushing, surface preparation, deformation, viscosity changes etc. – ferromagnetic particles and magnetic field introduction. If it is impossible to introduce $S_2$substance, the task can be solved with the help of natural frequency measurement object or inside $S_2$ external field and external $S_2$ are introduced; $S_2$ is introduced on time or in very tiny amounts; as $S_2$ is used as the $S_1$ part; inside the object copy of object is used; $S_2$ is introduced as a chemical compound.

**∢ In initial system there is full SuField, but SuField interaction between elements is punk**

Such SuField is called harmful it is necessary to destroy this SuField. There are some techniques to destroy harmful SuField. For example, the third substance is introduced. This third substance is existing substances modification. The second field opposed to the first harmful one can be introduced.

**∢ SuField "forcing"**

SuField "forcing" is used while action but it is necessary to reinforce this action in order to increase the original system effectiveness. The SuField "forcing" essence is using more effective fields. New substance $S_2$ is introduced, the field $F_1$ acts on this substance and $S_2$ changes its properties. It is easy to find out this change with the $F_1$ field help.

**∢ Substance or field has two properties which conflict one with another, it is necessary to improve one property but not to worsen the another one**

If there are property and anti-property (hot – cold, strong – week, magnetic – non-magnetic), the conflict can be removed by division in space, in time and in structure (when whole has one property but part– another). If division of substance in time is used then the effectual transition from one state to another has to be done by the substance itself. This substance has to change its forms (matter state change, magnetic transition temperature etc.).

SuField analysis is the tasks solving effective tool r. Moreover SuField is important for another instrument in TRIZ such as standards system for inventive problem solving. Standard is a combination from one or several principles for task solving and special physical effects. Now there are known 77 standards, which are divided into 5 classes:

1. **SuField systems building and destroying.** The main idea is in transition from non SuField to SuField. In this case the field is doing more or less and additional substance is introduced to defined zone to protect or reinforce action.

2. **SuField systems development.** Transition to complex SuField is realized. Ferromagnetic substances and magnetic field are introduced. System development is connected with its dynamization.
3. **Standards for transition to above-system and to micro-level.** Physical effects and phenomena are used (for example, heat expansion, phase transition etc.).
4. **Standards for measurement and revealing.** In this case SuField is completed to find and to measure the field.
5. **Techniques for introduction to SuField of the new elements without any elements:** copies use, emptiness, substances modification.

Now there could be formulated **the SuField increasing law**:

Technical system evolution is connected with SuField increasing, non SuField systems try to be SuField and in SuField systems the number of connections between elements is increasing.

### 3.2.2. Inventive principles for Technical Contradictions solving

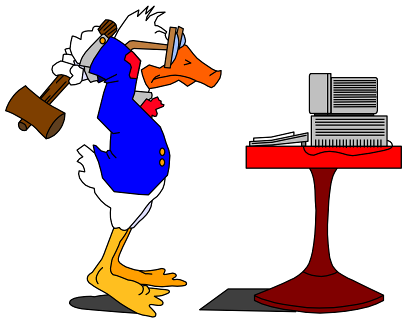
Patents analysis demonstrated that about 40 strongest principles exist in order to obviate technical contradictions using effective decisions. There was developed a set of 40 inventive principles and later a contradictions matrix. Matrix columns indicate 39 system features that one typically wants to improve, such as speed, weight, measurement accuracy and so on. Rows refer to typical undesired results. Each matrix cell points to principles that have been most frequently used in patents in order to resolve the contradiction.

Altshuler abandoned this defining and solving "technical" contradictions method in the mid 1980's and included in the solving inventive problems algorithm, ARIZ SuField modeling, the 76 inventive standards and a number of other tools. Also this matrix formed the "Inventive machine – principles" program basis.

The principles list is summarized below in original formulation by Altshuler [21].

## The List of Principles[37]

1. **Segmentation**
   - Divide an object into independent parts:
     *Replace mainframe computer by personal computers.*
     *Replace a large truck by a truck and a 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 fragmentation or segmentation degree:
     *Replace solid shades with Venetian blinds.*
     *Use powdered welding metal instead of foil or rod to get better joint penetration.*

2. **Taking out**
   - Separate an interfering part or property from an object, or single out the only necessary object part (or property):
     *Locate a noisy compressor outside the building where is used compressed air.*
     *Use fiber optics or a light pipe to separate the hot light source from the location where is needed the light.*
     *Use a barking dog sound, without the dog, as a burglar alarm.*

3. **Local quality**
   - Change an object's structure from uniform to non-uniform, change an external environment (or external influence) from uniform to non-uniform:
     *Use a temperature, density, or pressure gradient instead of a constant temperature, density or pressure.*
   - Make each part of the object function in conditions most suitable for its operation:
     *Lunch box with special compartments for hot and cold solid foods and for liquids.*

37 Translation from Russian to English: http://www.triz40.com/aff_Principles.htm

- Make each part of an object fulfill a different and useful function:
  *Pencil with eraser.*
  *Hammer with nail puller.*
  *Multi-function tool that scales fish, acts as a pliers, a wire stripper, a flat-blade screwdriver, a Phillips screwdriver, manicure set, etc*

4. **Asymmetry**
   - Change the object shape from symmetrical to asymmetrical:
     *Asymmetrical mixing vessels or asymmetrical vanes in symmetrical vessels improve mixing (cement trucks, cake mixers, blenders).*
     *Put a flat spot on a cylindrical shaft to attach a knob securely.*
   - If an object is asymmetrical, increase its asymmetry degree.
     *Change from circular O-rings to oval cross-section to specialized shapes to improve sealing.*
     *Use astigmatic optics to merge colors.*

5. **Merging**
   - Bring closer together (or merge) identical or similar objects, assemble identical or similar parts to perform parallel operations:
     *Personal computers in a network.*
     *Thousands of microprocessors in a parallel processor computer.*
     *Vanes in a ventilation system.*
     *Electronic chips mounted on both sides of a circuit board or subassembly.*

   - Make operations contiguous or parallel; bring them together in time:
     *Link slats together in Venetian or vertical blinds.*
     *Medical diagnostic instruments that analyze multiple blood parameters simultaneously.*
     *Mulching lawnmower.*

6. **Universality**
   - Make a part or object perform multiple functions; eliminate the other parts need:
     *Toothbrush handle that contains toothpaste.*
     *Child's car safety seat converts to a stroller.*
     *Mulching lawnmower (it demonstrates both Principles 5 and 6, Merging and Universality).*

*Team leader acts as recorder and timekeeper.*
*CCD (Charge coupled device) with micro-lenses formed on the surface.*

7. **Nested doll**
   - Place one object inside another; place each object, in turn, inside the other:
     *Measuring cups or spoons.*
     *Russian dolls.*
     *Portable audio system (microphone fits inside transmitter, which fits inside amplifier case).*

   - Make one part pass through a cavity in the other:
     *Extending radio antenna.*
     *Extending pointer.*
     *Zoom lens.*
     *Seat belt retraction mechanism.*
     *Retractable aircraft landing gear stow inside the fuselage (also demonstrates Principle 15, Dynamism).*

8. **Anti-weight**
   - To compensate the object weight, merge it with other objects that provide lift:
     *Inject foaming agent into a logs bundle, to make it float better. Use helium balloon to support advertising signs.*
   - To compensate the object weight, make it interact with the environment (e.g. use aerodynamic, hydrodynamic, buoyancy and other forces):
     *Aircraft wing shape reduces air density above the wing, increases density below wing, to create lift (This also demonstrates Principle 4, Asymmetry).*
     *Vortex strips improve lift of aircraft wings.*
     *Hydrofoils lift ship out of the water to reduce drag.*

9. **Preliminary anti-action**
   - If it is necessary to do an action with both harmful and useful effects, this action should be replaced with anti-actions to control harmful effects:
     *Buffer a solution to prevent harm from pH extremes.*
   - Create beforehand stresses in an object that will oppose known undesirable working stresses later on:
     *Pre-stress rebar before pouring concrete.*
     *Masking anything before harmful exposure: use a lead apron on body parts which aren't exposed to X-rays. Use masking tape to protect object parts which shouldn't be painted*

10. **Preliminary action**
    - Perform, before it is needed, the required object change (either fully or partially):
      *Pre-pasted wall paper.*
      *Sterilize all instruments needed for a surgical procedure on a sealed tray.*
    - Pre-arrange objects on such a way that they can come into an action from the most convenient place and without losing time for their delivery:
      *Kanban arrangements in a Just-In-Time factory.*
      *Flexible manufacturing cell.*

11. **Beforehand cushioning**
    - Prepare emergency means beforehand to compensate for the relatively low object reliability:
      *Magnetic strip on photographic film that directs the developer to compensate poor exposure.*
      *Back-up parachute.*
      *Alternate air system for aircraft instruments.*

12. **Equipotentiality**
    - In a potential field, limit position changes (e.g. change operating conditions to eliminate the need to raise or lower objects in a gravity field):
      *Spring loaded parts delivery system in a factory.*
      *Locks in a channel between 2 bodies of water (Panama Canal).*
      *Skillets in an automobile plant that bring all tools to the right position (also demonstrates Principle 10, Preliminary Action).*

13. **The other way round**

- Invert the action(s) used to solve the problem (e.g. instead of cooling an object, heat it):
  *To loosen stuck parts, cool the inner part instead of heating the outer part.*
  *Bring the mountain to Mohammed, instead of bringing Mohammed to the mountain.*
- Make movable parts (or the external environment) fixed, and fixed parts movable:
  *Rotate the part instead of the tool.*
  *Moving sidewalk with standing people.*
  *Treadmill (for walking or running in place).*
- Turn the object (or process) 'upside down'.
  *Turn an assembly upside down to insert fasteners (especially screws).*
  *Empty grain from containers (ship or railroad) by inverting them.*

