Advanced Master in

Innovative Design

Module 5

TRIZ: methods and tools

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objectives of the course

- **Understand** the mechanism of collecting the elements of a conceptual solution and the process of synthesizing an engineering solution.
- **Describe** problems in terms of contradictions using the Su-Field model.
- **Practice** the 76 Inventive Standards as a system and apply them to inventive problem solving.
- **Understand** the basic principles of the Pointers of Effects drawn from science.
- **Realize** the scope of the Inventive Standards and Su-Field modeling and formulate their limitations.

course contents

overview of the session's program

Day One: INTRODUCTION; Learners' specific cases.

Day Two: SU-FIELD ANALYSIS; LAWS OF TECHNICAL SYSTEMS EVOLUTION; Work on specific cases.

Day Three: 76 INVENTIVE STANDARDS; POINTERS OF EFFECTS AND PHENOMENA; Work on specific cases.

Day Four: ANALYSIS OF INITIAL SITUATION; ALGORITHM FOR INVENTIVE PROBLEM SOLVING; Work on specific cases.

Day Five: APPLICATION OF TRIZ TECHNIQUES; Presentation of case study results; Summary of the course.

INTRODUCTION

...It is not the problem that breaks you down, it is the way you approach it...

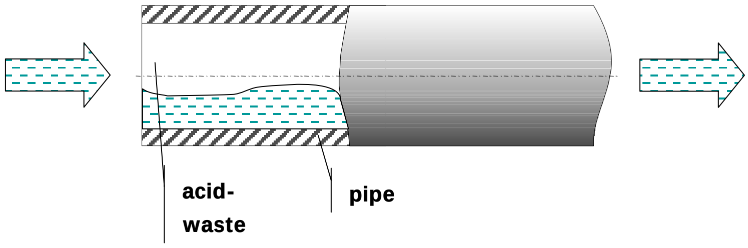
- **Why is it difficult to solve problems?**
- **Key task of Problem Solving**
- **Basic concepts for problem solving**
- **Psychological barriers and creative imagination**

pipeline for acid-waste removal

Some chemical plants require a method of preventing the rapid erosion of the pipes used for acid-waste removal. According to the deterioration of the pipeline it is necessary to change part of the pipes on a weekly basis.

It was proposed to use new materials to form a special protective coating. However the internal coating was expensive and it only partially solved the problem. Instead of weekly repair, monthly repair was required. The solution of using an internal coating results in increasing the maintenance cost of the pipeline.

What should be done?



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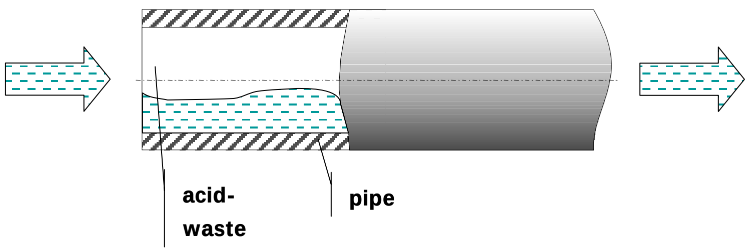
pipeline for acid-waste removal

<Acid-waste> must **<dissolve the internal surface of the pipe during transportation>**, because **<acid is an aggressive substance>**, BUT

<Acid-waste> must not **<dissolve the internal surface of the pipe during transportation>**, in order to **<use the pipes for a long time without repair>.**



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practice: what is it?

Feature -1	What is it that looks like a ball,
Feature -2	But stands still and does not fall
Feature -3	Off its thin and graceful legs?
Feature -4	Children like to turn it round,
Feature -5	Rivers, mountains, lakes are found,
Feature -6	Countries, states and their towns
Feature -7	Can be seen all around

Element:

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models for the description of elements

Question: How does one describe the Elements of the world efficiently for problem solving?

The **Elements** of the world –

(1) substantial or non-substantial things that we can think about;

(2) substantial or non-substantial things that can be described using the models "Element-Feature" or "Element-Name-Value".

- Common description using words, special terms, everyday names (Words).
- Name of Element and list of Features (Element - Feature).
- Name of Element - Name of Feature - Value of Feature (Element - Name - Value).

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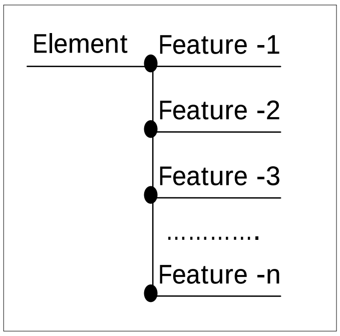
Element – Features Model (E-F Model)*

- The Element is described through its features according to the target of the analysis .
- According to the Axiom of description, the list of the Element's features can be infinite.
- The features are chosen by degree of importance with regards to their "usefulness" as a resource.

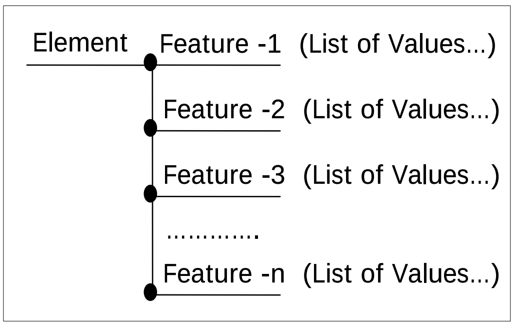


* N.Khomenko. 1997-2001. Materials for seminars: OTSM-TRIZ: Main technologies of problem solving, "Jonathan Livingston" Project.

Element–**N**ame of Features–**V**alue of Features

E-N-V Model*

- The behavior of the Element's *Feature* depends on its *Value*.
- The Element can be described *identically* only by fixing the list of features and their values.
- According to the Axiom of Process some of the Features have variable Values.



*N.Khomenko. 1997-2001. Materials for seminars: OTSM-TRIZ: Main technologies of problem solving, "Jonathan Livingston" Project.

The Blind Men & the Elephant (J.G.Saxe) <1>

It was six men of Hindostan,
To learning much inclined,
Who went to see the elephant
(Though all of them were blind);
That each by observation
Might satisfy his mind.
The first approached the elephant,
And happening to fall
Against his broad and sturdy side,
At once began to bawl,
'Bless me, it seems the elephant
Is very like a wall.'

The second, feeling of his tusk,
Cried, 'Ho! what have we here
So very round and smooth and sharp?
To me 'tis mighty clear
This wonder of an elephant
Is very like a spear.'
The third approached the animal,
And happening to take
The squirming trunk within his hands,
Then boldly up and spake;
'I see,' quoth he, 'the elephant
Is very like a snake.'

The Blind Men & the Elephant (J.G.Saxe) <2>

The fourth stretched out his eager hand
And felt about the knee,
'What most this mighty beast is like
Is mighty plain,' quoth he;
"Tis clear enough the elephant
Is very like a tree.'

The fifth who chanced to touch the ear
Said, 'Even the blindest man
Can tell what this resembles most;
Deny the fact who can,
This marvel of an elephant
Is very like a fan.'

The sixth no sooner had begun
About the beast to grope
Than, seizing on the swinging tail
That fell within his scope,
'I see,' cried he, 'the elephant
Is very like a rope.'

And so these men of Hindostan
Disputed loud and long,
Each of his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
They all were in the wrong.

what is a Problem?

A Vacuum cleaner produces a lot of noise (>53dB).

How does one reduce the vacuum cleaner's noise level?

GENERAL DEFINITION OF A *PROBLEM**

HOW DO WE OBTAIN:

these **needed value(s)**?

for these **specific feature(s)**?

of these **specific element(s)**?

for these **specific situation conditions**?

* N.Khomenko. 1997-2002. Materials for seminars: OTSM-TRIZ: Main technologies of problem solving, "Jonathan Livingston" Project.

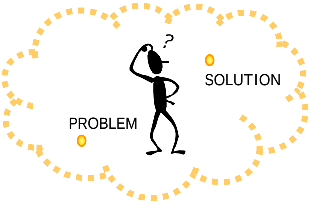
why do we have difficulties?

1. Non-identification of the root-cause of the problem.
2. Have paradigms (Thinking "outside of the box").
3. Lack of knowledge of the topic.
4. Statement of the problem.

1. Identify the root problem (Real problem).
2. Multidisciplinary teamwork.
3. Use of methodology.
4. Have the proper knowledge.

1. How the problem is defined.
2. Lack of knowledge and creativity.
3. Lack of vision for breaking down paradigms. Assumption that the known world is the only reality.
4. Lack of ability to transform ideas into practical solutions based on real problems.

THE KEY TASK of the problem solving process



How do we <reduce the area of Research into the Area of Solutions>

without <considerable trial and error

and the restrictions of mental inertia>

without <degrading the power of the solution?>*

Careful and systematic exhaustive search of all Concepts

- V: performed
  - R1-: Unacceptable expense of time, knowledge, and human resources
  - R2+: *Overcome mental inertia; Do not miss powerful conceptual solutions*
- Λ: not performed
  - R1+: *Adequate expense of time, knowledge, and human resources*
  - R2-: Restrictions of mental inertia; Possibility of missing "the best solution"

R2+ and R1+ → Desired result

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* N.Khomenko. 1997-2001. Materials for seminars: OTSM-TRIZ: Main technologies of problem solving, "Jonathan Livingston" Project.

what is a Solution?

The chief cause of problems is solutions...

GENERAL DEFINITION OF A ***PROBLEM***

HOW **DO WE OBTAIN**:

these **needed value(s)**?

for these **specific feature(s)**?

of these **specific element(s)**?

for **these specific situation conditions**?

Source: http://www.amazon.com

GENERAL CONCEPT OF A *SOLUTION**

Specific feature(s)

of the **specific element(s)**

get **specific value(s)**

for **specific situation conditions**

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* N.Khomenko. 1997-2002. Materials for seminars: OTSM-TRIZ: Main technologies of problem solving, "Jonathan Livingston" Project.

Basic concepts*

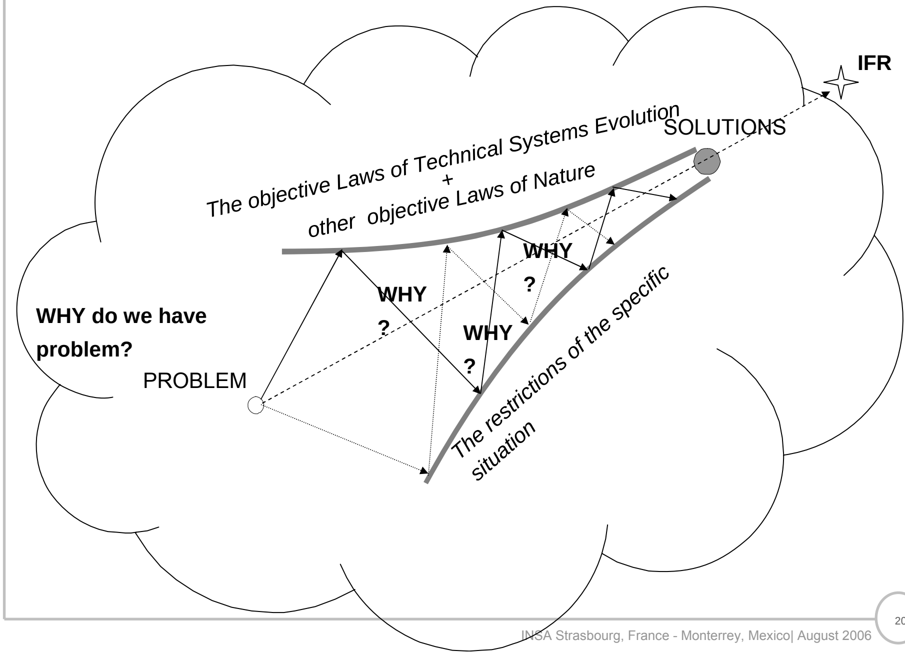
1. **Idea of Objective Laws of Systems evolution**
   - There exist objective laws of systems evolution. These Laws can be discovered, studied and purposefully applied for problem solving without resorting to a search for variants.
2. **Idea of Contradiction as a problem cause**
   - During their evolution the systems overcome the contradictions between objective restrictions and specific situation limits.
3. **Idea of Particular situation conditions**
   - Every problem can be solved only for particular situation conditions, using available resources.

* N.Khomenko. 1997-2001. Materials for seminars: OTSM-TRIZ: Main technologies of problem solving, "Jonathan Livingston" Project.

requirements and responses

❑ It is necessary to ensure the direction of the solution development before knowing the solution.	**Knowledge and skills to apply the *Objective laws of Systems evolution*.**
❑ It is necessary to reduce the research area systematically and to avoid any personal bias.	**Ability to define and formulate the contradictory requirements: to disclose *contradictions*.**
❑ It is necessary to evaluate results at each step of the problem solving process instead of being overwhelmed by evaluating hundreds of solutions.	**Knowledge about *particular situation conditions*: restrictions, barriers and available resources.**

how do we look for the solution to a problem?

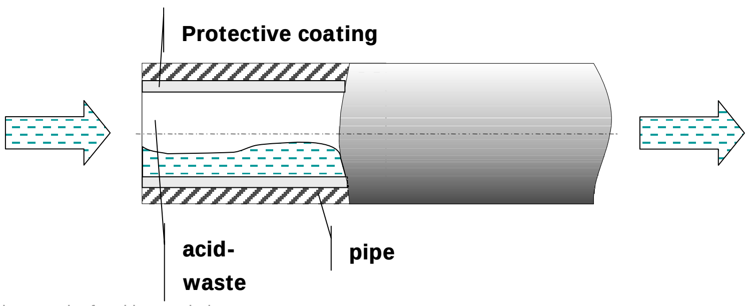


pipeline for acid-waste removal

Step 1. technical contradiction

If there is a protective coating on the internal surface of the pipe, then the pipe works for longer. However the cost of acid-waste transportation increases.

If there is no protective coating on the internal surface of the pipe, then the cost of acid-waste transportation is normal, but the pipe has to be changed weekly.



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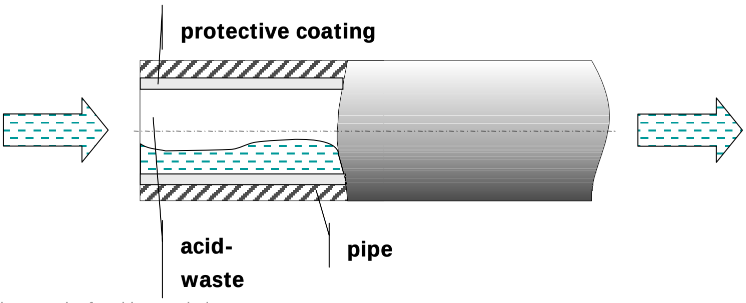
pipeline for acid-waste removal

Step 2. Ideal Final Result (IFR)

The protective coating shields the pipe's internal surface for years.



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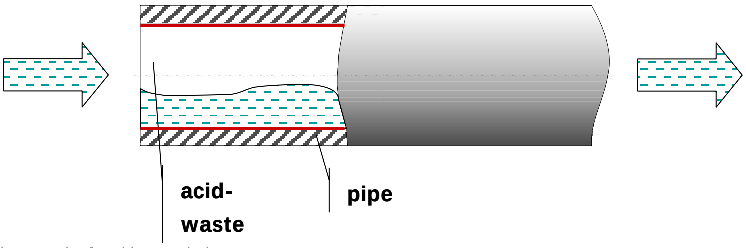
pipeline for acid-waste removal

Step 3. Resource analysis (why do we have a problem?)

Substances: **acid-waste (liquid), pipe surface, air**

Fields: **chemical, mechanical, gravity**

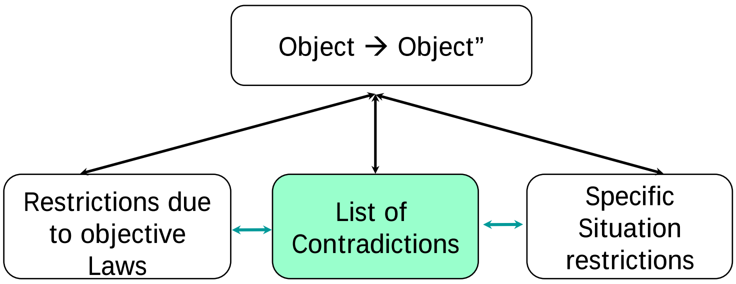


comments

The Negative Effect is usually produced by the impact of the Objective Laws!
It seems that a breakthrough solution has to "break" the Objective Laws.

However "mental inertia" stops us from doing this.

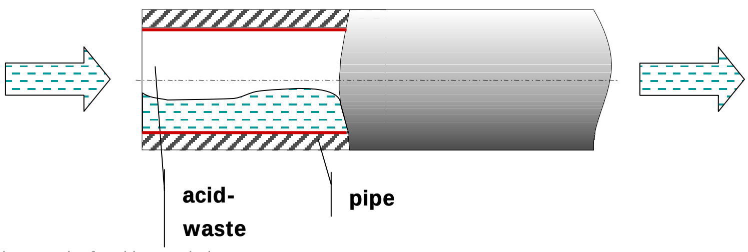
It is useful to determine which Objective Laws it is necessary to "break" and/or bypass.



pipeline for acid-waste removal

Step 4. The Objective Law which must be "broken"

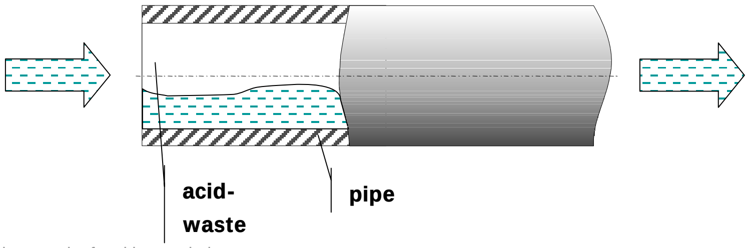
The law which must be broken is that of the chemical reaction between a strong solvent and a metallic surface.
According to this law, acid-waste must dissolve a metallic surface.
In order to solve the problem, one must "bypass" the indicated Objective Law.



pipeline for acid-waste removal

Step 5. Intensified Ideal Final Result (IFR)

Contrary to the laws of chemical reaction the internal surface of the pipeline should never be dissolved.



