TOMSK POLYTECHNIC UNIVERSITY

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INVENTIVE PROBLEM SOLVING

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

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

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Preface

To my students

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

- 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.

Attainments and skills which make us possible to connect manufacturing and marketing, economics, 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.

Special thanks to my students for their interest and enthusiastic work that encouraged me to create this lecture notes to help you be successful in the course Inventive Problem Solving.

Good luck!

Introduction

«Engineering»

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

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"[1]. 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"[2].

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.

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.

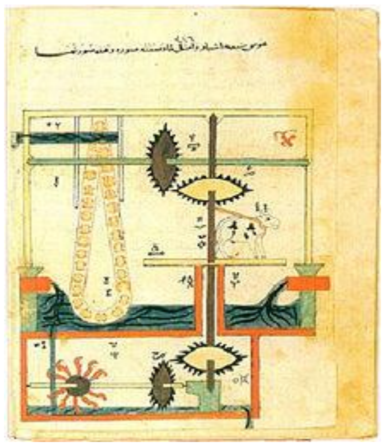

Fig. 1.1. Al-Jazari's hydropowered chain pump device

[1] Oxford English Dictionary.
[2] Random House Unabridged Dictionary, © Random House, Inc. 2006.

China has been a source of many inventions, including the four Great Inventions, such as papermaking, 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.

In Russia, Peter the Great 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 Bernulli, astronomer and geographer Joseph-Nicilas Delisle, physicist Georg Wolfgang Kraft and others.

Fig. 1.2. Théodule-Armand Ribot (1839–1916), French psychologist

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.

In the XIX century the French psychologist T. Ribot who did much to advance the subject in both its experimental and clinical aspects, investigated the dependence between the imagination and the age levels. In accordance with the Ribot's observation the imagination peak fits to the interval between 12 and 15 years (Fig. 1.3).

The question about inventiveness is the question about the intellect – is intellect innate characteristic or acquired property. Hans J.

Eysenck, the author of the book "Know your own IQ", best remembered for his work on intelligence and personality though he worked in a wide range of areas.

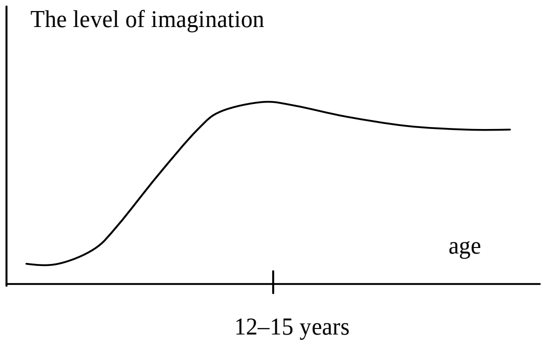

Fig. 1.3. The dependance between the imagination and age level

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

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

- *There is meaningful dependence between an intelligence quotient, or IQ*[3]*, 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).*

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[3] 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.

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

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 a far fantastic planet, to paint fantastic animal, to read popular science books and so on.

Quiz: Engineering

1. What is engineering? Please, give your own opinion:

____

____

____

____

2. What are the most important engineer's work parts:

____

____

____

____

____

____

3. Enumerate the most famous ancient inventions:

____

____

____

____

____

4. Who is *The Book of Ingenious Mechanical Devices Knowledge* **author? Mark the right answer.**

- ☐ Leonhard Euler
- ☐ Al-Jazari
- ☐ Gottfried Leibniz
- ☐ Georg Wolfgang Kraft

5. Please, point out the pick of imagination:

It fits to the interval between ______ and _________years old.

Part 1. Creative Approach Techniques

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

Niles Bohr

Unit 1.1. Psychological Inertia

It is well known about psychological inertia[4]. It is necessary to

break down stereotype and to create propriate conditions for new ideas generation. Psychological 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."[5]

In other words psychological inertia is the habit to do usual things. Of course, 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.

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[4] The lecture by S.S. Litvin "Kurs RTV" (in Russian) was used as the base of this part.

[5] James Kowalick "Psychological Inertia": http://www.triz-journal.com/archives/1998/08/c/index.htm

There exist different psychological inertia types. Below there are listed some of them.

∢ Functional direction/inertia of usual function

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

∢ Inertia of special terms

∢ Inertia of usual shape

For example, the pipe section is not only circle.

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

Some japanese cameras have lead 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.

∢ Ambiguity inertia

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

∢ 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 are available.

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

∢ **Non-existent prohibition effect**

Man used to operate under prohibition. If prohibition does not exist man creates it.

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

TRIZ always took into account psychology. So TRIZ includes some techniques for psychological inertia overcoming.