14. **Spheroidality – Curvature**

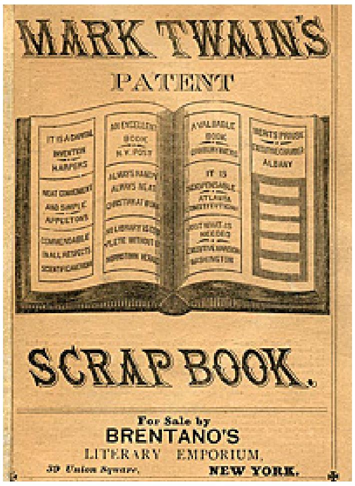
- Instead of using rectilinear parts, surfaces, or forms, use curvilinear ones; move from flat surfaces to spherical ones; from parts shaped as a cube (parallelepiped) to ball-shaped structures:
  *Use arches and domes for strength in architecture.*
- Use rollers, balls, spirals, domes:
  *Spiral gear (Nautilus) produces continuous resistance for weight lifting.*
  *Ball point and roller point pens for smooth ink distribution.*
- Go from linear to rotary motion, use centrifugal forces:
  *Produce linear cursor motion on the computer screen using a mouse or a trackball.*
  *Replace wringing clothes to remove water with spinning clothes in a washing machine.*
  *Use spherical casters instead of cylindrical wheels to move furniture.*

15. **Dynamics**

- Allow (or design) the object characteristics, external environment, or process to optimal change or to find an optimal operating condition:
  *Adjustable steering wheel (or seat, or back support, or mirror position...).*

- Divide an object into parts capable of movement relative to each other:
  *The "butterfly" computer keyboard, (also demonstrates Principle 7, "Nested doll').*
- If an object (or process) is rigid or inflexible, make it movable or adaptive:
  *The flexible boroscope for examining engines.*
  *The flexible sigmoidoscope, for medical examination.*

16. **Partial or excessive actions**




- If 100 percent of an object is hard to achieve using a given solution method then, by using 'slightly less' or 'slightly more' of the same method, the problem may be considerably easier to solve: *Over spray when painting, then remove excess. (Or, use a stencil--this is the Principle 3 application, Local Quality and Principle 9, Preliminary anti-action). Fill, then "top off" when filling your car gas tank.*

17. **Another dimension**

- To move an object in two- or three-dimensional space:
  *Infrared computer mouse moves in space, instead of a surface, for presentations.*
  *Five-axis cutting tool can be positioned where needed.*
- Use a multi-story objects arrangement instead of a single-story one:
  *Cassette with 6 CD's to increase music time and variety.*
  *Electronic chips on printed circuit board both sides.*
  *Employees *disappear* from the customers in a theme park, descend into a tunnel, and walk to their next assignment, where they return to the surface and magically reappear.*
- Tilt or re-orient the object, lay it on its side:
  *Dump truck*
- Use 'another side' of a given area:
  *Stack microelectronic hybrid circuits to improve density.*

18. **Mechanical vibration**

- Cause an object to oscillate or vibrate:
  *Electric carving knife with vibrating blades.*
- Increase its frequency (even up to the ultrasonic):
  *Distribute powder with vibration.*
- Use an object's resonant frequency:
  *Destroy gall stones or kidney stones using ultrasonic resonance.*
- Use piezoelectric vibrators instead of mechanical ones:
  *Quartz crystal oscillations drive high accuracy clocks.*
- Use combined ultrasonic and electromagnetic field oscillations:
  *Mixing alloys in an induction furnace*.

19. **Periodic action**

- Instead of continuous action, use periodic or pulsating actions:
  *Hitting something repeatedly with a hammer.*
  *Replace a continuous siren with a pulsed sound.*
- If an action is already periodic, change the periodic magnitude or frequency:
  *Use Frequency Modulation to convey information, instead of Morse code.*
  *Replace a continuous siren with sound that changes amplitude and frequency.*
- Use pauses between impulses to perform a different action:
  *In cardio-pulmonary respiration (CPR) breathe after every 5 chest compressions.*

20. **Continuity of useful action**

- Carry on work continuously; make all object work parts at full load, all the time:
  *Flywheel (or hydraulic system) stores energy when a vehicle stops, so the motor can keep running at optimum power.*
  *Run the bottleneck operations in a factory continuously, to reach the optimum pace (From theory of constraints, or tact time operations).*
- Eliminate all idle or intermittent actions or work:
  *Print during the printer carriage return – dot matrix printer, daisy wheel printers, inkjet printers.*

21. **Skipping**

- Conduct a process, or certain stages (e.g. destructible, harmful or hazardous operations) at high speed:
  *Use a high speed dentist s drill to avoid heating tissue.*
  *Cut plastic faster than heat can propagate in the material, to avoid deforming the shape.*

22. **"Blessing in disguise" or "Turn Lemons into Lemonade"**

- Use harmful factors (particularly, harmful effects of the environment or surroundings) to achieve a positive effect:
  *Use waste heat to generate electric power.*
  *Recycle waste (scrap) material from one process as raw materials for another.*
- Eliminate the primary harmful action by adding it to another harmful action to resolve the problem:
  *Add a buffering material to a corrosive solution.*
  *Use a helium-oxygen mix for diving, to eliminate both nitrogen narcosis and oxygen poisoning from air and other nitrox mixes.*
- Amplify a harmful factor to such a degree that it is no longer harmful:
  *Use a backfire to eliminate the fuel from a forest fire.*

23. **Feedback**

- Introduce feedback (referring back, cross-checking) to improve a process or action:
  *Automatic volume control is used in audio circuits.*
  *Signal from gyrocompass is used to control simple aircraft autopilots. Statistical Process Control (SPC) – measurements are used to decide when to modify a process (Not all feedback systems are automated!). Budgets – measurements are used to decide when to modify a process.*

- If feedback is already used, change its magnitude or influence.
  *Change sensitivity of an autopilot when within 5 miles of an airport.*
  *Change thermostat sensitivity when cooling vs. heating, since it uses energy less efficiently when cooling.*
  *Change a management measure from budget variance to customer satisfaction.*

24. **“Intermediary”**

- Use an intermediary carrier article or intermediary process:
  *Carpenter’s nail set, used between the hammer and the nail.*
- Merge one object temporarily with another (which can be easily removed).
  *Pot holder to carry hot dishes to the table.*

25. **Self-service**

- Make an object serve itself by performing auxiliary helpful functions:
  *A soda fountain pump that runs on the pressure of the carbon dioxide that is used to “fizz” the drinks. This assures that drinks will not be flat, and eliminates the need for sensors.*
  *Halogen lamps regenerate the filament during use--evaporated material is redeposited.*
  *To weld steel to aluminum, create an interface from alternating 2 materials thin strips. Cold weld the surface into a single unit with steel on one face and copper on the other, then use normal welding techniques to attach the steel object to the interface, and the interface to the aluminum. (This concept also has Principle 24, Intermediary, and Principle 4, Asymmetry elements).*
- Use waste resources, energy or substances:
  *Use heat from a process to generate electricity: “Cogeneration”.*
  *Use animal waste as fertilizer.*
  *Use food and lawn waste to create compost.*

26. **Copying**

- Instead of an unavailable, expensive, fragile object, use simpler and inexpensive copies:
  *Virtual reality via computer instead of an expensive vacation*
  *Listen to audio tape instead of attending a seminar.*
- Replace an object, or process with optical copies:
  *Do surveying from space photographs instead of that on the ground.*
  *Measure an object by measuring the photograph.*
  *Make sonograms to evaluate the fetus health, instead of taking risking damage by direct testing.*

- If visible optical copies are already used, move to infrared or ultraviolet copies:
  *Make images in infrared to detect heat sources, such as diseases in crops or intruders in a security system.*

27. **Cheap short-living objects**
    - Replace an inexpensive object with multiple inexpensive objects, comprising certain qualities (such as service life, for instance):
      *Use disposable paper objects to avoid the cleaning and storing durable objects cost. Plastic cups in motels, disposable diapers, different kinds of medical supplies.*

28. **Mechanics substitution**
    - Replace a mechanical means with a sensory (optical, acoustic, taste or smell) ones:
      *Replace a physical fence to confine a dog or cat with an acoustic *fence* (signal audible to the animal).*
      *Use a bad smelling compound in natural gas to alert users to leakage, instead of a mechanical or electrical sensor.*
    - Use electric, magnetic and electromagnetic fields to interact with the object:
      *To mix 2 powders, electrostatically charge one positive and the other negative. Either use fields to direct them, or mix them mechanically and let their acquired fields cause the grains of powder to pair up.*
    - Change from static to movable fields, from unstructured fields to those having structure:
      *Early communications used omnidirectional broadcasting. We now use antennas with very detailed radiation pattern structure.*
    - Use fields in conjunction with field-activated (e.g. ferromagnetic) particles.
      *Heat a substance containing ferromagnetic material by using varying magnetic field. When the temperature exceeds the Curie point, the material becomes paramagnetic, and no longer absorbs heat.*

29. **Pneumatics and hydraulics**
    - Use object gas and liquid parts instead of solid parts (e.g. inflatable, filled with liquids, air cushion, hydrostatic, hydro-reactive):
      *Comfortable shoe sole inserts filled with gel.*
      *Store energy from decelerating a vehicle in a hydraulic system, then use the stored energy to accelerate later.*