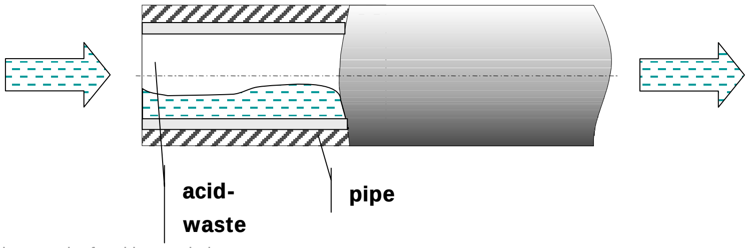
pipeline for acid-waste removal

How wonderful that we have met with a paradox. Now we have some hope of making progress.

Niels Bohr

Step 6. Deeper Intensified Ideal Final Result (IFR)

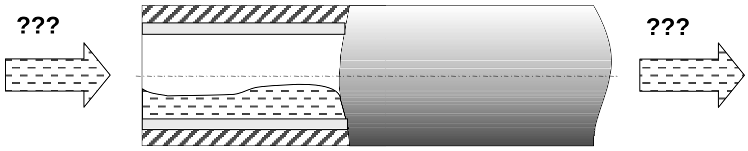
The liquid waste and the chemical field themselves form the protective coating.



pipeline for acid-waste removal

Step 7. Using TRIZ to find the needed resources (multi-screen scheme of thinking) – typical solution

If there are not enough resources to perform the requirements of the IFR, look to the super-system. It is necessary to find such a resource that will form the protective coating during the transportation of the liquid waste by a chemical field.



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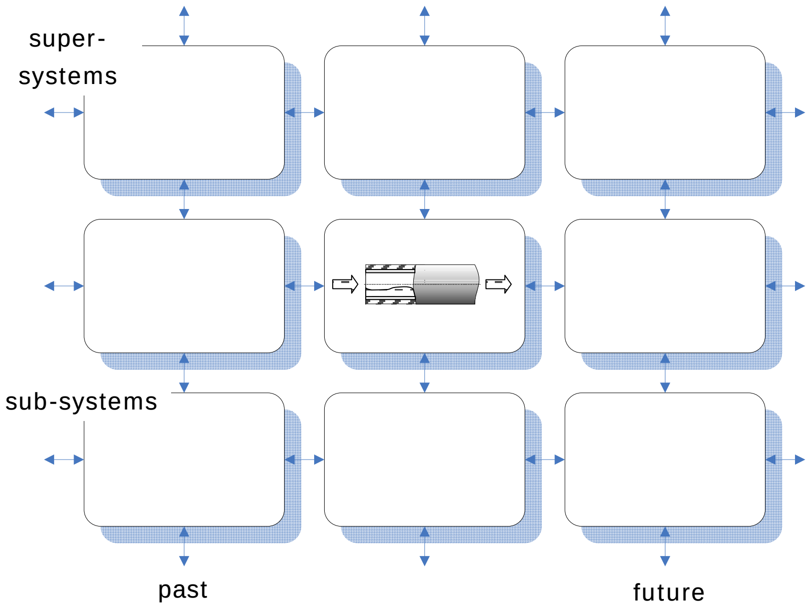
generalized approach of problem analysis

multi-screen scheme of talented thinking



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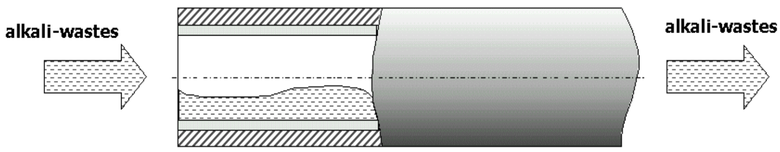
pipeline for acid-waste removal

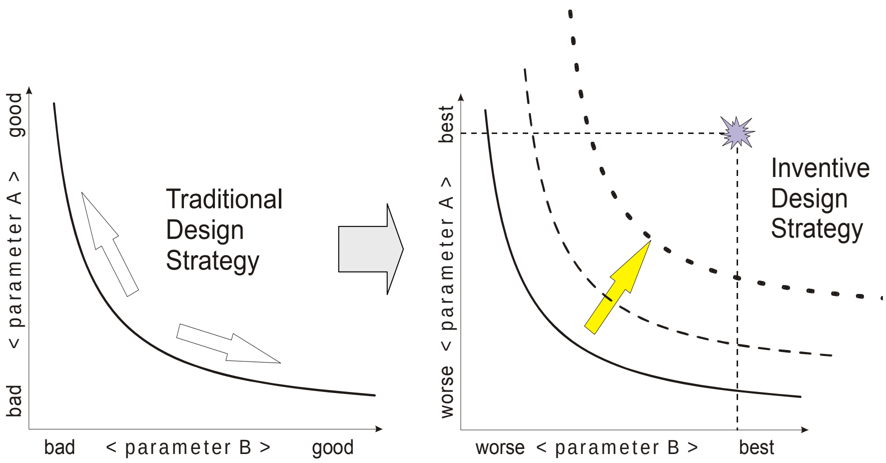
Step 8. Transition from the Typical Solution to the Specific Solution concept for the Specific Problem Situation

It was proposed to transport *alternately* through the same pipeline an alkali-waste and an acid-waste.

The alkali-waste forms the protective coating whereas the acid-waste dissolves it. Thus, the internal surface of the pipeline is safe.

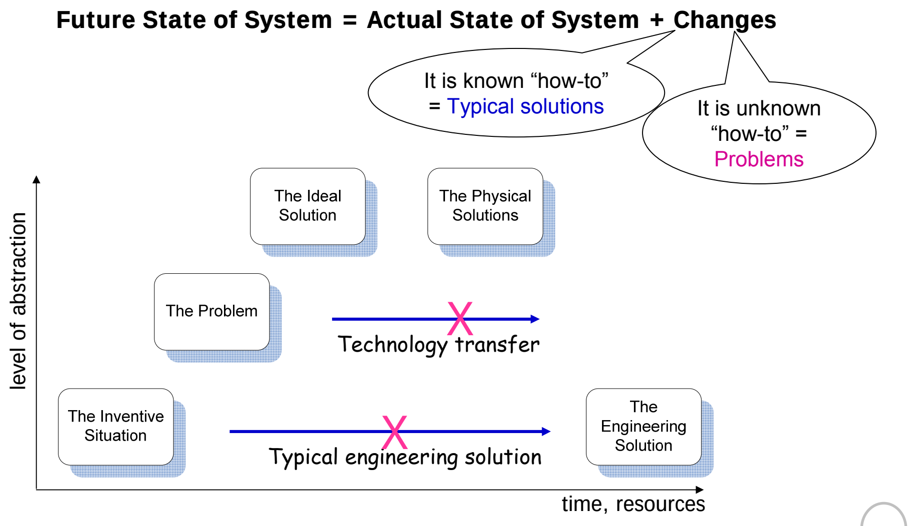


inventive vs. robust



process of solving an inventive problem

If you don't know where you're going, you're on the wrong track!



psychological barriers

include several layers:

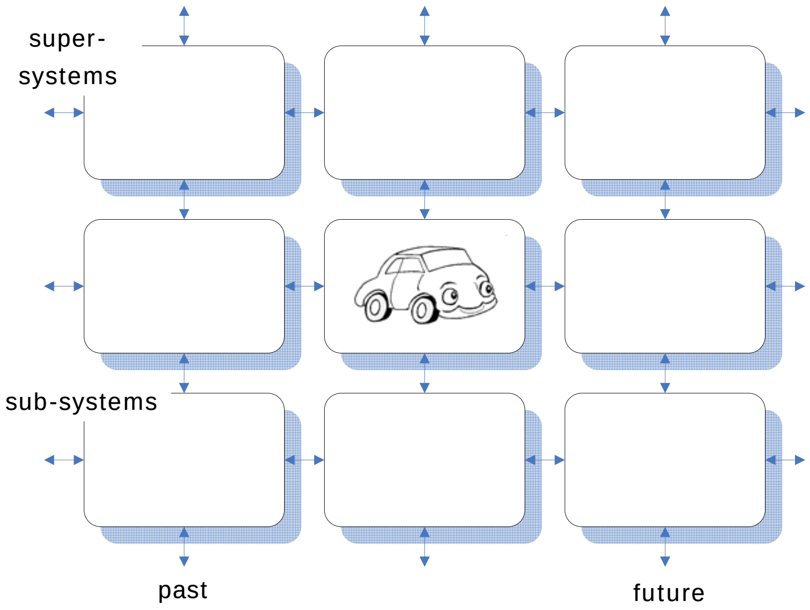
- the specific terms;
- well-known typical solutions from ones experience;
- nonflexible viewpoint of the problem situation;
- desire to get a solution as soon as possible...

...and creative imagination

Whatever a human being can imagine, others can make reality.
Jules Verne

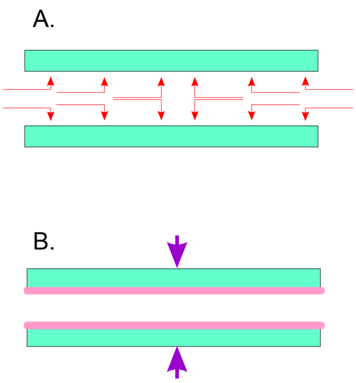
- Multi-screen scheme of talented thinking
- Size-Time-Cost operators
- Simulation with Little Creatures
- "Golden Fish" operator
- Phantogram
- The scale of fantasy...

multi-screen scheme of talented thinking



size-time-cost operators

What would happen to the problem situation, the features of objects and its environment if we were to increase or decrease the values of an object's parameters (Size/Time/Cost) by many times (by 10, 100, 1000 times)?



In order to assemble two glass panels a jet of hot air pre-heats their surfaces. The precise moment when the surface glass begins to melt must be detected ("running point"), and the panels must be joined at this moment.

A high-precision device which detects the melting point of the entire surface area is needed.

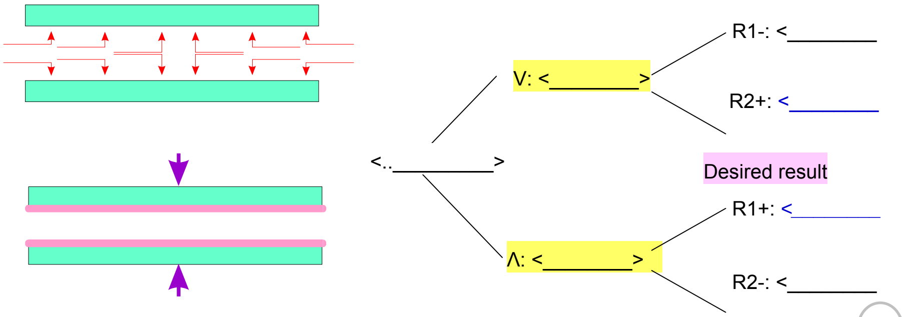
size-time-cost operators

How would I solve the problem if each of these characteristics were exaggerated ?..

Size – is the size of the Operational Zone (OZ) **Where?** conflict occurs.

Time – is the Operational Time (OT) **When?** conflict occurs.

Cost – is the cost of the known solution or allocated to the operation cost.



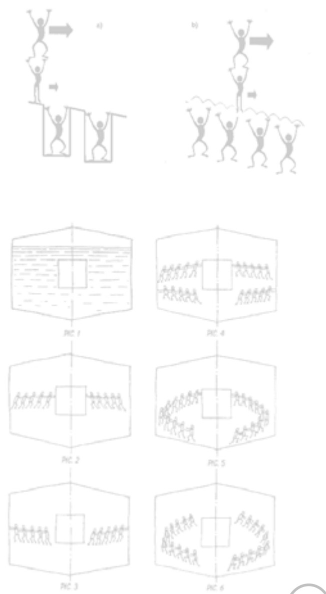
size-time-cost operators

Step	Procedure	Changing	How changed problem is solved	Principle used in the solution
1.	S –> ∞	10		
		100		
		1000		
2.	S –> 0	0.1		
		0.01		
		0.001		
3.	T –> ∞	10		
		100		
		1000		
4.	T –> 0	0.1		
		0.01		
		0.001		
5.	C –> ∞	10		
		100		
		1000		
6.	C –> 0	0.1		
		0.01		
		0.001		

Simulation with Little Creatures

A tool for breaking down mental inertia where the problem solver transforms the defined problem into a group of 'small little creatures'.

The method is primarily a means of getting the problem solver to zoom-in to the finer details of a problem and to see how it might be solved.



Simulation with Little Creatures

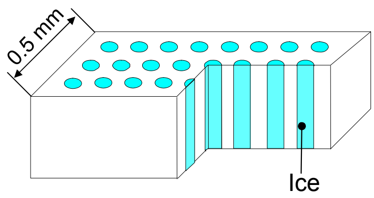
Test of a capillary-porous sample

During certain laboratory tests for strength a capillary-porous specimen should be saturated by water and frozen. For the next phase of tests it is required to completely remove ice from the pores of the specimen.

However, it is necessary to avoid any heating of the specimen.

Issue: Removing ice from such a sample without heating takes a long time.

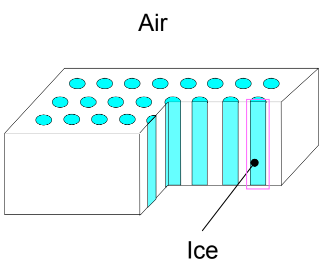
It is necessary to eliminate ice from the sample within an hour or faster. What should be done?

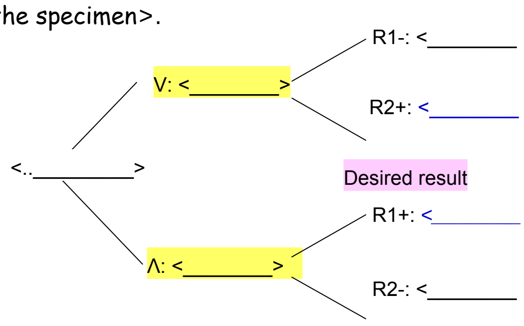


capillary-porous sample

TC#1: If <heat is not applied>, then <there is no damage of the capillary-porous sample>, but <ice is removed from the specimen over a long time>.

TC#2: If <heat is applied>, then <ice can be eliminated quickly>, <but high temperatures damage the specimen>.





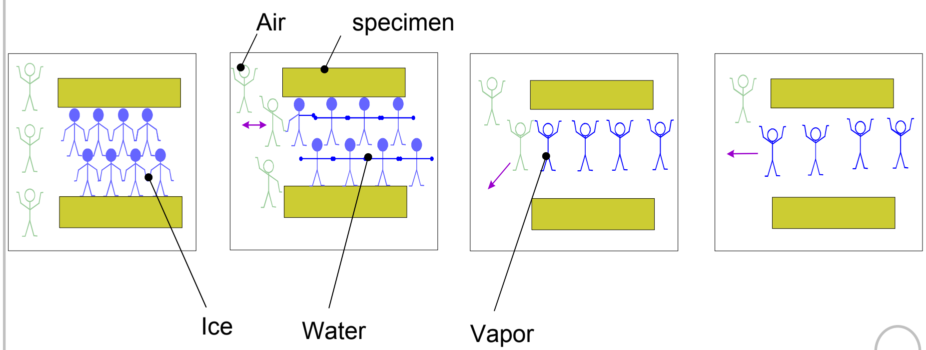
Simulation with Little Creatures

Simulation with Little Creatures includes representing the conflicting requirements as a drawing that describes how the Little Creatures operate (in a group, several groups, a crowd, etc.).

- The Little Creatures have to represent changeable elements of the Problem Model (the tool and/or the X-element) in the Operation Zone during the Operation Time.
- Sometimes it is preferable to modify the graphic model of the conflict by combining two figures in one drawing: the "bad action" and the "good action".
- If the events evolve in time, making several consequent drawings is appropriate.

capillary-porous sample modeling

a) describe a graphic model of the conflict using the Simulation with Little Creatures (SLC);
b) modify this graphic model so that the "Little Creatures" act without conflict;
c) transit to a technical description.



capillary-porous sample

Partial solution concepts:

____

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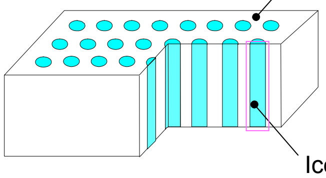


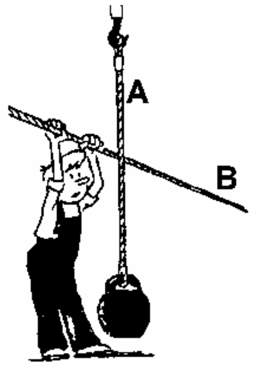
Simulation with Little Creatures

Two ropes*

*A load is hanging from steel rope **A**.*

*Rope **B** moves in a perpendicular direction.*

*What should be done to drive rope **B** and keep the functionality of rope **A** at the same time?*



* CHANCE FOR ADVENTURE, Petrozavodsk, Karelia 1991. [Ru]

summary

Psychological barriers	Methods for dealing with it

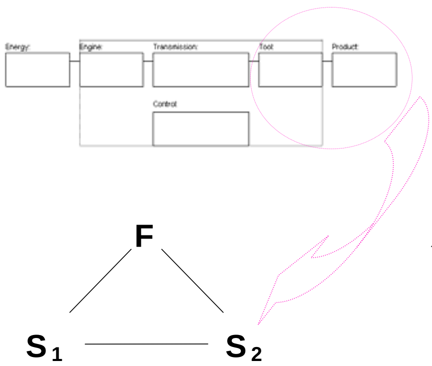
SU-FIELD ANALYSIS

Basic concept:
The transformation of a substance can be caused only by material (physical) factors: by Substance and by Energy (Field).

1. **substances and fields**
2. **su-field modeling**
3. **unsatisfactory interactions**
4. **applying su-field models**
5. **useful information**

models and aims

Substance-Field analysis is an analytical method for modeling the problem situation into an *Operational zone* during an *Operational time* according to the formulated *Contradiction*.



Subject of Substance-Field analysis:
to explore the transformation of the structure of the system's model according to the Laws of Technical Systems Evolution.