- ∢ *Terms and science terminology are the science knowledge part. They help specialists to understand each other. But in inventive activity terms are hindrance. It is necessary to change terms for simple words, which are known not only by specialists but by ordinary people. If a man cannot explain his task in terms to ordinary schoolchild, it means that he does not understand the task. Often the task may be solved during the explanation process for a "witless" searcher without special technique use.*
- ∢ *Knowledge as terms carries no visible limitations. Too well system knowledge, understanding what can be done and what cannot be done 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 happen if the system size should be reduced?
  What may happen if the system size should be increased?
  What may happen if time tends to zero/ infinity?

What may happen 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.*
- *More inventiveness prone.*

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.

Quiz 1.1: Psychological Inertia

Fig. 1.4. War and Peace by Jim Warren

1. Overcome psychological inertia:

a. Inertia of usual direction or measurement

Answer the question: how to upbuild four triangles from six matches?

b. Inertia of superfluous information

Answer the question: 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 ago. In what direction an egg is rolling down off the roof?

c. Inertia of special terms

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

d. Usual shape inertia

Point out pipe cross section form.

e. Usual parameters inertia (temperature, size, etc.)

There are three lamps in the room and a triple switch in the corridor. You cannot see the lamps. You may come to the switch but just once and try to determine which switch corresponds to each lamp.

2. Find the task decision:

You have six glasses in a line. First three are empty but the following three are full of water. You can take only one glass and have to do full and empty glass alternation.

3. Please, describe the life on imaginary planet and draw the imaginary animal.

Unit 1.2. Task solving:

Heuristic
Questions' Technique Control
Associative Thinking Technique

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

Robert Sheckley

Firstly the term *Evristica* appeared in *Collection* of the old Greek mathematician Pappus of Alexandria[6]. 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.

It was Peter K. Engelmaier, an engineer and engineering philosopher, who made serious contribution to the engineering science development.

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 psychological features and psychologists did not take into consideration science and engineering development laws. All attempts to create sketches were as Julius Caesar's expression: "Veni.Vedi.Vici."


PAPPI
ALEXANDRINI
MATHEMATICAE
Collectiones.
A FEDERICO
COMMANDINO
VRBINATÆ
In Latinum Conuersæ, & Commentarijs
Illustratæ.
VENETIIS,
Apud Franciscum de Franciscis Senensem.
M. D. LXXXIX.

Fig. 1.5. Title page of Pappus's Mathematicae Collectiones

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

A Hungarian Jewish mathematician G. Pólya[7] 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 mathematics to students and a mini-encyclopedia of heuristic terms. Here are a few commonly used heuristics, from book "How to solve it":

> 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 1.1 contains the heuristics groups classifications example.

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[7] 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.

Table 1.1

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

Questions' Technique Control may be considered as 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 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 an 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 in detail? 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 can you 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 the past? What can you copy? What technical object is it necessary to outstrip?

3. Which modification possibilities can be there? 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 extent could they be changed? Is it possible to use another material, process, generation, 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 20th century the Department of the Interior in the USA recommended to corporations to use the improved techniques system. It was suggested to answer the following questions: Can we make this operation simpler? Can we improve the work?

An English inventor T. Eiloart[8] made the fullest and most successful question list:

1. To enumerate all qualities and invention definitions. To transform them.
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 other analogies.
5. To construct mathematical, hydraulic, electronic, mechanical and other models (model expresses an idea better than analogy).
6. Try to use:
   different materials: gas, liquid, solid, foam, paste, etc.;
   different types of energy: warm, magnet energy, light, impact value;
   various wave lengths, surface's quality;
   transient conditions: freezing, condensation, Curie peak;
   Joule–Thomson, Faraday's effects, etc.

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[8] Tim Eiloart (1936–2009) was unwittingly crucial in driving the so-called "Cambridge phenomenon", manifested by the dozens of hi-tech companies: http://www.guardian.co.uk/education/2009/may/28/obituary-tim-eiloart

7. To establish relations variants, possible connections, logical coincidence.
8. To know under-briefed people's opinion.
9. To make a 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 a bath, drink, eat, play tennis – all with this task!
12. To ramble among creative 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 his/her?
19. Who was the first? The history of the question. What were the false problem interpretations?
20. Who solved this problem? What did he/she do?
21. To determine conventional restrictions and restrictions' establishment causes.

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.

S.I. Churumov and E.S. Dgarikov 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.

Quiz 1.2: Associative Thinking Technique

1. **Term “evristica” firstly was mentioned:**

 by an old Greek mathematician Pappus of Alexandria

 in Gottfried W. Leibniz and Rene Descartes articles

 in Peter K. Engelmaier book

Please, mark the right answer.

2. **Play “Unnecessary word” game** with chance words using the *Edward de Bono* book [References, 16]:
   - Choose four random words.
   - Determine unnecessary word on any sign base.
   - Justify this sign.

Your random words:

1. ____
2. ____
3. ____
4. ____

Unnecessary word: ____

Point the sign: ____

3. **Play “Grouping” game** with chance words using the *Edward de Bono* book [References, 16]:

- Choose six random words.
- Divide words in two groups on base of any sign.
- Justify this sign.