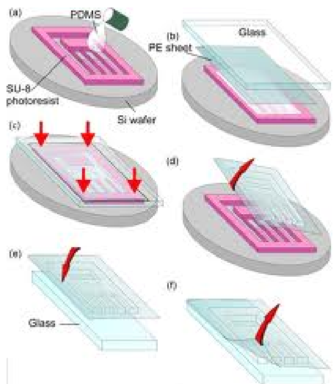
30. **Flexible shells and thin films**

- Use flexible shells and thin films instead of three dimensional structures:
  *Use inflatable (thin film) structures as winter covers on tennis courts.*
- Isolate the object from the external environment using flexible shells and thin films:
  *Float a bipolar material film (one end hydrophilic, one end hydrophobic) on a reservoir to limit evaporation.*

31. **Porous materials**

- Make an object porous or add porous elements (inserts, coatings, etc.):
  *Drill holes in a structure to reduce the weight.*
- If an object is already porous, use the pores to introduce a useful substance or function.
  *Use a porous metal mesh to wick excess solder away from a joint.*
  *Store hydrogen in the pores of a palladium sponge. (Fuel "tank" for the hydrogen car--much safer than storing hydrogen gas).*

32. **Color changes**




- Change the object color or its external environment:
  *Use safe lights in a photographic darkroom.*
- Change the object transparency or its external environment:
  *Use photolithography to change transparent material to a solid mask for semiconductor processing. Similarly, change masks material from transparent to opaque for silk screen processing.*
- Use coloring agents for oversight by objects which are invisible.
- Use radioactive tracers.

33. **Homogeneity**

- Make objects interacting with the same material object (or material with identical properties):
  *Make the container out of the same material as the contents, to reduce chemical reactions.*
  *Make a diamond cutting tool out of diamonds.*

34. **Discarding and recovering**

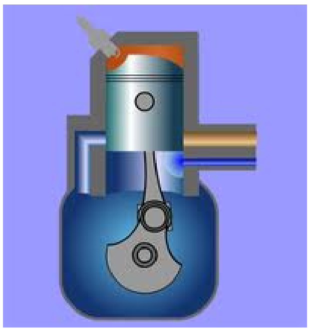
- Make object portions that have fulfilled their functions (discard by dissolving, evaporating, etc.) or modify these directly during operation:
  *Use a dissolving capsule for medicine.*
  *Sprinkle water on cornstarch-based packaging and watch it reduce its volume by more than 1000X!*
  *Ice structures: use water ice or carbon dioxide (dry ice) to make a template for a rammed earth structure, such as a temporary dam. Fill with earth, then, let the ice melt or sublime to leave the final structure.*
- Conversely, restore consumable object parts directly in operation:
  *Self-sharpening lawn mower blades.*
  *Automobile engines that give themselves a 'tune up' while running (the ones that say '100,000 miles between tune ups').*

35. **Parameter changes**

- Change an object's physical state (e.g. to a gas, liquid, or solid):
  *Freeze the liquid centers of filled candies, then dip in melted chocolate, instead of handling the messy, gooey, hot liquid.*
  *Transport oxygen or nitrogen or petroleum gas as a liquid, instead of a gas, to reduce volume.*
- Change the concentration or consistency:
  *Liquid hand soap is concentrated and more viscous than bar soap at the point of use, making it easier to dispense in the correct amount and more sanitary when shared by several people.*
- Change the flexibility degree:
  *Use adjustable dampers to reduce the noise of parts falling into a container by restricting the container walls motion.*
  *- Vulcanize rubber to change its flexibility and durability.*
- Change the temperature:
  *Raise the temperature above the Curie point to change a ferromagnetic substance to a paramagnetic substance.*
  *Raise the food temperature to cook it. (Changes taste, aroma, texture, chemical properties, etc.)*
  *Lower the medical specimens' temperature to preserve them for later analysis.*

36. **Phase transitions**

- Use phenomena occurring during phase transitions (e.g. volume changes, loss or absorption of heat, etc.):
- *Water expands when frozen, unlike most other liquids. Hannibal used this water phenomenon when marched to Rome a few thousand years ago. Large rocks blocked passages in the Alps. He poured water on them at night. The overnight cold froze the water, and the expansion split the rocks into small pieces which could be pushed aside. Heat pumps use the vaporization heat and condensation heat of a closed thermodynamic cycle to do useful work.*

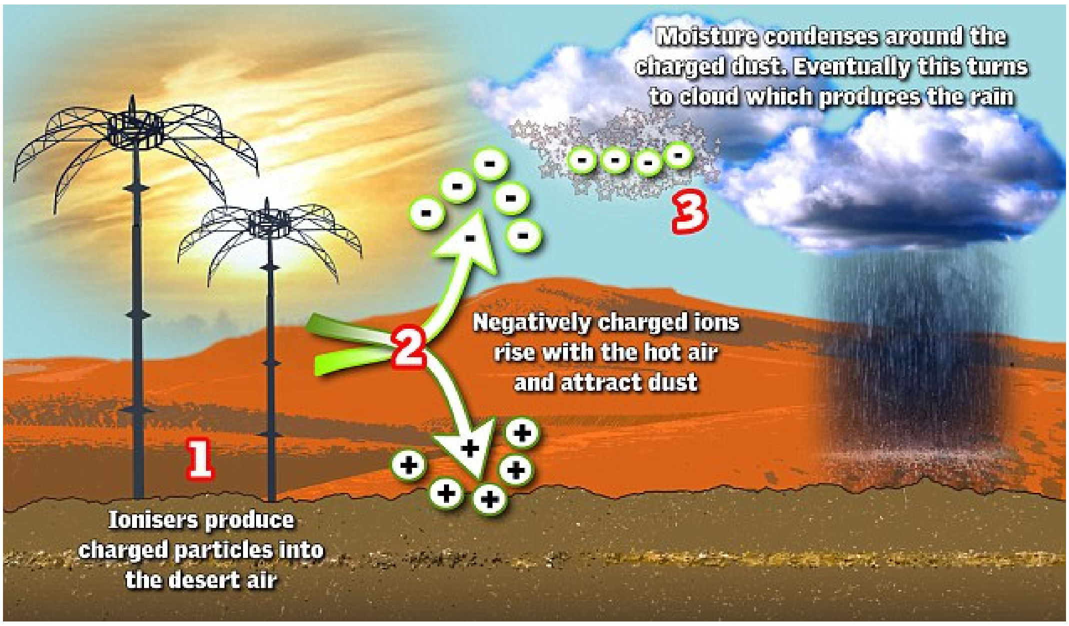


37. **Thermal expansion**

- Use thermal materials expansion (or contraction):
  *Fit a tight joint together by cooling the inner part to contract, heating the outer part to expand, putting the joint together, and returning to equilibrium.*
- If thermal expansion is being used, use multiple materials with different thermal expansion coefficients.
  *The basic leaf spring thermostat: (2 metals with different expansion coefficients are linked so that it bends one way when warmer than nominal and the opposite way when cooler).*

38. **Strong oxidants**

- Replace common air with oxygen-enriched air:
  *Scuba diving with Nitrox or other non-air mixtures for extended endurance.*
- Replace enriched air with pure oxygen:
  *Cut at a higher temperature using an oxy-acetylene torch.*
  *Treat wounds in a high pressure oxygen environment to kill anaerobic bacteria and aid healing.*
- Expose air or oxygen to ionize radiation.
- Use ionized oxygen:
  *Ionize air to trap pollutants in an air cleaner.*
- Replace ozonized (or ionized) oxygen with ozone.
  *Speed up chemical reactions by ionizing the gas before use.*




39. **Inert atmosphere**
  - Replace a normal environment with an inert one:
    *Prevent degradation of a hot metal filament by using an argon atmosphere.*
  - Add neutral parts or inert additives to the object:
    *Increase the powdered detergent volume by adding inert ingredients. This makes it easier to measure with conventional tools.*
  - To lead process in vacuum.

40. **Composite materials**
  - Change from uniform to composite (multiple) materials:
    *Composite epoxy resin/carbon fiber golf club shafts are lighter, stronger and more flexible than metal. The same is used for airplane parts. Fiberglass surfboards are lighter and more controllable and easier to form into a variety of shapes than wooden ones.*

Later some attempts were done to systemize the principles on groups:

- Contrary demands dividing in space.
- Contrary demands dividing in time.
- Contrary demands satisfaction by chemical and physical system's parameters change
- Transition to above-system.
- Transition to sub-system.
- Transition to anti-system.
- Dismissal from system.

Principles complex gives more strong decisions then individual principles. S.A. Faer proved it in his work “System Analysis Principles. Algorithm for Principles Choosing” [28]. He shows how to choose the principle in accordance with two contrary demands. Principles are divided on four groups depending on working character with technical contradiction (TC), every group has its own design practice and principles interaction. On Picture 3.9 is shown the algorithm for principles choosing fragment.

Frequently the task initial formulation is not clear for inventor. It is very important to understand how to solve the task: use the primary problem definition or it is necessary to restate the task. The overall conclusion may be done that in many cases to solve conflict means to change the task and to solve it on another hierarchy level.