***Aims*:**
to build a clear "termless" model of the problem situation in order to apply the Inventive Rules and 76 Inventive Standards.

why do we apply su-field analysis?

Practical conclusions from applying 40 Inventive principles:

- Compound Inventive principles produce concepts which are closer to the Ideal solution.
- High level inventions are constructed using a combination of several Inventive principles. If one Inventive principle is missed the whole sequence becomes useless.
- A frequent combination of principles includes segmentation (1), combining (5) using an electromagnetic field (28), construction of a porous structure (31), which can change its dimensions (15).

*Source: (Ru) Altrshuller G. 1973. Su-Field analysis: first session. Manuscript. www.altshuller.ru

substances and fields

The same technical system for different problem descriptions can be described by different su-field models (SFM):

How do we **increase the speed** of an ice-breaker?

Product (S1): *ice*
Tool (S2): *hull of ice-breaker*

How do we **improve the mechanical resistance** of the hull of the ice-breaker?

Product (S1): *hull of ice-breaker*
Tool (S2): *ice*

The technical system can be considered as a ***Substance*** in an environment.
Thus, interaction between the Substance and the environment has to occur.
This interaction (energy exchange) is named a ***Field***.

Figure: www.wm.edu/wmnews/research/ ship.html.

practice: unfortunate expander

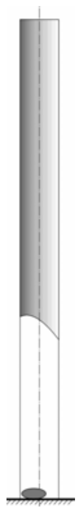
A part of a helium liquefaction plant is called an "expander"; this is a vertical fixed cylinder of 25 cm in diameter and 3 m in height.

During repair something falls into the cylinder. It must be removed

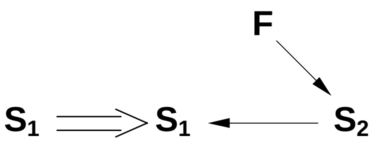
Tennis-ball;

Pliers;

Bronze chisel.

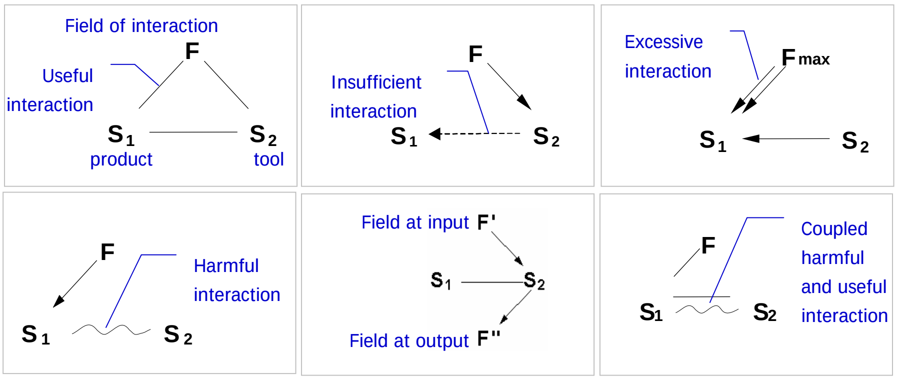


What should be done?



su-field modeling

S-Field is a model of minimal, functioning and controllable technical system.



Su-field modeling employs a specific graphic language to represent the cause of problem (contradiction).

practical: su-field modeling

Pipe for acid-waste removal

Contradiction:

Anchor to fasten boat

Contradiction:

Heavy metallic cone in river

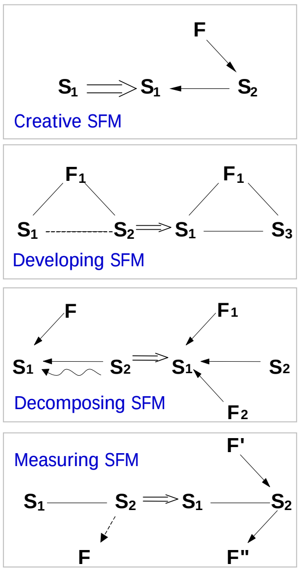
Contradiction:

SFM - graphical model

- If the SFM is **incomplete** – it is necessary to complete it.
- If the SFM is complete but it is **not efficient** – it is necessary to develop (evolve) the SFM using new substances and fields (or modification of already present substances and fields).
- If the SFM is **harmful** – it is necessary to decompose the initial SFM and build a new one.

All inventive problems can be considered as two large groups:

- ✓ ***modification** problems (to develop new systems or to change features of present systems);*
- ✓ ***measurement** (detection) problems (to collect information about features of the system).*



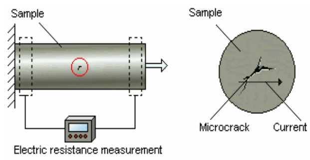
G.I.Ivanov: 1994, THE FORMULES OF CREATIVITY OR HOW TO LEARN TO INVENT. Prosveschenie, Moscow. ISBN 5-09-004135-0

practice: modification or measurement?

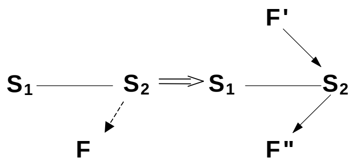
- **A rotor excavator's scoop is blocked by wet clay. This effect decreases productivity. What should be done?**
- **How do we measure the stress placed on the support beam of a building?**
- **How do we increase productivity for driving a metallic pile into strong water-saturated rock?**
- **How do we detect the integrity of the pile as it drills into the rock?**
- **How do we identify a hidden crack in a product?**
- **How do we easily dismantle stuck concrete and metallic shutters?**
- **How do we identify the damage caused by use in a cutter?**

measurement (detection) problem

How do we detect the first cracks during a test of samples for metal fatigue (strength properties)? It is proposed to monitor the electrical resistance of the material. The sample is connected into a sensitive (Wheatstone bridge) electric circuit. When micro-cracks develop, the circuit resistance changes. [A.c.246901]



4.2.1. Synthesis of measurement SFM



Where S_1 – sample; S_2 – cracks; F – "detection" field (visually); F' – electric current field; F" – modified electric current field at the output)

For measurement or detection problems the resulting Su-Field model should include at least two fields:
input Field' of interaction + output Field" that conveys needed information.

five simple rules

1. If there is an incomplete SFM, the problem is to be solved by synthesizing a complete SFM.
2. If there is a complete SFM, the transition tends towards an easily-controlled (e.g. ferromagnetic) SFM.
3. If there is a harmful SFM, the problem is to be solved by decomposition of the harmful interaction.
4. If there is a complete SFM, the S_2 tends to evolve into a self-supporting SFM.
5. If there is a complete SFM with F_1 at input and it is required to obtain F_2 at output, the name of the effect can be found by combining the field names (rule to reveal effect).

G.S.Altshuller & A.B.Selutsky: 1980, WINGS FOR ICARUS, Karelia, Petrozavodsk.

practice: creative SFM

During assembly of a device it is necessary to install a spring into a narrow groove. The spring has to be compressed during assembly of the other elements, but it has to work (to be free) once all elements are installed.

What should be done?

practice: developing an SFM

We need to measure the straightness of a horizontal surface on a difficult to access surface (e.g. in a narrow bay). A spirit level is used to measure the straightness of the surface. It is possible to place the spirit level in the narrow bay, but the position of the air bubble is not visible.

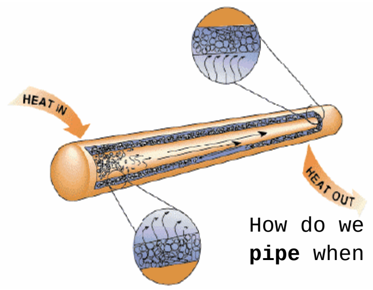
What should be done?

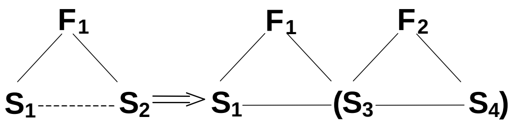
practice: decomposing an SFM

An abrasive mixture is stirred in a cylindrical container. However the particles of the mixture wear out (scuff) the bottom of the container within two days. The installation of hard plates on the bottom of the container did not resolve the problem.
What should be done?

evolution into a self-supporting SFM

If there is a complete SFM, the S_2 tends to evolve into a self-supporting SFM and to form a chain SFM.
In its turn a new S_4 may evolve into a self-supporting SFM with S_5, F_3.





How do we increase the **efficiency of a heating pipe** when it is placed horizontally?

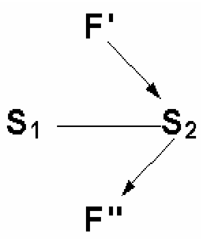
<Water> has to <return to the cooling zone>, to <transmit heat from one point to another>
<Water> does not have to <return to the cooling zone>, because <gravity can not move it>.

Where S_1 – water; S_2 – internal surface of pipe ; F_1 – "transportation" field; F_2 – capillarity; S_3 – inner surface of capillary, S_4 – void in capillarity

* What is a Heat pipe? http://www.cheresources.com/htpipes.shtml

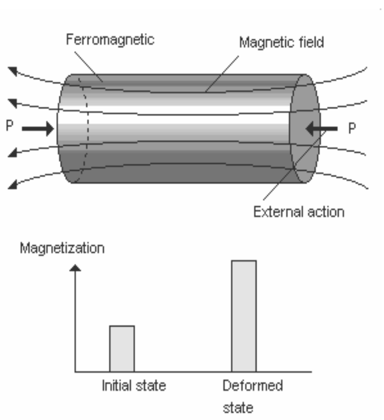
rule to reveal effect

If there is a complete SFM with F_1 at input and it is required to obtain F_2 at output, the name of the effect can be acquired by field names combination (rule to reveal effect).



If the name of field F' is mechanical and the name of field F" is magnetic the needed effect will be mechanic+magnetic = Magnetoelastic effect.

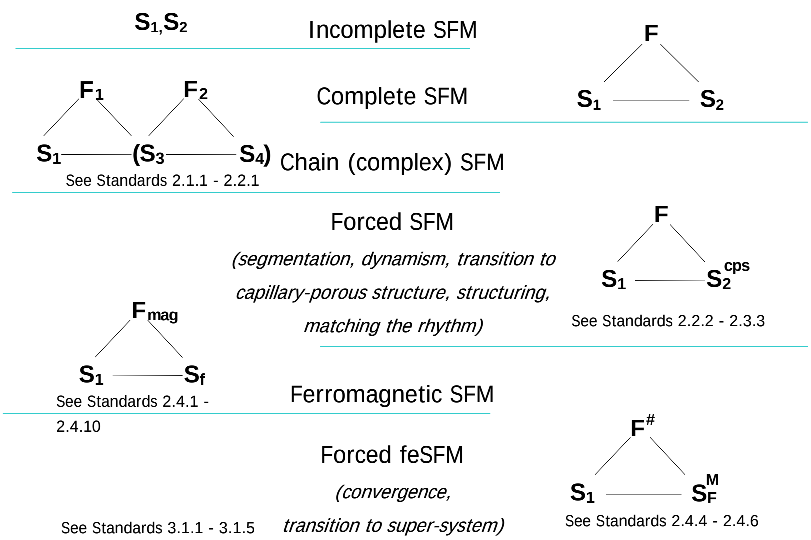
magnetoelastic effect



The magnetoelastic effect (or Villari effect) refers to a change in the magnetization of a ferromagnetic subjected to mechanical strains.

When a constant elastic strain is superimposed on a ferromagnetic sample, the change in the sample magnetization first grows with an increase in the magnetic field, then passes through the maximum (Villari point) and decays to zero in the limit. When some ferromagnetics, such as the Ni (65%) - Fe (35%) alloy, are subjected to tension, their magnetization increases, and when they are compressed, it decreases. Other ferromagnetics, for instance, Ni, feature the negative Villari effect (their magnetization decreases under tension and increases under compression).

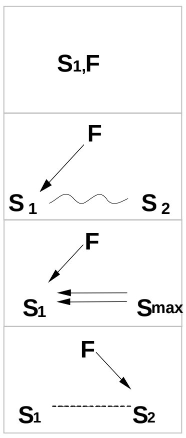
line of evolution for SFM



G.I.Ivanov: 1994, THE FORMULES OF CREATIVITY OR HOW TO LEARN TO INVENT. Prosveschenie, Moscow. ISBN 5-09-004135-0/

types of unsatisfactory interactions

The Su-Field analysis and Inventive standards are applied when a problem is represented as unsatisfactory interactions between two or more of the system's components.



Missing interaction:
a parameter of a component has to be changed during the operation, but we do not know how to change it. *(Group 1.1)*

Harmful interaction:
a component produces a harmful effect. *(Group 1.2)*

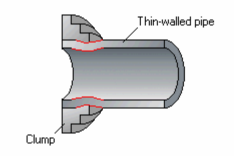
Excessive interaction:
an action of one component upon another is too strong. *(Group 1.2)*

Insufficient interaction:
an action of one component upon another is too weak. *(Classes 1, 2)*

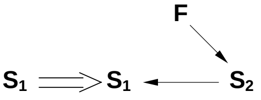
missing interaction

Thin-walled Ni-Cr pipes are made by drawing (heating and stretching) the pipes.

Disadvantage: The pipes are easily deformed when clamped, machined or transported.

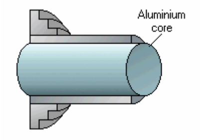


1.1.1. Synthesis of SFM: If there is an object which is not easy to change as required, and the conditions do not contain any restrictions on the introduction of substances and fields, the problem is to be solved by synthesizing a SFM: the object is subjected to the action of a physical field which produces the necessary change in the object.



It is proposed to form an aluminum core inside the pipe to prevent it from deforming.

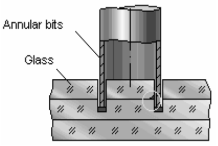
When processing is finished, the core is removed by etching with an alkali reagent. [SU A.c. 182661] (S1 – thin-walled pipe; S2 – aluminium core; F – mechanical)



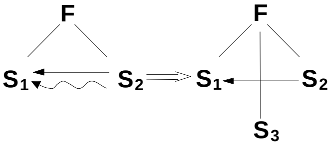
Figures: TechOptimizer 3.0 © 1997-1999 Invention Machine corp.

harmful interaction

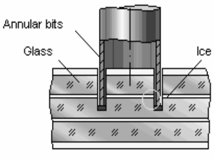
Annular bits are used to cut disks out of a pile of glass sheets. However, the cracks and spalls are formed that reduce productivity and quality.



1.2.1. Elimination of the harmful interaction by introducing a foreign substance: If useful and harmful effects appeared between two substances in a SFM and it is not required that these substances be closely adjacent to one another, the problem is solved by introducing a third substance (available or cheap) between these two substances.



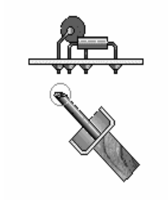
It is proposed to introduce ice between the glass sheets. The sheets are moistened with water and frozen. The ice fastens the sheets together forming a monolithic structure, thereby preventing the development of cracks and spalls. [A.c. 400534] (S1 - glass sheet; S2 - annular bits; F - mechanical; S3 - ice)



Figures: TechOptimizer 2.51 © 1995-1997 Invention Machine corp.

excessive interaction

Soldered joints are dismantled using a hot tip. However, solder sticks to the tip and is difficult to remove from the joint.

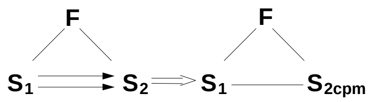


2.2.3. Transition to a capillary porous substance:

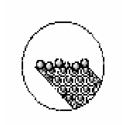
The efficiency of a SFM is enhanced by the transition from a solid substance to a capillary porous one:

Monolith substance → substance with one cavity → substance with multiple cavities (perforated) → capillary porous substance → capillary porous substance with a definite pore structure and size.

Transition to a capillary porous substance enables a liquid substance to be placed in the pores and physical effects to be used.



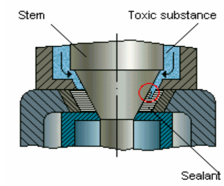
It is proposed to transform the soldering tip into a capillary-porous structure. Surface tension forces draw the solder into the tip. To make it porous, the tip is made of sintered metal powder.
[A.c.404517]
(S1 - solder; S2 - tip; F - wetting)



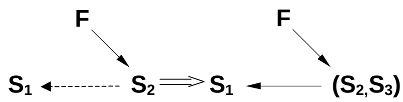
Figures: TechOptimizer 2.51 © 1995-1997 Invention Machine corp.

insufficient interaction

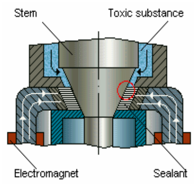
A porous insert filled with sealant keeps a toxic agent from leaking by a stem. This is done using a tight fit of the insert against the stem surface. However, at high pressure, the toxic substance may press the seal away from the stem forming a blowhole.



1.1.2. The transition to an internal complex SFM: If there is a SFM which is not easy to change as required and the conditions do not impose any restrictions on the introduction of additives to given substances, the problem is to be solved by a transition (permanent or temporary) to an Internal Complex SFM...

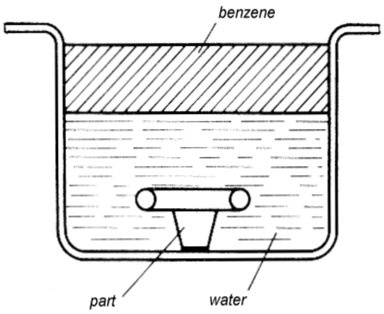


It is proposed to introduce ferromagnetic particles into the sealant, pressing them (with a magnetic field) against the stem. The particles hold fast, increase sealant viscosity, and prevent formation of blowholes.
[A.c. 1044879]
(S3 - ferromagnetic particles)



Figures: TechOptimizer 3.0 © 1997-1999 Invention Machine Corp.

practical: test for corrosion resistance



After heat-painting, a metal part is blown all over with cold air and sent to the assembly line. From time to time a part is chosen to be tested for corrosion resistance.

The chosen part is dipped into water (because if painted badly, the part will develop surface spots and rust). The part is given a coat of benzene-thinned paint and should be fully submerged into water without either damaging the coat of paint or bringing any extra substances into benzene and water.