Your random words:

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____

Point the sign 1: ____

Group 1:

1. ____
2. ____
3. ____

Point the sign 2: ____

Group 2:

1. ____
2. ____
3. ____

Unit 1.3. Brainstorming & Synectics

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 technique types.

Brainstorming – psychological technique, but the author A. Osborn was not a psychologist. His top achievement was a job 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 idea generation process from reviewing process is such a technique milestone. Under idea 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 a condition – no critics and to encourage any suggestion.

A little and motley “idea generators” group is chosen to organize brainstorming. Top-managers are not included in this group and work is conducted in an ad hoc space. 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 with ideas before he took the floor.

For successful ideas generation it is necessary to overcome psychological inertia and create conditions for irrational ideas break from subconsciousness.

The brainstorming force is in the criticism prohibition. On the other hand it is necessary to find out all shortcomings for idea development. It means that in any case we do need criticism. George M. Prince and William J.J. Gordon[9] overcame this contradiction by forming and teaching special groups. Groups' participants gradually began to enjoy working together, without having fear of criticism. Within time the problem solving experience increases. Gordon managed to streamline the task solving process and to save brainstorming spontaneity.

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

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[9] 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

analogy finding way in different knowledge fields or object behavior investigation under other conditions up to the fantastic ones.

The synectics procedure[10] (Fig. 1.6) is a comprehensive creative procedure, containing problem analysis techniques, ideas generation and the selection stage. Synectics concentrates on the idea 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.

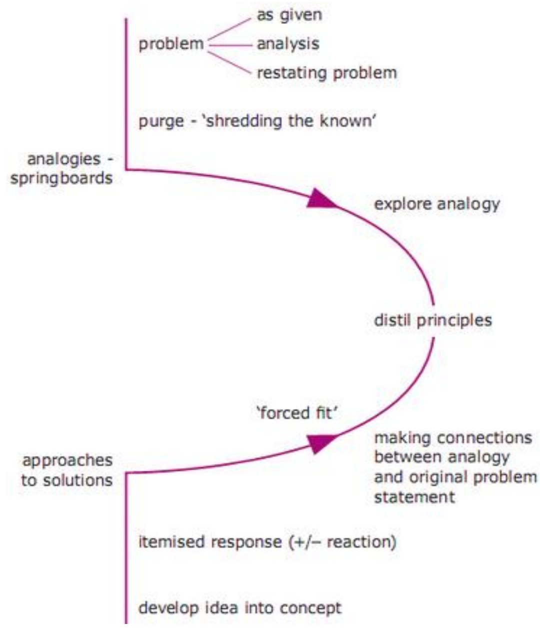

Fig. 1.6. The Synectics process (Tassoul, 2006)

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 1.2.

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

Table 1.2

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?
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 sea”)
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,
- at engineering leading branch – in accordance with the task conditions,
- in engineering branches where there is a great solving similar tasks experience,
- in engineering branches where similar tasks is a solved under more stringent conditions.

The next Pólya questions could be 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 the task and try to remember the task with similar unknown items?
- We have a 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 made similar to another object on exterior form. For example usual table and PC table.

Structure analogy – it is necessary to find analog object's structure in surrounded world, this structure has 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 a *which*-question. 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 a word list: a 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 different orders. Put yourself in the place of these little men in order to sense and understand the object's structure through actions and interaction between little men.

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


Fig. 1.7. Example of a nature analogy[11]:
King Fisher and Shinkansen Bullet Train

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

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*[12] 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."

One case where many oxymorons 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 crea-

---

[12] An **oxymoron** (plural **oxymorons** or **oxymora**) – from Greek ὀξύμωρον, "sharp dull"

tivity 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 your mind (shredding the known).
4. Find a relevant analogy in one of the listed analogies categories (personal, nature, fantastic, etc.).
5. 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?
6. Force the appropriate various solutions to the reformulated problem statement.
7. Generate, collect and record the ideas.
8. Test and evaluate the ideas. Use the itemized response method to select among the ideas.
9. Develop the selected ideas into concepts.
10. 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.

Quiz 1.3: Brainstorming & Synectics

1. **Solve the task** *in a group* **using brainstorming technique.**

One day during a boxing professional match sportsmen and their trainers encountered with some sort of a mystery. Not a strong boxer won some matches under favorites and all by knockout. Losers told that in the beginning his punches were ordinary, but then punches had grown heavier. It looked like that the boxer punched by a stone.

But referee checks boxing gloves before boxing. What has happened?

Your variants:

____

____

____

____

____

2. **Give the examples of an oxymoron.**

____

____

3. **Give the definitions as oxymoron of**

marble – ______________________________________

cloud – ______________________________________

4. **Using different types of analogy with a tiger give the description of a pen.**

5. Solve task in group using Synectics (different types of analogy in discussion):

How to prevent illegal fir-trees cutting near the cities before Christmas without administrative measures?