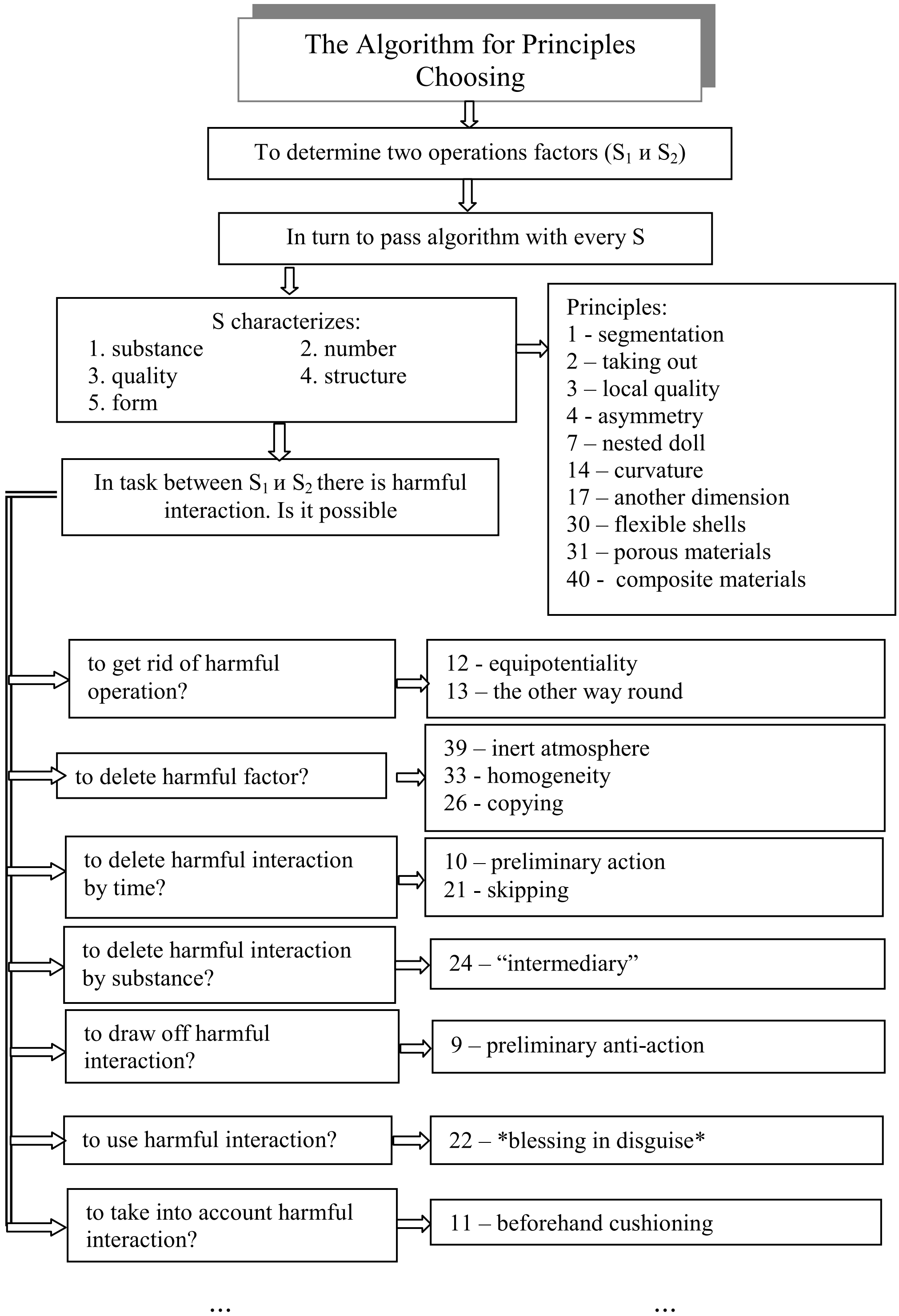



*Fig. 3.10. Principles choosing algorithm fragment*

## 3.3. Various Effects Use

In the first technical system men used macro mechanical properties of the world. It is not accidental because scientific nature cognition began from mechanical process under the substance. Man could sense the substance as an object with its forms and geometrical parameters. It is the matter organization level where this matter is a phenomena, quality or form. Therefore every technological technique corresponds to the simple form matter movements – mechanical.

Techniques improvement is connected with technical development. Mechanical techniques are replaced by more effective physical and chemical. For example in mining industry inside of mechanical bucking and ore lifting on the surface now there exist new techniques: ore body lixiviation, metal solution acceptance and the metal via chemical way extraction.

In manufacturing the micro technology leads to revolution transformation: complex details are raised as mono-crystal, inner substance properties are changed by strong electrical, optic or magnetic fields. In building the substance fundamental properties use allows refusing from complex and expansive mechanisms.

For example, thermal expansion helps to design crushproof jack, to build arc bridges at least five times faster without false work and lifting gears use. On the building place it is possible to make load-carrying part of arc bridge by height near 20 meters: two metallic plates by length 100 meters are juxtaposed one on another and asbestos washer is situated between them. Lower sheet is heating by high frequency current up to 700 degree Celsius, combining with upper sheet and arc is ready when such "pie" will get cool.

By what effect micro technology efficiency may be explained? It is difficult to understand where there are the substance as an action instrument and the substance as labor subject. There are not instrument for treatment, labor subject or machine working part as it may be when mechanical methods are used. The substances particles (molecules, atoms) implement labor subjects function. We can impact by definite field on system parts, create special conditions and the process itself is becoming handy.

Transition from mechanical and macro physical techniques to micro physical allows to simplify every technological process and to get economical effect and non-polluting processes.

Nature leads their manufacturing on atoms level automatically without noise and without waste. But it is necessary to remember about possible bounds and saving of nature.

### 3.3.1. Physical Effects

Every principle is connected with physics in fact. For example, segmentation on a micro-level is dissociation – association, desorption – sorption etc. Complex changes are the main typical principles. The bridge between inventive tasks and physics is building up to date [29].

Lower there are some examples from "Index of Physical Effects and Phenomena".

**∢ Centrifugal force**

Centrifugal force appears when the body changes its movement direction but body energy is saved. This force is directed only from rotation center.

Means of formed surfaces polishing by moving abrasive band: band is pressed to template's work surface by centrifugal forces.

Method used for products processing with parabolic shape: there used tank rotation with liquid and liquid with greater specific weight is used as moulding forming element. Liquid with lesser specific weight is hardened under rotation. It permits to cheapen and to improve the surface accuracy.

**∢ Memory effects**

Some metal alloys (titan – nickel, gold – cadmium, copper – aluminum) have memory effect. If there is a need to manufacture a detail from such an alloy and to deform this detail, then after hitting up to certain temperature detail returns to its original shape. A titanium nickelide (TiNi)–based alloy now is the most famous and unique.

TiNi–based alloys produce a huge force during originate return form. A.A. Boikov's Institute of Metallurgy staff used this alloy property. Complex shape detail is produced from TiNi-alloy, alloy remembers shape and after that detail is formed to flat sheet. The sheet surface is covered by another alloy or metal with usual different techniques use – by rolling, by sputtering, by explosive bonding etc. After hitting up this metal "layer cake" turns to detail with complex shape.

This technique may be used for sandwich products creation of any shapes when it is impossible to produce such form by usual ways. TiNi-alloys are good for working, efficient, corrosion-proof, reduce the vibration. Designers used TiNi-alloy for sputnik's antenna: when launching antenna is rolled up and compact, but in space after hitting up by sun antenna takes very complex shape.

Potential for alloys with memory effect use are great: this is thermal automatics, high-speed sensors, relay, control devices, thermal jacks etc.

### ∢ Thermal expansion

Under thermal expansion or solid matters pressing huge forces are produced. This effect may be used in technological processes.

For example, this property is used in electrical jack for reinforcing steel tension when ferroconcrete is produced. The principle is very simple: ferroconcrete is bonded with metal bar, which has suitable thermal expansion quotation. The bar is hit by current from welding transformer, then bar is hard fastened and heat is taken away. The tug in hundreds of tons is appeared after cooling and bar linear dimensions shortening. This tug can stretch cool ferroconcrete to the value demanded. In this jack the molecular forces work and jack can't crack.

### ∢ Phases change

Under 1-st phase change the matter density and energy are changed discontinuously, always a certain heat energy amount is separated out or consumed. Under 2-nd phase change the matter density and energy are changed continuously, but heat and heat conduction are changed discontinuously. Heat energy is **not** separated out or consumed under the 2-nd phase's change.

The typical example of *1-nd* phase change– matter transition from one to another aggregate state. There exist four aggregate states in physics: solid, liquid, gas and plasma. Often matter aggregate state changes allow to solve technical tasks, which seemed at first extremely difficult.

The *2-nd* phase changes examples:

liquid helium change to super fluid state,
ferromagnetic change to paramagnetic under Curie peak,
alloys crystals inversion etc.

For example: how to fulfill container layer wise by liquids which can be mixed among themselves? The first liquid in container had to be frozen, after that next liquid was poured on the first liquid frozen layer and then the first liquid was unfrozen.

## ∢ Resonance

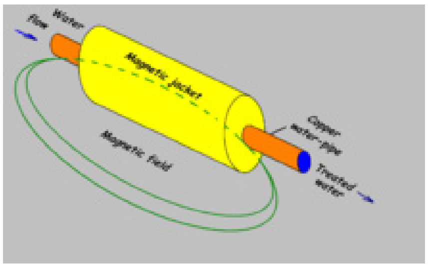
Resonance has the significant role in oscillating processes. Resonance is the system tendency to oscillate at greater amplitude at some frequencies than at others. Resonance effect is used for technological processes intensification.

*Examples*

The metal details working out way: detail was heated up to drawback temperature with simultaneous mechanical vibration use. To prevent fatigue cracks and to relieve internal welded connection stresses the treatment is processed with local weld zone heating with simultaneous resonance vibration.

The measurement way of matter mass in container: mechanical resonance oscillations are exited in system “container-matter”, the measured frequency will be the mass indicator.