How can this be done?

Y.Salamatov: 1999, TRIZ: THE RIGHT SOLUTION AT THE RIGHT TIME. Insytec B.V. 256 pages. ISBN 90-804680-1-0

summary

- **SFM is the smallest useful model of a system. SFM describes the most important features of a system for a formulated problem.**
- **Su-Field analysis describes what is given and what should be developed using the termless graphical language. Thus, SFM gives ability to overcome mental inertia restrictions and to focus attention on the physical contradictions.**
- **Representation of the problem as an SFM allows one to use the Inventive Standards and to apply essential scientific knowledge (effects and phenomena) for engineering practice.**

LAWS OF TECHNICAL SYSTEMS EVOLUTION

- **Technical systems evolve in accordance with certain objective rules (so-called Laws).**
- These rules can be revealed from accumulated knowledge about technical systems evolution.
- **These laws can be used for deliberate invention of new technical systems and for systematic improvement of existing systems.**
- It is possible to transform the inventive problem solving process into an exact science of technical systems evolution using disclosed objective laws.

Module 5: TRIZ: methods and tools

INSA Strasbourg, France - Monterrey, Mexico| August 2006

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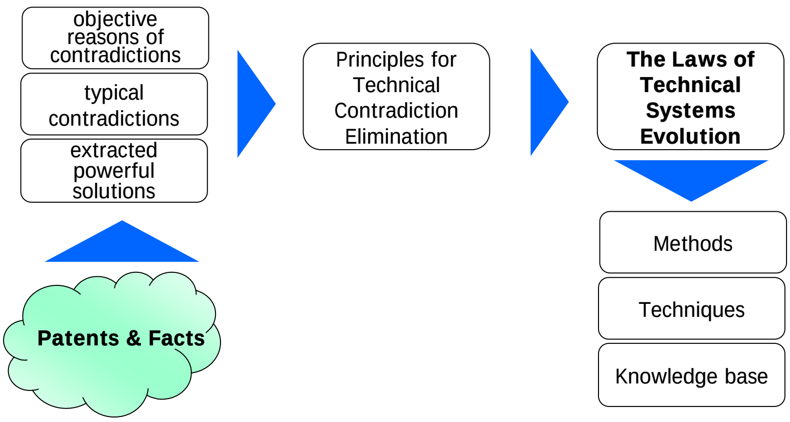
information sources

The classic definition of Laws of Technical Systems Evolution is the result of research into an immense body of facts and practical problem solving over more than 30 years.



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classic system of **Laws of Technical Systems Evolution**

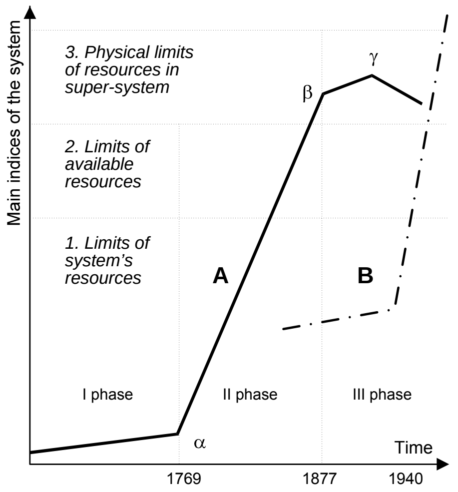
Laws of Technical Systems Evolution describe fundamental, firm, and repeating relationships of system elements and the external environment during their evolution.

- *law of System Completeness*
- *law of Energy Conductivity in systems*
- *law of Harmonization*

o law of Dynamics Growth
o law of Increasing Substance-Field Interactions
o law of Irregularity of the Evolution of a System's Parts
o law of Transition from Macro- to Micro-level
o law of Transition to the Super-system

✓ LAW OF INCREASING IDEALITY

S-curve of systems evolution



Four phases of evolution:

I. birth, childhood;
II. adolescence;
III. maturity & decline.

A - Steam engine
B - Internal-combustion engine

It is useful to depict a <u>system's position on an S-curve</u> in order to take a decision about the direction of problem solving.

example: evolution of heat-engines

1663 : **Steam-boiling** machine was patented

1816 : Robert Stirling, Scottish clergyman, **Stirling engine**.
Efficiency - 30-45%

1860 : Etienne Lenoir, French inventor, **gas engine**.

1877 : Nikolaus August Otto, German inventor, **Internal-combustion engine** (four-cycle). Max. efficiency - 20-25%.

1879 : Karl Benz, German inventor, Automobile engine (two-cycle).

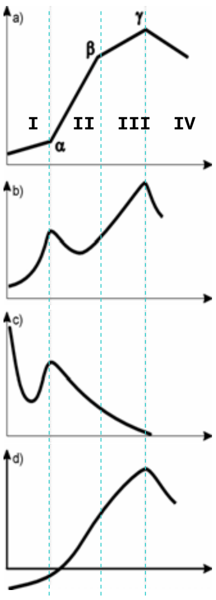
1893 : Rudolf Diesel, German inventor, **Diesel engine**.
Max efficiency - 30-40%

1913 : Rene Lorin, French inventor, **Ramjet engine**.

1930 : Sir Frank Whittle, British inventor, **Gas-turbine engine**.

1941 : Sir Frank Whittle, British inventor, **Turbojet aircraft engine**...

how to define a system's position?*

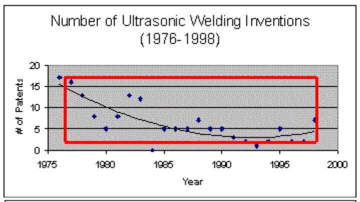


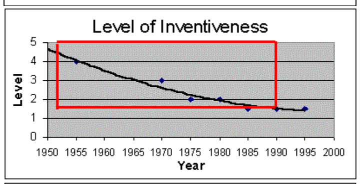
The interpolation of several individual curves from other perspectives gives the analyst an indication of the technologies location on the S-curve.

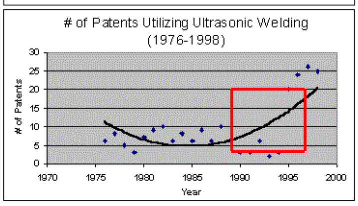
Number of inventions
(number of patents)

<u>**Levels of inventions**</u>
(1, 2, 3, 4, 5)

Profitability of inventions ($, €)



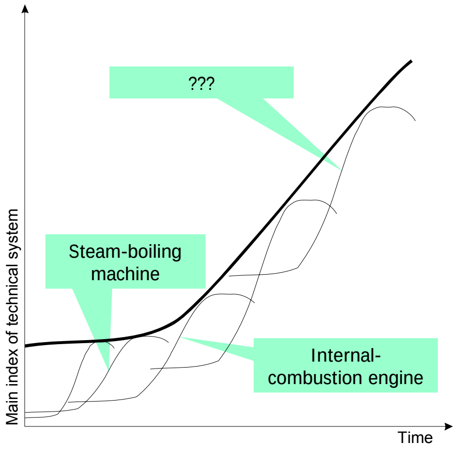




** Nathan Gibson. 1999. The Determination of the Technological Maturity of Ultrasonic Welding. www.triz-journal.com

* G.S.Altshuller: 1979. CREATIVITY AS AN EXACT SCIENCE. Sovietskoe radio, Moscow.

long-term view: combination of S-curves



When does "system 2" replace "system 1" ?

increasing Ideality of technical systems

During their evolution technical systems tend to improve the ratio between SYSTEM PERFORMANCE and the EXPENSE required to achieve this performance.

$$I = \frac{\sum P}{\sum E} \quad \begin{array}{l}\text{(performance)} \\ \text{(expense)}\end{array}$$

Useful for practice*:

Ideal machine – there is no machine, but the required action is performed.

Ideal process – there are no energy expenses and no time expenses, but required action is performed (self-acting control).

Ideal substance – there is no substance, but function is performed.

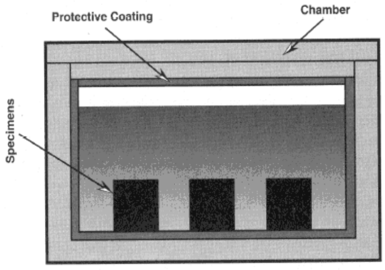
*G.S.Altshuller: 1979. CREATIVITY AS AN EXACT SCIENCE. Sovietskoe radio, Moscow

studying effects of acids on metal alloys

To study the effects of acids on metal alloys, specimens are placed into a hermetically sealed chamber. The chamber is filled with acid, then closed, and various combinations of pressure and temperature are created inside.

The acid is not only reacting with the specimens but also with the walls of the chamber. To protect the walls, they are glass-coated. This glass coating was cracking and had to be reapplied repeatedly for some tests (e.g. vibration).

What should be done?



* English text source: Fey, V.R. and E.I. Rivin, THE SCIENCE OF INNOVATION: A Managerial Overview of the TRIZ Methodology. 1997: The TRIZ Group. 82. p. 8-10

viability of a technical system

Any technical system is the result of the synthesis of several parts into a single whole in accordance with the demands placed on the system .

Wright brothers fly first motorized plane - 1903

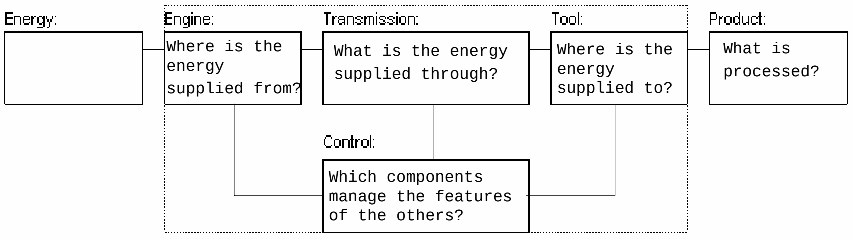
A viable technical system must satisfy the requirements of at least three laws:

- **Law of System Completeness**
- **Law of Energy Conductivity in System**
- **Law of Harmonization**

Photo source: Wright brothers. (2006, August 14). In Wikipedia, The Free Encyclopedia. http://en.wikipedia.org/w/index.php?title=Wright_brothers&oldid=69600748.

system completeness

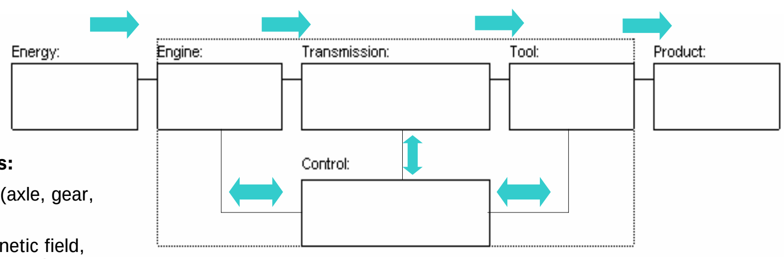
In order to get a viable system the principal components of the technical system have to be present and perform minimal working efficiency.



Consequence: to make a technical system controllable, at least one of its principal components has to be controllable.

energy conductivity in systems

In order to get a viable system the energy flow has to pass through all the principal components of the technical system.

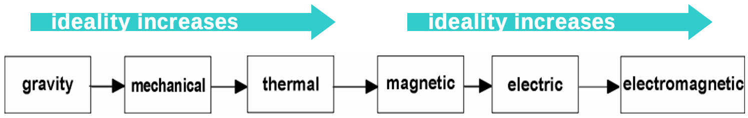


Energy flows:

- Substantial (axle, gear, blow...);
- Fields (magnetic field, electric current...);
- Substantial-field (stream of charged particles...).

Consequence: to make a part of the system controllable it is necessary to provide energy conductivity between a given part and the control unit.

energy conductivity in systems



- during the synthesis of a system it is useful to apply one sort of energy;

  It is proposed to use wind energy for heating a hothouse directly, without converting it to electrical power. Wind turns the wheel of the compressor. Compressor squeezes air. Air warms up to 170⁰C through a squeezing effect. [Japanese patent]

- if it is not possible to replace the substances of a system's components it is useful to apply another field (well conducted by all substances);

  In order to check the thickness of a thin metallic wire during manufacturing it is proposed to use the Corona Discharge effect.

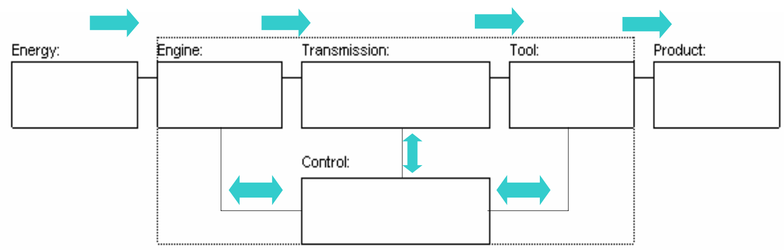
- if changing the substances of a system's components is allowed it is useful to replace poorly controlled substances by well controlled ones by using available fields:

  In order to improve the productivity of a process for metal cutting, it was proposed to replace the metal blade with a water jet blade.

Y.P. Salamatov [1991] *System of evolution of Technique Laws.* /Chance for adventure, Petrozavodsk, Karelia 1991. [Ru]

Module 5: TRIZ: methods and tools

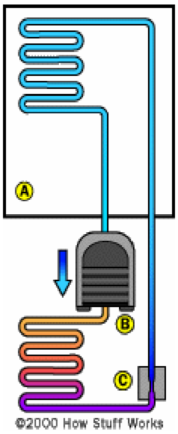
practical: energy conductivity in systems



- **Does energy pass through all components of the system?**
- **Does energy pass through the engine, transmission, tool, and Control?**
- **What is the best conducted field for the substances in the system?**
- **Is it possible to apply a better controlled field?**
- **What is the best field for use in the new system (available or free)?**

Module 5: TRIZ: methods and tools

practical: energy conductivity in systems

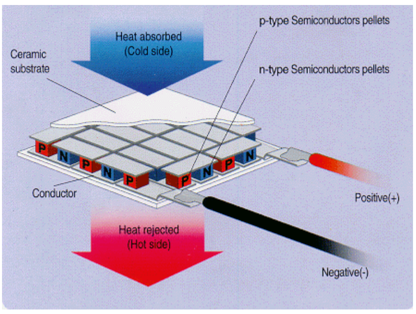


* The basic mechanism of a refrigerator:

1. The compressor compresses the refrigerant gas. This raises the refrigerant's pressure and temperature (orange), so the heat-exchanging coils outside the refrigerator allow the refrigerant to dissipate the heat of pressurization.
2. As it cools, the refrigerant condenses into liquid form (dark blue) and flows through the expansion valve.
3. When it flows through the expansion valve, the liquid refrigerant is allowed to move from a high-pressure zone to a low-pressure zone, so it expands and evaporates (light blue). In evaporating, it absorbs heat, making it cold.
4. The coils inside the refrigerator allow the refrigerant to absorb heat, making the inside of the refrigerator cold. The cycle then repeats.

* Credit: http://www.howstuffworks.com/refrigerator.htm/printable

Peltier effect



* In 1834, French physicist Jean Peltier discovered that when electrical current is sent though a circuit made of dissimilar conducting materials that heat is absorbed at one junction and given up at the other.

This phenomenon is known as the "Peltier Effect."

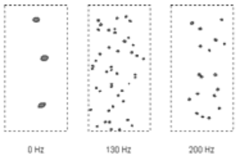
Related:

http://www.digit-life.com/articles/peltiercoolers/

* http://en.wikipedia.org/wiki/Peltier-Seebeck_effect

harmonization

In order to get a viable system all principal components have to be coordinated or specially de-coordinated (e.g. by shape, by type of energy, by frequency of vibration, by periodicity of operation).

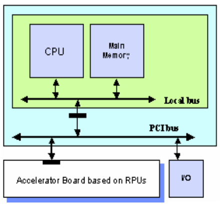


Conclusions for practice:

1. In technical systems, the field's effect should be coordinated and/or de-coordinated with natural frequency of the product and/or tool.

   Example: To dissolve powdered material in water faster it is proposed to coordinate the frequency of the vibrations of the mix with the size of the particles of the powder.

harmonization: conclusions for practice



2. The frequency of fields applied in technical systems should be coordinated or specially de-coordinated.

   Example: In order to improve the performance of a computer the frequency of a local bus has to be coordinated with the frequency of the CPU.

3. If two operations are incompatible (e.g. transformation and measurement), one operation should be done when the other operation pauses. In other words, a pause in one operation should be filled by another operation.

   Example: In 1915 the aircraft designer A.Fokker proposed to coordinate the rotational speed of the propeller axle and the frequency of the machine-gun lock in order to solve the problem of shooting through the propeller.

summary

- The first group of Laws of Technical Systems Evolution includes: Law of System completeness, Law of Energy Conductivity in the System, and Law of Harmonization.
- This group of laws determines the principal requirements for the first phase (birth, childhood) of the technical system's "life".
- Analysis of technical systems using the laws from this group allows one to reveal the causes of a problem from a system standpoint.

dynamics growth

In order to improve their performance rigid systems should become dynamic, i.e. pass to a more flexible and rapidly changing structure which could adapt to changes in working conditions and the requirements of the environment.

Transformation of substances:

One joint → Many joints → Elastic substance → Liquid → Gas → Field

Transformation of fields:

Constant field → Variable field → Variable field (variable frequency, wave-length …) → Variable field + physical effect → Nonlinear field

Y.P. Salamatov [1991] *System of evolution of Technique Laws*. /Chance for adventure, Petrozavodsk, Karelia 1991. [Ru]

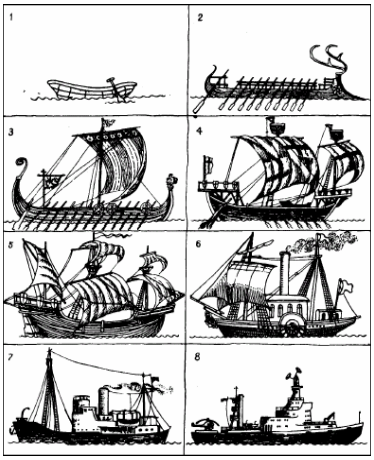
long-term evolution

Wheel:

```
Rigid stone wheel (3500 BC) -> wooden wheel with nave ->
wheel with wire spokes under tension -> wheel with monolith
rubber rim -> pneumatic wheel -> ??
```

Ship tool:

```
Punt-pole -> oars ->
paddle-wheel -> screw propeller ->
hydro-jet -> air cushion -> ??
```



Conclusion for practice:

The first component of the system to be made dynamic is the part which stays under the strongest impact from the environment.