Direct Analogy:

____

Personal Analogy:

____

Nature Analogy:

____

Fantastic Analogy:

____

Paradoxical Analogy:

____

6. Find the task decision:

One American movie theatre was having a great fail. There was viewers' displeasure when ladies did not put off their hats and therefore closed the screen. Theatre management used different ways in order to prevent ladies from wearing their hats during the movies, they put up advertisements, used loudspeaker but didn't have any results.

What has to be done for getting ladies to put off their hats during the performance?

Your variants:

1. ____
2. ____
3. ____
4. ____
5. ____

Unit 1.4. Morphological Analysis

It is “Ars magna” that is considered as the morphological analysis prototype for problem solving. Raymond Llull[13] (1232–1315) Ars Magna (or Ars Generalis Ultima) is an astonishing attempt to systematise all possible knowledge using a rigorous computational procedure. For this purpose Llull invented numerous 'machines'. One method is now called the *Lullian Circle*[14], 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. 1.8. Ars magna

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.

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[13] http://en.wikipedia.org/wiki/Ramon_Llull
[14] http://lullianarts.net/downloads.htm

In contemporary form General Morphology[15] was developed by Fritz Zwicky. Among others, Zwicky applied Morphological Analysis (MA) to astronomical studies and the development of jet and rocket propulsion systems.

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.

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. 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 1.3).

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

Table 1.3

The Metalworking Processing Morphological Model

№ of sign	Sign	№ meaning of sign	Alternative meaning of signs
01	product matter change (transformation) type	01 02 03 04 05 06	form change volume change property change form and volume change form and property change form & volume & property change
02	product's matter aggregate state type, that is deleted during manufacturing process	01 02 03 04 05 06	solid fluxed ionized fluid chemically coherent matter is absent
03	physical & chemical effect in transformation base	01 02 03 04 05 06	diffusion erosion anode dissolution water hammering sintering electrolysis of solution/liquid
04	power type for physical & chemical effect	01 02 03 04 05 06 07	thermal mechanical proof resilience electrical chemical nuclear electromagnetic
05	power admission and distribution character during transformation	01 02 03	point linear surface
06	power character in time	01 02	continuous pulse

07	workspace physical state type	01 02 03 04 05	liquid gaseous solid viscous / fluid vacuum
08	tool physical state type	01 02 03 04	solid liquid gaseous viscous / fluid
09	tool movement during trans-formation	01 02 03 04	rotation progressive rotation & progressive 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.

Quiz 1.4: Morphological Analysis

1. **Find ways of house building under different conditions using morphological tables.**

   You build a house

   - near the North Sea on a stony shore,
   - in a desert,
   - in the forest near the river.

It is necessary to determine heating facilities, water facilities, decrease energy consumption.

Near the North Sea on a stony shore:

	…				
heating facilities					
water facilities					
energy consumption					
…					

In a desert:

	…				
heating facilities					
water facilities					
energy consumption					
…					

In the forest near the river:

	…				
heating facilities					
water facilities					
energy consumption					
…					

7. Find different package types for liquid poison. Build a morphological table.

Part 2. Technical System Evolution

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

Friedrich Engels

Unit 2.1. Laws in System Evolution

Contemporary machineries and devices represent a set of elements (*'components'*), which are in special relationships and form complicated systems[16]. There are a lot of *system* definitions, including *meaningful* and *structural*.

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 approach permits to choose optimal variant at the technical system design stage. In due time Vitruvius[17] 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.

---

[16] 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.

[17] 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").

- 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.

The object cannot be considered as a technical system if it doesn't include any of the listed features[18].

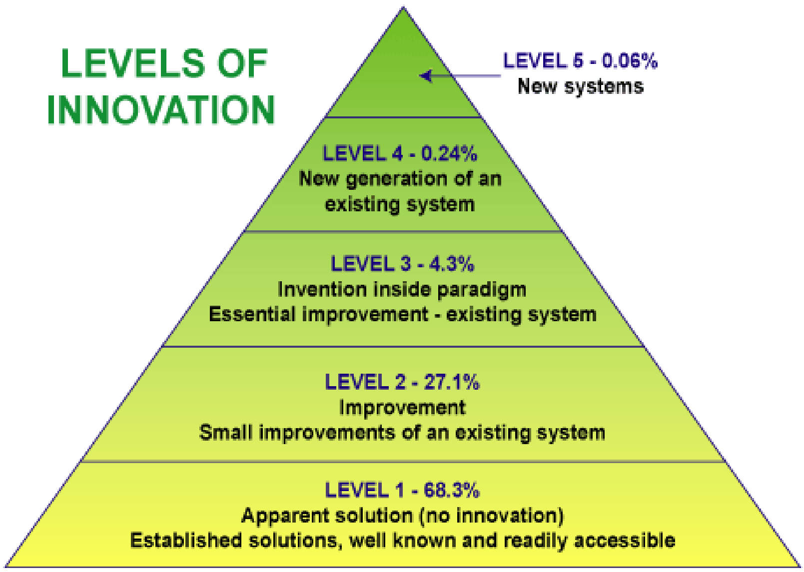

Fig. 2.1. Levels of Innovations

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

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

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[18] In detail see [9].