## ∢ Water magnetization




Until now there is no explanation for water magnetization effect but the use of this effect permits to intensify different processes.

For example, structural mixes preparation way to product concrete article: the water is working up by rotating magnetic field (FI=100-2000A, water penetration velocity is 0.5-2.5 m/sec). This technique permits to increase product durability.

## ∢ Friction

*Friction*[38] is the force resisting the solid surfaces relative motion, fluid layers, and material elements sliding against each other. There are several friction types:

**Dry friction** resists relative lateral motion of two solid surfaces in contact. Dry friction is subdivided into *static friction* between non-moving surfaces, and *kinetic friction* between moving surfaces, kinetic friction is subdivided into *rolling resistance* and *sliding friction*.

**Fluid friction** describes the friction between layers within a viscous fluid that are moving relatively to each other.

**Lubricated friction** is a fluid friction case where a fluid separates two solid surfaces.

[38] http://en.wikipedia.org/wiki/Friction

**Skin friction** is a drag component, the force resisting a solid body motion through a fluid.

**Internal friction** is the force resisting motion between the elements making up a solid material while it undergoes deformation.

When surfaces in contact move relatively to each other, the friction between the two surfaces converts kinetic energy into heat. This property can have dramatic consequences, as illustrated by the friction use created by rubbing pieces of wood together to start a fire. Kinetic energy is converted to heat whenever motion with friction occurs, for example when a viscous fluid is stirred. Another important consequence of many friction types can be worn, which may lead to performance degradation and/or components damage. Friction is a component of the tribology. Friction is not itself a fundamental force but arises from fundamental electromagnetic forces between the charged particles constituting the two contacting surfaces. The complexity of these interactions makes the friction calculation impossible and necessitates the empirical methods use for analysis and the theory development.

Dry friction can induce several instabilities types in mechanical systems, which display a stable behavior in the friction absence. For instance, friction-related dynamical instabilities are thought to be responsible of brake squeal and glass harp 'song', phenomena which involve stick and slip, modeled as a friction coefficient drop with velocity. For example, a connection between dry friction and flutter instability in a simple mechanical system has been discovered.

Usually the rolling resistance force is less then sliding friction force. But if the rolling velocity is equal the deformation velocity the rolling resistance force will be huge, so under great velocity to use sliding friction is more effective.

The static friction force is more than the kinetic friction force and it is the reason why precision device receptiveness is lowered. It is necessary to decrease the friction – this task may be solved by the oscillation use.

For example, the bearing bush was produced from piezoelectric matter and was covered by electro-conductive foil. Electric current-induced piezoelectric oscillation eliminates static friction.

## 3.3.2. Geometrical Effects

There exist the number of geometrical effects; some of them are described in “Geometrical Effects Catalogue” [26]. This “Catalogue” can help to find the main principle, the main idea, but not a structure in detail. It is important to understand the geometrical effects place in TRIZ informational fund. Chemical effects allow to enable one property from others with emission or energy absorption or to convert one energy type to another. Geometrical effects usually distribute energy streams or substance. Patent fund analysis shows that geometry in systems is developed in synthesis direction with control geometry, with physical effects geometry etc.

The next direction is SuField recourse and geometrical effects. The shape is inventive resource which is used effectively less frequently.

Lower there are given some examples [26].

**∢ Dry substances**

Dry substances are between liquids and solids. In comparison with solid dry substances have movable particles and have more surfaces which can cover relief.

Dry substance is not compressible if to increase pressure on dry substance in confined space. Such substance allows using dry substance as bulking agent under hollow components manufacturing for subsequent deformation.

Long since carpenters used packets with sand for fixed of figure details. Then inventions appeared where dry substance particles are manufactured from flexible materials or particles are covered by fusible materials which supply emptiness after being melted.

**∢ Brush-type structure**

Most famous brush-type structures function is the ability to fit close to figure surfaces. Usually brush-type structures are used for coating processing, surfaces cleaning, forming acoustic, electrical, magnetic contact etc.

The brush-type structures surface allows the surface area increase for heat exchange. This effect may be used for heating or for cooling.

Brush can not only repeat detail forming but operate surface too. It was invented needle-cutter, which can operate different materials – metals, plastic, and rubber. Needle-cutter allows to polish surface and to cut 5 mm in one pass. If to combine the brushes couple by nap directed towards each other it is possible to get quick-disconnected joints. Brush-type structures may be used for gripper, fixing and figure details joint with different shapes. Brush-type structures are of the dinamization type and increased flexibility.

**∢ Spirals**

Now spirals are the most popular form from classic geometrical figures.

Archimedean spiral has remarkable properties. For example, the distance between two consecutive spiral coils is the constant value. This property is used in concentric jaw chuck.

Cylindrical helix with constant step is formed by plane covering with direct line on circular cylinder. Such lines are used in screw conveyors, worm presses for smooth step variation. Manufacturing and assembling automation of different complex shapes can be accomplished by synthetic tows spinning.

Details manufacturing by spinning has one more advantage: belt threads may be placed in the main mechanical stresses direction in accordance with the effort distribution picture.

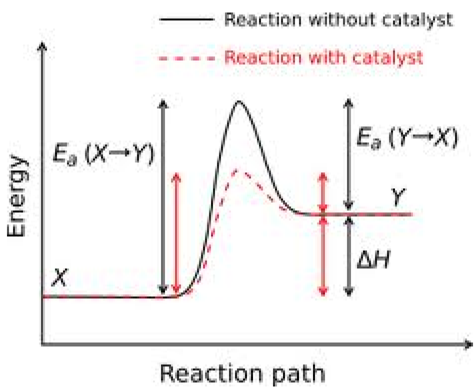
### 3.3.3. Chemical Effects

Chemical effects use in invention activity allows providing higher technical decisions level [27].

For example, surface metallization (appearance – matter disappearance) allows improving the surface properties, to increase corrosion resistance, to control frictional coefficient, to strengthen pressed details contact, to regenerate wearing out surfaces. Dissoluble metal salts, metal & organic compounds, metal oxides, volatile metal compounds are used for such purposes. Reduction is made by reagents (glycerin for oxides, sodium solution in liquid ammonia) or by electrical current on cathode. Control is realized by heating or by electrical field.

Metal discharge in volume allows to produce metal-wood (or metal in other porous bodies), photosensitive glass (association – dissociation of silver chloride).

Sometimes it is necessary to make substance disappear by physical (evaporation, melding), physical & chemical or by chemical way (chemical bounding with dissolution, volatilization, evaporation).




It is known that the most of chemical transformations are connected with energy release or energy absorption (exo- and endothermic reactions). Mechanical energy release is attended by such reaction products release as gas (steam) and by pressure increase in closed system. Changing pressure may be done by introduction into system of gel, polymers or under thermal metal-organic compounds dissociation (metal lubrication).

Heat energy store creation is heat absorption a process. Under salt dissolution in water low temperature grade may be distinguish.

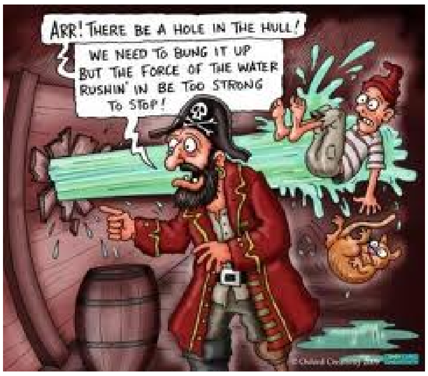
It is possible to get electrical energy by well known chemical current source. The most popular polymers are non-conductor, but electro-conduct properties may be done by the hydrophilic paint use.

Polymers synthesis use in electromagnetic field allows getting new substances – electrets films, which have constant allocated electric charge. Such films may be used as a low-power electric energy source , as different parameters control sensors etc.

Here there are described only small parts of effects, which made the Inventive Machine – Effects" (Developer: IM–Lab, Minsk) program base ".

## 3.4. Psychological Inertia and How to Overcome It

It is well known about psychological inertia[39]. Brainstorming (part 2.3) presupposes that it is necessary to break down stereotype and to create appropriate conditions for new ideas generation. chological Inertia (PI) represents the many barriers to personal creativity and problem-solving ability, barriers that have as their roots "the way that I am used to doing it." In solving a problem, it is the inner, automatic voice of PI whispering "You are not allowed to do that!" Or, "Tradition demands that it be done this way!" Or even, "You have been given the information, and the information is true."[40]




By the other words psychological inertia is the habit to do usual things. Off cause, one of the most important forms of knowledge is knowledge of how long things last. It is experience that was gotten with difficulties and victims.

There exist different psychological inertia types. Below there are some of them. In addition you can see the article by James Kowalick "Psychological Inertia" in Appendix 1.

**∢ Functional direction/inertia of usual function**

Familiar subject performs familiar function (pen's function – to make mark on the paper, the main car function – to be driven).

**∢ Inertia of special terms**

For example, determine the main icebreaker function. If you get "to break ice" – not be in despair.

**∢ Inertia of usual shape**

For example, the pipe section is not only circle.

**∢ Usual parameters and properties (temperature, size etc.) inertia**

[39] The lecture by S.S. Litvin "Kurs RTV" (in Russian) was used as the base of this part
[40] James Kowalick "Psychological Inertia" (http://www.triz-journal.com/archives/1998/08/c/index.htm)

Some japans' cameras have plumbeous plate, the main function of this plate is to make camera heavy, because some people consider that camera is more prestigious if camera has got weight.

∢ **Usual direction or measurement (searching on line, when decision is on plate, searching on plate when decision is in space etc.) inertia**

For example, try to answer the question: how to upbuild four triangles from six matches?