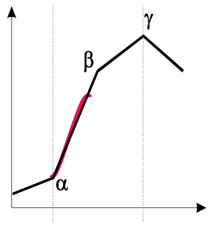
dynamics growth

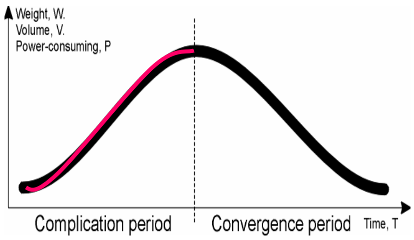
increasing Su-Field interactions

increasing the degree of controllability

In order to improve its performance the system should become more controllable: (1) an incomplete SFM transits to a complete SFM; (2) simple SFMs transit to complex SFMs; (3) the number of controllable links increases; (4) the new substances and fields allow one to use additional effects.

The area of application for this law is the complication phase of system evolution.

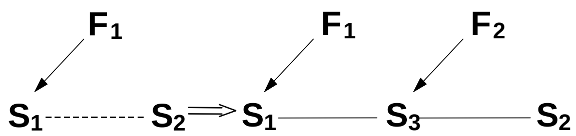




Altshuller G.S.: 1986; 1991, TO FIND AN IDEA. Nauka, Novosibirsk p.79

practical: increasing controllability

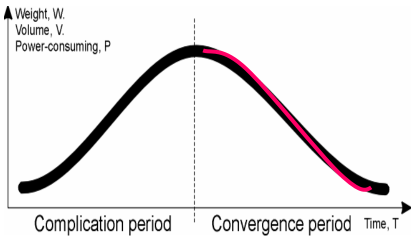
The first candidate of the system to be changed is the part which sustains the strongest stress according to the main function of the system.



A shaft coupling includes external and internal rotors, an electromagnet, and magnetic liquid between the rotors. If the electromagnet is turned off, the rotors can rotate independently. If the electromagnet is turned on, the liquid becomes hard, links the rotors, and transmits torque. [UK Patent 824047].
(S1 - internal rotor; S2 - external rotor; F1 - liquid friction field; S3 - magnetic liquid; F2 - solid friction field).

transition from Macro- to Micro-level

Evolution of Tools begins on the macro-level and tends toward the micro-level.
The system tends to replace a physical principle behind the component which delivers its main function with a new physical principle. This new physical principle utilizes properties of dispersed materials; particles of physical fields.



Some mechanisms:

- increasing the degree of object segmentation and integration of particles into a new system;
- increasing the degree of "mixture" (substance and empty space) segmentation (transition to the capillary-porous materials);
- replacement of the substantial parts of the system with a field.

Y.P. Salamatov [1991] *System of evolution of Technique Laws.* /Chance for adventure, Petrozavodsk, Karelia 1991. [Ru]

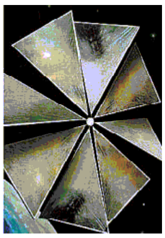
segmentation and combination

Fuels for heat-engines:

Solid: wood, coal → Powder, coal → Black oil → Gasoline, kerosene → Gas → Field →

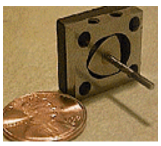
Propulsion system of crafts:

Propeller → Gas jet → Ions jet → Solar wind →



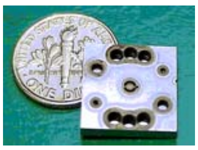
http://www.howstuffworks.com/solarsail.htm/printable

Micro-engines and gearboxes:



http://www.e4engineering.com

http://www.sandia.gov/



http://www.wired.com/news/technology

irregularity of the evolution of a system’s parts

Components of technical systems evolve irregularly. The more complex the system, the more irregularities occur.

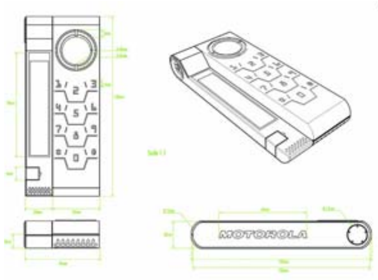
Conclusions for practice:

- Irregularities in the evolution of a system's parts are the origins of contradictions.
- Further development of the system becomes difficult due to internal contradictions arising between the system's parts.
- Modification of one part of the system generates a “chain reaction” of problems. It becomes the reason for modifying most components of the system.

how does irregularity arise?

1. Super-systems require an increase in the performance of the main useful function.
   It is required to increase the operating time for a mobile phone without recharging the batteries.
2. It is necessary to improve the features of a system's component in order to improve its performance.
   It is necessary to decrease the size and weight of a mobile phone’s battery and improve the capacity and/or to decrease the energy consumption of a mobile phone’s components.
3. While improving the performance of a component the links with other components degrade. As a result contradictions arise.
   The <Battery> has to be <small>, to be attached to a small size mobile phone.
   The <Battery> has to be <large>, to provide the needed capacity and reliability.
4. As a consequence of resolving the contradictions new components (substance, subsystems) appear.
   ...Ni-Cad -> NiMH -> Li-Ion battery -> Li-Polymer ->... ???

Motorola PVOT



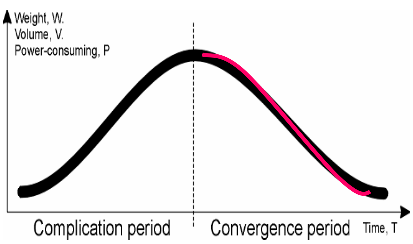
http://www.andreminoli.com/index.php?go=por&por=moto
http://www.andreminoli.com/imgs/moto/large/7.jpg

transition to the super-system

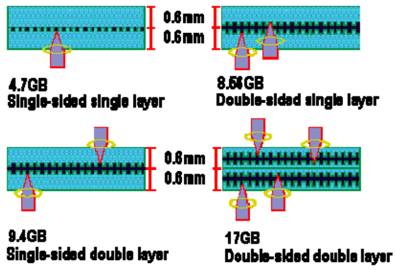
During their evolution technical systems merge to constitute bi- and poly-systems. In the future the system continues its evolution as a part of the super-system.

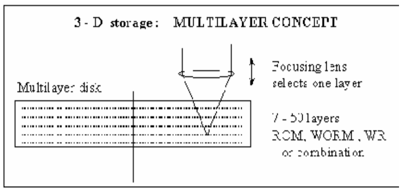
Some mechanisms:

- part of the functions are transferred to a super-system;
  `installing software through the Internet;`
- some of the sub-systems are merged into the new system and they are excluded from the old one;
  `a wireless connection instead of a personal modem for every computer;`
- new functions and properties appear for integrated systems.
  `a telephone conversation and a radio broadcast through the Internet.`



mono-, bi-, poly-systems transitions



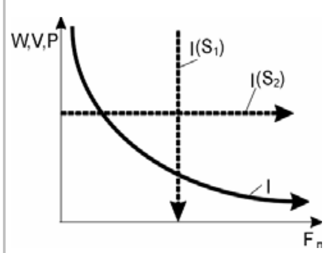


http://www.dircon.co.uk/pctechguide/; http://www.c-3d.net/tech.htm

increasing IDEALITY of technical systems

During their evolution technical systems tend to improve the ratio between SYSTEM PERFORMANCE and the EXPENSE required to achieve this performance.

$$I = \frac{\sum P}{\sum E} \quad \begin{matrix}\text{(performance)} \\ \text{(expense)}\end{matrix}$$

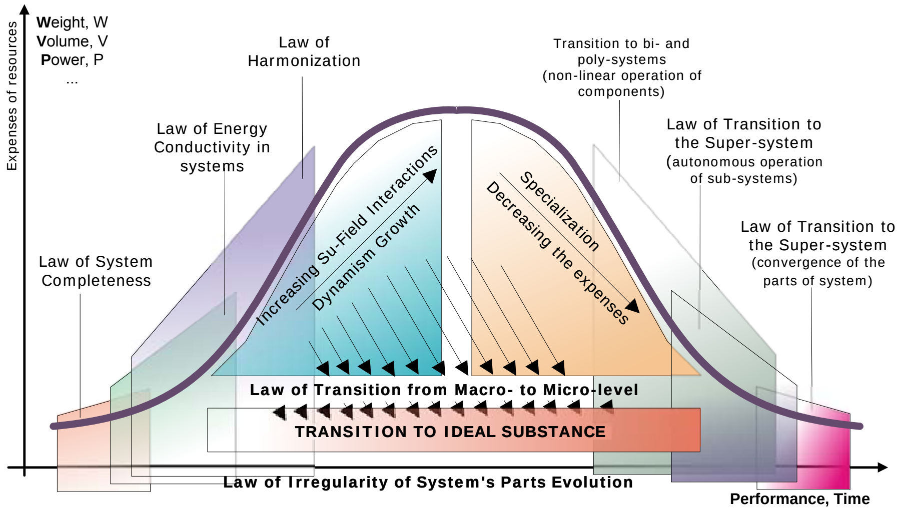


Possible directions:

1. Improvement of the system's performance without increasing additional expenditure (S_2).
2. Decreasing the expenses without performance degradation (S_1).
3. Transition to the super-system.

Figure: Y.P. Salamatov [1991] *System of evolution of Technique Laws*. /Chance for adventure, Petrozavodsk, Karelia 1991. [Ru]

wave model of Technology Evolution



Y.P. Salamatov [1991] *System of evolution of Technique Laws.* /Chance for adventure, Petrozavodsk, Karelia 1991. [Ru]

summary

- The mechanisms of the **Law of Increasing Ideality** of technical systems may be explored in detail through the laws of **Dynamics Growth**, **increasing Su-Field Interactions**, **transition from Macro- to Micro-level**, **transition to the Super-system**.

- The law of **Irregularity of the evolution of a system's parts** helps to understand the reasons of a problem from a system standpoint; this is done using **multi-screen thinking**.

- Analysis of technical systems through the **laws of system evolution** gives opportunities to foresee the future of a technical system.

76 INVENTIVE STANDARDS

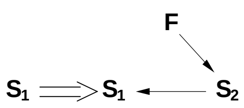
what are the Inventive Standards?

The Inventive Standards are a system of rules that uses Su-Field models of the problem situation in order to facilitate the development of solution concepts.

Each of the Standards includes two principal parts:

- ❑ *the Specific condition of the problem situation*;
- ➢ the framework of the solution concept.

1.1.1. Synthesis of SFM



- ❑ *If there is an object which is not easy to change as required, and the conditions do not contain any restrictions on the introduction of substances and fields,*
- ➢ the problem is to be solved by synthesizing a SFM: the object is subjected to the action of a physical field which produces the necessary change in the object; the missing elements being introduced accordingly.

background

Inventive Standards are the next step of evolution for techniques to facilitate the development of conceptual solutions.

- Author of Su-Field analysis and System of Inventive Standards is G.Altshuller. The modifications of Inventive Standards made by G.Altshuller adopted the experience, comments, and suggestions of much other TRIZ research.
- The first version of a System of Inventive Standards was published widely for the first time in the book by G.S.Altshuller: 1979. “CREATIVITY AS AN EXACT SCIENCE”. Sovietskoe radio, Moscow.
- The modern version of a System of Inventive Standards was published in “A THREAD IN THE LABYRINTH”, Karelia, Petrozavodsk, 1988.

Module 5: TRIZ: methods and tools

SYSTEM OF 76 INVENTIVE STANDARDS

CLASS 1. COMPOSITION AND DECOMPOSITION OF SFMs
- GROUP 1.1. Synthesis of SFMs [8 Standards]
- GROUP 1.2. Decomposition of SFMs [5 Standards]

CLASS 2. EVOLUTION OF SFMs
- GROUP 2.1. Transition to complex SFMs [2 Standards]
- GROUP 2.2. Evolution of SFMs [6 Standards]
- GROUP 2.3. Evolution by coordinating rhythms [3 Standards]
- GROUP 2.4. Complex-forced SFMs [12 Standards]

CLASS 3. TRANSITION TO SUPER-SYSTEM AND MICRO-LEVEL
- GROUP 3.1. Transition to bi- and poly-system [5 Standards]
- GROUP 3.2. Transition to micro-level [1 Standard]

CLASS 4. MEASUREMENT AND DETECTION STANDARDS
- GROUP 4.1. Bypass ways [3 Standards]
- GROUP 4.2. Synthesis of measurement system [4 Standards]
- GROUP 4.3. Improvement of measurement systems [3 Standards]
- GROUP 4.4. Transition to ferromagnetic measurement systems [5 Standards]
- GROUP 4.5. Evolution of measurement systems [2 Standards]

CLASS 5. HELPERS (STANDARDS FOR APPLYING THE STANDARDS)
- GROUP 5.1. Substance introduction [4 Standards]
- GROUP 5.2. Introduction of fields [3 Standards]
- GROUP 5.3. Use of phase transition [5 Standards]
- GROUP 5.4. Physical effects applying [2 Standards]
- GROUP 5.5. Substance particles obtaining [3 Standards]

Module 5: TRIZ: methods and tools

Inventive Standards - Laws of evolution

The Inventive Standards propose some directions for the transformation of the initial technical system which are in accordance with the laws of technical systems evolution.

- CLASS 1. COMPOSITION AND DECOMPOSITION OF SFMS
  System Completeness, **Energy Conductivity in the System**
- CLASS 2. EVOLUTION OF SFMs | GROUP 2.1. Transition to complex SFMs
  Increasing Su-Field Interactions
- CLASS 2. EVOLUTION OF SFMs | GROUP 2.2. Evolution of SFMs
  Dynamics Growth
- CLASS 2. EVOLUTION OF SFMs | GROUP 2.3. Evolution by coordinating rhythms
  Harmonization
- CLASS 3. TRANSITION TO SUPER-SYSTEM AND MICRO-LEVEL
  Transition to the Super-System, Transition From Macro- to Micro-Level
- CLASS 5. HELPERS (STANDARDS FOR APPLYING THE STANDARDS)
  Increasing Ideality of technical systems

Composition and Decomposition of SFMs

This class includes two groups, Synthesis and Decomposition, and is intended for modification problems

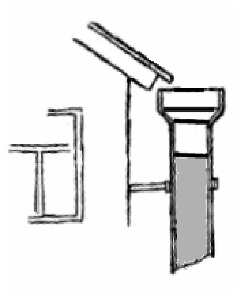
GROUP 1.1. **Synthesis of SFMs**

The main idea is explained in Standard 1.1.1: to synthesize a new working system it is necessary to transit from non-SFM to the SFM. Sometimes the synthesis of the SFM presents difficulties due to the limits of the problem situation on introducing substances and fields. Standards 1.1.2 – 1.1.8 propose the typical ways for dealing with these situations.

GROUP 1.2. **Decomposition of SFMs**

Group 1.2 includes Standards of decomposition of SFMs and elimination, or neutralization, of harmful interactions.
The most powerful idea of this group is the mobilization of needed elements by using available substance-field resources.
Standard 1.2.2 is very important, because functions of the new substance are executed through the modification of existing substances

practice: ice stopper



In winter a lot of snow gathers in the drain-pipes of buildings. In spring, the snow melts during the day and freezes at night. As a result, ice stoppers are formed inside the drain-pipes . However when the sun shines, the ice stopper rushes down the pipe and damages the bottom of the drain-pipe.
What should be done?

The <ice cork> must <be melted 'from the outside' in the 'daytime'>, because <the sun shines and radiation provides the heat energy through the drain-pipe>, BUT
the <ice cork> must not <be melted 'from the outside' in the 'daytime'>, because <the sticking forces have to support the ice cork until it is completely melted>.

G.I.Ivanov: 1994: *THE FORMULES OF CREATIVITY OR HOW TO LEARN TO INVENT*. Prosveschenie, Moscow. P. 124

Evolution of SFMs

This class includes four groups; the standards propose to increase the efficiency of solution concepts through some complications of the system

GROUP 2.1. **Transition to complex SFMs**

Efficiency of SFMs can be enhanced through the transition from simple SFMs to complex ones (chain SFM and dual SFM).

GROUP 2.2. **Evolution of SFMs**

The general idea is to increase efficiency of the SFM (simple and complex) without introducing new fields or substances.

GROUP 2.3. **Evolution by coordinating rhythms**

Group 2.3 includes Standards for evolution of the SFM by especially advantageous methods. Standards of group 2.3 propose modifying only the values of parameters, instead of introducing or modifying the substances and fields.

GROUP 2.4. **Complex-forced SFMs**

Evolution of the SFM can go through several standard paths at the same time.

practice: chemical reaction and foam

A chemical reaction is conducted in a closed container. The container is half full with a liquid. A by-product of this reaction is the generation of foam . It is necessary to disperse (suppress) the foam.

For previous systems the blades of an electric fan were used. For a closed container this solution is unacceptable.
What should be done?

If there is <a fan with blades>, then <the foam is well dispersed>, but <the container is not well closed>
If there is no <fan with blades>, then <the foam is not dispersed>, but <the container can be well closed without leakage>.

G.I.Ivanov: 1994: *THE FORMULES OF CREATIVITY OR HOW TO LEARN TO INVENT.* Prosveschenie, Moscow. P. 106

Transition to the Super-system and the Micro-level

This class includes two groups; the standards continue in the direction of Class 2 and propose to increase the efficiency of solution concepts through the convergence of systems

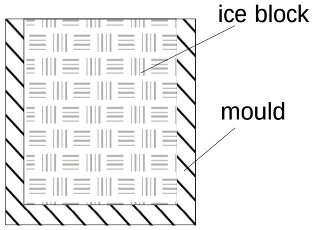
GROUP 3.1. **Transition to the bi- and poly-system**

An "Inner-system" (the Standards of class 2) is developed at the same time as an "external-system": at any stage of its evolution the system can be combined with other systems to form a super-system with new qualities.