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

Technological criteria allow 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.

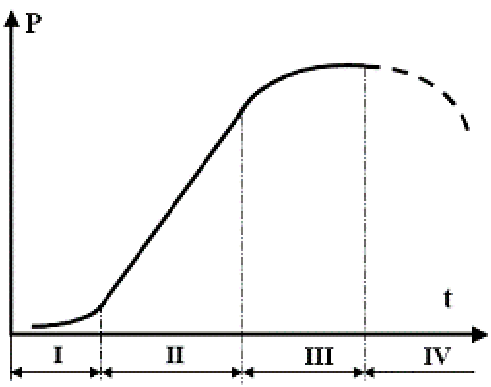


Fig. 2.2. S-Curve of technical system development

In accordance with TRIZ the main technical system development law is the Law of some criteria without worsening the other's improvement.

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 (regardless of their purpose) pass the stages of system (Fig. 2.2):

I. *System or idea birth* – slow improvement of one of the main performances.
II. *Development* – production 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". At 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).

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

Technical system evolution laws in accordance with the Theory of Invention problem solving were first formulated by G.S. Altshuller in his book "Creativity as Exact Science". 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:

$$\text{Ideality} = \text{benefits} / (\text{cost} + \text{harm})$$

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 elements 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 tendencies. 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 electromagnetic fields. The substances dispersion increases in the S-fields. The links number in the F-fields increases and the whole system responsiveness also tends 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 is 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.

At 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.

Quiz 2.1: Technical System Evolution Laws

1. **Please, give YOUR OWN system definitions and draw the system** *(in the way you personally understand!)*

   ____

   ____

   ____

   ____

2. **Give the technical system development criteria examples:**

Functional:

   ____

Technological:

   ____

Economical:

   ____

Anthropogenic:

   ____

3. **Distribute in the table below the technical system evolution laws in certain order in accordance with S-Curve:**

   - *System parts uneven development law*
   - *System parts completeness law*
   - *The degree increase system ideality law*
   - *Transition from macro to micro level*
   - *System dynamics increase law*
   - *Rhythms harmonizing system parts law*
   - *Super-system transition law*
   - *System energy conductivity law*

System birth	
System development	
Old age	
“Dying”	

Unit 2.2. Contradictions in Technical System

The contradictions appear as a result of system parts uneven development. In every system the elements life paces are different and it is

because the system gradually dies away. Then there appears a system crisis. At 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.

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. 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.

If it is possible to overcome contradictions – the system evaluates, if it is not possible – the system "dies away" because of the limited resource. You can overcome contradictions by different ways:

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

For example, for more effective work the so called “rigid” system[19] 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. At 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 are limited by physical bounds. Therefore the transition to micro-level is necessary: there are new energy reserves and possibility to use new substance properties. In other words molecules, atoms, ions, electrons, etc. work inside of wheels, shafts, gears. They are easily ruled by fields with the help of physical and chemical effects.

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 Darwin’s evolution theory, such as genetic code mutation and different construction variants intraspecific competition.

---

[19] Rigid system in TRIZ is system with rigid links

Quiz 2.2: Contradictions in System

1. **Enumerate system contradiction types:**

   ____
   ____
   ____
   ____

2. **Point out the ways to overcome contradictions:**

   ____
   ____
   ____
   ____

3. **Find the task decision:**

It will be better to protect pilot and airplane from enemy projectiles. Different countries engineers found an idea about airplane armoring. There were many attempts but the planes were extremely heavy and were flying on a slow-speed.

What decision was made?

4. **Find the task decision:**

Once the Greek ambassador Ismeny came to Percian Tzar Artaxerxes I. Ambassador was whispering: “Bow down to the ground, otherwise Tzar did not notice you”. But it is not the custom for proud Greeks to bow to enemy tzars.

It is necessary to bow – otherwise negotiations will not take place – but it is not the custom. What could be done?

Unit 2.3. 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 at every stage their own practice is used.

Fig. 2.3.
V. Vasnetsov. Flying-carpet. 1880

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

The second system evolution stage began – "trees correction". Inventors improved separate system parts, tried to find the best dimensions, shape, etc. At 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. 2.4. 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.

Quiz 2.4: Technical System Evolution:

Information Gathering
Analytic Investigation
Presentation

Your task is to survey technical system search laws in the system evolution

Present the system investigation result, such as:

- railway transport
- clock
- airplane
- bicycle
- submarine, etc.