∢ **Superfluous information inertia**

You possess superfluous information but cannot determine what information you need.

*Example:* A cock had just laid an egg. Now a cock is sitting on the top of house with triangle roof. This house was built not so long. In what direction an egg is rolling?

∢ **Ambiguity inertia**

In usual understanding the task may have only one answer or an object may have only one function.

For example, determine side *c* of the triangle, if it is known sides *a, b* and altitude *h* from vertex *A*.

∢ **Known decision inertia**

Usually engineers are afraid of other science fields or they ensure that it is not allowed to change an object although such constraints available.

For example, T. Edison asked his listeners: what is the place for absolute dissolvent keeping? Usually listeners could not to solve this task. But once one of the listeners suggest to transform dissolvent to another phase condition – to keep it in solid state (there exist analogy: water and sugar – ice cannot dissolve sugar).

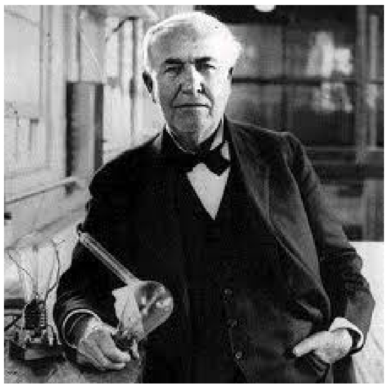


*Fig. 3.10.*
*Thomas Alva Edison*

∢ **Non-existent prohibition effect**

Man used to operate under prohibition. If prohibition is not exist man create it. For example, there are six glasses in line. First three are filled with water. How to replace only one glass and to provide interleaving of full and empty glasses?

Psychological inertia is as immune, which saves man from different trouble. But on the other hand immune does not allow coming true transplantation. Invention is the same: it changes rut things, but man instinctively resists to this changing.

TRIZ always took into account that it is man who improves technique and it is necessary to take into consideration psychology. So TRIZ includes some techniques for psychological inertia overcoming.

- *Terms and science terminology are the science knowledge part. They help to specialists to understand each other. But in inventive activity terms are hindrance. It is necessary to avoid terms under inventive tasks solving. It is necessary to change terms on simple words, which are known not only to specialists but to every people. If a man cannot to explain his task in terms for knowing schoolchild, it means that he does not understand the task. Often the task may be solved during process explanation for "witless" searcher without special technique use.*

- *Knowledge as terms carries no visible limitations. Too well system knowledge, understanding what can do and what cannot do leads to psychological inertia. It is useful to imagine system as system in mist – non real, soft, changing. It is possible to do such operations by operator STC (size – time – cost) use. This operator includes brain practices:*
  *What may be if the system size should be reduced?*
  *What may be if the system size should be increased?*
  *What may be if time will tend to zero/ infinity?*
  *What may be if for problem solving there are millions/ is nothing?*

- *Successful solving demands help to imagine what actions are in system. TRIZ operates by "Modeling by Little Men" (MLM) technique. The object is modeled as little men crowd that is ready to move, transform, appear and disappear by order.*

## 3.5. Algorithm of Inventive Problem Solving

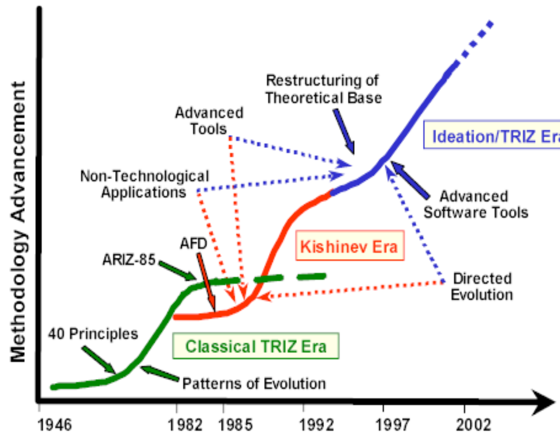



*Fig. 3.11. TRIZ-History*

Algorithm of inventive problem solving[41] (ARIZ) is a complex program based on the technical system development laws. ARIZ allows the inventive task analyzing for finding contradiction in the system. ARIZ is operations sequence for uncertain inventive task analysis. Often this task is described incorrectly.

Because the program is realized by men ARIZ contains operations for psychological factors control. Such operations decrease psychological inertia and encourage imagination. ARIZ is provided with information fund. Information fund includes:

procedures for contradiction removing,
standards for inventive problem solving,
bank of physical, chemical and geometrical effects.

### 3.5.1. Task Analysis

The ARIZ first part contains 7 steps for transition from uncertain inventive situation to clear and simple problem model.

∢ **Step 1 – Mini-task.** The task is formulated in accordance with special form:

- to write down the technical system function and basic system components;
- to formulate two technical contradictions (TC1 and TC2), each of them is connected with contrary tool in system conditions;
- to point the result which must be realized.

[41] The part is prepared with the [8] and [26] use

Mini-task does not mean that the task is "small". On the contrary, additional demand is included to get the result without essential changes in system.

- **Step 2 – Conflict couple.** It is necessary to determine the elements (product and tool) couple, which conflict with each other.

- **Step 3 – Conflict schema.** Drawings show contradictions TC1 and TC2 (step 1) schemas.

- **Step 4 – Conflict schema choosing.** One of the schemas (step 3) is chosen. The decision direction is determined. The choice must provide the best main production process.

- **Step 5 – Conflict intensification.** This step is very important because it eliminates the trading possibilities.

- **Step 6 – Task Model**. The analysis result is summarized and there are indicated the following:
  conflict couple;
  strong conflict;
  the demand for x-element in system (x-element is unknown system change, which can solve all problem as result).

### 3.5.2. Task's Model Analysis

The goal of this part – system's resources search which can be used for task solving: space resource, time resource, substances and fields resources. Three steps have to be done:

- **Investigating of operational zone** as space, where conflict appears.
- **Investigating of operational time.**
- **Investigating of substance & field resources.** Substance & field resources (SFR) are written as table in order: resources in operational zone (intra-system resources), resources beyond operational zone (off-system resources) and above-system resources.

### 3.5.3. Ideal Result and Physical Contradiction Definition

The ARIZ third part goal is the decision image creation. This image points out the strongest answer and allows finding physical contradiction which prevents to reach the best result.

This part contains six steps:

- **Step 1 – Ideal Finish Result Definition** (IFR-1).
  The main demand IFR-1: introduced into system x-element does not complicate system, does not cause additional harmful effects, does not interfere for system tool but has to eliminate harmful effects.

- **Step 2 – Reinforcement of formulation IFR-1.** Formulation IFR-1 is intensified by additional demand: it is impossible to introduce extraneous substances and fields; x-element has to be from existing resources.

- **Step 3 – Physical contradiction on macro-level.** It is one of the most important steps for solution, it is formulated physical contradiction, when contrary demands are put forth for operative zone physical condition.

- **Step 4 – Physical contradiction on micro-level.** Physical contradiction is formulated on micro-level for operative zone particles: particles contrary actions or states.

- **Step 5 – Ideal Finish Result IFR-2.** This step finishes analysis and ARIZ analytical part. New physical task is realized. The task is to supply with contrary macro- (step 3) and micro- (step 4) operative zone conditions in operative time. The task may unrecognizably change.

- **Step 6 – Standards system use.** Physical contradiction on micro-level (step 4) allows to use standards system [26, 27].

### 3.5.4. Substances' and Fields' Resources use

The goal is to apply systematic operations for system resources use. This part is the beginning of searching. The actions order is the following:

- **To use the little men MLM** (modeling by little men) **method**. The method use order: the first figure shows the conflict, on the next figure it is necessary to rearrange little men so that they acted without conflict.

- **To carry of step back from IFR.** When sought-for system is clear and task is to find way for getting of this system it aids step back from IFR. It is necessary to draw finish system and to insert minimal dismantle change (one man) and determine how to eliminate this "man". Often this task solving is very simple and can show the way for all task solving.

- **To understand**, may be task could be solved by the mixed resources use.

- **To replace existing resources** by vacuum or resources mix with vacuum.

- **To use substances**, derivative from resources (phase transitions or chemical reactions result).

- **To introduce electrical field or two electrical fields interaction**. Every substance has resources which are opportune for using – own electrons and ions.

- **To introduce typical couple** field and substance, "remarked" on field. For example it may be magnetic field and ferromagnetic substance, ultraviolet and phosphor, heat field and metal with memory effects.

### 3.5.5. Information Fund Use

The main 5-th part goal is to find solution by inventive experience use from TRIZ information fund. Table with techniques for physical contradictions solution is strong tool in inventive practice [26, 27]. There are the next techniques groups in above-mentioned table:

- Dividing of contrary properties in space.
- Dividing of contrary properties in time.
- System transitions use:

similar and dissimilar systems joining into above-system,
transition from system to anti-system or system with anti-system combination,
giving to system of one contradiction property, but system parts – of another property,
transition to system on micro-level.

- Phase transitions use:
  system part or external medium phase condition change,
  be-phase system part (transition from one condition to another according to condition of operation)condition,
  effects with phase transition use,
  one-phase substance with two-phase substance change.
- Physical and chemical transitions use: substance appearance – disappearance at the decomposition-combination expense, ionization-recombination.

It is the algorithm search part end.

### 3.5.6. Task Changing

This part goal is an initial conditions task change, if the analysis in part 5 did not produce the needed result. Probably the task was not correctly formulated. Work with difficult problem is connected with the meaning change. The solving process is a task correction process.

If the task is solved successfully the transition from idea to "ironmongery" must be done. The way is formulating and principal schema is working out. If the result is not obtained it is necessary to return to the beginning and check task formulation. May be the task formulation contains a number of tasks.