GROUP 3.2. **Transition to the micro-level**

There are two general directions for the transition to new systems:
Transition to the super-system ("way upwards" – Standards of group 3.1) and
Transition to use of a " deep" subsystem ("way downwards" – Standards of group 3.2).

practice: Removal of ice blocks



Blocks of ice are made for industrial purposes. How should one removes these from the mould?

Removing an ice cube from a plastic mould is easy when dealing with a domestic refrigerator. However a plastic mould has low durability and low heat conductivity.
When dealing with industrial refrigerators the block of ice is removed by using special complex devices or waiting for the ice to melt a little.
It is necessary to improve productivity and decrease the cost of this operation.

What should be done?

Ideal Final Result (IFR):
The <Mould> itself,
without additional cost
<removes the block of ice>
during <___________>
inside <____________>

Y.P.Salamatov: 1990, HOW TO BECOME AN INVENTOR: *50 HOURS OF CREATIVITY.* Prosveschenie, Moscow.

Measurement and Detection Standards

This class includes five groups and is intended for detection and measurement problems; some standards have similarities with standards from Classes 1, 2, 3.

GROUP 4.1. **Bypass methods**
Measurement and detection serve the main "metering" action. It is advisable to redesign the main action of a technical system to exclude (or reduce) the necessity of "measurement-detection" activity.

GROUP 4.2. **Synthesis of a measurement system**
Similar principles to those used for "modification" systems are applied for the synthesis of measurement systems : it is necessary to complete the SFM by introducing the needed substance or field.

GROUP 4.3. **Improvement of measurement systems**
The measurement SFM can be improved by applying physical effects and by coordinating the rhythm of the fields used.

GROUP 4.4. **Transition to ferromagnetic measurement systems**
Measurement SFMs have a steady trend of transition to a ferromagnetic SFM.

GROUP 4.5. **Evolution of measurement systems**

practice: detection of water

Precision techniques for measuring water in motor oil require special equipment.
How do we detect water in motor oil without special equipment?

<Water in motor oil> must <be recognizable in 'a drop of oil' after 'several minutes'>, because <it is necessary to detect water in motor oil>, BUT <Water in motor oil> must not <be recognizable in 'a drop of oil' after 'several minutes'>, because <there is no special equipment>, <the water particles are invisible>.

Y.P.Salamatov: 1990, HOW TO BECOME AN INVENTOR: *50 HOURS OF CREATIVITY*. Prosveschenie, Moscow.

Standards for Applying the Standards

This class includes five groups; it is important to use this class for all kinds of problems in order to improve the Ideality of the solution concepts developed.

GROUP 5.1. **Substance introduction**

The Standards from this group provide recommendations on how "to introduce substances without introducing them" . Various bypass methods are proposed.

GROUP 5.2. **Introduction of fields**

The Standards from this group provide recommendations for introducing new fields without complicating the technical system.

GROUP 5.3. **Use of phase transition**

The contradicting requirements for introducing substances and fields without introduction can be satisfied by using resources derived from phase transitions.

GROUP 5.4. **Application of Physical effects**

Some principles to improve the efficiency of applying physical effects are described in this group.

GROUP 5.5. **Obtaining substance particles** (experimental Standards)

practice: porous walls of a container

To produce a ceramic container for laboratory use one must make multiple micro-channels of a particular shape (capillary structure). Usually during production a thin wire is placed into the material used to make the container.
After baking the container, the wire is drawn out. This technology is inappropriate when the diameter of the micro-channel is less than 0.01 mm. The wire breaks when it is drawn out.
What should be done?

G.I.Ivanov: 1994: *THE FORMULES OF CREATIVITY OR HOW TO LEARN TO INVENT.* Prosveschenie, Moscow. P. 106

types of substance-fields resources

SUBSTANCE - solid, liquid, gas, plasma substance.

FIELD - mechanical, thermal, chemical, electrical, magnetic, electromagnetic fields, vibration, etc.

Resources of SPACE - empty space in the system, sub-systems, super-systems, artificial and natural void, constant and variable empty space.

Resources of TIME - time before carrying out the main useful function, time of carrying out the main function, time after realization of the main function.

Resources of INFORMATION - information transferable by substance, by field.

FUNCTIONAL resources - using available elements to perform additional functions.

useful engineering fields

Mechanical
- Centrifugal forces
- Gravity forces
- Inertia
- Elasticity
- Internal tension
- Friction forces
- Wetting forces
- Diffusion
- Buoyancy
- Pressure of liquids and gases
- Hydrodynamic and Aerodynamic forces

Acoustic & Vibration
- Sound
- Ultrasound
- Resonance field

Thermal
- Heating
- Cooling
- Phase transition
- Thermal tension
- Thermal shock
- Infrared radiation

Chemical
- Chemical Diffusion
- Chemical interactions
- Osmosis
- Smell
- Taste
- Adhesion forces
- Burning of substances

Electrical & Magnetic
- Electric current
- Electric charge
- Electric discharge
- Electrostatic field
- Electromagnetic
- Magnetic

- Electron beam
- Laser
- Light
- Infrared rays
- Microwaves
- Radio waves
- Ultraviolet rays
- X-rays

structure of useful fields

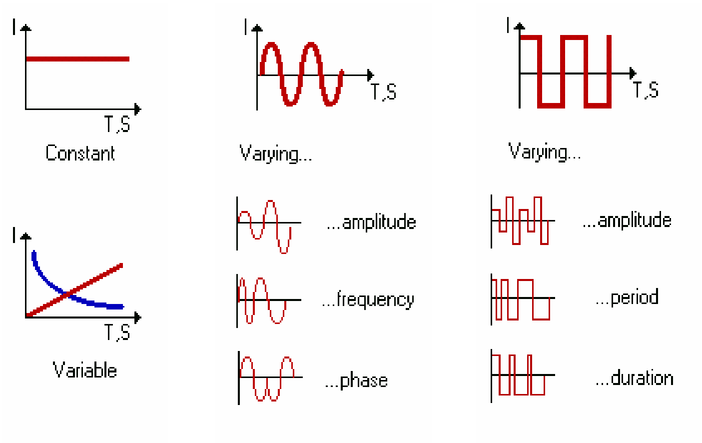
CONSTANT **ALTERNATING** **PULSING**

S *- Space,*

T *- time,*

F *- frequency,*

I *- parameter of Fields*



how to put into practice the Inventive Standards

1. Identify the desired result and formulate the contradictions.

2. Analyze the Operational Time, Operational Zone and available Resources for the formulated contradiction.

3. Identify S_1(Product), S_2(Tool), the Field of interaction, and the type of interaction: missing, harmful, excessive, insufficient.

5. Draw an SFM model starting from the Product and transform the obtained SFM according to the recommendations of the Inventive Standards.

6. Summarize the features of the required Substance-Field Resource.

7. Collect the Partial concept solutions. Synthesize the collected Partial concept solutions into the Preliminary solution concept.

If steps 1-3 are difficult to realize, build the problem model through Parts 1, 2, and 3 of ARIZ.

practice: grinding capillary channels

To produce a ceramic container for laboratory use it is necessary to grind multiple channels into its walls (see problem "Porous walls of a container"). When the channels are large enough it is possible to use a grinding tip and flexible shaft. To grind tiny capillary channels a grinding tip is unacceptable.

What should be done?

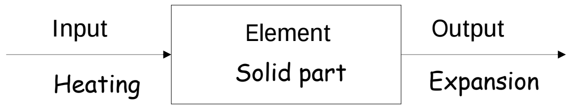
summary

Advantages of 76 Inventive Standards	**Disadvantages** of 76 Inventive Standards	In comparison with **Inventive Principles**

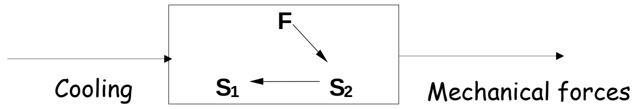
POINTERS OF EFFECTS AND PHENOMENA

Pointers of effects are specially organized information registries. They are developed in order to assist inventors in accessing modern scientific knowledge.

POINTERS OF EFFECTS AND PHENOMENA



Effect – repeated interaction of elements with an equal dependence between Input and Output.



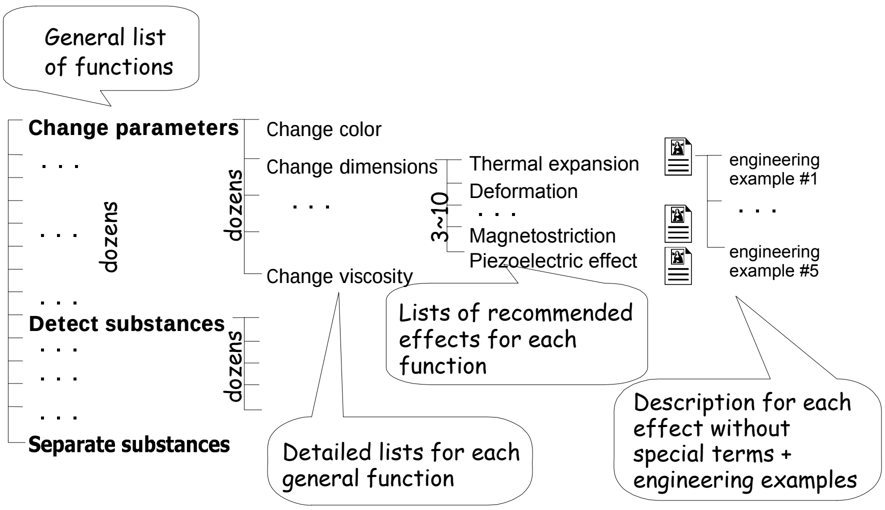
S_2 – transition phase of water to ice;
S_1 – metallic pipe; F - thermal

background

- 1969 – start of research; 5000 patents were analyzed;
  1971 – first pointer of physical effects;
  1973 – 300 page register of physical effects (manuscript);
  1978 – second version of the Pointer of effects.
  1979 – table of application of the Pointer of effects with ARIZ-77 in [G.S.Altshuller: 1979. “CREATIVITY AS AN EXACT SCIENCE”. Sovietskoe radio, Moscow].
- First publication in 1981 in the technical magazine “Technika i nauka” (Technologies and science) ##1-9.
- First pointer of *physical* effect was published widely for the first time in [DARING FORMULAS OF CREATIVITY, Karelia, Petrozavodsk, 1987].
- Pointer of *chemical* effect was published widely for the first time in [A THREAD IN THE LABYRINTH, Karelia, Petrozavodsk, 1988]
- Pointer of *geometrical* effect was published widely for the first time in [RULES OF A GAME WITHOUT RULES”, Karelia, Petrozavodsk, 1989].

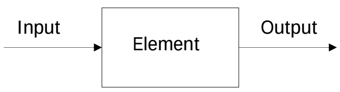
classical structure of the pointers of effects

physical, chemical, geometrical



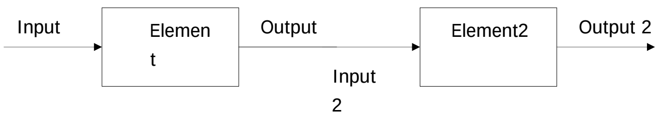
types of effects

- **Plain effects:**



- **Complex effects:**

- **Reversible effects:** piezo-crystal, resilience (elastic deformation)
- **Irreversible effects:** irreversible adsorption, plastic deformation
- **Connected effects:**



- **Combined effects:** chain of several connected effects

how to put into practice pointers of effects

1. Identify the desired result and formulate the contradictions of the Initial situation. Analyze the Operational Time, Operational Zone and available Resources for the formulated contradiction.
2. Identify S_1(Product), S_2(Tool), and the Field of interaction.
3. Identify the Function that must be performed in order to satisfy the Contradiction requirements.
4. Select the required Function(s) from the Table of Functions in the Pointer of effects.
5. Look up and read the list of recommended effects accomplished by the defined function. If several functions are selected, identify the intersections of the proposed effects.
6. Interpret the proposed effects in terms of the problem situation.
7. Collect the partial conceptual solutions. Synthesize the collected Partial conceptual solutions.

practice: how do we make a hole?

To produce a ceramic container for laboratory use it is necessary to make several holes near the side of its neck (see problems: "Porous walls of a container", "Grinding capillary channels").
However, ceramic is a fragile material.

How do we make these holes?

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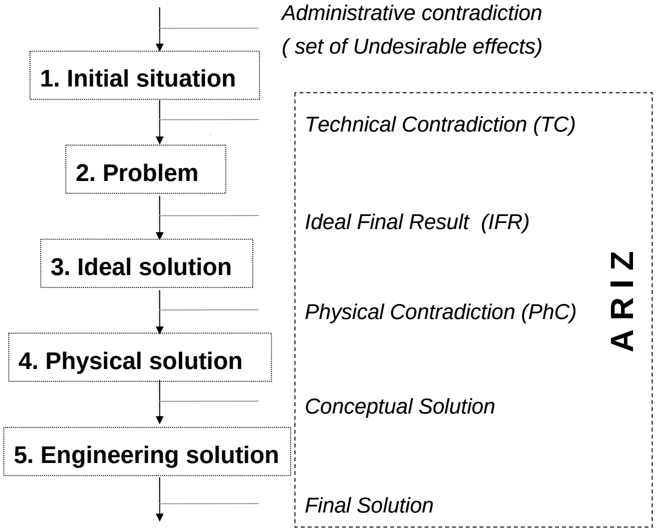
summary

- **It is essential for an inventor to apply scientific knowledge in an efficient way.**
- **The Pointers of effects play the role of an "interface" between engineering practice and scientific knowledge.**
- **In order to apply the functional pointers of effects it is necessary to define the function(s) which resolve contradictions, rather than choosing the main function of the analyzed technical system.**

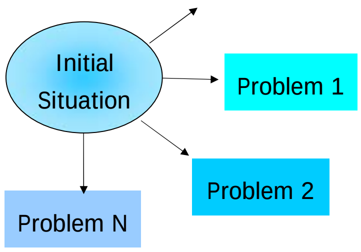
PROCESS OF SOLVING AN INVENTIVE PROBLEM



* G.S.Altshuller, [1975]. PROCESS OF SOLVING AN INVENTIVE PROBLEM

ANALYSIS OF INITIAL SITUATION

We fail more often because we solve the wrong problem than because we get the wrong solution to the right problem.
Russell Ackoff



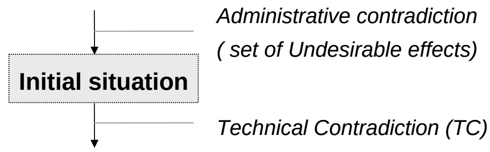
In order to reduce the research area it is necessary to transform an *Initial situation* into a specific *Problem*.

Initial situation - is any situation with chosen undesirable (harmful) feature(s) or properties.

analysis of initial situation

Discontent is the first necessity of progress.
Thomas A. Edison

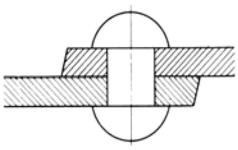
Any **initial situation** can be transformed into a **particular problem** by introducing (or specially removing) some additional restrictions.



Known techniques and methods:

- Algorithm of inventive problem solving up to ARIZ-85a
- Functional and Ideality Modeling
- Adapted “Golden fish” operator (N.Khomenko)
- Algorithm to define problems (AVIS – G.Ivanov)
- “New Problem technology” – OTSM-TRIZ (N.Khomenko)

mini- AND maxi- problems



Initial situation:

RIVETED JOINT*: It is necessary to rivet two flat plates in order to make the riveted joint. If the rivet is deformed enough, the plates are well fixed, but cannot work as a joint. If the rivet isn't deformed enough, the plates are movable, but they aren't adjusted enough. How should the rivet joint be manufactured ?

MINI-problem:

- solution should be developed with minimum changes of existing system;
- solution concepts are easy to implement.

Riveted joint: The riveted joint makes a firm junction. The mobility of the junction is performed for the rivet joint.

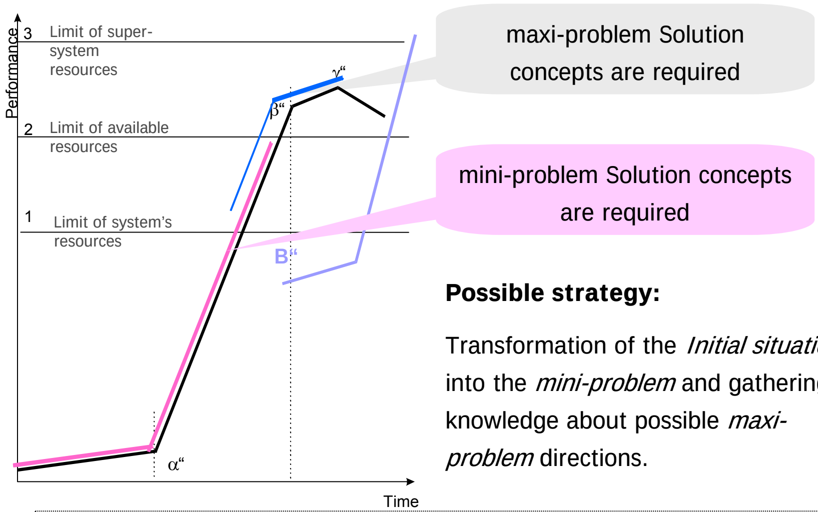
MAXI-problem:

- To develop a solution the maximum changes are allowed (only the function is kept);
- solution concepts are difficult to implement.

Riveted joint: The mobile junction of the two flat plates has to be performed. It is not necessary to keep the principle of the riveted junction.

* Ivanov, G.I., THE FORMULES OF CREATIVITY OR HOW TO LEARN TO INVENT. 1994, Moscow: Prosveschenie Publishing House. 208.

mini- OR maxi- problem?



Possible strategy:

Transformation of the *Initial situation* into the *mini-problem* and gathering knowledge about possible *maxi-problem* directions.