CONFERENCE WEEK: INTERMEDIATE ASSESSMENT

TECHNICAL SYSTEM EVOLUTION (PRESENTATION)

Part 3. System Contradictions Overcoming

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].

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.

Unit 3.1. Substance-Field Analysis

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

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 to describe easily 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.

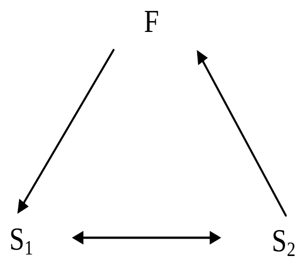


Fig. 3.1. SuField model

SuField (Fig. 3.1) 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 contradiction),
- 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" distinguishes 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 these fields and substances are. To get technical answer it is necessary to select the proper ones. TRIZ recommends to begin with fields because the fields number is less than substances.

In TRIZ 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 hydrodynamical 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;

E – electrical field including electrostatic and constant/alternating current field;

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

Lately there appeared 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. 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 comlex 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.

Quiz 3.1: Substance-Field Analysis

To build Su-Field model, analyze and find decision for next tasks.

1. It is necessary to bring diamond granules on base by angle up. How to do it without manual labor use?
2. There exists group way for ampoules' soldering: 25 ampoules are placed in iron holder and group burner is placed upon the holder. Fire control is too bad. As a result some ampoules over-heated and medicine became worse, but other ampoules were not soldering.
3. Liquid helium obtaining machine has an important detail – pressure reducer valve. This detail represents a vertical 3 m height tube with approx 10 cm diameter. Ones upon a resin ball, an iron bolt and a copper nut were dropped into tube.
4. Small parts from ceramics are attached to the grinding machine table by special mix from colophony and paraffin. It is expansive and laborious. What could replace these materials?

5. In a highly populated district there was found a huge unexploded bomb, which was in the ground for many years. Sappers arrived, overviewed bomb and heard ticking. No doubt – the bomb clock mechanism began working. How much time there would remain before the bomb explosion – nobody knew. People have been evacuated but explosion will bring huge damage…
6. It is necessary to find quickly cracks in a cooling unit.
7. Micro wire is produced on a plant with the automatic machine use. Diameter control is realized in a rather primitive way: machine is stopped, micro wire part is cut and weighed. Diameter is calculated by relative density. Find a simple and effective way for the diameter control.
8. Hundreds of millions cups, saucers and plates are produced annually. Every product pots twice. After the first furnacing the products are sorted and potted again. New conditions depend on the first furnacing result. For sorting workwoman strikes each product item by hummer carefully and determines the burning degree by the product sound. It is necessary to create automatic machine for such work. What is the automated work base principle?
9. There was produced a deep hole and a thread in a detail. Chips get on the bottom of the hole. It’s possible to rescue chips via compressed air. In this case these chips may stick or carry out and hurt machine operator. It’s impossible to change the part location. What could be done?

Unit 3.2. Principles to Overcome Contradictions

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, 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.

The List of Principles[20]

1. Segmentation

- Divide an object into independent parts:
  Replace mainframe computer by personal computers.
- Make an object easy to disassemble:
  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 compressed air is used.

[20] Translation from Russian to English: http://www.triz40.com/aff_Principles.htm

Use fiber optics or a light pipe to separate the hot light source from the location where the light is needed.
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 temperature, density, or pressure gradient instead of 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.
- 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.

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.

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.
  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):
  Sterilize all instruments needed for a surgical procedure on a sealed tray.
- Pre-arrange objects in 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. 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.
- Go from linear to rotary motion, use centrifugal forces:

  Produce linear cursor motion on the computer screen using a mouse or a trackball.

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.

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.
- 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.
- 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:
  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.

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.
- Use waste resources, energy or substances:
  Use heat from a process to generate electricity.
  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.
- 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 mechanical means with 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 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.

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 mask 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.
Ice structures: use water ice or carbon dioxide (dry ice) to make a template for a rammed earth structure, such as a temporary dam.

- Conversely, restore consumable object parts directly in operation:
  Self-sharpening lawn mower blades.

35. Parameter changes

- Change an object's physical state (e.g. to 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 liquid, instead of 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.

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.

Frequently the task initial formulation is not clear for inventor. It is very important to understand how to solve the task: to use the primary problem definition or to restate the task.