There exist scheming tasks which may appear as usual tasks with well formulated technical contradiction. But really each such task consists of several tasks. If it is possible eliminate special terms from mini-task the decision may be easily found.

There may be another situation. The task analysis have been made, the interesting decision have been done, but it is impossible to use this solution because the new task appears. It is usual situation in TRIZ for high level tasks. It is necessary to solve new task inside of solution renunciation.

If you cannot find task decision it is necessary to return to the beginning and try to choose another technical contradiction. May be the main process in system was determined incorrectly. May be it is necessary to refuse from old system and move up to new system design in total.

Often the task cannot be solved in old problem statement but if to break down all barriers the decision could be easily found.

### 3.5.7. How to Eliminate Physical Contradiction

The main 7-th part goal is to get answer verification. It is necessary to eliminate physical contradiction because only in this case the inventive decision could be carried out. This part has got four steps:

- **Step 1.** Decision improving possibility at the recourses expense and self adjust substances (which can change their condition at the expense of physical and chemical effects) use.

- **Step 2.** Previous decision assessment with the control questions help. If decision does not satisfy the demands it is necessary to make a fresh start.

- **Step 3.** Novelty decision inspection. It is necessary to analyze patent libraries funds.

- **Step 4.** All tasks formulating, which appear under technical idea analysis: inventive, design, calculate, organizational etc.

### 3.5.8. Answer use

This part goal is to provide idea with maximum of the recourses. It is necessary to define what changes may be done in above-system when our system became this above-system part. May be having changed system / above-system acquired new useful or, contrary, harmful properties. The job has to be done for possibilities finding in order to use idea for other tasks. The main principle is formulated and then there should be considered the possibility to use this principle for other tasks solving.

Morphological tables are created as “parts relative position– substance aggregate state” or “field use – environment aggregate state”. At the same time there are investigated common principle changes under system sizes or system parts (in accordance with operator Size – Time – Cost) change. In reality it is forecast for a new system and application possible range finding.

## 3.6. Diversion Technique


Inside of the real defect case on manufactory details and structures there may have been hidden faults which should be found in time. It is a task for engineer – to predict possible faults on system design stages.
Such problems solution may be done by modification of “reverse” technique. This modification name is diversion technique. The subversive technique essence is to question inside “What faults may be in this structure or in this technology?” or “How to spoil this structure or technology?” In reality it concerns subversive act or diversion [30].

Diversion has to be checked on practice – is the diversion possibility real or it isn’t under stating conditions. If the diversion possibility is real it is necessary to understand how to prevent this diversion? The prime virtue of this method is the possibility to expose unfounded tasks.

Technique is in a step by step thorough system analysis.

- **Another task formulation** –initial system description and the problem statement how this system could be damaged.
- **Finding of possibilities for harmful effects creation** initial system analysis, including functional analysis, harmful effects searching for the given system model, harmful influence implementation on technical systems possibility check on nature and man.
- **Resources description and use** – typical dangerous zones system research and others resources capable to cause harmful effects.
- **Harmful effects in informational funds search** – physical, chemical, geometrical effects use and typical mistakes in technical system evolution special lists use.

- **Harmful effects search by the forecast use**. There could be used two variants – back system forecast in the useful functions worsening direction and forward forecast in the "payment factor" intensification direction.
- **New solution search** – TRIZ use for diversion tasks solving (how to worse system).
- **Harmful effects "Camouflage"** – searching how to hide defects and provide with difficult detection.
- **Harmful effects analysis** and determination which effects could be realized in system, what is the probability and their appearance risk.
- **Harmful effects elimination** by typical methods or TRIZ use.

# CONCLUSION

The course is completed. Appropriately question is – how to use the studied (mastered!) techniques in practice, what conditions have to be when techniques are effective?

The task type defines the technique that has to be used. For example brainstorming and synectics may be successfully used for advertising. It should be understood that brainstorming is costly for company because of the staff's large contingent and a long time job diversion.

Morphological tables are the best when the data should be streamlined and systematized under attribute signs.

TRIZ is used for the new ideas search in different ways. There are definite signs for task solving with TRIZ:

- Task solving possibility from any engineering field;
- A lot of task solving including cheap (ideal);
- High speed for task solving.

So it is possible to make decision for inventive tasks as engineering procedure. TRIZ is actively used worldwide. TRIZ is the tool which helps to manage with theoretical and practice tasks from different fields of knowledge. There may be not only technical systems but scientific, artistic, social etc. Different systems development obeys similar laws, so lot of ideas and TRIZ techniques were used for theory creation for nontechnical tasks solving (for example TRIZ–Шанс). Now the informational findings are created in business, art, literature and so on.

Anyway you have the right to make choices and only you solve what way is the most preferable.

Be audacious – and you'll reach the result!

# BIBLIOGRAPHY


1. Крик Э. *Введение в инженерное дело*. – М.: Энергия, 1970. – 176 с.
2. Иловайский И.В. *К инженерному образованию XXI века* // Качество образования. Проблемы оценки. Управление. Опыт: тезисы докладов II Междунар. научно-методической конференции. – Новосибирск, 1999. – С. 225
3. http://www.altshuller.ru
4. ИМ-ФСА. *Руководство по анализу технических устройств*. – Минск: ИМ-Lab, 1991. – 190 с.
5. Лев Гумилевский. *Русские инженеры*. – М.: Молодая гвардия, 1953. – 440 с.
6. Hans J. Eysenck. *Know your own IQ*. – Penguin Books; Reprint edition – 1962. – 192 pgs.
7. John R. Dixon. *Design Engineering: Inventiveness, Analysis and Decision Making,* McGraw-Hill,1966. – 354 c.
8. Альтшуллер Г.С. *Найти идею*. – Новосибирск: Наука, 1986. – 210 с.
9. Половинкин А.И. *Законы строения и развития техники*. – Волгоград: ВолгПИ, 1985. – 202 с.
10. *Приемы настройки творческого инженерного коллектива* // Изобретатель и рационализатор. – 1970. – № 5 – С. 27–29.
11. Пойа Д. Как решить задачу? – М.:Учпедгиз, 1961. – 230 с.
12. Чурюмов С.И. и Жариков Е. С. *Об одном способе повышения эффективности мышления ученого* // Сб. Материалы по науковедению. – Киев, 1970. – Вып. 6. – С. 35 – 37.
13. Gordon, William J.J. *Synectics: The Development of Creative Capacity*. New York: Harper and row, Publishers, 1961
14. http://www.wikid.eu/index.php/Synectics
15. http://www.georgemprince.com/booksarticles.htm
16. http://www.rushitech.ru/inventor.htm
17. Гнеденко Б.В. и др. *За советом в природу*. – М.: Знание, 1977. – С. 45.
18. Кориков А.М., Сафьянова Е.Н. *Основы системного анализа и теории систем.* – Томск: Изд-во Томск. ун-та, 1989. – 207 с.

19. Саламатов Ю.П. *Система Законов Развития Техники (Основы Теории Развития Технических Систем)*. Издание 2-е исправленное и дополненное. Книга для изобретателя, изучающего ТРИЗ – теорию решения изобретательских задач. – Красноярск, 1996. – 250 с.
20. Прангишвили И.В. *Общесистемные закономерности функционирования сложных систем различной природы*. // Приборы и системы управления. – 1996. – № 12.
21. Альтшуллер Г.С. *Творчество как точная наука*. – М.: Советское радио, 1979. – С. 122–127.
22. K. Sagan. *The Dragons of Eden: Speculations on the Evolution of Human Intelligence*. Ballantine Books, 1978, ISBN 0-345-34629-7, 288 pgs.
23. Герасимов В.М., Литвин С.С. *Зачем технике плюрализм* // Журнал ТРИЗ. – 1990. – №1. – С. 11.
24. Альтов Г. *И тут появился изобретатель*. – М.: Детская литература, 1989. – 144 с.
25. *Как стать еретиком* / сост. А.Б. Селюцкий. – Петрозаводск: Карелия, 1991. – 365 с.
26. *Правила игры без правил* / сост. А.Б. Селюцкий. – Петрозаводск: Карелия, 1989. – 280с.
27. Михайлов В.А. *Как решаются изобретательские задачи (Сто задач по ТРИЗ)*. – Чебоксары: Чувашский ЦНТИ, 1992. – 143 с.
28. Фаер С.А. *Системный анализ приемов. Алгоритм выбора приемов, разрешающих ТП*. – Ленинград, 1991.
29. Денисов С., Ефимов В., Зубарев В., Кустов В. *Указатель физических эффектов и явлений.* – Обнинск, 1979.
30. Злотин Б.Л., Зусман А.В. *К вопросу о применении ТРИЗ в науке* // Журнал ТРИЗ. – 1990. – № 1. – С. 45-54.
31. Joseph E. Shigley, Charles R. Mischke. 2001. *Mechanical Engineering Design.* McGraw-Hill Higher Education, 2001.
32. Jones J. 1982. *Design Methods.* John Willey & Sons, New York, Toronto, Chichester, Brisbane, 1982.
33. Edward de Bono. *How to Have Creative Ideas*. London: Vermilion, McQuaig Group Inc., 2007
34. James Kowalick. *Psychological Inertia.*
http://www.triz-journal.com/archives/1998/08/c/index.htm

http://www.triz-journal.com/archives/1998/08/c/index.htm

## PSYCHOLOGICAL INERTIA

James Kowalick, TRIZ Master
Renaissance Leadership Institute
(530) 692-1944 ~ E-Mail: headguru@oro.net

**PSYCHOLOGICAL INERTIA DEFINITION.** The psychological meaning of the word "inertia" implies an indisposition to change – a certain "stuckness" due to human programming. It represents the inevitability of behaving in a certain way – the way that has been indelibly inscribed somewhere in the brain. It also represents the impossibility – as long as a person is guided by his habits – of ever behaving in a better way.