Practical conclusion:
Solution of mini-problem – solution for short-term implementation.
Solution of maxi-problem – solution concepts for long-term strategy and R&D.

nine steps to analyze the initial situation

(an adapted extract from ARIZ 85A)

0.1. Determine the final goal of a solution.

0.2. Investigate a "bypass approach".

0.3. Determine which problem, the original or the bypass, makes the most sense to solve.

0.4. Determine the required quantitative characteristics.

0.5. Increase the required quantitative characteristics by considering the time of invention implementation.

0.6. Define the requirements for the specific conditions in which the invention is going to function.

0.7. Examine if it is possible to solve the problem by direct application of the Inventive Standards.

0.8. Define the problem more precisely utilizing patent information.

0.9. Use STC (Size, Time, Cost) operator.

* Altshuller G.S. ARIZ 85A in PROFESSION: TO SEARCH FOR NEW. 1985, Kishinev: Kartya Moldovenyaske Publishing House. 196. (in Russian)

160 pin PCB-to-PCB horizontal Connector

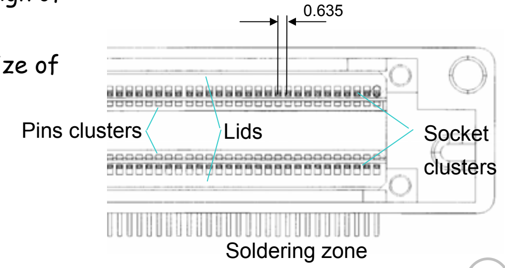
Initial situation:

To connect a notebook to a dock expansion station a specific connector is used. For modern notebook models with expanded multimedia features, a 160 pin connector is installed. In order to decrease the size of the connector, forces of mating and disassembling, and EMI (Electromagnetic Interference) shield effectiveness a special design of connectors is used.

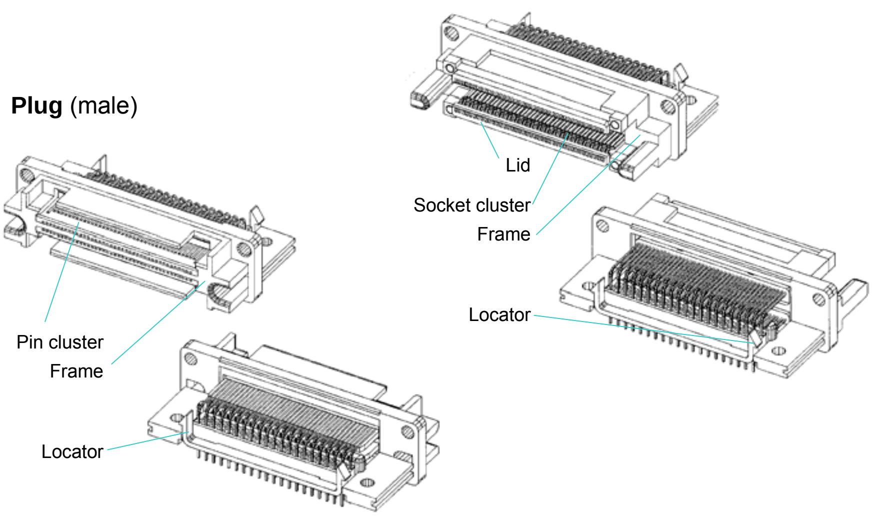
It is necessary to decrease the size of the connector by 15%.

What should be done?

Connector cross section



160 pin PCB-to-PCB horizontal Connector



nine steps: 0.1.

Determine the final goal of a solution

a. What is the technical goal (what characteristic of the object must be changed)?

It is required that we:

- decrease theconnector's size or increase the pin number for the same size;
- decrease the forces of mating and disassembling and improve reliability;
- improve the EMI shield effectiveness for the connector (contact reliability, completeness of covered area).

b. What characteristic of the object cannot be obviously changed in the process of solving a problem?

- It is restricted to replace the mechanical principle of connection.
- It is required to keep the frame material Zn alloy.
- It is not allowed to change the direction of the connection.

* Supplementary materials see: How the Algorithm Works / G.Altshuller: 1999, THE INNOVATION ALGORITHM: TRIZ, systematic innovation, and technical creativity. Worchester, Massachusetts: Technical Innovation Center. 312 pages, ISBN 0964074044 p.p. 171-181

nine steps: 0.1.

Determine the final goal of a solution (continued)

c. Which expense will be reduced if the problem is solved?

Material cost; Weight of connector; Size of connector; Production cost; Maintenance cost.

d. What is the roughly acceptable expense?

Production cost of a new-design-connector must be lower than when the existing connector is produced.

Cost to design and test a new connector is limited by the budget of a three month project.

e. What is the main technical / economical characteristic that must be improved?

The goal is to reduce the size of the connector for a notebook with dock expansion station (mm^3/pins).

nine steps: 0.2.

Investigate a "bypass approach".

Imagine that the problem, in principle, cannot be solved. What other, more general problem, can be solved to reach the required final result (desired result)?

a. Proceed to the super-system (for the given system where the problem originated from) and reformulate the original problem at the level of the super-system.

The bypass direction is to "get rid of the connector". The connector is a machine to connect the docking station with the notebook. If a connection can be made (signal transmitted) without physical contact, the connector will not be necessary.

How to transmit all necessary signals without physical contact?

b. Proceed to the sub-systems (the given system contains a set of sub-systems) and reformulate the original problem at the level of sub-systems (e.g. substances).

How to transmit all necessary signals using as a means of connection frames, lids and locators? Problem might be solved if signals were transmitted through all points of contact between the docking station and the notebook.
How to transmit signals through other components of the notebook-docking station joint?

nine steps: 0.2.

Investigate a "bypass approach" (continued)

c. Reformulate the original problem for three levels (super-system, system, sub-system) by replacing the required action (or feature) with an opposite action (or feature).

Required action: to provide the electrical contacts for many conductors simultaneously.

Opposite action: to prevent the electrical contacts for many conductors simultaneously.

How to provide the electrical contacts within a limited area of interconnection when multiple pins are impeding the connection of the others?

nine steps: 0.3.

Determine which problem, the ORIGINAL or the BYPASS, makes the most sense to solve.
Choose which to pursue: take into account the objective factors (what are the system reserves of evolution);
take into account the subjective factors (which problem it is supposed to solve – Mini-problem or Maxi-problem).

There is a clear tendency toward a "modular structure" in the notebook. Necessary components should be connected only when we need their functionality.

A tendency towards wireless connections can also been seen.

Due to the EMI issue and the necessity to secure a connection with a high transfer speed the original problem is chosen.

nine steps: 0.4. - 0.5

0.4. Determine the required quantitative characteristics:

- The forces of mating and disassembling should be less than 3kgf.
- Connector has to work for 5000 cycles without failure.
- The time of mating and disassembling has to be 1-2 sec.
- … etc.

0.5. Increase the required quantitative characteristics by considering the time of invention implementation.

- The forces of mating and disassembling should be less than 2.5 kgf.
- Connector has to work for 8000 cycles without failure.
- The time of mating and disassembling has to be 1 sec.
- … etc.

nine steps: 0.6

Define the requirements for the specific conditions in which the invention is going to function.

a. Consider specific conditions for manufacturing the product: in particular, the acceptable degree of complexity.

____

____

b. Consider the scale of future applications.

____

____

nine steps: 0.7

Examine if it is possible to solve the problem by direct application of the Inventive Standards. If the problem has been solved, go to the development of a technical solution. If the problem is still unsolved, go to 0.8.

nine steps: 0.8

Define the problem more precisely utilizing patent information.

a. How are problems close to the given one solved in other patents?

____

____

b. How are similar problems solved in leading industries?

____

____

c. How are opposite problems solved?

____

____

nine steps: 0.9

Use STC operator:

Step	Procedure	Changing	How changed problem is solved	Principle used in the solution
1.	S –> ∞	10		
		100		
		1000		
2.	S –> 0	0.1		
		0.01		
		0.001		
3.	T –> ∞	10		
		100		
		1000		
4.	T –> 0	0.1		
		0.01		
		0.001		
5.	C –> ∞	10		
		100		
		1000		
6.	C –> 0	0.1		
		0.01		
		0.001		

ALGORITHM FOR INVENTIVE PROBLEM SOLVING

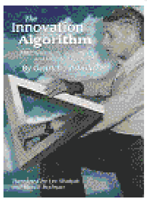
1. **what is ARIZ?**
2. **structure of ARIZ**
3. **case example**

ARIZ is...

The algorithm of inventive problem solving (ARIZ) is an integrated method to assist in the resolution of inventive problems, based on the knowledge of laws of Technical Systems Evolution.

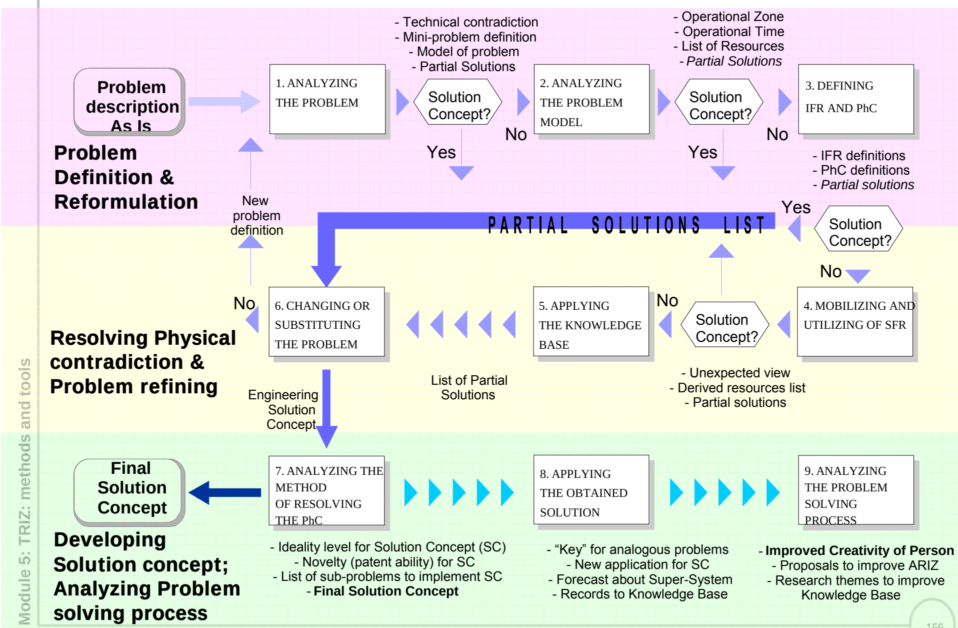
- ARIZ focuses on modeling the problem as a physical contradiction and resolving the PhC.
- ARIZ systematizes the use of various types of TRIZ techniques.
- ARIZ helps to gradually refine a problem model which contains a Technical Contradiction and translates it into a Physical Contradiction.

background



- The author of ARIZ is G.S.Altshuller. The first version of the Method for inventing was proposed in 1956.
- The name *Algorithm of Inventive Problem Solving (ARIZ)* was applied for the first time in 1964.
- Modifications of ARIZ were named ARIZ-68, ARIZ-71, ARIZ-77, ARIZ-82...
- The name "Altshuller's ARIZ" is applied to indicate the latest version of the classical algorithm known as ARIZ-85C.
- G.Altshuller: 1999, **THE INNOVATION ALGORITHM**: TRIZ, systematic innovation, and technical creativity. Worchester, Massachusetts: Technical Innovation Center. 312 pages, ISBN 0964074044

ARIZ flowchart



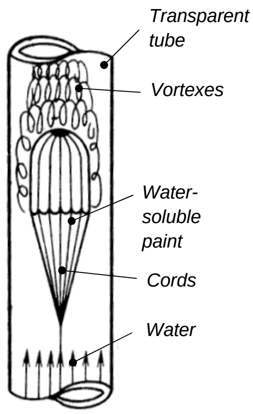
testing the parachute model

A model parachute is placed in a transparent tube and a flow of water is provided for testing purposes .

The test is observed. However, colorless water limits the visibility of vortexes. If paint were added to the water flow it would make observation even more difficult: colored vortexes are not at all visible.
To produce pictures of vortex formation, the top cords are covered in water-soluble paint. It allows the production of colored vortexes in the water flow.

Unfortunately, the paint is consumed quickly.

What should be done?



part 1. analyzing the problem

The main focus of Part 1 is the transition from an uncertain initial problem situation to a clearly formulated and extremely simplified description (model) – Problem Model.

1.1. formulate the mini-problem

Description: a system for <observing vortex formation> consists of <a transparent tube, water flow, vortexes in water flow, parachute model, layer of water-soluble paint on the model>.

TC#1: *If there is <a thin layer of paint>, then <it does not distort the image>, but <it colors vortexes for a short time>.*

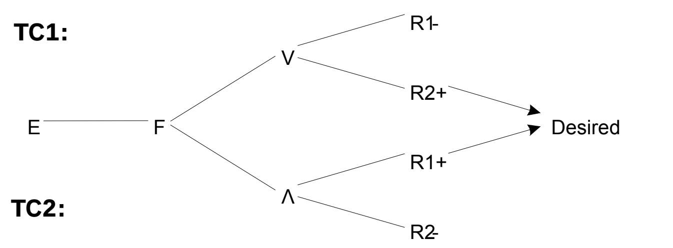
TC#2: *If there is <a thick layer of paint>, then <it distorts the image>, but <it colors vortexes for a long time>.*

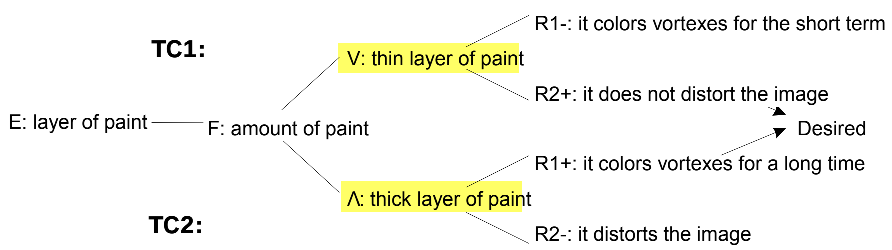
The desired result:

It is necessary, with minimum changes to the system, <to provide a long term test without distorting the image>.

comments for problem description

ENV model*





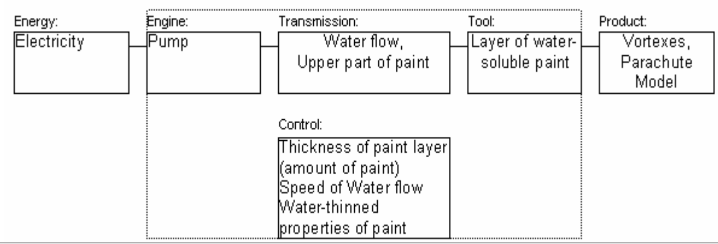
*N.Khomenko. 1997-2001. Materials for seminars: OTSM-TRIZ: Main technologies of problem solving, "Jonathan Livingston" Project.

1.2. define the conflicting elements

Identify and write down a conflicting pair: ***product*** and ***tool***.

comments for the definition of products and tools

Law of System completeness + Law of Energy conductivity in systems:

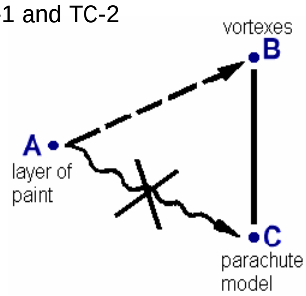


Conflicting pair:
Product *- Vortexes and parachute model.*
Tool *- layer of paint (thick / thin) on the model.*

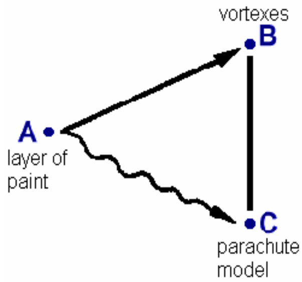
1.3. describe graphic models ...

Develop two graphic models for conflicts TC-1 and TC-2

TC#1
thin layer of paint
(CONJUGATED ACTION)



TC#2
thick layer of paint
(CONJUGATED ACTION)



1.4. select a graphic model...

From the two graphic models of conflict it is necessary to choose the one which provides the best performance for the Main Manufacturing Process*.

Main Useful Function of the Main Manufacturing Process: *<to obtain a correct model of vortex formation>*

Chosen contradiction:

TC#1: *If there is <a thin layer of paint>, then <it does not distort the image>, but <it colors vortexes for the short term>.*

* see Multi-screen analysis

1.5. intensify the conflict

Intensify the conflict by indicating the extreme state* (action) of the elements.

Let's consider that instead of "a thin layer of paint" there is "a missing layer of paint" for TC#1.

* see Size-Time-Cost operator (STC)

1.6. describe the problem model

Formulate the Problem Model to indicate the following:

1) the conflicting pair;
2) the intensified conflict definition;
3) what the introduced X-element should do to solve the problem (what the X-element should keep, eliminate, improve, provide, etc.).

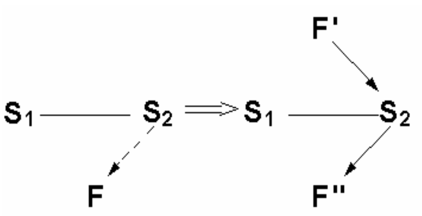
Problem Model*:

(1) Conflicting pair:
<vortexes in the water flow> and <the missing layer of paint>.
(2) Intensified Conflict:
<The missing layer of paint> does not distort the model (experiment), but it does not change the color of the vortexes.
(3) Problem:
It is necessary to find an X-element which
<keeps the properties of the missing layer of paint>
does not produce distortions, and
<provides long term coloring of vortexes>.

* compare with the Initial situation description

1.7. apply the inventive standards

Check the possibility of applying the System of Standard Solutions for Inventive Problems to solve the Problem Model.



When,

S_1- water flow, S_2 – visible vortexes;

F, F" - visibility field;

F' - ???

part 2. analyzing the problem model

The main purpose of Part 2 is to identify the available resources (space, time, substances, and fields) that may be useful for solving the problem .

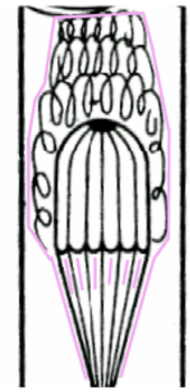
2.1. define the operational zone (OZ)

2.2. define the operational time (OT)

2.3. define the substance-field resources (SFR)

2.1. define the operational zone (oz)

Analyze and describe the **Operational Zone** (OZ).