Quiz 3.2: Principles to Overcome Contradictions

Make decision using the principles

1. A plant got an order to produce a large number of 1 mm thickness glass plates. Blanks were cut, there was blank edges operating, but the plates were often broken. It's impossible to increase the plates thickness. *What could be done*?
2. The smelting furnaces body is cooled by the water that circulates in the pipes which are situated behind in order to protect layer. One day pipes got broken, the water went into the furnaces with smelt and there was a high risk of explosion. *What could be done? Water system must be saved.*
3. When there is a flaw in an acid pipe the acid is pouring off, pipe should be washed and filled by inert gas. Once the maintenance had to be done quickly but the inert gas was out of stock. *What could be done?*
4. Special radial sliding tool is used for the finishing treatment by diamond hone of hole in vanadic alloys. This tool is complex and expensive. For a new product treatment it is necessary to get more precise tool. A tool with sliding mechanism is too complex and fretful. *What could be done?*
5. When producing artificial limb for physically challenged it is necessary to get artificial limb form. Such work requires an ex-

perienced sculptor, but it is not always possible to find one. There might be done a copy of the original limb but there will be two left or two right limbs. *What could be done?*

6. It usually takes several hours to precipitate sediment to the bottom of the plug. To facilitate the control purification index activators there is used a process with active chemical sedimentation or centrifuges, but it is very complex and expensive. Inventor Martianov showed a trick. He took a tube with liquid, turned away and demonstrated the tube with precipitated sediment. *How did he make it?*

7. You have a glass parallelepiped. *How to measure its grand diagonal without calculations?*

Unit 3.3. Physical & Chemical Effects in Inventive Tasks

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 falsework 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 heated by high frequency current up to 700 degrees 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 is no direct action, 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 becomes 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 its manufacturing on atoms level automatically without noise and without waste. But it is necessary to remember about possible bounds and saving nature.

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.

∢ 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 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 when returning their original 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 heating 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, they reduce the vibration. Designers used TiNi-alloy for sputnik’s antenna: when launching antenna is rolled up and compact, but in space after being heated up by sun antenna takes very complex shape.

Potential for alloys with memory effect use is 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 heated 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 the 1st phase change the matter density and energy are changed discontinuously, always a certain heat energy amount is separated out or consumed. Under the 2nd 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 2nd phase change.

The typical example of the 1st 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 2nd 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 by layer with intermixable liquids. The first liquid in container had to be frozen, after that the 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.

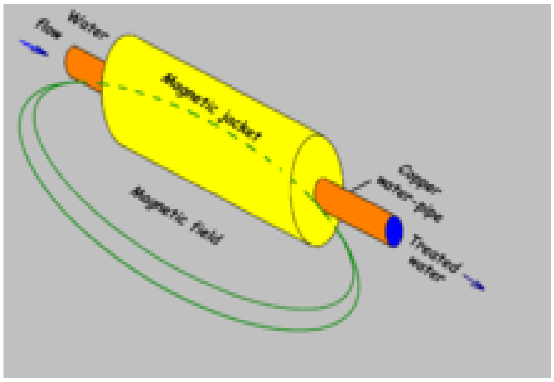
Examples

The metal details working out way: a 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 a water magnetization effect but the use of this effect permits to intensify different processes.



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

≺ Friction

Friction[21] 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.

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

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

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 a 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 a 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 piezo-electric oscillation eliminates static friction.

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

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 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 a system of gel, polymers or under thermal metal-organic compounds dissociation (metal lubrication).

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

It is possible to get electrical energy by a 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 an 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.

Quiz 3.3: Physical & Chemical Effects in Inventive Tasks

1. Carry out tasks on cards on table base (3 actions / properties to choose). Point out a physical / chemical phenomena or an effect that may be used to get demand action in inventive task. Describe the phenomena. Describe its nature. Give the examples.

№	Demand action / property	Physical phenomena / effect
1.	Temperature measure	
2.	Temperature stabilization	
3.	Object position & movement indication	
4.	Object movement control	
5.	Gas / liquid motion control	
6.	Aerosol stream control (powder, spray, etc.)	
7.	Mixing Solutions formation	
8.	Mixture separating	
9.	Object position stabilization	
10.	Power action Force control Large pressure making	
11.	Friction’s change	
12.	Object destruction	

13.	Mechanical and thermal energy accumulation	
14.	Interaction control between movable and immovable objects	
15.	Object’s dimensions measure	
16.	Surface properties control	
17.	Surface properties change	
18.	Objects dimensions change	
19.	Electrical and magnetic fields control	
20.	Electromagnetic fields control	

2. Make decision for the next inventive tasks using physical & chemical effects:

a. Il-2 reputation as one of the best attack aircrafts started in mid-1943, is owed to a great number of inventions administered by S.V. Ilyushin. Among these inventions the Design Bureau has to solve the following task. Explosion is a result of the bullet hit into the fuel tank if the tank is not full. If tank is full the explosion doesn’t occur.

What decision was found by engineers to prevent the explosion when the tank is not full??

b. There is an old clock in museum that has been working for two centuries.

How could it be?

Unit 3.4. Geometry in Inventive Tasks

There exist a 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.

Below there are given some examples.

∢ Dry substances

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

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

Long since carpenters used packets with sand to fix 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

The 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. A needle-cutter was invented, 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.