Psychological Inertia (PI) represents the many barriers to personal creativity and problem-solving ability, barriers that have their roots "the way that I am used to doing it." In solving a problem, it is the inner, automatic voice of PI whispering "You are not allowed to do that!" Or, "Tradition demands that it be done this way!" Or even, "You have been given the information, and the information is true."

**PSYCHOLOGICAL INERTIA AND THE TRIZ PRACTICE**. PI is also what causes the followers of a given approach not to deviate from that approach. For example, practicing "TRIZniks" are prone to becoming stuck in TRIZ procedures that have been practiced and passed along over the years and decades – forgetting that the goal is not necessarily to "follow the rules," but rather to achieve excellent results. One result of this is the call for "standardization" in the way that procedures are followed. This makes a given practice or approach "safe" but not better, and acts as a damper to further development.

In science, it is PI that retards the science progress rate. What is new, is rarely accepted by the status quo – even if it is far better. The "guardians of the status quo" unknowingly become the barriers.

**ILLUSTRATING DIFFERENT FORMS OF PSYCHOLOGICAL INERTIA**. Psychological Inertia takes on different forms, many of which are quite invisible to personal observation. Different PI forms, although they are quite subtle during problem-solving, can be recognized in, and exemplified by, simple problems and "brain-teasers." The following simple problems, puzzles and brain-teasers each illustrates a different psychaological inertia form.

1. The Retarding Power (or Inertia) of a Word: CARRYING STRINGS ON A SHOPPING BAG. For years shopping bags used to have strings attached for carrying purposes. When the bag contents reached a certain weight, the strings caused damage to the carrier's fingers. The word "strings" implied that all shopping bags must have strings (the idea of using strings was attractive from a cost point of view), and served as a psychological inertia form to prevent progress in designing a "shopping bag system" that did not have this problem. An entire family of new shopping bags – based on the inventive principles of "Segmentation" and "Merging" – ultimately emerged. One is tape-like: "many strings (lines) that form a surface." Another is a fluid-filled (from one line, to many molecular fluid particles) carrier that, like the tape solution, also distributed stresses over a broader area. Words themselves (like "strings") are often enough to halt progress in a given technology for decades, because "this is the way it has always been understood."

2. A Partial Restriction Becomes a Blanket Restriction: There are two people groups. Each group member # 1 weighs exactly 150. Each group member #2 weighs exactly 200. Three people selected from these two groups have a total weight of 550 – but one of these persons cannot be from group #1! How many people are selected from each group? It is left to the reader to answer this question; if you cannot, then you may be operating under one of the laws of psychological inertia.

3. Tradition Cannot be Broken: The managers in a certain company were unaware of what was going on in manufacturing, and the President didn't like it. The company's managers had a history of being "standoffish" – looking down upon those employees who were not managers. The President wanted to change this situation as soon as possible, but unfortunately, remaining behind the "sacred" doors of one's managerial office had become quite a "tradition." What the President did was to initiate a weekly exchange at his staff meetings: each manager, in turn, had to discuss and present a manufacturing procedure in significant depth, with the other managers being encouraged to ask penetrating questions. In no time at all, the managers were spending time in the

manufacturing area. The general solution to problems like this (i.e., changing tradition or changing the culture) is: "Create a situation where the individuals involved in the change strongly want to change." Such cultural and traditional barriers are one form of psychological inertia, because they represent cultural and "traditional" programming.

4. Words and Their Assumed Properties or Characteristics: How can a pipe fit through a square hole (the area of the pipe and the whole are just about equivalent, with the square hole only having slightly less cross-sectional area)? Many persons will think of "pipes" as being "round." But a pipe need not be round – it could be square. This is another psychological inertia form.

5. Inadmissible Data Range: Scientists were conducting a test. They had attached one rope end to a frying pan, and the other rope end to the dog pulling-harness. At what speed should the dog run so that the frying pan won't rattle? Some problem-solvers are "stuck" in the psychological inertia of inadmissible data points. The problem as stated may imply to them that the dog must be moving, when in fact this is not a constraint. The answer: zero.

6. Objects with Senses Association: Three light bulbs in a room are operated by three respective switches outside the room – at a point inaccessible by sight to the room. The initial condition is that no lights are on. How is it possible to know which switch is for which light – if, from the site of the switches outside the room, only one trip to check on the status of the lights is allowed? HINT: use more than one of your senses (the sense of sight is usually connected with a light bulb). The psychological inertia form illustrated in this problem is related to "associations." It is often the case that a particular object is related to a particular sensation or function in one's mind – without opening up the possibility that other relationships are also possible. Overcoming this barrier leads to higher creativity.

7. All Information Given is Valid: Three worms are crawling along a perfectly straight line, in the same direction, and at the same continuous speed. The first worm says "I am (lead) worm number one, and there are two worms crawling behind me." The second worm says "I am worm number two, and there is a worm crawling in front of me and a worm crawling behind me." The third worm says "I am worm number three, and there are two worms crawling in front of me, and two worms crawling behind me." How can this be? (Hint: is all the information

valid?). Wrong information is often a powerful barrier for problems solving. Some problem-solvers believe everything that is presented. The answer here is simple: "The third worm is lying!"

Although there are many other various forms examples of psychological inertia, these seven are adequate to illustrate what PI is. In actual technical problems that engineers and scientists work on daily, these and other PI forms are very difficult to observe – because they are a strong part of personal programming, which emerges subconciously, PI is mostly quite invisible. It can only be "seen" through a prolonged, intentional effort. The psychological inertia result is an inferior product or process design, or an inferior solution to the problem.

**HOW PSYCHOLOGICAL INERTIA CAN BE AVOIDED, REDUCED OR ELIMINATED**. Fortunately there are exercises and techniques for methodically eliminating or reducing (or avoiding) the effects that PI has on one's personal creativity. Some of these are the TRIZ regular part procedures (Ideal Final Result; Physical Contradictions Statement; Functional Goal Setting; etc.).

Other approaches take the form of special psychological "anti-PI" exercises. For example, the author teaches exercises to engineers and scientists that force them to be "out of pattern." Such exercises are geared to break the inertia that would take them down a habitual problem-solving path. These exercises have been demonstrated and verified (but not published) by the author over the past twenty years.

These anti-PI exercises may appear, on the surface, to be quite simple. In fact, however, they are extremely difficult. Readers may want to attempt one very specific exercise that has worked well for the author, who uses this exercise with professionals in American corporations: "For ten days, while speaking, avoid using the word "the".

Initially this exercise is virtually impossible for anyone who seriously wants to use it to "break out the PI box." This is because (as explained in the author's previous TRIZ Journal articles on human functions) human functions involving movements occur at speeds that are far more rapid than intellectual (thinking) functions. What happens is that the word "the" comes out of the mouth before the speaker can think about it. Seriously following this exercise, however, will result in more control of that part of the mind responsible for higher-level thinking! Another way of saying this is that the practitioner begins to break through the prison walls of ordinary thinking. Exercises like these become even more powerful when several members of a technical staff are practicing them at once – they can kindly remind each other of the exercise when the other person speaks the inadmissable word. Such an effort raises the creative level of the professional team.

This exercise is only one of the powerful anti-PI exercises used by the author.

Although the practice of TRIZ, with its various tools and procedures, increases a person's creative capacity, it is also necessary to raise one's level of creative thinking (something that TRIZ, for the most part, does not do!). This is the very area that Altshuller, the father of TRIZ, rejected in his early search for a process of creativity. In essence, this area relates to the quest for achieving "creative enlightenment" all the time. It is indeed possible to raise one's level of personal creativity (as opposed to merely increasing one's creative capacity at the same level) through certain regular practices that the author has verified many times. Such exercises* have never been a part of the TRIZ approach, and represent "beyond TRIZ."

**ACKNOWLEDGEMENT.** The author thanks those whose research into "going beyond TRIZ" have contributed to this article – particularly to the researchers at the Leonardo da Vinci Institute (a division of the Renaissance Leadership Institute), who have been developing world-class creative and problem-solving algorithms and course materials now being routinely applied by the technical staffs of major corporations.

*NOTE: These creative exercises are not to be confused with various types of brainstorming, the use of analogy, the use of sympathy, etc., as offered by such groups as Synectics and through the DeBono's approaches – which, although they are effective, produce lesser results.

Educational Edition


Национальный исследовательский
Томский политехнический университет

ШАМИНА Ольга Борисовна


# ТЕОРИЯ РЕШЕНИЯ ИЗОБРЕТАТЕЛЬСКИХ ЗАДАЧ


Учебное пособие

Издательство Томского политехнического университета, 2013

На английском языке

**Published in author's version**

Science Editor
*Doctor of Physical and Mathematical Sciences, Professor Yu.Yu. Kryuchkov*

Cover design *T.V. Bulanova*

**Printed in the TPU Publishing House in full accordance with the quality of the given make up page**

Signed for the press 22.05.2013. Format 60x84/16. Paper "Snegurochka".
Print XEROX. Arbitrary printer's sheet 5,0. Publisher's signature 4,52.
Order 548-13. Size of print run XXX.

---

TPU PUBLISHING HOUSE. 30, Lenina Ave, Tomsk, 634050, Russia
Tel/fax: +7 (3822) 56-35-35, www.tpu.ru