Definition of the Operational Zone:

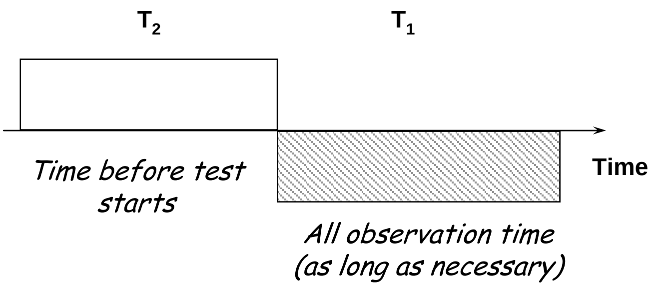
space beside the model parachute.

2.2. define the operational time (ot)

Analyze and describe the **Operational Time** (OT).

Comment:

The operational time where there are available resources of time:
the time when conflict occurs - T_1 and
the time before the conflict - T_2.



2.3. define the substance-field resources

Define the Substance and Field Resources (SFR) of the analyzed system, the environment, and the product*. Compose a list of SFRs.

Comment:

The SFRs are available resources and thus should be utilized first.

System (internal) resources:
Water flow (inexhaustible amount of water);
Vortexes;
Model parachute
Available (external) resources:
Transparent tube (optical properties);
Observer;
Light;
SFR of the super-system
Gravity;
Air pressure;
The Earth's Magnetic Field.

* see Multi-screen analysis

part 3. defining the ideal final result (ifr) and physical contradiction (PhC)

An image of the Ideal Final Result (IFR) should be formulated as a result of applying Part 3.
The Physical Contradiction (PhC) that prevents achievement of the IFR should be identified.

3.1. formulate ifr-1

Formulate and describe the IFR-1 using the following pattern:
The X-element, without complicating the system and without harmful side effects, eliminates
<indicate the harmful action>
within the <Operational Time>
inside the <Operational Zone>,
and keeps the tool's ability to provide
<indicate the useful action>.

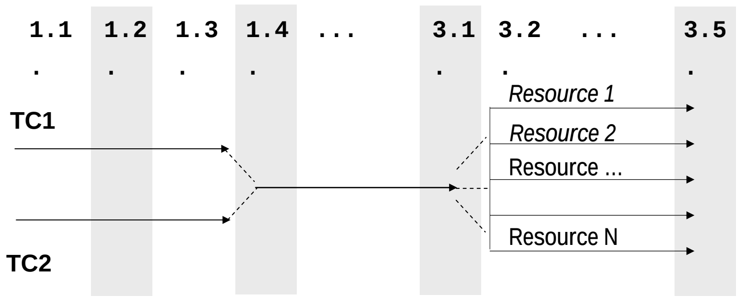
The X-element, without complicating the system and without harmful side effects, eliminates:
<*distortions in the image of vortexes*>
within <*all observation periods*>
inside the <*space beside the model parachute*> and provides
<*long term coloring of vortexes*>.

3.2. intensify the definition of ifr-1

Intensify the formulation of IFR-1 by introducing additional requirements:
the introduction of new substances and fields into the system is prohibited, it is necessary to use the SFR only.
<Existing resource> without complicating the system and without harmful side effects eliminates:
<the negative effect>
inside <the Operational Zone>
within <the Operational Time> and provides
<a useful effect>.

<*water*> without complicating the system and without harmful side effects eliminates:
<*distortions in the image of vortexes*>
inside the <*space beside the model parachute*>
within <*all observation periods*> and provides
<*long term coloring of vortexes*>.

some particularities of analysis



3.3. identify the physical contradiction for the macro-level

Identify and describe the Physical Contradiction at **macro-level** using the following pattern:

the <Operational zone>,
within the <Operational time>,
has to... <indicate the physical macro-state>
in order to perform <indicate one of the conflicting actions> and
does not have to <indicate the opposite physical macro-state>
to perform <indicate another conflicting action or requirement>.

the <*water beside the model parachute*>,
within the <*observation period*>,
has to... <*be just water*>
to <*not consume the indicator*> and
does not have to <*be water (has to be non-water / has to be the indicator)*>
to <*color the vortexes*>.

3.4. identify the physical contradiction for the micro-level

Identify and describe the Physical Contradiction at **micro-level** using the following pattern:

there should be particles of a substance <indicate their physical state or action>

in the <Operational Zone> within the <Operational Time>

in order to provide <indicate the macro-state according to step 3.3>

and there should not be the particles (or particles should have the opposite state or action)

in order to provide <indicate another macro-state according to step 3.3>

there should be <*particles/molecules of water*>
in the <*water beside the model parachute*>
in order that <the *indicator is not consumed*>
within the <*observation period*>
and there should not be the <*particles/molecules of water*>
to <*color the vortexes*>.

3.5. formulate ifr-2

Identify and describe the Ideal Final Result (IFR-2) using the following pattern:

The Operational Zone <indicate>

has to provide <indicate the opposite macro- or micro-states>

itself within the <Operational Time>.

The operational zone <*water beside the model parachute*>
has to provide <*molecules of water / and molecules of a non-water (indicator)*> itself
within the <*observation period (infinitely long time)*>.

Partial solution concept:

The molecules of water should be converted into an indicator in <the water beside the model parachute>. Consumed molecules of water will be replaced by molecules of water from the flow of water.

3.6. apply the inventive standards to resolve the physical contradiction

Check the possibility of applying the Inventive Standards to solve the new Physical Problem that was formulated as the IFR-2.

Notes:
The problem can be solved using **Inventive Standard 5.1.1.9.**

This step is passed over for the purposes of this study.

part 4. mobilizing and utilizing substance-field resources (sfr)

Part 4 of ARIZ includes systematic procedures to increase the availability of resources. One considers the derivative SFRs that can be obtained almost free of charge through slight modification of the already available resources.

4.1. simulation with little creatures (passed over)
4.2. to take a "step back" from the ifr (passed over)
4.3. using a combination of substance resources (passed over)
4.4. using "voids"
4.5. using derived resources
4.6. using an electrical field
4.7. using a field and field-sensitive substances (passed over)

4.4. using "voids"

Consider the possibility of solving the problem by replacing the existing substance resources with an empty space or a mixture of substance resources and empty space.

Partial Solution concept:

A mixture of water and a “void” is bubbles. An available option is to use bubbles instead of paint (indicator).

Sub-problem:

How do we make bubbles in the *water beside the model parachute*?
Bubbles have to appear near the cords of the model parachute.

4.5. using derived resources

Consider the possibility of solving the problem using derived substance resources or with a mixture of derived substances with empty space.

Comments:

Derived substance resources can be obtained *by changing the “phase” state* of existing substance resources.
For instance, if there is liquid as a substance resource, the derived resources that can be considered are ice and vapor.
On the other hand, the result of decomposing the substance resource can be considered as a derived resource as well.

New problem:

It is necessary to find an effect or phenomena:

How **to get gas** (bubbles) **from a liquid** (water flow)?

4.6. using an electrical field

Consider the possibility of solving the problem by introducing an electrical field or two interacting electrical fields instead of a substance.

Is it possible to make bubbles
in the <*water beside the model parachute*>
using an electrical field?

Preliminary solution concept:

a. *It is proposed to use the little bubbles of gas as an indicator.*
b. *Gas can be obtained by Electrolysis.*
c. *It is necessary to use electro-conductive wires to make the cords of the model parachute, to enable them to act as electrodes.*
d. *Another electrode can be placed outside the transparent tube.*

part 5. applying the knowledge base

The purpose of Part 5 of ARIZ is to mobilize all experience accumulated in the TRIZ knowledge base.

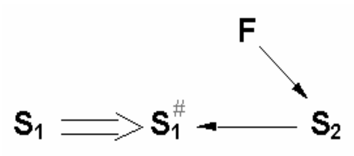
5.1. applying the system of standard solutions for inventive problems
5.2. applying the problem-analogues (passed over)
5.3. applying the principles for resolving physical contradictions
5.4. applying the pointer to physical effects and phenomena

Comment:
In most cases, Part 4 of ARIZ helps to obtain a solution concept, so it is possible to go to Part 7 of ARIZ.
If no solution is obtained after step 4.7, Part 5 is recommended.

5.1. applying the system of standards

Consider the possibility of solving the problem (formulated as IFR-2, keeping in mind the SFRs considered in Part 4) by applying Inventive Standards.

IFR-2:
The operational zone <*water beside the model parachute*>
has to provide <*molecules of water / and molecules of non-water (indicator)*> itself
during the operational time <*observation period (infinitely long time)*>.



When,
S_1 - water beside the model;
S_2 - electrodes (cords and water);
F - electric field;
S_1# - molecules of non-water (bubbles);

5.3. applying the principles for resolving physical contradictions

Consider the possibility of resolving Physical contradictions using typical transformations (see Table 2. Principles for resolving Physical Contradictions).

Principle 11.

Physical-chemical transition: substance appearance-disappearance as a result of decomposition-combination, ionization-recombination.

Partial solution concept:
The water should be converted into an indicator in <the water beside the model parachute> using physical decomposition of the water instead of chemically changing its properties.

5.4. applying the pointer to physical effects and phenomena

Physical Contradiction:
‹Water› has to ‹be water›, to ‹avoid consumption of the indicator›
‹Water› has to ‹be non-water›, to ‹indicate vortexes›.

...

3. Identify the Function that must be performed in order to satisfy the Contradiction requirements.
   Change (partially) the properties of water
4. Select the required function(s) from the Table of Functions in the Pointer of effects.
   Change optical properties of the substance
5. Look up and read the list of recommended effects which accomplish the defined function. If several functions were selected, identify the intersections of the proposed effects.
   . . .Electrolysis... Light polarization.... Light reflection... Magnetooptical Faradey effect...
6. Interpret the proposed effects in terms of the problem situation.
7. Collect the Partial concept solutions. Synthesize the collected Partial concept solutions into the Preliminary solution concept.

part 6. changing or substituting the problem

The process of problem solving is the process of correcting (reformulating) the problem statement.

6.1. transition to the technical solution

It is proposed to use thin metallic wires to make the cords of the model. A current is passed through the cords and water. As a result small bubbles are produced.

6.2. checking the problem formulation for combinations of several problems

6.3. changing the problem

6.4. reformulation of the mini-problem

part 7. analyzing the method of resolving the PhC

The main purpose of Part 7 of ARIZ is to check the quality of the obtained solution concept.

7.1. checking the solution concept

For complex canopy shapes the bubbles can produce a false image of the vortex. *What should be done?*

7.2. preliminary estimation of the solution concept

7.3. checking the priority of the solution concept through patent funds

7.4. estimation of sub-problems to implement the obtained solution concept

7.2. preliminary estimation of the solution concept

Questioner:

a) Does the solution concept provide the main requirement of IFR-1?

The bubbles do not distort the vortex image of the tested model and they provide the possibility of long term testing.

b) Which Physical Contradiction is resolved by the solution concept?

<Water> has to <be water>, to <avoid consumption of the indicator>
<Water> has to <be non-water> to <indicate vortexes>.

c) Does the new system contain at least one easily controlled element? Which element? How is it controlled?

The new system contains an easily controlled element - an electric current. The electric current enables control of the amount of bubbles.

d) Does the solution concept found for a "single-cycle" Problem Model fit the real conditions, multi-cycle conditions?

The solution concept can be useful for the real conditions of multiple tests in a laboratory.

Comment:
If the solution concept does not comply with all of the above, return to: step 1.1.

part 8. applying the obtained solution

The purpose of Part 8 of ARIZ is to maximize the utilization of resources discovered by the obtained solution concept.

8.1. estimation of changes in the super-system

8.2. find a new application for the obtained solution

8.3. apply the solution concept to other problems

part 9. analyzing the problem solving process

Every problem solved using ARIZ must increase the creative potential of the person.

9.1. Compare the real process of problem solving with the theoretical one (that is, according to ARIZ). Write down all, if any, differences.

9.2. Compare the obtained solution concept and knowledge from TRIZ.

Inventive Principles: *a similar general solution concept is absent*

Inventive Standards: *a similar general solution concept is described in the Inventive Standards:*

1.1.5. Transition to an SFM by using the external environment with additions

4.2.4. Transition to a measurement SFM by using properties of the external environment

5.1.1.9. Introduction of substances: Bypass method

5.1.2. Division of the product

ARIZ thinking & Ordinary inventive thinking

	Ordinary Inventive thinking process	ARIZ thinking process
1.	Tendency to make the problem easier, simpler.	Tendency to make the problem heavier, more complex.
2.	Tendency to avoid "fantastic" (crazy, wild) steps.	Tendency to follow the path of increasingly "fantastic" (crazy, wild) steps.
3.	Visual image of an object is unclear and related to the object-prototype.	Visual image of an object is clear and related to the object-IFR.
4.	A flat image of an object.	A 3-D image of an object: not only the object itself is imagined but simultaneously its subsystems and super-systems.
5.	The object's image is in a frozen time frame.	The object is seen in an historically mobile process: as it was yesterday, it is today, and will be tomorrow (if the line of evolution is preserved).

* G.S.Altshuller, ALGORITHM OF INVENTION. Moscow: Moscowskiy Rabochy. 2nd ed.-1973 p.p. 272-289

ARIZ thinking & Ordinary inventive thinking

	Ordinary Inventive thinking process	ARIZ thinking process
6.	The image of an object is rigid.	The image of an object is elastic, open to significant changes in space and time.
7.	Memory prompts to a familiar (and, therefore, weak) analogy.	Memory prompts to a distant (and, therefore, powerful) analogy. At the same time, the reservoir of information constantly grows through the collection of new methods, principles, and so on.
8.	Over the years the barrier of specialization grows.	The barrier of specialization disintegrates.
9.	The degree of control over the thought process does not increase.	The thought process becomes more controllable: the inventor can see the path of the thought as if an outsider; he easily controls the thought process (for instance, he has no problem diverting from "suggested variants," to easily making imaginary experiments, and so forth).

* G.S.Altshuller, ALGORITHM OF INVENTION. Moscow: Moscowskiy Rabochy. 2nd ed.-1973 p.p. 272-289

summary

- The problem solving process according to ARIZ leads us in the direction of an increase in Ideality.
- ARIZ provides firm links between the problem solving process, the Inventive Standards, the Pointer of Effects, the Laws of Technical Systems Evolution, and other knowledge issued from TRIZ.
- The second half of ARIZ is devoted to the elaboration and applicability of ideas that have been developed.
- Using ARIZ for the resolution of problems improves personal problem solving skills if parts 7, 8 & 9 are carried out carefully.

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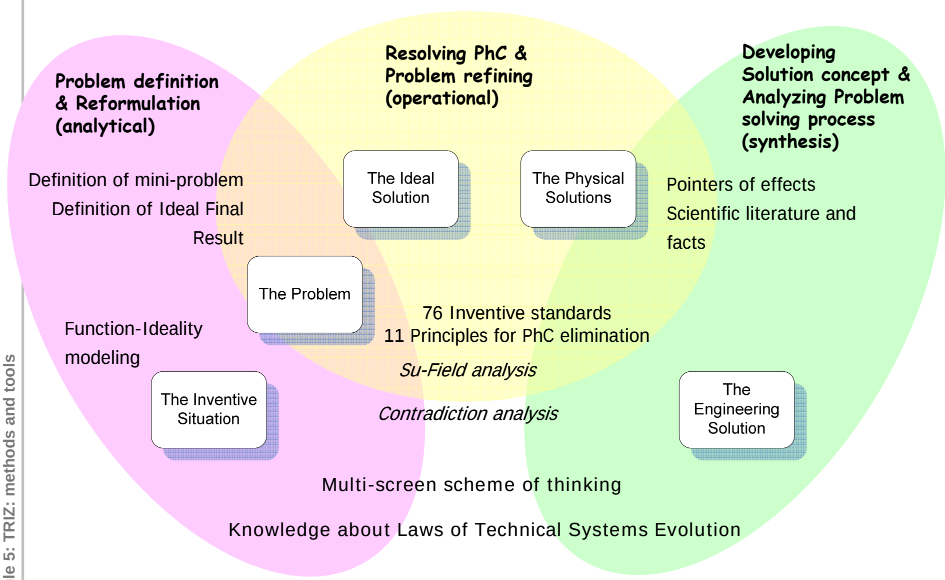
APPLICATION OF TRIZ TECHNIQUES



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SUMMARY

Advantages	Limitations	In comparison with non-TRIZ techniques

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references

1. G.S.Altshuller: 1969, 1973. **ALGORITHM OF INVENTION**, Moscowskiy Rabochy, Moscow (equivalent in English is: *G.Altshuller: 1999, THE INNOVATION ALGORITHM*. Worchester, Massachusetts: Technical Innovation Center. 312 pages, ISBN 0964074044) (Ru/En)
2. G.S.Altshuller: 1979. **CREATIVITY AS AN EXACT SCIENCE**. Sovietskoe radio, Moscow. (Ru/En)
3. G.S.Altshuller: 1986; 1991, **TO FIND AN IDEA**: introduction to the theory of inventive problem solving, Nauka, Novosibirsk. (Ru)
4. DARING FORMULAS OF CREATIVITY. 1987. Karelia, Petrozavodsk. (Ru)
5. RULES OF A GAME WITHOUT RULES, Karelia, Petrozavodsk, 1989. (Ru)
6. CHANCE TO ADVENTURE. 1991. Karelia, Petrozavodsk. (Ru)
7. G.I.Ivanov: 1994, THE FORMULES OF CREATIVITY OR HOW TO LEARN TO INVENT. Prosveschenie, Moscow. (Ru)
8. Y.Salamatov: 1999. TRIZ: THE RIGHT SOLUTION AT THE RIGHT TIME, Insytec B.V. (Ru/En)
9. N.Khomenko: 1997-2005. **Materials for seminars: OTSM-TRIZ**: Main technologies of problem solving, “Jonathan Livingston” Project. (En/Ru)
10. D.Kucharavy: 1998-2006. **Materials for seminars: TRIZ Techniques**, OTSM-TRIZ Technologies Center. (En)

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