∢ 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 a direct line on a 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.

Quiz 3.4: Geometry in Inventive Tasks

1. Glue Möbius Stick belt. Determine what changes will be there if to cut belt half-and-half. Find the Möbius belt use in technical systems.

2. Build 2 meters tower high from 20 A4-size papers. Task has to be carried out in 3 to 5 persons per group. Time – 30 minutes. Tower has to stay during at least 1 minute.

3. Make a decision for the next inventive geometry tasks:

   a. High-quality concave reflector must be of paraboloid shape. It is difficult to get such a shape on the lathe.

      How to provide mass paraboloids production?

   b. When producing a steel pipe it is important to cut blank from ingot with precisely given weight – in this case all pipes will have one equal length. But ingots have different sizes and shapes..

      What has to be done?

Unit 3.5. Inventive Problem Solving Algorithm

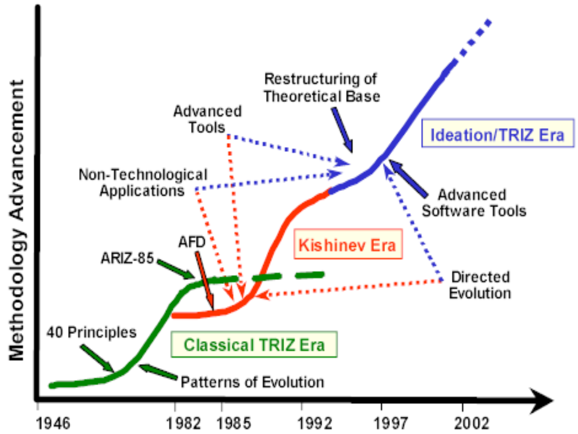


Fig. 3.11. TRIZ History

Algorithm of inventive problem solving (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 a 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 a contrary tool in system conditions;
  - to point the result which must be realized.

  Mini-task does not mean that the task is “small”. On the contrary, an additional demand is included to get the result without essential changes in the 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 the system (x-element is an unknown system change, which can solve all problems as the 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 a table in the following order: resources in an operational zone (intra-system resources), resources beyond the 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: x-element introduced into the system does not complicate system, does not cause additional harmful effects, does not interfere with the system tool but has to eliminate harmful effects.

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

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

- **Step 4 – Physical contradiction on a micro-level.** Physical contradiction is formulated on a 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. A 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 a micro-level (step 4) allows to use standards system.

3.5.4. Substances' and Fields' Resources Use

The goal is to apply systematic operations for system resources use. This part is the solution searching beginning. 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 step back from IFR.** When sought-for system is clear and task is to find a way for getting of this system it aids to step back from IFR. It is necessary to draw a finish system and to insert minimal dismantle change (one man) and to determine how to eliminate this “man”. Often this task solving is very simple and can show the way for all task solving.

- **To understand**, maybe the 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 a magnetic field and ferromagnetic substance, ultraviolet and phosphor, heat field and metal with memory effects.

3.5.5. Information Fund Use

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

- Dividing of contrary properties in space.

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

  similar and dissimilar systems joining into the 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 a 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 the 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 a 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 the task formulation. Maybe the task formulation contains a number of tasks.

There exist scheming tasks which may appear as usual tasks with a 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 has been carried out, the interesting decision has been made, but it is impossible to use this solution because the new task appears. It is a usual situation in TRIZ for high level tasks. It is necessary to solve a new task inside of solution renunciation.

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

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

3.5.7. How to Eliminate Physical Contradiction

The main 7th part goal is to get answer verification. It is necessary to eliminate a 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 the 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 the above-system when our system became this above-system part. Maybe having changed system / above-system acquired new useful or, on the 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.

Quiz 3.5: Algorithm of Inventive Problem Solving

Use algorithm of IPS and find out decision for the next tasks:

1. After tooling there exist burrs, which have to be cleared off manually. Operation cannot be automated because the gears are too small.

How to decrease laboriousness?

2. It is necessary to join two thin-shelled containers. Flange connection demands place and its assembly is very laborious. Telescope's joint is complex and laborious too.

What could be done?

3. Sometimes plate details make layers in a vibrating bunker. Details' orientation is disturbed and may lead to failure.

What could be done?

4. Turbine vanes are produced from alloyed steel by die forging and precise shape is got on duplicate-milling machine. Vane is pressed in rotating supports. Shaper cutter moves and repeats tracer template form. To provide vane with precise shape the steady support is used. It is necessary to adjust steady support every time when steady support moves.

How to increase operating laborious without the precision decrease?

CONCLUSION

The course is completed. Appropriately question is – how to use the studied (mastered!) techniques in practice, under what conditions are they 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 a 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 a decision for inventive tasks as an 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 a 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 decide what way is the most preferable.

Be audacious – and you'll reach the result!

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